TO: Randy Smith, Vice Provost for Academic Programs

FROM: Graduate School Curriculum Services

DATE: **10/23/2025**

RE: Proposal to **Establish an Interdisciplinary MS in Quantum Information Science (QuGIP)** in **The Center for Quantum Information Science within ERIK.**

The **Department of Physics** in the **College of Arts and Sciences** is proposing an **Interdisciplinary MS in Quantum Information Science (QuGIP).**

The proposal was received by the Graduate School on **3/21/2025**. The combined GS/CAA subcommittee first reviewed the proposal on **4/10/2025** and revisions were requested. Revisions were received on **8/21/2025** and were reviewed on **10/8/2025** additional revisions were requested and received on **10/13/2025** with additional supporting documentation received on **10/17/2025.** It is supported for review by the Council on Academic Affairs.

Kowalsky, Lisa

From:	Vankeerbergen, Bernadette
Sent:	Friday, March 21, 2025 4:38 PM
To:	Miriti, Maria; Kowalsky, Lisa
Cc:	Nagar, Ila; Martin, Andrew; Steele, Rachel; Tomasko, David; Quinzon-Bonello, Rosario; Gupta, Jay
Subject:	Quantum Information Science and Engineering MS & PhD Proposal
Attachments:	QISE Proposal Revised 03-11-2025.pdf; New Master of Science PhD Quantitative Information Science and Engineering Letter of Motion.pdf; Quantum_Information_Science_and_Engineering_QuGIP_COE_Approval.pdf

Dear Maria and Lisa,

Please find attached a proposal for a new MS & PhD in Quantum Information Science and Engineering. The ASC Curriculum Committee (ASCC) approved the proposal today, Friday, March 21, 2025.

Please note that the proposal was previously fully approved by the College of Engineering Committee on Academic Affairs.

We are now advancing the proposal to be reviewed by the Graduate School. The attached documents are (1) the actual proposal, (2) the Natural and Mathematical Sciences Subcommittee cover letter to ASCC, and (3) the memo confirming approval by the College of Engineering.

Please use this email as a cover letter indicating that the proposal has been duly reviewed and approved by the appropriate ASC curricular bodies (including the full ASC Curriculum Committee).

Could you please confirm that you will also need a letter from Dean Horn (ASC) and a letter from Dean Howard (ENG)? If so, we will contact Dean Horn, and our colleagues in Engineering will provide the letter from Dean Howard.

My best,
Bernadette

THE OHIO STATE UNIVERSITY

Bernadette Vankeerbergen, Ph.D.
Assistant Dean, Curriculum
College of Arts and Sciences
114F University Hall, 230 North Oval Mall.
Columbus, OH 43210
Phone: 614-688-5679
http://asccas.osu.edu

THE OHIO STATE UNIVERSITY

Department of Chemistry and Biochemistry
1118 Newman and Wolfrom Laboratory
100 West 18th Avenue
Columbus, OH 43210-1106

614-292-2251 Phone
614-292-1685 Fax
http://chemistry.osu.edu

Christopher M. Hadad
hadad.1@osu.edu
614-688-3141

March 14, 2025

Chair, Arts and Sciences Curriculum Committee
Ohio State University
CAMPUS

Dear Chair and Members of the Arts and Sciences Curriculum Committee:

On Wednesday, March 5, 2025, the Natural and Mathematical Sciences Subcommittee reviewed new program and course requests for the Interdisciplinary graduate program for MS and PhD degrees in Quantum Information Science and Engineering (QISE) along with new courses: QISE 7100, 7101, 7102, 7111, 7112, & 7113.

The QISE team proposes to develop and launch QuGIP, a new Interdisciplinary Graduate Program at OSU, focused on quantum information science and engineering (QISE). The launch phase of this program (through academic year 2028-2029) will be supported by a National Science Foundation National Research Traineeship (NRT) award, which will directly fund 25 trainees with first-year fellowships, including approximately 7-10 MS students and 15-18 PhD students.

The QuGIP curriculum is structured to prepare and facilitate transition of QuGIP students into research groups, including externally-funded research assistantship positions with a primary faculty advisor after the first year. This interdisciplinary graduate program will help to expand the research portfolio of QISE teams at OSU.

The NMS Subcommittee voted unanimously to approve the request with four minor contingencies. A revised submission addressing these contingencies was reviewed and approved by myself, Chair of the Natural and Mathematical Sciences Subcommittee, on March 11, 2025.

The QISE proposal is now advanced to the ASCC with a motion to approve.

Sincerely,

Christopher M. Hadad
Professor of Chemistry and Biochemistry
Vice Chair for Research and Administration, Department of Chemistry and Biochemistry
Director, Campus Chemical Instrument Center (Nuclear Magnetic Resonance | Mass Spectrometry and Proteomics)
Ohio State University

THE OHIO STATE UNIVERSITY

College of Engineering

Undergraduate Education & Student Services

122 Hitchcock Hall
2070 Neil Avenue
Columbus, OH 43210-1278

614-292-2651 Phone
614-292-9379 Fax

engineering.osu.edu

Memo

To: Professor Jay Gupta, Department of Physics Vice Chair for Graduate Studies and Postdoctoral Affairs

From: Rosie Quinzon-Bonello, Assistant Dean for Curriculum and Assessment

Date: October 11, 2024

Re: Quantum Information Science and Engineering MS/PhD Proposal

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On October 10, 2024, Subcommittee B of the College of Engineering Committee on Academic Affairs, chaired by Jeff Chalmers, recommended approval to support the vision of the proposal to establish an interdisciplinary MS/PhD program in Quantum Information Science and Engineering. The motion was put forward to the full committee and approved with no votes to oppose or abstain.

Yours sincerely,

Rosario Quinzon-Bonello

Rosie Quinzon-Bonello

THE OHIO STATE UNIVERSITY

College of Engineering

142 Hitchcock Hall
2070 Neil Ave
Columbus, OH 43210

14 October 2025

Maria Miriti, Associate Dean for Academic Excellence
Graduate School
The Ohio State University
CAMPUS

Re: Support for Quantum Information Science Interdisciplinary Graduate Program

Dear Maria,

The College of Engineering supports the development of the proposed interdisciplinary graduate program and it being housed in the Center for Quantum Information Science and Engineering. We are open to discussing a financial commitment in FY28, prior to the NSF grant's conclusion, to allow program outcomes to be collected. We elect not to commit fellowships or other financial resources ahead of those discussions. Further, we encourage exploration of other options for supporting staff beyond the conclusion of the grant or alternatives for staffing given the small number of projected students.

Sincerely,

Ayanna Howard

Ayanna Howard, Ph.D.
Dean of Engineering
Monte Ahuja Endowed Dean's Chair
College of Engineering
142 Hitchcock Hall, 2070 Neil Ave, Columbus, OH 43210
614-292-2836 (option 0) Office

Outlook

Fw: Letter of support for quantum grad curriculum

From Gupta, Jay <gupta.208@osu.edu>
Date Thu 10/16/2025 10:51 AM
To Miriti, Maria <miriti.1@osu.edu>

HI Maria,

Since Dean Horn is on vacation until next week, can we proceed with this email thread as a concurrence until we can get a proper letter on letterhead?

Thanks, Jay

Jay Gupta, PhD
Professor
Department of Physics
Vice Chair for Graduate Studies and Postdoctoral Affairs
Co-Director, Physics Bridge Program
Director, NSF NRT - QuGIP
Offices: 2056 (personal), 1040F (Vice Chair) Physics Research Building
191 West Woodruff Avenue, Columbus, OH 43210-1117
+1-614- 247-8457 Office
http://u.osu.edu/guptagroup/

Book time to meet with me

From: Horn, David <horn.5@osu.edu>
Sent: Tuesday, October 14, 2025 12:43 PM
To: Gupta, Jay <gupta.208@osu.edu>; Howard, Ayanna <howard.1727@osu.edu>
Cc: Reano, Ronald <reano.1@osu.edu>; Johnston-Halperin, Ezekiel <johnston-halperin.1@osu.edu>; Stiner-Jones, LaTonia <stiner-jones.1@osu.edu>; Olesik, Susan <olesik@chemistry.ohio-state.edu>; Penneys, David <penneys.2@osu.edu>
Subject: Re: Letter of support for quantum grad curriculum

Dear Jay,

This looks good to me.

David

From: Gupta, Jay <gupta.208@osu.edu>
Date: Tuesday, October 14, 2025 at 10:41 AM
To: Horn, David <horn.5@osu.edu>, Howard, Ayanna <howard.1727@osu.edu>
Cc: Reano, Ronald <reano.1@osu.edu>, Johnston-Halperin, Ezekiel <johnston-

halperin.1@osu.edu>, Stiner-Jones, LaTonia <stiner-jones.1@osu.edu>, Olesik, Susan <olesik@chemistry.ohio-state.edu>, Penneys, David <penneys.2@osu.edu>
Subject: Letter of support for quantum grad curriculum
Dear Deans Horn and Howard,

I'm writing to request a letter of support from you confirming that you support the OSU CQISE to serve as the administrative and curricular home for the proposed quantum MS/PhD program. The curricular proposals have now been reviewed by a CAA subcommittee, and Vice Provost Randy Smith suggested that we include a letter of support from you before it is reviewed by the full CAA. Generally, Centers are not curricular homes for degree programs at OSU, though there are exceptions, like the Center for TDAI. Your letter of support would help pave the way for CQISE to serve as the home for the new quantum program. I've included a draft below for your review. If the wording looks good to you, I'd be happy to send via Docusign on appropriate letterhead.

Thanks, Jay

Dear Colleagues,

This letter confirms our support for the development of an interdisciplinary graduate program in quantum information science and engineering, to be housed under the OSU Center for Quantum Information Science and Engineering (CQISE). The establishment of this new interdisciplinary program will strengthen Ohio State's ability to create knowledge and educate students to be leaders in this rapidly developing field. Consistent with the need for a quantum workforce articulated in the US National Quantum Initiative Act, Ohio State has invested heavily in quantum science, including CQISE, which was launched in 2022 under the Enterprise for Research, Innovation and Knowledge (ERIK). Since this time, CQISE has supported interdisciplinary research through seed grants, faculty recruiting, infrastructure development, student training and community outreach. CQISE is a natural administrative and curricular home for the new graduate program, and its co-Directors (Ron Reano in ECE and Zeke Johnston-Halperin in Physics) are also participating faculty in the new quantum program.

The curriculum proposals for the MS and PhD degrees in QISE have been reviewed and approved by six participating departments in our colleges, as well as our respective College-level curriculum committees. The proposal presents a sustainable budget model that leverages the NSF funding already in place, and will ensure that the program can continue to grow and thrive in the future. With the support from CQISE and the continuing efforts of our faculty who are leading and participating in the program, we are confident that the new quantum curriculum will be properly assessed and continuously improved according to the high curricular standards of other programs in our Colleges.

Sincerely,

Dean David Horn
College of Arts and Sciences

Dean Ayana Howard
College of Engineering

Jay Gupta, PhD
Professor
Department of Physics
Vice Chair for Graduate Studies and Postdoctoral Affairs
Co-Director, Physics Bridge Program
Director, NSF NRT - QuGIP
Offices: 2056 (personal), 1040F (Vice Chair) Physics Research Building
191 West Woodruff Avenue, Columbus, OH 43210-1117
+1-614- 247-8457 Office

http://u.osu.edu/guptagroup/

Book time to meet with me

Proposal for an Interdisciplinary Graduate Program in Quantum Information Science and Engineering

The Ohio State University, College of Arts and Sciences and College of Engineering

Mode of delivery: on campus

Participating Departments: Chemistry and Biochemistry, Computer Science Engineering, Electrical and Computer Engineering, Materials Science Engineering, Mathematics, Physics.

Executive Summary

We propose to develop and launch a Quantum Graduate Interdisciplinary Program (***QuGIP***), at Ohio State University (OSU), focused on quantum information science and engineering (QISE). The launch phase of this program (up to AY 2028-29) will be supported by an NSF NRT award, which will directly fund 25 trainees with first year fellowships, approximately 5-10 Masters students, and 15-20 students in the companion PhD program to be developed subsequently. While an increasing number of QISE programs have emerged in recent years, these are often hosted in traditional units such as Physics Departments. However, the grand challenges in QISE research, and the national need for a quantum workforce, require a more interdisciplinary approach. Toward that end, QuGIP features a team of faculty leaders in Physics, Chemistry, Mathematics, and Engineering (Electrical and Computer, Computer Science, Materials Science), and will be administratively housed under the OSU Center for Quantum Information Science and Engineering (CQISE). QuGIP will feature a compact common core of QISE courses, designed to accommodate variations in student preparation from these disciplines. QuGIP students will develop a common vernacular and teaming skills through the compact core sequence, research rotations across disciplines, informal community building and industry engagement. Skill-building in ethics, technical writing and communication will be integrated in both classroom and research activities. QuGIP students will thus be uniquely prepared to make new insights and research connections that would not otherwise occur. The QuGIP Masters curriculum is structured to prepare and facilitate transition of QuGIP students to the quantum workforce, offering an accelerated course-based option, and a more research-focused thesis-based option. This leverages, and will help expand, the portfolio of QISE research at OSU.

QuGIP will make broader impacts as envisioned in the National Quantum Workforce Strategic plan, through interdisciplinary research to solve grand challenges in QISE, with broad dissemination in national networks and by training a diverse quantum workforce. In addition to the directly-funded trainees, we estimate another 10-20 degree students will be funded from other sources such as assistantships and competitively awarded university fellowships. In their research at OSU, QuGIP students will work at the forefront in QISE and will be well prepared to translate their experiences to other problems, applications and fields after graduating. As a new model for graduate training, QuGIP will feature a flexible specialization structure that facilitates industry engagement and professional development. The QuGIP course curricula have been designed with evidence-based methods and implemented with expert guidance from the OSU Drake Institute of Teaching and Learning. QuGIP courses will be available as electives to graduate students in existing programs, and based on experience with pilot courses, we estimate another 100 students will take QuGIP courses during the launch period. The QuGIP model will be broadly disseminated by leveraging OSU membership in national networks, including QuSTEAM and the Chicago Quantum Exchange. Lastly, QuGIP will help fill a critical need for a *quantum workforce*, as nearly 60% of OSU graduates take positions in industry, and the top employers of OSU graduates: Google, Intel, and Amazon all have made substantial investments in QISE and in Central Ohio. QuGIP students will benefit from a network spanning these large industry partners down to small quantum startups, and will have the broad skillset to develop quantum technologies and solve societal needs.

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Projected impacts

Impact on OSU: Quantum information science and engineering is a rapidly developing field in STEM that has captured the attention of the general public, large and small technology companies, government and education. The proposed Quantum Graduate Interdisciplinary Program (QuGIP) will be an innovative 21st century graduate program featuring interdisciplinary courses designed with evidence-based methods and seamless integration with industry, nonprofit and national lab experiences. The proposed program will position OSU in the vanguard of institutions developing QISE degree programs and will be visible and attractive to a growing number of students and professionals seeking training in this area. We anticipate positive impacts on collaborative research in quantum at OSU, which will be evidenced by external funding and high impact publications.

Impacts to OSU students in other graduate programs: QuGIP courses will be available and appropriate for STEM graduate students to take as electives. The courses are designed to accommodate varying background preparation in e.g. linear algebra and quantum mechanics, and could help students from other disciplines build a foundation in quantum as well.

Impacts to OSU undergraduate students: OSU undergraduate students will benefit from an increased development of interdisciplinary research opportunities that QuGIP will help foster. There are also natural synergies between the proposed graduate program, and the QuSTEAM undergraduate minor program, which is currently under development. For example, quantum-related seminars, internships and professional development opportunities will be disseminated to both communities.

Impacts on participating units (c.f. Appendix for Concurrence letters): QuGIP is expected to have small or negligible impact on graduate recruiting to the 6 participating Departments (Physics, Math, Chemistry and Biochemistry, ECE, MSE, CSE), as some Departments do not have active Masters programs (Physics, Chemistry and Biochemistry), and the program will target a pool of students with complementary interests. The establishment of QuGIP would give these students a second option at OSU, and will likely increase the chances of OSU to attract these students. The new program will moreover, develop new recruiting pipelines to increase the number of applicants to OSU. The program will also likely positively impact faculty research programs, through the development of new interdisciplinary projects in quantum science and increased competitiveness for the growing pool of external funding in quantum at DOE, NSF and other federal agencies. In addition, we anticipate that the increased interactions among faculty and students in the participating departments will also seed collaborative efforts not directly related in quantum science, and thus could have additional impacts on research and education.

Impacts to other units: Though the field is still at an early stage, it is likely there will be corollary benefits of QISE research to other programs at OSU. For example, quantum sensing has a broad range of potential applications from medical imaging to geodesy. Quantum cryptography has a similarly broad range of applications in finance and national security. We thus expect that the program will help grow a dense network of collaborative work between participating faculty and those in other units. No negative impacts are anticipated.

Review process

This QuGIP Curriculum proposal has been reviewed and approved by the following academic units:

OSU Departments (c.f. appendix for concurrence letters):

- Department of Chemistry and Biochemistry
- Department of Computer Science and Engineering
- Department of Electrical and Computer Engineering
- Department of Materials Science Engineering
- Department of Mathematics
- Department of Physics

College of Arts and Sciences Curriculum Committee

College of Engineering Curriculum Committee

Stakeholder input

This curriculum proposal was informed by numerous discussions with faculty and students in the participating Departments, the broader OSU STEM community, and in collaboration with other universities through NSF-sponsored events. Included in the appendix are some examples including:

- NSF National Research Traineeship Annual Meeting (Oct 29-31, 2023, hosted by Arizona State University): The NSF NRT program makes training grant awards in a broad range of fields, including quantum-related NRTs at University of Washington, UCSB, Univ. Arkansas, Univ. Tennessee, Colorado School of Mines and Yale. QuGIP Director Gupta attended this meeting, and is coordinating a satellite meeting in 2024 with the other quantum NRTs to share best practices in quantum education and training.
- OSU Center for QISE Quantum Collaborators Kickoff Meeting (Sep 22, 2023). This meeting provided an opportunity for networking and to learn about the quantum activity occurring across the University and regionally. QuGIP presented a poster at this meeting, and QuGIP personnel were available for questions and discussions from attendees.
- Open solicitations to faculty in the participating departments: Shortly after the NSF NRT award was made public, we sent out emails to faculty lists announcing the award and soliciting input. The co-PIs on the NSF proposal are serving as points of contact for these interactions.
- Weekly QuGIP happy hours – these informal get togethers of the QuGIP leadership team have helped build a sense of community among stakeholders, and inspired creative brainstorming for program components.
- Outreach to expanded base of participating faculty: To build a broad base of support for the program (and advisors for QuGIP students), emails were sent out to participating faculty and soliciting input and suggestions.
- Informal discussions with students: QuGIP faculty have had numerous informal discussions with students at OSU and externally about the program. In particular, suggestions for program components and feedback were solicited in these interactions.
- Sustained discussions with OSU leadership: the proposal has been informed by discussions with the OSU Graduate School (Dean Stromberger and Associate Dean Miriti), Office of Academic Affairs (Vice Provost Smith), ASC (Dean Horn, Assistant Dean Vankeerbergen), and CoE (Associate Deans Tomasko and Stiner-Jones).

SUMMARY OF SUPPORTING RESOURCES

The administrative and research infrastructure are in place to support the proposed program. Here we provide a bulleted list, with links to the relevant sections below.

Administrative infrastructure: The OSU Center for Quantum Information Science and Engineering (CQISE) will be the administrative home for the new graduate program, administering admissions, student tracking and finances. Discussed further here.

Financial support: NSF funding will provide first year fellowships to all MS students admitted into the program through AY28-29 (budget: $3M / 5 years from 2023-2028 + planned 1 year no-cost extension). As described in the Appendix, NSF funding includes 1 yr fellowships for trainees, the program coordinator position, curriculum development (faculty teaching buyout, OSU Drake Institute of Teaching and Learning) and program evaluation (Strategic Evaluations LLC.). As the program becomes well established, we expect to admit ~ 20 MS students per year as a sustained target. More detailed budget information can be found in the Appendix.

Non-thesis MS students will be able to finish their degree by the end of their first year, while thesis MS students will likely require up to one additional year for their thesis research. During this time, the student will be supported via a funding plan developed by their advisor for any subsequent terms. Following the launch phase, MS students will be charged tuition to cover program expenses.

Research infrastructure support: Students in the new program will benefit from and contribute to the strong culture of collaborative and interdisciplinary research at OSU that is nurtured by OSU Centers, including CQISE, the Ohio State University Institute for Materials and Manufacturing Research, and the OSU Center for Emergent Materials (CEM). The research by QuGIP students will benefit from the extensive network of equipment and computational facilities at OSU. Examples include the Ohio Supercomputing Center (OSC), NanoSystems Laboratory (NSL), Semiconductor Epitaxy and Analysis Laboratory (SEAL), Center for Electron Microscopy and Analysis (CEMAS), Nanotech West Laboratory (NTW), the NSF NeXUS facility, the Campus Chemical Instrumentation Center (CCIC). These Centers and Facilities are discussed in more detail here.

PROGRAM NARRATIVE - BASIC CHARACTERISTICS

Purpose

The National Quantum Initiative Act was signed into law in 2018 “to accelerate quantum research and development for the economic and national security of the United States.” Representing a community consensus developed through subsequent workshops and planning roundtables, the 2022 U.S. National Strategic Overview for Quantum Information Science and Engineering (QISE) calls for (*i*) QISE to be recognized as its own discipline, calling for new faculty, programs and initiatives, (*ii*) a *science-first approach* fostering collaboration across disciplines to solve Grand Challenges in QISE, and (*iii*) *deepened engagement* with industry for workforce development.

To meet this national need, we propose to launch one of the first truly interdisciplinary QISE MS programs in the U.S. at The Ohio State University. This program leverages and will reinforce federal, university and regional investments in QISE. These include an NSF-funded training award to OSU, the OSU Center for QISE, cross-cutting faculty hires in quantum science, and partnership programs such as StarLab and the OSU/Air Force Institute of Technology Intercity Quantum Network. As QISE spans algorithms, fundamental physics, and hardware implementations from atoms to architectures, a new approach to graduate education is needed so that students in physics, chemistry, mathematics and engineering (electrical, computer, and materials) can combine efforts to solve complex Grand Challenges in the field. Our program will build a common vernacular to overcome structural barriers to interdisciplinary graduate education, is developed with evidence-based methods from the start and will accelerate the transition to experiential learning through research and industry internships. In addition to technical content learning outcomes, the program places equal priority on our students developing communication skills and a moral compass for ‘quantum ethics’, so they can become leaders in industry, government and academia.

Program focus

The proposed graduate program will provide students with foundational coursework and accelerate their transition to experiential learning through quantum science research and industry graduate internships. Not only will these students have the interdisciplinary and professional skills needed for the quantum workforce, but they will also help OSU faculty who are interested in pivoting some of their research activity into this field. The proposed curriculum will feature a compact core of four graduate-level QISE courses with content specifically designed to accommodate students with Bachelor’s degrees in Chemistry, Physics, Math, Computer Science and Engineering, Materials Science Engineering or Electrical and Computer Engineering. Students will be recruited into one of four program specializations that integrate advanced elective courses, research rotations and experiential learning opportunities. The Quantum Computing specialization is focused on the development, implementation and scaling of quantum algorithms for solving complex problems and error correction. The Quantum Networking and Communication specialization is focused on the transportation and multiplexing of quantum information using elements such as photonics and microwave cavities. The Quantum Simulation specialization is focused on quantum-enabled methods to better understand physical systems whose complexity exceeds even the best classical high performance computing algorithms. Lastly, the Quantum Materials and Sensing specialization is focused on the physical materials (solid state and molecular) used for quantum bits, sensors and storage. These specializations will be included on student diplomas to highlight the specific content and experiential knowledge students gain in the program.

Rationale

Graduate degrees in Quantum Information Science and Engineering demonstrate proficiency in an interdisciplinary curriculum that requires strong communication skills and an active growth mindset for continued learning as the field evolves. Depending on their career goals, Masters students may choose either thesis- or non-thesis degree experiences (described further below). The degree and specialization certifications will be attractive for employers in industry, government and academia.

Duration of Program

Example curricula for Masters students are discussed in more detail here.

Course requirements: A minimum of 30 credit hours will be required for Masters degree recipients. These requirements are consistent with the OSU Graduate School, and national expectations for graduate education in related STEM fields. Of these credit hours, at least 9 credit hours will be for foundational graduate coursework, at least 6 credits will be for seminar-style professional development courses (ethics, writing, journal club), and at least 3 credit hours will be for experiential learning (research, internships).

Time to degree: Depending on their preparation and career goals, the Masters degree program can be completed by students in 3-6 semester terms, typically 1-2 academic years. The time to degree will be similar for the four program Specializations. MS students will enter the program in a cohort taking the graduate core courses and seminars, but will progress through the program at rates determined by their career goals and research program. These degree times and support models are typical for STEM programs at OSU and nationally.

Admission timing

The program will recruit one cohort of students per year, to start classes in Autumn semester. The admissions application will be launched the preceding Autumn semester, and review of the applications will be conducted by a Graduate Admissions Committee on a rolling basis after the application submission deadline (Dec 15th). MS applications will be considered for a number of slots that will be based on program priorities as determined by the QuGIP Director and *Graduate Studies Committee*.

Primary target audience

The Masters program will primarily target traditional college-age students, but will encourage a greater variety of workforce outcomes than traditional programs, such as K-12 education, industry technician, government data analyst and startup entrepreneurs. In addition to students coming into the program straight from their Bachelors institution, we will actively recruit professionals in related industries by leveraging existing relationships.

Admissions will be conducted through the OSU Office of Graduate Education, and students will meet Graduate School requirements, including a 3.0 GPA and an official transcript showing proof-of-degree completion. As there are few Bachelors degree programs in QISE, students recruited into the program will typically have Bachelors degrees and minors in the related disciplines: Physics, Chemistry, Mathematics, Engineering (Electrical and Computer, Materials Science, Computer Science). The admissions process will include a rubric-based review of written applications which will include a personal statement describing student motivations for applying to the program, challenges overcome and future goals and at least three letters of recommendation. All international applications whose native language is not English will be required to take the TOEFL test and provide an official score report. In addition to the written materials, admissions will be based on Zoom interviews conducted by the Graduate Admissions Committee. These interviews will help assess student non-cognitive factors, research interests and identify potential faculty advisors.

During the NSF-funded launch phase of the program (up to AY28/29), applicants must be eligible for NRT Fellowship funding, which stipulates that trainees are US Citizens, nationals or permanent residents. International students may come in self-funded, or with their own fellowship funding. After the launch phase, self-funded domestic and international students will be eligible for the program.

Recruiting plan: Our recruiting goal is to consistently attract a pool of applicants from a wide range of backgrounds to the QISE program by leveraging our substantial existing networks. For example, the Physics and Chemistry Departments draw on the NSF IGEN network, which provides a nationwide, free, common application. In 2025, the IGEN pool featured 186 applications, with at least 30 students expressing interest in QISE or related areas. OSU is also a founding member of the Open Quantum Initiative summer research program hosted by the Chicago Quantum Exchange network. In 2025, there were 350+ applications from students all over the country, coming from large R1 research institutions, as well as smaller colleges, with majors including Physics, Engineering and double majors with various combinations (Physics/Math, Computer Science/Physics etc.). OSU has hosted 12 summer students since the program launched in 2021.

Retention through graduation: The participating Departments in QuGIP have demonstrated a commitment to degree attainment, with an average of over 90% of students achieving a Masters degree or higher, while maintaining a time-to-degree consistent with disciplinary national averages. To achieve our target of at least 80% degree attainment, QuGIP will leverage and uniformly apply mentoring best practices that have grown from OSU engagement with networks such as the National Math Alliance and the APS IDEA. For example, peer, near peer and faculty mentoring networks will be established for each student when they first arrive on campus, ensuring they have a broad support system that has been proven critical for degree attainment.

PROGRAM NARRATIVE - INSTITUTIONAL PLANNING

Physical Infrastructure

Organizational infrastructure: The OSU Center for Quantum Information Science and Engineering (CQISE) will serve as the administrative home of the new graduate program. Sufficient office space for the program students will be provided by the participating departments. Student research needs (e.g. primary laboratory space, computing clusters etc.), will be provided as per their advisor. Participating faculty (c.f. Appendix A) have the extensive infrastructure already in place for cutting-edge research in quantum information science and engineering.

Students in the new program will benefit from and contribute to the strong culture of collaborative and interdisciplinary research at OSU among the participating departments. For example, CQISE sponsors a variety of community-building programs, including seminars, project seed funding, and networking events with regional industries. In addition to CQISE, the Ohio State University Institute for Materials and Manufacturing Research is a campus-wide, multidisciplinary institute that facilitates, promotes and coordinates research activities and infrastructure related to the science and engineering of materials throughout The Ohio State University. IMR's community-building activities include a Distinguished Lecture series, and the annual Materials Week conference, which draws several hundred attendees from both academia and industry. Students will also benefit from externally-funded centers, such as the OSU Center for Emergent Materials (CEM), one of the flagship materials centers sponsored by the NSF which has 20+ participating faculty at OSU in Physics, Chemistry and Biochemistry, Materials Science and Mechanical Engineering. CEM hosts a variety of seminar speakers, technical workshops, outreach events and professional development opportunities.

New opportunities in quantum infrastructure: QuGIP students will have the opportunity to contribute to regional investments in quantum infrastructure. For example, a team at OSU is leading the development of an intercity quantum network with the Air Force Institute of Technology (AFIT) in Dayton. This project has just received a congressionally-directed three year, $1M award. Quantum communication may also play a role in the new StarLab venture, led by a team comprising OSU, The Universities Space Research Association, Zin Technologies, and the International Association of Science Parks and Areas of Innovation. This effort has been chosen by Voyager Space to build terrestrial analogue laboratories to help guide the development of a commercial space station.

OSU research user facilities: The research by QuGIP students will benefit from the extensive network of equipment and computational facilities at OSU. Examples include the Ohio Supercomputing Center (OSC), NanoSystems Laboratory (NSL), Semiconductor Epitaxy and Analysis Laboratory (SEAL), Center for Electron Microscopy and Analysis (CEMAS), Nanotech West Laboratory (NTW), the NSF NeXUS facility, the Campus Chemical Instrumentation Center (CCIC). These user facilities employ technicians and engineers to support training and project execution as needed by the research community. Some examples of relevant capabilities for student researchers in the quantum graduate program include:

- The Ohio Supercomputer Center empowers researchers via high performance computing, advanced networking, and training resources; partners with leading scientific investigators in developing joint proposals to regional, national, and international organizations; and leads research activities of strategic interest to OSC, the state, and the country.

- NSL has a 1,500 sq. ft. class 1000 cleanroom and operates the following instruments: 1) an optical lithography maskless aligner, 2) a Kurt Lesker sputtering/ion-milling/e-beam evaporation system, 3) an ICP-RIE, 4) an FEI Helios dual-beam FIB/SEM with e-beam lithography, 5) a Bruker triple-axis x-ray diffraction system, 6) two AFM/MFM systems, 7) two Quantum Design 7-T SQUID magnetometers, 8) a Quantum Design 14-T PPMS, 9) a Magneto-Optical Kerr Effect Microscope, 10) a diamond CVD System, 11) a low-temperature flow cryostat magneto-transport system, 12) a Montana Instrument cryogen-free magneto-optical system, 13) a Bruker Electron Paramagnetic Resonance (EPR) spectrometer, 14) a suite of microwave instruments including network analyzers, signal generators, and amplifier.
- SEAL is OSU's primary facility for MBE and is located within the 4,000 sq. ft. Dreese Lab Cleanroom. SEAL houses 6 state-of-the art MBE chambers each dedicated to different, complementary material systems, including group IV and III-V (III-As, III-P, III-N, and III-Sb) semiconductor epitaxial heterostructures, and TMD 2D materials for both basic studies and true device development.
- CEMAS operates two FEI Titan Scanning Transmission Electron Microscopes (S/TEM), one FEI Tecnai S/TEM, one FEI Tecnai G2 TEM, two Apreo Scanning Electron Microscopes (SEM), one FEI SEM, Two FEI dual-beam FIB/SEMs, and two Rigaku XRD systems.
- NTW is the largest nanotechnology user facility in Ohio and supports more than 100 research and development projects per year for commercial, government, and academic clients including many external users. NTW consists of a 6,000 sq. ft. class 100 cleanroom and possesses the following capabilities for 4" wafers: MOCVD, ALD, LPCVD, PECVD, e-beam evaporation and sputter deposition, ICP-RIE, ashing, and wet chemical etching.
- NSF NeXUS is a first-of-its-kind facility for ultrafast science, funded and maintained at OSU in partnership with the National Science Foundation. A kW-class laser drives the generation of extreme ultraviolet (XUV) and soft x-ray pulses with durations from femtoseconds to attoseconds. NeXUS has a "beamline" arrangement so that three distinct XUV beams, each with its own time and spectral characteristics, can be generated from a single laser. The laser and XUV pulses are then coupled into an "end station" that directly support user measurements. The NeXUS System is being built with multiple end stations to support user measurements of angle-resolve photoelectron spectroscopy (ARPES), element-specific scanning tunneling microscopy (STM), x-ray absorption spectroscopy (XAS), x-ray reflection spectroscopy (XRS), attosecond science, and laser induced electron diffraction (LIED). All of these measurements can be time resolved using combinations of the laser and XUV pulses.
- The CCIC hosted by the Department of Chemistry and Biochemistry hosts a wide range of analytical equipment for magnetic resonance, surface analysis, x-ray crystallography, mass spectrometry and ultrafast dynamics measurements.

Market Demand

At the societal level, the National Quantum Initiative Act signed into law in 2018 represents an 'all of government' approach to develop quantum technologies for future economic growth and national security. Substantial federal investments in QISE have been made through the NSF, DOE and DOD, and include awards for fundamental research, technology transfer and workforce development. These investments are matched by industry research and development, including by leading information technology companies such as Intel, Google, IBM, Microsoft, Amazon, and Meta. A variety of other large companies such as JP Morgan Chase, Corning, Applied Materials, and Boeing and startups are interested in recruiting talent in this area as well. To grow this 'quantum ecosystem', regional hubs have been established in recent years, led for example by the Chicago Quantum Exchange, which facilitates exchange among academic (including OSU), national lab and industry partners. Recent job postings attest to the rapidly growing opportunities in this field.

The growing employment opportunities (c.f. Appendix) and rapid progress publicized in the media (such as IBM's 1000 qubit report (12/4/2023) and Google's quantum supremacy report (10/23/2019) are catalyzing growing student interest in QISE. This is directly evidenced by one of the recruiting pools OSU faculty has helped establish: the Open Quantum Initiative (OQI). Launched in 2021, the OQI is an innovative, multi-institution summer research program for undergraduate students interested in QISE. For example, there were 350+ applicants to OQI summer research program in 2025 from all over the country, with 30% annual growth in the number of applications since the program started in 2022. These students applied from a variety of institutions, ranging from large R1 universities (Berkeley, Illinois) to primarily undergraduate institutions (Rhodes College, Kenyon College), and had a range of majors, including Physics, Mathematics, Computer Science, Electrical Engineering, with many double-majoring in various combinations. In addition to the ~ 20 OQI Fellows per year selected to participate in the program, we can draw on the full applicant pool for recruiting students to the proposed graduate program at OSU.

Ohio State's mission for undergraduate and graduate education plays a crucial role in connecting societal needs and student interests. OSU is leading the development of a quantum minor program at the undergraduate level through the NSF-funded QuSTEAM network (https://qusteam.org/). QuSTEAM is a non-profit, membership-based organization serving a network of academic institutions and industry employers. The purpose is to facilitate the national scale-up of equitable and effective undergraduate quantum education by building and supporting a collaborative network of academic institutions (currently 30+), private sector employers, and a community of instructors. Ohio State has also invested heavily in QISE, including the establishment of CQISE in 2022 and faculty cluster hiring in Physics, Math, Chemistry and Biochemistry and Computer Science Engineering. The establishment of a graduate QISE degree program will help integrate and expand these efforts. Not only will the program spur the development of new QISE courses that will be available for STEM graduate students, but the dissertation research of MS and PHD students in the program will lead to a growing portfolio of new experiential learning opportunities including industry internships.

PROGRAM NARRATIVE - STATEWIDE ALTERNATIVES

Faculty leaders have been polled at other universities in Ohio, including University of Cincinnati, Case Western Reserve and Ohio University. None of these universities currently have QISE degree programs, although all have developed QISE-related courses.

QuGIP will be one of the first dedicated and interdisciplinary MS programs in the U.S., but there are a number of related programs that have launched in the last few years which provide models for the proposed program (c.f. Table). Two close comparison points for the proposed MS program are the MS programs at Univ. Wisconsin and UCLA. Discussion with program leaders at those institutions indicates substantial demand (100+ applications annually) and a steady-state cohort size of ~ 20 *self-funded* Masters students per year. Unlike our program however, these are housed in Physics departments, and thus are not as interdisciplinary as our program is designed to be. Thus, the establishment of a stand-alone MS QISE program at a land-grant institution such as Ohio State will provide a national model for graduate education in this field.

Institution	Degree name	Host Unit (if applicable)	Comments
Univ. Chicago	PhD in Quantum Science and Engineering	Pritzker School of Molecular Engineering	stand-alone, interdisciplinary, launched 2021
Harvard	PhD in QSE	n/a	stand-alone, interdisciplinary, first cohort in AY22-23
USC	MS in QIS	ECE	takes in BS from Chem, CS, ECE, Math, Physics
Univ. Washington	Grad Certificate in QISE	n/a	participating faculty in Phys, Chem, ECE, CSE, MSE
Univ. Wisconsin - Madison	MS Physics - Quantum Computing Specialization	Physics	separate admissions from Physics PhD program, can finish program in 1 calendar year
Univ. Arizona	MS in QISE	Optical Sciences	Specialization within program
George Mason	MS in Physics w/ QISE concentration	Physics	
UCLA	MS of Quantum Science and Technology	Physics & Astronomy	

CO School of Mines	MS in Quantum Engineering	n/a	has hard/soft specializations, also Thesis, nonthesis, certificate versions
Univ. Rhode Island	MS in Quantum Computing	Physics	
Duke	Master of Science, Master of Engineering	ECE	Quantum Software/Hardware specializations as part of the two MS programs

1. **Address appropriateness of specific locale for the new program.**

OSU is centrally located in Ohio, both geographically and scientifically and is a top 10 producer of STEM graduate degrees. OSU also benefits from and contributes to nearby technology hubs, including the new Intel semiconductor fabrication plants in Columbus, and the quantum technology hub being developed with the Chicago Quantum Exchange. Ohio State faculty have a broad portfolio of externally-funded QISE research that will form the basis for dissertation work by students in the new program. These students will also benefit from OSU engagement in emerging institutional networks in QISE, including the Chicago Quantum Exchange, and QuSTEAM, which OSU leads. Lastly, OSU has made substantial investments in this field, including the Center for QISE (launched in 2022), and cluster faculty hiring in QISE (Physics, Chemistry and Biochemistry, Computer Science Engineering, Electrical and Computer Engineering, Mathematics).

2. **Address opportunities for inter-institutional collaboration.**

There are numerous opportunities for collaboration, both in terms of curricular development, and in terms of QISE-related research. At the curricular level, QuGIP faculty will be encouraged to share best practices with other institutions seeking to launch similar programs. There is already a culture of this in the participating departments, evidenced by the QuSTEAM network for example, which develops undergraduate minor curricula and is disseminating these to network partners, including 10+ universities. The breadth of opportunity and the collaborative environment at OSU will ensure that the OSU program maintains unique aspects that will help us compete for students as the number of programs in this field grows.

QuGIP participating faculty have a broad network of research collaborations in QISE-related research, including institutions in Ohio, in the U.S. and internationally. This will provide QuGIP students with a broad variety of research options, and help prepare them to be leaders in the field by being able to collaborate across traditional disciplines.

PROGRAM NARRATIVE - GROWTH OF THE PROGRAM

We currently have NSF training grant funding to launch the program and fund 25 x 1 year fellowships, including full stipend and tuition. These funds are sufficient to launch initial cohorts in the proposed Masters program, and the PhD program to be developed subsequently. The training grant includes funds for staff support, curriculum development and program evaluation. We have funded a number of current OSU graduate students to help pilot program components (e.g. courses, professional development, internships), providing feedback that has informed this program proposal. Our target for sustaining the program after the launch period will be to matriculate 20 self-funded Masters students and 6 PhD students into the program per year. Masters students will be either self- or employer-funded, or will have won other fellowships or scholarships. Returned tuition from Masters students, industry sponsorships and leveraging for external funding will help defray program costs.

	AY24-25	AY25-26	AY26-27	AY27-28	AY 28-29	Sustained (≥AY29-30)
Masters						
# NSF funded students	0	0	2	2	0	0
# self-, OSU- or employer-funded students	0	0	6	10	16	20
PhD						
# NSF funded students	1	5	5	5	5	0
# OSU funded students	0	0	0	0	0	6

CURRICULUM AND INSTRUCTIONAL DESIGN

Program Learning Goals

Learning Goals for MS

At the end of the program, the learner will be able to:

1. Demonstrate fundamental knowledge in quantum information science and engineering (QISE)
   a. Demonstrate quantum advantage using a real-world problem (e.g., how does one algorithm demonstrate quantum advantage over a classical counterpart).
   b. Explain pros and cons of leading physical systems for implementing qubits (e.g., coherence and decoherence).
   c. Explain pros and cons of different approaches for multi-qubit entanglement.
   d. Distinguish different approaches to error correction.
2. Demonstrate the ability to use analytical and computational methods to solve QISE problems (e.g., Python, Qiskit, LMS (e.g., qBraid), IBM Composer).
   a. Quantum circuits.
   b. Disciplinary methods.
3. Be able to connect their coursework to real-world applications in QISE as currently being developed by industry
4. Demonstrate a familiarity with QISE methods based on experiential learning in project rotations or thesis research
5. Be able to discuss course concepts and present research with a broad STEM community.

<u>New graduate courses in QISE</u> (c.f. Appendix for <u>course syllabi</u>).

QISE 7100 - Foundations in QISE (3 cr) will focus on the foundational mathematics and physics needed to describe quantum information and related phenomena.

QISE 7101 – Quantum Circuits and Algorithms (3 cr) is designed to provide students with a broad introduction to quantum computing. Using tools such as IBM Quantum Composer, students from diverse backgrounds will visualize quantum computing concepts, and compare them with classical computing models.

QISE 7102 – Grand Challenges in QISE (3 cr) will focus on grand challenges toward realizing quantum computers, including scalable multi-qubit entanglement, long-distance networking, error correction and algorithms, with a particular focus on physical platforms and their pros/cons.

QISE 7111 – Graduate seminar: Journal Club (1 cr): This student-led seminar-style course will meet once weekly during the term, and will feature regular presentations by students on a journal article of current interest. Students will gain experience in presenting technical content to a multi-disciplinary audience.

QISE 7112 – Graduate seminar: Professional Development (1 cr): This seminar-style course will feature a variety of discussions including aspects of professional skills (e.g., writing and presentation skills, literature research) and ethical questions posed by QISE (e.g. quantum cryptography).

QISE 7113 – 1st year research rotation (1.5 credits): This course will introduce students to research techniques through a 7 week experience with one of the QuGIP faculty advisors. This course may be repeated in 1.5 credit increments for multiple rotations, or taken for 3 or 4.5 credits for a more sustained effort during one rotation.

Degree requirements – MS in QISE

Course requirements: A minimum of 30 credit hours will be required for Masters degree recipients. These requirements are consistent with the OSU Graduate School, and national expectations for graduate education in related STEM fields. As summarized in the tables below, the course requirements include foundational graduate coursework, seminar-style professional development (ethics, writing, journal club), and experiential learning (research, internships). All of the courses will be delivered in person. Two Masters options will be offered. Option A is a course-focused Masters, which will include foundational and elective coursework, and two 7-week research rotations (3 total credits) focused on learning and applying research methods to specific, well-defined problems. Option B is a thesis-based Masters, which will feature the same foundation of four courses (QISE 7100-7012 plus a computational methods course), but will replace some elective coursework with a greater emphasis on experiential learning through research rotations, followed by a sustained period for thesis research with a specific faculty advisor.

As an introduction to elements of responsible conduct in research, Option A students will take the CITI RCR training offered through the university. As option B is a thesis-based Masters, with a greater focus on research, these students are required to take GRADSCH 8000 to develop a solid foundation for responsible conduct in research.

Time to degree: Depending on their preparation and career goals, the Masters degree program can be completed by students in 3-6 semester terms, typically 1-2 academic years. Though there are some variations in the elective courses by program Specialization, these will not impact the overall time to degree for the students. In addition to coursework, Masters students pursuing the thesis option will have a 1-2 term period for experiential learning, including research with a faculty advisor and/or industry internship. Students will be enrolled in the program full-time, and will be supported with fellowships in their first year, and with Research or Teaching Assistantships in following years, depending on the Departmental affiliation of their primary faculty advisor. Masters students wishing to transition into the PhD program may do so with permission of the QuGIP Graduate Studies Committee (QGSC).

MS in QISE Curriculum

Required core courses for degree: MS			
course # **(red = new course)**	**Course Title**	**Credits for non-thesis**	**Credits for thesis based**
QISE 7100 (and cross-lists)	Foundations in QISE	3	3
QISE 7101 (and cross lists)	Quantum Circuits and Algorithms	3	3
QISE 7102 (and cross lists)	Grand Challenges in QISE	3	3
PHY 6810, CHEM 6540, MATSCEN 6756.72, CSE 6321, ECE 5510, MATH 6601	Computational/Numerical Methods	1	1
QISE 7111	Journal club	2	2
QISE 7112	Professional development seminar	2	2
QISE 7113	1st year Research Rotations	3	6
XXXX-7999	Thesis research	0	10
GRADSCH 8000	Responsible conduct in research	0	1

Specializations: While the core course requirements are the same for all students in the program, choice of specialization will guide the choices of the required computational methods course, elective courses and the faculty advisors for research rotations. Students will choose from one of four transcriptable specializations:

1) The *Quantum Computing* specialization is focused on the development, implementation and scaling of quantum algorithms and associated hardware for solving complex problems and error correction.

Specialization	**Example electives (# cr)**
Quantum Computing	CSE 6429 Advanced Computer Architecture (1-3); ECE 7005 Information Theory (3); MATH 6251 Theory of Probability (4), MATH 5801 General topology and knot theory (3), ECE 6531 Semiconductor Devices (3), ECE 7022 Advanced RF integrated circuits (3), MATSCEN 6295 Superconducting Materials and Properties (2), PHY 5680 Big Data Analysis in Physics (3),

2) The *Quantum Networking and Communication* specialization is focused on the transportation and multiplexing of quantum information using elements such as photonics and microwave cavities.

Specialization	**Example electives (# cr)**
Quantum Networking and Communication	ECE 6511 Nonlinear Optics (3), CSE 6469 Advanced Studies in Computer networking (1-3); CSE 6422 Advanced Computer Architecture (3), Physics 8820 Special topics: Atomic, molecular and optical physics (3), MATSCEN 6777 Electronic properties of materials (2), ECE 6010 EM Field Theory (3), ECE 6101 Computer Communication Networks (3)

3) The *Quantum Simulation* specialization is focused on quantum-enabled methods to better understand physical systems whose complexity exceeds even the best classical high performance computing algorithms.

Specialization	**Example electives (# cr)**
Quantum Simulation	MATH 6801 Algebraic Topology (3); MATH 6151 Commutative Algebra (3); PHY 8820 Special Topics: Quantum information theory (3), ECE 5200 Digital Signal Processing (3), ECE 5307 Machine Learning (4), MATSCEN 6756 Computational Materials Modeling (2), CSE 6521 Artificial Intelligence (3),

4) The *Quantum Materials and Sensing* specialization is focused on the physical materials (solid state and molecular) used for quantum bits, sensors and storage.

Specialization	**Example electives (# cr)**
Quantum Materials and Sensing	MATSCEN 7835 Point Defects in Crystalline Materials (2); PHY 8806 Topics in Condensed Matter Physics (3); CHEM 6510 Quantum Mechanics and Spectroscopy (1.5) , CHEM 6540 Electronic Structure (1.5), CHEM 7370 Nanochemistry and Nanomaterials (1.5), ECE 5033 Surfaces and Interfaces of Electronic Materials (3),

These tables are not an exhaustive list of courses, and requests for additional courses will be reviewed by the QGSC each semester.

<u>Course-based Masters</u> students are required to complete 3 elective courses, including 2 within the list for their specialization. The third elective course can be chosen from the list of electives

for one of the other specializations, or any (PHY 6000+, MATSCEN 6000+, ECE 5000+, CHEM 6000+, CSE 5000+, MATH 6000+) course with permission of the QGSC. Students will also choose research rotations with faculty whose expertise aligns with their specialization.

Thesis-based Masters students are required to complete 1 elective course from the list for their specialization. Students will also choose research rotations and thesis research with faculty whose expertise aligns with their specialization.

Example progress in MS program:

MS		# cr		# cr		# cr		# cr
	Y1-Au		Y1-Sp		Y1-Su		Y2+	
Common core	QISE 7100	3	QISE 7101	3				
	Comp. Methods	3	QISE 7102	3				
	QISE 7111	1	QISE 7111	1				
	QISE 7112	1	QISE 7112	1				
Course-based	Elective #1	4	QISE 7113	3				
	Elective #2	4	Elective #3	3				
	TOTAL	16		14				
	Cumulative	16		**30**				
Thesis-based	QISE 7113	3	QISE 7113	3	Research - 7999	6	Research - 7999	TBD
	GRADSCH 8000	1	Elective #1	3	QISE 7111	1	QISE 7111	1
	TOTAL	12		14				
	Cumulative	12		26		**33**		**34+**

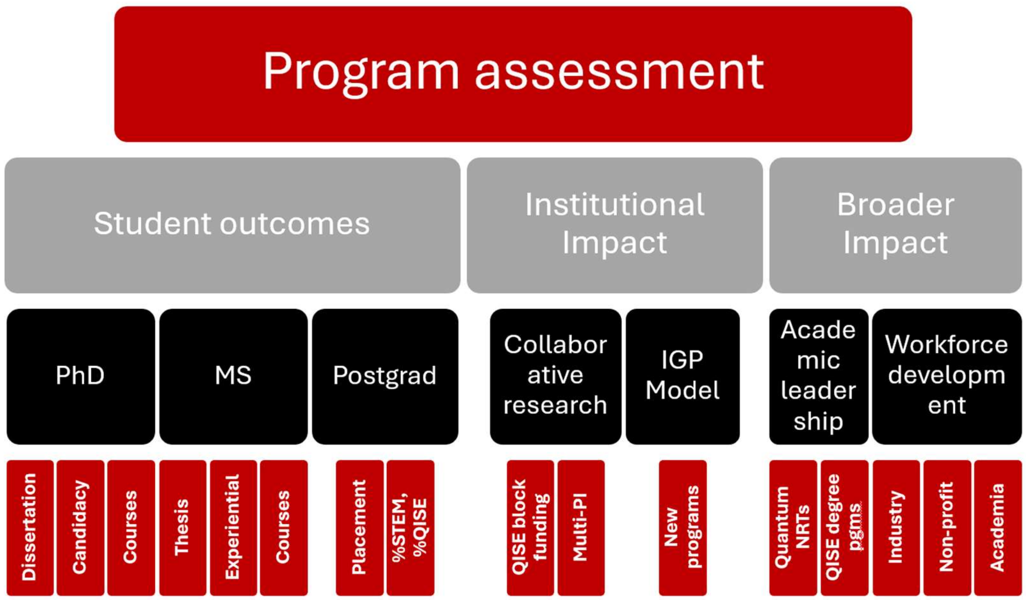
Culminating experience: Masters in QISE: Masters degree recipients will have demonstrated strong academic performance in the core coursework listed above, and will have gained professional skills in communication, ethics and interdisciplinary collaboration through seminar-style courses and program events.

In the course-focused track, students will complete a short-format oral exam with a committee of two QuGIP faculty. The exam will consist of course-related questions, probing understanding of fundamental concepts in QISE. The degree will be considered complete upon successful completion of this exam and the required courses.

Thesis-based Masters students will conduct 1+ semesters of sustained research on a project developed in consultation with a faculty advisor, or an industry internship. The culminating requirement for these students will be a thesis document (typically 20-50 pages) with an introduction that builds on course concepts and places the results and methodologies of the research/internship experience in the context of the field as a whole. The Masters candidate will defend this document in a short-format oral exam to a committee of 2-3 program faculty. The exam will comprise a ~15min presentation by the student on their research results and methodologies, followed by questions from the committee.

Program Assessment Plan

As shown here, the QuGIP program will be assessed in terms of *student outcomes*, *institutional impact* within OSU, and *broader impact* at the national level. For example, student outcomes will be assessed through course grades, thesis document and oral defense. Both formative and summative rubrics will be used for thesis and defense (discussed further below). Institutional impact will be assessed by tracking extramural funding among QuGIP participating faculty and students, including programs in QISE and non-QISE. More broadly, program components will be disseminated through workforce and academic networks, thus contributing to a rapidly-developing, nationwide infrastructure for QISE.



Assessment data will be compiled by several QuGIP stakeholders. The QuGIP *Graduate Studies Committee* will be tasked with assessing the quality of the applicant pool and curating collected data including demographic information, applicant institutions, Bachelors fields of study, GPAs, prior research experience, and Specialization interest. These data will be collected by the QuGIP *Program Coordinator.*

In addition, the NSF NRT award has subaward funding reserved for the development of initial program assessment by Strategic Evaluations, Inc. (SEI). SEI is a HUB-certified evaluation consulting firm located in Durham, North Carolina specializing in evaluating science education grants, particularly training grants. SEI will help the QuGIP team develop an assessment infrastructure that can then be sustained locally after the NSF NRT award ends in AY28-29, such as the following:

Expected Student, Faculty Teaching, and Institutional Competencies and Outcomes: The program leaders will work with SEI to document and measure targeted competencies and outcomes for stakeholders such as:

Trainees

- Increase QISE knowledge and technical skills
- Increase skills in ethics, technical writing, and communication
- Increase students' self-efficacy, science identity and sense of belonging
- Increased growth mindset

Faculty Instruction/Mentorship

- QISE courses and research opportunities utilize best practices and pedagogies, and and are aligned to students' long-term career interests (via Drake Institute)
- Instruction promotes a growth mindset across faculty and trainees in the QISE graduate program
- High quality mentorship (research mentors required to participate in mentorship training)
- Increased recruitment and training of students in QISE research projects in faculty labs
- Strengthened interdisciplinary research/course development

Institution

- Development of a QISE Graduate Interdisciplinary Program at OSU
- Industry partnerships result in graduate internships and sponsored research
- Relationships between participating departments are strengthened

During Year 1, the evaluation team will work closely with project leaders to further develop a project logic model and related evaluation framework that will serve as the guide for activities and the key metrics for documenting outcomes.

Table 2. Evaluation framework for QuGIP Logic Model

Sample Evaluation Questions for OUTCOMES	Possible Indicators/Measures	Possible Data Collection Methods and Information Sources
1. To what extent is the program able to garner buy-in from participating departments and industry partners? 2. Is the program able to obtain approvals from all the necessary groups and in a timely manner to launch new courses? 3. To what extent to the members/key stakeholders work together towards effectively and efficiently a common goal? 4. Is the program able to recruit its targeted number trainees, and retain these trainees to obtain terminal degrees (20% Master's/60%PhD/20%Other)? 5. Do students who participate in QISE courses exit with more confidence, stronger lab abilities, greater content knowledge, and higher interest in completing a degree/certificate program in QISE? 6. To what extent does participation increasae students' ethics, technical writing, and communication skills? 7. Does participation in the QISE interdisciplinary degree program lead to a sense of belonging and greater confidence that students are well prepared for the emerging careers in QISE? 8. To what extent are QISE courses inclusive and based on a "growth mindset"? 9. To what extent are trainees provided inclusive and convergent QISE	• Documentation of approval of QuGIP courses/curriculum • Documentation of trainees in OSU labs/industry partner training • Documentation of numbers of students enrolled in QISE courses and of students' obtaining QISE degrees, certifications, etc. • Documentation of job application data • Student self-report of content knowledge, research skills, job competitiveness, and career interest (pre/post) • Research mentors/industry mentors' ratings of trainees' QISE knowledge and skills and career preparedness • Student and course instructors' ratings of the inclusiveness of the courses and extent to which courses include a "growth mindset" (post course) • Student self-report of interest in QISE careers • Measure of working of the program partnership (Partnership self-assessment tool)	OSU Departments/Graduate School ▪ Records of approval of QuGIP courses/curriculum ▪ Records of departments accepting trainees in research labs/training ▪ QISE course enrollment records ▪ Records of QISE degrees/certificates earned Industry Partners ▪ Records of partners accepting trainees in labs/training Student Trainees ▪ Document course enrollment ▪ Track students' thoughts on program, growth in research self-efficacy, sense of belonging, growth in knowledgge and career interests and preparedness on pre- and post-surveys ▪ Document students' thought on the inclusiveness of courses and extent to which courses include a "growth mindset" (post-course survey and focus group interviews) ▪ Qualitively document quality and impact of courses/research opportunties as well as suggested improvement through focus group interviews Research Mentors/Industry Mentors ▪ Document students' growth in QISE knoweldge, skills and job preparedness via surveys Course Instructors ▪ Document students' thought on the inclusiveness of courses and extent to

The evaluation timeline of performance measures is presented in the Table below:

Performance Measures Timeline	Yr1	Yr2	Yr3	Yr4	Yr5
Finalizing of logic model / competency tools to be embedded in project	X				
Structuring of Year-by-year evaluation plan in alignment with logic model (with monthly calendar of deliverables)	X	X	X	X	X
Document analysis (e.g. participation, degrees earned, internal course evaluations, student interests, industry needs, curriculum development)		X	X	X	X
Instrument development (e.g., trainees' baseline survey, trainees' annual/exit survey, research/industry mentors survey, partnership survey, trainees' and course instructors' focus group protocols)		X			
Partnership self-assessment	X		X		X
Trainees' surveys/assessments (baseline upon entering and annually until exiting)			X	X	X

Research/industry mentors' surveys (end of every trainee's internship/IDP)			X	X	X
Faculty surveys (when piloting a new course)			X	X	X
Focus group in-depth feedback on new course from trainees (after first implementation)			X		
Focus group in-depth feedback on new course from instructors (after second implementation to specialization improvements)				X	
Reporting/Communicating Evaluation Results (website, IAC meetings annually, etc.)	X	X	X	X	X

Feedback Mechanisms for Improving Practice: Four reporting and data sharing strategies will be included in the evaluation to facilitate QuGIP leaders' ability to assess progress in a timely manner, make any necessary mid-course adjustments, and report findings to outside stakeholders.

- Monthly Evaluation Update Calls - The evaluation team will lead monthly update calls in which program data will be shared across the partnership.
- Formative Evaluation Data Throughout – There are several surveys and focus group interviews planned across the 5 years. Data tables with evaluator's comments will be shared with the program at the conclusion of each data collection period (e.g., annually for partnership self-assessment survey, once a year with each new cohort for baseline trainee survey, etc.)
- Annual Summative Evaluation Report - As is customary, the evaluation team will prepare annual executive summary reports detailing all evaluation activities and findings, along with recommendations from stakeholders for improvement. At the end of the final project year, the external evaluation team will submit a summative evaluation report detailing the extent to which the project achieved its goals.

Program Academic Assessment Plan

As discussed in the Program Learning Goals above, we have identified a specific series of Learning Goals for MS students. The extent to which these goals are met by students in the program will be assessed in several ways.

Course assessments: Each course (c.f. course syllabi in the Appendix) has its own set of learning goals and a concrete plan for how these will be assessed through course components such as presentations, written exams and homework problems.

MS thesis and defense: rubrics (c.f. Appendix) will be used to assess the extent to which the MS thesis document and oral defense reflect Program Learning Goals.

The table here illustrates how program components provide targeted assessment of the program learning goals articulated above.

	MS
Program Component	Learning goals
QISE 7100	2
QISE 7101	1d
QISE 7102	1a-d,3
QISE 7111	5
QISE 7112	5
QISE 7113	4
XXXX-7999 research	4
Computational	2
Professional	3,5
Candidacy	n/a
Internship	n/a
Thesis	1-5

INSTITUTIONAL STAFFING, FACULTY AND STUDENT SUPPORT

Faculty

As listed in the Appendix, we have assembled a team of 30+ participating faculty during this initial phase of the program, drawn from the six participating Departments. These faculty were selected based on their track records of QISE-related research (including externally-funded programs), commitment to evidence-based teaching and curriculum development, and all have ‘P’ status for graduate advising. This broad participation is essential for matching applicant interests to faculty advisors’ expertise and availability. Although no faculty will be hired as a result of this new graduate program, there are significant synergies with recent cluster hiring in quantum science in the participating departments, including new hires in Chemistry and Biochemistry (Prof. Joe Zadrozny), Math (Prof. Kaifeng Bu), and Physics (Prof. Kevin Singh), and anticipated searches in

Electrical and Computer Engineering, and Computer Science Engineering. Faculty wishing to join the program will submit an application detailing their QISE-related research experience or future interests, and their track record or plans for external funding and graduate advising. These applications will be reviewed by the QuGIP Graduate Studies Committee.

Administration and support

The OSU Center for Quantum Information Science and Engineering (CQISE) will be the administrative home for the new graduate program. The Program Director (Professor Jay Gupta, Physics) will be the lead program manager, responsible for fund raising, unit MOUs and stakeholder reporting. The principal administrative staff will be a Program Coordinator (position housed in CQISE), whose duties will include program financial and progress reporting, admissions, website maintenance, event planning and team communication. Admissions will be conducted by a Graduate Admissions Committee, comprising faculty from each of the six participating Departments. Student progress monitoring will be the responsibility of a Graduate Studies Committee, also comprising faculty from the participating Departments, as well as 1-2 student representatives. Oversight of the program will be provided by (i) an OSU Advisory Board, comprising unit leaders at the Department, College, Grad School and OAA levels and (ii) an Independent Advisory Board (Chair, Dr. Chris Porter, IBM Quantum) comprising external leadership in academia, industry and national labs.

Sufficient funding for the program through AY 28-29 is provided through an NSF training grant (budget: $3M / 5 years from 2023-2028 + planned 1 year no-cost extension). As described in the Appendix, NSF funding includes 1 yr fellowships for 25 trainees over the 5 year launch phase, the program coordinator position, curriculum development (faculty teaching buyout, OSU Drake Institute of Teaching and Learning) and program evaluation (Strategic Evaluations LLC.). In subsequent years, MS students will be self-funded; returned tuition from these students will be used to cover program costs. This is outlined more fully in the Appendix.

The Ohio State University

Proposal for an Interdisciplinary Graduate Program in Quantum Information Science and Engineering

APPENDIX

Table of Contents

Faculty Matrix

Name	Rank or Title	Department	Instructor Qualification			Role in program: RA = Research advisor; CCI = Core course instructor, ECI = Elective Course Instructor
			Degree Title, Discipline, Institution, Year	Teaching experience (yrs)	Additional qualifications	
Jay Gupta	Professor	Physics	PhD, Physics, UCSB 2002	20	Quantum surface science, Vice Chair for Graduate Studies (Physics)	Program administration, RA, ECI
Kaveh Ahadi	Assistant Professor	Materials Science and Engineering	PhD, Materials Science, UCSB, 2019	4	Epitaxy of quantum materials	RA, ECI
Shamsul Arafin	Assistant Professor	Electrical and Computer Engineering	PhD, Electrical Engineering, Technical University of Munich, 2012	6	Semiconductor optoelectronics and quantum point defects	RA, ECI
Syedah Zahra Atiq	Assistant Professor of Practice	Computer Science and Engineering	Ph.D., Engineering Education (College of Engineering), Purdue University, 2019	10+	Non-cognitive factors influencing student learning of programming	Curriculum Development
Robert Baker	Professor	Chemistry and Biochemistry	PhD, Chemistry, UC Berkeley, 2012	10	Ultrafast chemical physics	General interest
Daniel Brandenburg	Assistant Professor	Physics	PhD, Rice University, 2018	1	Experimental nuclear physics	CCI, ECI
Jackie Chini	Associate Professor	Physics	PhD, Physics, Kansas State University, 2010	15	Improving participation in Physics via Education Research	RA
Michael Chini	Associate Professor	Physics	PhD, Physics, University of Central Florida, 2012	8	Experimental ultrafast laser atomic physics	RA, ECI

Enam Chowdhury	Assistant Professor	Materials Science and Engineering/Electrical and Computer Engineering	University of Delaware 2004	5	Ultrafast laser-matter interactions	ECI
Geraldine Cochran	Associate Professor	Physics	PhD, Curriculum & Instruction/ Cognate: Physics, FIIU 2013	11	Identifying barriers to URM participation in Physics	ECI
Dan Gauthier	Professor	Physics	Ph.D., Optics, University of Rochester, 1989	31	Quantum computing and communication, Fellow, Optica and the American Physical Society	RA
Tyler Grassman	Associate Professor	Materials Science and Engineering	PhD, Materials Science and Engineering, UC San Diego, 2007	8	Materials integration for electronic and photonic technologies	RA, ECI
Andrew Heckler	Professor	Physics	PhD Physics, University of Washington, 1994	35	Quantitative modeling of learning and assessment	ECI, Building Curriculum, curricular materials
Zeke Johnston-Halperin	Professor	Physics	PhD Physics, UCSB 2003	18	Quantum transduction via magnetism. PI of NSF QuSTEAM network.	RA, CCI, ECI, Lead Industry Engagement
Thomas Kerler	Professor	Math	PhD, Theoretical Physics, ETH Zürich	35+	Topology and Quantum Field Theories	ECI, Support for Mentoring & DEI Programs;
Bern Kohler	Professor and Ohio Eminent Scholar	Chemistry and Biochemistry	PhD, Physical Chemistry, MIT 1990	29	Ultrafast photochemical dynamics	RA, ECI
Alexandra Landsman	Associate Professor	Physics	PhD, Princeton 2005	9	Theory of ultrafast laser/matter interactions	RA, CCI, ECI
Yuanming Lu	Associate Professor	Physics	PhD, Physics, Boston College, 2011	9	Quantum matter and topology	RA, CCI, ECI
Roberto Myers	Professor	Materials Science and Engineering	PhD, Materials, UCSB 2006	16	Magneto/opto electronics of quantum point defects	RA, CCI, ECI
David Penneys	Associate Professor	Math	PhD Mathematics, UC Berkeley 2012	19	Mathematics of topological qubits	RA, CCI, ECI

Ronald Reano	Professor	Electrical and Computer Engineering	PhD, Electrical Engineering, University of Michigan 2004	19	Quantum photonics	RA, CCI, ECI
Salva Salmani-Rezaie	Assistant Professor	Materials Science and Engineering	PhD, Materials Science , UCSB 2021	1	Atomic resolution microscopy of quantum defects	RA, ECI
Kevin Singh	Assistant Professor	Physics	PhD, Physics, UCSB 2019	1	Neutral atom quantum computation and simulation	RA, CCI, ECI
Brian Skinner	Assistant Professor	Physics	PhD, Physics, University of Minnesota 2011	4	Theory of quantum materials	RA, ECI
Alexander Sokolov	Associate Professor	Chemistry and Biochemistry	Ph.D., Chemistry, UGA, 2014	7	Quantum computational chemistry	RA
Fernando Teixeira	Professor	Electrical and Computer Engineering	PhD, Electrical Engineering, University of Illinois, 1999	24	Computational electromagnetics	RA, ECI
Nandini Trivedi	Professor	Physics	PhD, Physics, Cornell 1987	30	Quantum phase transitions	RA, CCI, ECI
Wolfgang Windl	Professor	Materials Science and Engineering	Dr. rerum naturalium, Physics, University of Regensburg, Germany, 1995.	22	Computational materials science; Industrial experience: Principal Staff Scientist at Motorola (1997-2001); co-founder and VP of device company GonioTech (current).	RA, CCI, ECI
Joe Zadrozny	Associate Professor	Chemistry and Biochemistry	PhD, Chemistry, UC Berkeley 2013	6	Magnetic resonance of molecular qubits	RA, ECI
Zhihui Zhu	Assistant Professor	Computer Science and Engineering	PhD, Electrical Engineering, Colorado School of Mines 2017	4	Theoretical data science	RA

Faculty CVs

Included here are 2pg CVs for all participating faculty listed in the Faculty Matrix

NSF BIOGRAPHICAL SKETCH

Provide the following information for the Senior personnel.
Follow this format for each person. **DO NOT EXCEED 3 PAGES.**

IDENTIFYING INFORMATION:

NAME: Ahadi, Kaveh

ORCID: 0000-0003-2280-4037

POSITION TITLE: Assistant Professor

ORGANIZATION AND LOCATION: The Ohio State University, Columbus, OH, U.S.A

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	DATE RECEIVED	FIELD OF STUDY
University of California Santa Barbara, Santa Barbara, CA, US	Ph.D.	12/2019	Materials
University of Alberta, Edmonton, AB, CA	M.Sc.	12/2015	Materials
Sharif University of Technology, Tehran, IR	M.Sc.	09/2012	Materials
Islamic Azad University , Karaj, Karaj, IR	B.Sc	09/2010	Materials

Appointments and Positions

2023 - present Assistant Professor, The Ohio State University, Columbus, OH, U.S.A

2020 - 2023 Assistant Professor, North Carolina State University, Raleigh, NC, U.S.A

Products

Products Most Closely Related to the Proposed Project

1. Schwaigert T, Salmani-Rezaie S, Barone MR, Paik H, Ray E, Williams MD, Muller DA, Schlom DG, Ahadi K. Molecular beam epitaxy of KTaO3. Journal of Vacuum Science & Technology A. 2023 February 03; 41(2):022703. Available from: https://avs.scitation.org/doi/full/10.1116/6.0002223
2. Arnault EG, Al-Tawhid AH, Salmani-Rezaie S, Muller DA, Kumah DP, Bahramy MS, Finkelstein G, Ahadi K. Anisotropic superconductivity at $KTaO_3$(111) interfaces. Sci Adv. 2023 Feb 15;9(7):eadf1414. PubMed Central PMCID: PMC9931206.
3. Al-Tawhid AH, Kanter J, Hatefipour M, Irving DL, Kumah DP, Shabani J, Ahadi K. Oxygen vacancy-induced anomalous Hall effect in a nominally non-magnetic oxide. Journal of Electronic Materials. Winter 2022; 51(12):7073-7077. Available from: https://link.springer.com/article/10.1007/s11664-022-09941-9
4. Al-Tawhid AH, Kanter J, Hatefipour M, Kumah DP, Shabani J, Ahadi K. Superconductivity and Weak Anti-localization at KTaO3 (111) Interfaces. Journal of Electronic Materials. 2023 August 19; 51:6305–6309. Available from: https://link.springer.com/article/10.1007/s11664-022-09844-9

5. Al-Tawhid A, Kumah D, Ahadi K. Two-dimensional electron systems and interfacial coupling in LaCrO3/KTaO3 heterostructures. Applied Physics Letters. 2021 May 10; 118(19):192905-. Available from: https://aip.scitation.org/doi/10.1063/5.0049119 DOI: 10.1063/5.0049119

Other Significant Products, Whether or Not Related to the Proposed Project

1. Salmani-Rezaie S, Ahadi K, Stemmer S. Polar Nanodomains in a Ferroelectric Superconductor. Nano Lett. 2020 Sep 9;20(9):6542-6547. PubMed PMID: 32786945.
2. Mori R, Marshall PB, Ahadi K, Denlinger JD, Stemmer S, Lanzara A. Controlling a Van Hove singularity and Fermi surface topology at a complex oxide heterostructure interface. Nat Commun. 2019 Dec 4;10(1):5534. PubMed Central PMCID: PMC6892806.
3. Ahadi K, Galletti L, Li Y, Salmani-Rezaie S, Wu W, Stemmer S. Enhancing superconductivity in $SrTiO_3$ films with strain. Sci Adv. 2019 Apr;5(4):eaaw0120. PubMed Central PMCID: PMC6486228.
4. Kim H, Marshall PB, Ahadi K, Mates TE, Mikheev E, Stemmer S. Response of the Lattice across the Filling-Controlled Mott Metal-Insulator Transition of a Rare Earth Titanate. Phys Rev Lett. 2017 Nov 3;119(18):186803. PubMed PMID: 29219551.
5. Ahadi K, Stemmer S. Novel Metal-Insulator Transition at the SmTiO_{3}/SrTiO_{3} Interface. Phys Rev Lett. 2017 Jun 9;118(23):236803. PubMed PMID: 28644662.

Synergistic Activities

1. Developing semiconductor industry decadal roadmap with Semiconductor Research Corp (SRC) and National Institute of Standard and Technology (NIST).
2. Member of Materials Research Society, American Physical Society, American Ceramics Society, and American Vacuum Society.
3. Reviewer for several journals including Science Advances, Nature Communications, Applied Physics Letters, Physical review letter, Materials Letter, Journal of Alloys and Compounds.
4. Developing graduate course (Modern Concepts in Materials Science) and coauthoring a review article on topological materials (Materials Science and Engineering: R: Reports 145, 100620, 2021)
5. Symposium organizer in MRS Spring and APS March Meetings.

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Ahadi, Kaveh in SciENcv on 2023-07-01 13:46:40

IDENTIFYING INFORMATION:

NAME: Arafin, Shamsul

ORCID iD: https://orcid.org/0000-0003-4689-2625

POSITION TITLE: Assistant Professor

PRIMARY ORGANIZATION AND LOCATION: The Ohio State University , Columbus, Ohio, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Technical University of Munich, Munich, Not Applicable, N/A, Germany	PHD	02/2012	Electrical Engineering
Ulm University, Ulm, Not Applicable, N/A, Germany	MENG	04/2008	Electrical Engineering
Bangladesh University of Engineering and Technology, Dhaka, Not Applicable, N/A, Bangladesh	BS	07/2005	Electrical and Electronic Engineering

Appointments and Positions

2018 - present	Assistant Professor, The Ohio State University , Columbus, Ohio, United States
2014 - 2018	Assistant Project Scientist, University of California Santa Barbara, Santa Barbara , California, United States
2013 - 2014	Postdoctoral Research Scholar, University of California Los Angeles , Los Angeles , California, United States
2012 - 2012	Postdoctoral Fellow, McGill University, Montreal, Quebec, QC, Canada

Products

Products Most Closely Related to the Proposed Project

1. Saha S, Sankar S, Nikor S, Arafin S. A Review of Intercalation of Rare Gas Solids on Graphene and Hexagonal Boron Nitride. physica status solidi (RRL) – Rapid Research Letters. 2023 June 20; :-. Available from: https://onlinelibrary.wiley.com/doi/10.1002/pssr.202300066 DOI: 10.1002/pssr.202300066
2. Hasan S, You W, Ghosh A, Sadaf S, Arafin S. Selective Area Epitaxy of GaN Nanostructures: MBE Growth and Morphological Analysis. Crystal Growth & Design. 2023 May 16; 23(6):4098-4104. Available from: https://pubs.acs.org/doi/10.1021/acs.cgd.2c01506 DOI: 10.1021/acs.cgd.2c01506
3. Mahafuzur Rahaman M, Saha S, Hasan S, You W, Ghosh A, Saiful Islam Sumon M, Shafaat Saud Nikor S, Freeman B, Sankar S, Colijn H, Md. Sadaf S, Garg J, Arafin S. Luminescence and Raman spectroscopic properties of cubic boron nitride grown by drop-casting technique. Journal of Crystal Growth. 2022 September; 593:126781-. Available from: https://linkinghub.elsevier.com/retrieve/pii/S002202482200269X DOI:

10.1016/j.jcrysgro.2022.126781

4. Saha S, Chang Y, Yang T, Rice A, Ghosh A, You W, Crawford M, Lu T, Lan Y, Arafin S. Sub-bandgap photoluminescence properties of multilayer h-BN-on-sapphire. Nanotechnology. 2022 February 28; 33(21):215702-. Available from: https://iopscience.iop.org/article/10.1088/1361-6528/ac5283 DOI: 10.1088/1361-6528/ac5283
5. Saha S, Rice A, Ghosh A, Hasan S, You W, Crawford M, Bissell L, Bedford R, Arafin S. Characterization and Analysis of Large-Area h-BN on Sapphire. 2021 IEEE Research and Applications of Photonics in Defense Conference (RAPID). 2021 IEEE Research and Applications of Photonics in Defense Conference (RAPID); ; Miramar Beach, FL, USA. IEEE; c2021. Available from: https://ieeexplore.ieee.org/document/9521461/ DOI: 10.1109/RAPID51799.2021.9521461

Other Significant Products, Whether or Not Related to the Proposed Project

1. Ghosh A, Dominic Merwin Xavier A, Hasan S, Rahman S, Blackston A, Allerman A, Myers R, Rajan S, Arafin S. Low voltage drop AlGaN UV-A laser structures with transparent tunnel junctions and optimized quantum wells. Journal of Physics D: Applied Physics. 2023 October 26; 57(3):035105-. Available from: https://iopscience.iop.org/article/10.1088/1361-6463/ad039c DOI: 10.1088/1361-6463/ad039c
2. Sumon M, Sankar S, You W, Faruque I, Dwivedi S, Arafin S. Design of GaSb-based monolithic passive photonic devices at wavelengths above 2 μm. Journal of Physics: Photonics. 2023 July 18; 5(3):035005-. Available from: https://iopscience.iop.org/article/10.1088/2515-7647/ace509 DOI: 10.1088/2515-7647/ace509
3. You W, Dwivedi S, Faruque I, John D, McFadden A, Palmstrom C, Coldren L, Arafin S. Toward GaSb-Based Monolithically Integrated Widely-Tunable Lasers for Extended Short- and Mid-Wave Infrared Wavelengths. IEEE Journal of Quantum Electronics. 2023; 59(1):1-9. Available from: https://ieeexplore.ieee.org/document/10017255/ DOI: 10.1109/JQE.2023.3236395
4. M N Hasan S, Ghosh A, Md Sadaf S, Arafin S. Effects of InGaN quantum disk thickness on the optical properties of GaN nanowires. Journal of Crystal Growth. 2022 June; 588:126654-. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0022024822001427 DOI: 10.1016/j.jcrysgro.2022.126654
5. Arafin S, McFadden A, Paul B, Hasan S, Gupta J, Palmstrøm C, Coldren L. Study of wet and dry etching processes for antimonide-based photonic ICs. Optical Materials Express. 2019 March 18; 9(4):1786-. Available from: https://opg.optica.org/abstract.cfm?URI=ome-9-4-1786 DOI: 10.1364/OME.9.001786

Synergistic Activities

1. • Subcommittee Chair in 6-Materials, Foundries and Fabrication (MFF) within IEEE Photonics Conference 2023 (annual meeting), Orlando, FL, USA
   • General Chair, Optica's Advanced Photonics Congress, IPR 2022, Maastricht, Netherlands.
   • Technical Program Committee in 28th International Semiconductor Laser Conference 2022, Matsue, Japan
   • Technical Program Committee in "S&I3 Semiconductor Lasers" in Optica's CLEO 2022, San Jose, CA, USA

• Subcommittee Chair in Optoelectronics and Integrated Photonics in Compound Semiconductor Week (CSW) 2022, Ann Arbor, Michigan, USA.
• Guest Editor of the Feature Issue on “Mid-Infrared Lasers for Medical Applications” in Biomedical Optics Express, OSA, 2018

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Arafin, Shamsul in SciENcv on 2023-11-25 11:34:25

IDENTIFYING INFORMATION:

NAME: Atiq, Syedah Zahra

ORCID iD: https://orcid.org/0000-0002-7905-2553

POSITION TITLE: Assistant Professor of Practice

PRIMARY ORGANIZATION AND LOCATION: The Ohio State University, Columbus, Ohio, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Purdue University, West Lafayette, Indiana, United States	PHD	08/2019	Engineering Education
Lahore University of Management Sciences, Lagore, Not Applicable, N/A, Pakistan	MS	05/2005	Computer Science

Appointments and Positions

2019 - present Assistant Professor of Practice, The Ohio State University, Columbus, Ohio, United States

Products

Products Most Closely Related to the Proposed Project

1. Atiq Z, Loui M. A Qualitative Study of Emotions Experienced by First-year Engineering Students during Programming Tasks. ACM Transactions on Computing Education. 2022 June 09; 22(3):1-26. Available from: https://dl.acm.org/doi/10.1145/3507696 DOI: 10.1145/3507696
2. Villanueva Alarcón I, Anwar S, Atiq Z. How multi-modal approaches support engineering and computing education research. Australasian Journal of Engineering Education. 2023 December 30. Available from: https://www.tandfonline.com/doi/full/10.1080/22054952.2023.2274513
3. Batra R. Work in Progress: Understanding CS1 Students’ Code Comprehension Behaviors using Multi-modal Data. Minneapolis, MN: ASEE Annual Conference & Exposition; 2022 June.
4. Awasthi S, Batra R, Atiq Z. Validation of the Programming Emotions Questionnaire. Providence, RI: Proceedings of the 53rd ACM Technical Symposium on Computer Science Education; 2022 March.
5. Batra R, Atiq Z. Understanding Students' Frustration and Confusion during a Programming Task: A Multimodal Approach. College Station, Tx: IEEE Frontiers in Education; 2023.

Other Significant Products, Whether or Not Related to the Proposed Project

Synergistic Activities

1. As the PI for the NSF funded grant (Award Abstract # 2104729), I have been mentoring one Ph.D. student and 5 undergraduate researchers.Self-Efficacy of Novice Students during Programming Tasks: A Multi-Modal Approach.
2. With my collaborators (University of Florida) and (Texas A&M), I conducted a panel on multi-

modal methodology at the IEEE Frontiers in Education conference, held at College Station, TX in Oct 2023.

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Atiq, Syedah Zahra in SciENcv on 2024-01-14 19:26:08

L. Robert Baker, The Ohio State University

Education and Training

Brigham Young University	Chemistry	B.S. 2007
Brigham Young University	Chemistry	M.S. 2008
University of California, Berkeley	Chemistry	Ph.D. 2012

Research and Professional Experience

2022–present	Professor, Chemistry and Biochemistry, The Ohio State University
2019–2022	Associate Professor, Chemistry and Biochemistry, The Ohio State University
2014–2019	Assistant Professor, Chemistry and Biochemistry, The Ohio State University
2012–2014	University of California, Berkeley, Postdoctoral Advisor: Stephen R. Leone
2008–2012	University of California, Berkeley, Ph.D. Advisor: Gabor A. Somorjai

Honors and Awards

1. ***John Von Neumann Distinguished Fulbright Scholar***, 2023
2. ***Coblentz Award in Molecular Spectroscopy***, Coblentz Society, 2022
3. ***Emerging Leader in Atomic Spectroscopy***, Spectroscopy Magazine, 2021
4. ***Camille Dreyfus Teacher Scholar***, Camille and Henry Dreyfus Foundation, 2020
5. ***Journal of Physical Chemistry / PHYS Division Lectureship***, American Chemical Society, 2019
6. ***Young Innovator Award in NanoEnergy***, Highlighted in NR45 special issue of *Nano Research*, 2019
7. ***Early Career Award***, Department of Energy, 2015
8. ***Young Investigator Award***, Air Force Office of Scientific Research, 2015

Funding

Principal Investigator for total federal funding of $17.3M, 12 active grants

1. ***AFOSR Molecular Dynamics and Theoretical Chemistry,*** 2023–2026, $507,922 *(Role: PI)*
2. ***AFOSR MURI,*** 2023–2028, $650,246 to Baker *(Role: co-PI, PI: D. Waldeck)*
3. ***DOE Catalysis Science***, 2023–2026, $354,864 *(Role: PI)*
4. ***NSF Chemical Catalysis,*** 2022-2025, $585,000 *(Role: PI)*
5. ***US-Israel Binational Science Foundation***, 2021–2024, $149,731 to Baker *(Role: co-PI, PI: H. Wang)*
6. ***DOE Condensed Phase and Interfacial Molecular Science***, 2020–2024, $551,255 *(Role: PI)*
7. ***Camille Dreyfus Teacher-Scholar Award***, 2020–2025, $100,000 *(Role: PI)*
8. ***NSF Center for Emergent Materials***, 2020–2026, $418,970 to Baker *(Role: co-PI, PI: P. C. Hammel)*
9. ***NSF NeXUS,*** 2019–2024, $9,986,000 *(Role: PI)*

Oral Presentations

106 talks, including 88 invited talks since 2014. Invited talks include:

- Coblentz Award Lecture, International Symposium on Molecular Spectroscopy, Champaign, IL, 2023
- Max Planck Institute for Nuclear Physics, Bothe Colloquium, Heidelberg, Germany, 2023
- Extreme Light Infrastructure Attosecond Light Pulse Source, Szeged, Hungary, 2023
- Surface Chemistry of Catalytic Systems, Rehovot, Israel, 2022 (Virtual)
- International Workshop on Oxides, Pyeongchang, South Korea, 2022 (Virtual)
- NanoGE Solar Fuels Keynote Speaker, Madrid, Spain, 2021 (Virtual)
- Emerging Leader in Atomic Spectroscopy Award Lecture, Ljubijana, Slovenia, 2021 (Virtual)
- Journal of Physical Chemistry / PHYS Division Award Lectureship, 2020 (Virtual)
- 14th Femtochemistry Conference, Shanghai, China, 2019
- International School on Frontiers of Attosecond and Ultrafast X-Ray Science, Erice, Italy, March 2019
- 18 Invited talks at ACS/APS/ECS national meetings

Selected Publications († Corresponding author)

10. H. Gajapathy, S. Bandaranayake, E. Hruska, A. Vadakkayil, B. P. Bloom, S. Londo, J. McClellan, J. Guo, D. Russel, F. M. F. de Groot, F. Yang, D. H. Waldeck, M. Schultze, and **L. R. Baker**†, "Spin Polarized Electron Dynamics Enhance Water Splitting Efficiency by Yttrium Iron Garnet Photoanodes: A New Platform for Spin Selective Photocatalysis," *Chemical Science*, **2024**, DOI: 10.1039/D3SC03016D.
9. J. Rebstock, Q. Zhu, and **L. R. Baker**†, "Exploring the influence of interfacial solvation on electrochemical CO_2 reduction using plasmon-enhanced vibrational sum frequency generation spectroscopy," *ChemCatChem*, **2024**, DOI: 10.1002/cctc.202301301.
8. S. Bandaranayake, A. Patnaik, E. Hruska, Q. Zhu, and **L. R. Baker**†, "Electronic Structure and Ultrafast Electron Dynamics in CuO Photocatalysts Probed by Surface Sensitive Femtosecond X-ray Absorption Near-Edge Structure Spectroscopy," *Journal of Physical Chemistry Letters*, **2023**, *14*, 3643–3650.
7. G. Deng, Q. Zhu, J. Rebstock, T. Neves-Garcia, and **L. R. Baker**†, "Direct Observation of Bicarbonate and Water Reduction on Gold: Understanding the Potential Dependent Proton Source During Hydrogen Evolution," *Chemical Science*, **2023**, *14*, 4523–4531.
6. S. Biswas and **L. R. Baker**†, "Extreme Ultraviolet Reflection-Absorption Spectroscopy: Probing Dynamics at Surfaces from a Molecular Perspective," *Accounts of Chemical Research*, **2022**, *55*, 893–903.
5. Z. Zhu, C. J. Murphy, and **L. R. Baker**†, "Opportunities for Electrocatalytic CO_2 Reduction Enabled by Surface Ligands," *Journal of the American Chemical Society*, **2022**, 144, 2829–2840. **(Invited Perspective)**
4. Z. Zhu, S. Wallentine, G. Deng, J. Rebstock, and **L. R. Baker**†, "Solvation-Induced Onsager Reaction Field Rather than Double Layer Field Controls CO_2 Reduction Kinetics on Gold," *JACS Au*, **2022**, 2, 472–482.
3. H. Shang, S. Wallentine, D. M. Hofmann, Q. Zhu, C. J. Murphy, and **L. R. Baker**†, "Effect of Surface Ligands on Gold Nanocatalysts for CO_2 Reduction," *Chemical Science*, **2020**, *11*, 12298–12306. **(Cover Article)**
2. S. Biswas, J. Husek, S. Londo, and **L. R. Baker**†, "Highly Localized Charge Transfer Excitons in Metal Oxide Semiconductors," *Nano Letters*, 18, 1228–1233 (2018). **(Highlighted by Advances in Engineering)**
1. J. Husek, A. Cirri, S. Biswas, and **L. R. Baker**†, "Surface Electron Dynamics in Hematite (α-Fe_2O_3): Correlation Between Ultrafast Surface Electron Trapping and Small Polaron Formation," *Chemical Science*, 8, 8170–8178 (2017).

Editorial Service:

- Editorial Advisory Board, *Journal of Physical Chemistry A/B/C*, 2021–2026
- Editorial Advisory Board, *Spectroscopy* Magazine, 2022–Present
- Guest Editor, *Journal of Chemical Physics*, Special issue: Oxide Chemistry and Catalysis, 2019–2020

Workshop Participation and Symposium Organization:

- NSF National eXtreme Ultrafast Science (NeXUS) User Workshop (July 2022)
  Role: Organizer, Host, and Plenary Speaker (120 participants from 47 institutions and 12 countries)
- NSF National eXtreme Ultrafast Science (NeXUS) User Workshop (July 2020)
  Role: Organizer, Host, and Plenary Speaker (>200 participants from 75 institutions and 13 countries)
- DOE Basic Research Needs Workshop: Next Generation Electrical Energy Storage (March 2017)
  Role: Panel Writer: Structure, Interphases, and Charge Transfer at Electrochemical Interfaces
- Organized 9 symposia at ACS, APS, and ISMS national/international meetings

James Daniel **Brandenburg**

jdbburg.com | +1 321-266-3121 | brandenburg.89@osu.edu |
0000-0002-6327-5947 | jdbrice

Assistant Professor | High Energy Nuclear Physicist

Publication Metrics

According to my google scholar profile — Updated on March 14, 2024

- Total citations: 8814
- h-index: 49
- i10-index: 119

Education

Doctor of Philosophy in Nuclear Physics — *2015 - 2018*
Rice University — *Houston, TX, USA*
- Thesis: Systematic Measurement of Dimuon Production in pp, pA, and AA collisions with the STAR Experiment
- Thesis Award: RHIC-AGS Thesis Award runner-up

Master of Physics — *2013 - 2015*
Rice University — *Houston, TX, USA*
- GPA: 3.92/4.0

Bachelors of Science in Physics, Minor in Mathematics — *2009 - 2013*
University of Florida — *Gainesville, FL, USA*
- Honors: Magna Cum Laude
- GPA: 3.84/4.0

Research Appointments

Assistant Professor — *2023 - Present*
The Ohio State University — *Columbus, OH, USA*
- **Electron-Ion Collider**
  - Member of the Electron-Ion Collider (EIC) detector collaboration actively developing the EIC physics program and detector design.
  - Team leader for the OSU involvement in the ePIC collaboration and the hardware develoment related to the backward hadronic calorimeter project to be constructed by OSU
- **STAR Collaboration**
  - Member of the STAR collaboration conducting research in high energy nuclear physics.
  - Conducting research on novel entanglement enabled aspects of quantum mechanics and non-linear QED processes exploring the physics of ultra-strong fields

STAR Upgrade Management Team | ePIC Team Leader

Goldhaber Distinguished Fellow — *2020 - 2022*
Brookhaven National Laboratory & The Center for Frontiers in Nuclear Science — *New York, NY, USA*
- Discovery of the Breit-Wheeler process and vacuum birefringence in heavy-ion collisions (published in Physical Review Letters with one of the top 50 Altmetric scores of all time)
- Discovery of entanglement enabled spin interfernce and utilization of this newfound tool to perform the first measurement of nuclear skin depths in high-energy A+A collisions

Funding | Award

Post-doctoral Research Associate — *2018 - 2020*
Brookhaven National Laboratory — *New York, NY, USA*
- Contributed to STAR fixed target program, enabling STAR to operate in both the collider mode and fixed-target modes.
- Primary author on the paper containing the first physics result from the STAR fixed-target program
- Member of the Muon Telescope Detector upgrade team and primary author on the first physics result resulting from the STAR upgrade.

Fixed-target experiment | Muon Telescope Detector

Scientific Collaborations

2023 - current	**Electron Proton Ion Collider Experiment (ePIC)**, OSU Team Leader & council representative
2013 - current	**Solenoidal Tracker at RHIC (STAR)**, PhD Advisor: Frank Geurts, Rice University
2010-2013	**Compact Muon Solenoid (CMS)**, Advisor: Ivan Furic, University of Florida

Awards & Honors

2023 **Early Career Research Award**, Department of Energy, Office of Science

2022 **Blavatnik Regional Award for Young Scientists, Finalist**, Blavatnik Family Foundation and New York Academy of Sciences

2020 **Goldhaber Distinguished Fellowship**, Brookhaven National Laboratory

2019 **Young Scientist Award**, Nuclear Physics A, presented by Elsevier at Quark Matter 2019

2019 **RHIC & AGS Thesis Award, Runner Up**, Rice University

2016 **Chuoke Award for Excellence**, Rice University

2013 **Sam & Helen Worden Fellowship**, Rice University

2009-2013 **Undergraduate Fellowship**, Naval Office of Advanced Research

2009 **Congressional Medal of Merit**, U.S. Congressman Bill Posey

2009 **Ying Grand Award & Ying Scholar**, Dr. Nelson Ying Foundation

Teaching Experience

Fall 2023 PHYS1250 Recitation and Laboratory
Spring 2024 PHYS5300 Theoretical and Computational Physics
2013-2015 Teaching Assistant, Introductory Physics Laboratory, Rice University

Leadership & Service Roles

General

2020-Current **Journal and Grant Peer Review**
EPJA | Physical Review Journals | Nature Physics | Nuclear Physics A | PPNP | DOE SBIR | DOE Experimental Nuclear Physics | FAPESP (Funding program in Brazil)

Dec 2023 **Student Mentor & Session Convener**, The first international workshop on Ultra-Peripheral Collisions
- Responsible for inviting speakers and chairing discussion sections
- Met with students at various career stages to share advise develop mentoring relationships

2017-2018 **Student/Post-Doc Member**, RHIC & AGS User's Executive Committee
- Member of the Funding, Politics, & Programmatics (FPP) committee
- Member of the Meetings, Communication & Outreach (MCO) working group

2020-Current **Open Source Scientific Projects**
- RNUPlot - a tool for using making publication quality plots with ROOT data formats using the popular GNUPlot program
- rootMD - a Markdown parser for reproducible data science and analysis based on the ROOT analysis framework

Ohio State University

2023 **Colloquium committee member**, OSU Physics department
- Invited guest speakers from the field of nuclear physics
- Sought invitations from early career candidates in under-represented minorities

2023 **Local organizing committee**, PIKMO (Phenomonology in Indiana, Kentucky, Michigan, and Ohio) workshop hosted at OSU
- Invited guest speakers and organized submitted talks
- Helped run the program (chairing sessions and organizing agenda)

STAR Collaboration

2020-2023 **Co-convener of Light Spectra & Ultra-Peripheral Collisions**, STAR Physics Working
- Advise and oversee > 30 students and post-doctoral researchers.
- Participate in convener meetings to review all STAR papers before initiating publication process.

2020-current **Software Coordinator**, Management Team, STAR Forward Rapidity Upgrade
- Develop detector geometries, simulations, custom tracking algorithms, and data reconstruction software for the suite of detectors in the STAR forward upgrade (silicon and gas chamber tracking detectors, electromagnetic and hadronic calorimetry).
- Manage tasks and effort among members of the forward upgrade team including students / post-doctoral researchers from various institutions

IDENTIFYING INFORMATION:

NAME: Chini, Jacquelyn

POSITION TITLE: Associate Professor

PRIMARY ORGANIZATION AND LOCATION: University of Central Florida, Orlando, Florida, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of Central Florida, Orlando, Florida, United States	Postdoctoral Fellow	2012 - 2013	physics
Kansas State University, Manhattan, Kansas, United States	PHD	12/2010	Physics
Drew University, Madison, New Jersey, United States	BA	05/2006	Physics

Appointments and Positions

2024 - present Associate Professor, Ohio State University, Department of Physics, Columbus, Ohio, United States

2020 - 2024 Associate Professor, University of Central Florida, Physics Department, Orlando, Florida, United States

2015 - 2020 Assistant Professor, University of Central Florida, Physics Department, Orlando, Florida, United States

2013 - 2015 Director of Learning Assistant Program & Lecturer, University of Central Florida, Physics Department, Orlando, Florida, United States

2012 - 2013 Postdoctoral Researcher, University of Central Florida, Physics Department, Orlando, Florida, United States

2011 - 2012 Visiting Assistant Professor, University of Central Florida, Physics Department, Orlando, Florida, United States

2010 - 2010 Adjunct, Cloud County Community College, Junction City, Kansas, United States

2009 - 2010 GK-12 Fellow, National Science Foundation, Kansas State University, Manhattan, Kansas, United States

2006 - 2010 Graduate Research and Teaching Assistant, Kansas State University, Physics Department, Manhattan, Kansas, United States

Products

Products Most Closely Related to the Proposed Project

1. Chini J, Scanlon E. Teaching Physics with Disabled Learners: A Review of the Literature. In: Taşar M, Heron P, editors. The International Handbook of Physics Education Research: Special Topics [Internet] AIP Publishing LLCMelville, New York; 2023-03-17. 1-1-1-34p. Available from: https://pubs.aip.org/books/book/161/chapter/81721516/Teaching-Physics-with-Disabled-Learners-A-Review DOI: 10.1063/9780735425514_001
2. Scanlon E, Legron-Rodriguez T, Schreffler J, Ibadlit E, Vasquez E, Chini J. Postsecondary chemistry curricula and universal design for learning: planning for variations in learners'

abilities, needs, and interests. Chemistry Education Research and Practice. 2018; 19(4):1216-1239. Available from: http://xlink.rsc.org/?DOI=C8RP00095F DOI: 10.1039/C8RP00095F

3. Scanlon E, James W, Vasquez III E, Chini JJ.. Postsecondary physics curricula and Universal Design for Learning: Planning for diverse learners. Physical Review Physics Education Research. 2018 July 02; 14:020101. DOI: 10.1103/PhysRevPhysEducRes.14.020101
4. Schreffler J, Vasquez III E, Chini J, James W. Universal Design for Learning in postsecondary STEM education for students with disabilities: a systematic literature review. International Journal of STEM Education. 2019 March 04; 6(8). DOI: 10.1186/s40594-019-0161-8
5. Scanlon E, Taylor Z, Raible J, Bates J, Chini J. Physics webpages create barriers to participation for people with disabilities: five common web accessibility errors and possible solutions. International Journal of STEM Education. 2021 April 02; 8(1):-. Available from: https://stemeducationjournal.springeropen.com/articles/10.1186/s40594-021-00282-3 DOI: 10.1186/s40594-021-00282-3

Other Significant Products, Whether or Not Related to the Proposed Project

1. James W, Bustamante C, Lamons K, Scanlon E, Chini J. Disabling barriers experienced by students with disabilities in postsecondary introductory physics. Physical Review Physics Education Research. 2020; 16(2):-. Available from: https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.16.020111 DOI: 10.1103/PhysRevPhysEducRes.16.020111
2. Chini JJ, Saitta EKH, Kara A, Scanlon E. Explicating Universal Design for Learning-aligned Instructional Strategies for Postsecondary STEM. Proceedings of the Physics Education Research Conference. 2021. DOI: 10.1119/perc.2021.pr.Chini
3. Saitta EK.H., Wilcox M, James WD., Chini JJ.. The views of GTAs impacted by cross-tiered professional development: Messages intended and received. International Journal of Research in Undergraduate Mathematics Education. 2020 October; 6:421. DOI: https://doi.org/10.1007/s40753-020-00115-8
4. Oleynik DP., Scanlon EM., Chini JJ.. Examining physicists' perspectives of career viability and knowledge of impairment. Proceedings of the 2021 Physics Education Research Conference. 2021. DOI: 10.1119/perc.2021.pr.Oleynik
5. Coffie CA., James W, Scanlon EM., Chini JJ.. Identifying Academic Ableism: Case Study of a UDL-Learning Community Participant. Proceedings of the 2022 Physics Education Research Conference. 2022. DOI: 10.1119/perc.2022.pr.Coffie

Synergistic Activities

1. Invited chapter lead for National Academies of Science, Engineering, and Mathematics Disrupting Ableism and Advancing STEM workshop, Summer 2023
2. Invited presenter to National Academies of Science, Engineering, and Mathematics Board on Science Education, Meeting #38, January 9-10, 2023
3. Chair-Elect, American Physical Society Group on Physics Education Research, 2022 - present
4. Dissertation advisor for American Physical Society Bridge Program students, 2016 - present
5. Department leader of the American Physical Society Inclusion, Diversity and Equity Alliance team, 2020 - 2023.

Certification:
When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

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IDENTIFYING INFORMATION:

NAME: Chini, Michael

ORCID iD: https://orcid.org/0000-0002-9058-928X

POSITION TITLE: Associate Professor of Physics

PRIMARY ORGANIZATION AND LOCATION: The Ohio State University, Columbus, Ohio, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of Central Florida, Orlando, Florida, United States	Postdoctoral Fellow	07/2014 - 08/2015	Mentor: Martin Richardson
University of Central Florida, Orlando, Florida, United States	Postdoctoral Fellow	08/2012 - 07/2014	Mentor: Zenghu Chang
University of Central Florida, Orlando, Florida, United States	PHD	08/2012	Physics
Kansas State University, Manhattan, Kansas, United States	Graduate Student	08/2007 - 12/2010	Physics
McGill University, Montreal, Quebec, QC, Canada	BS	05/2007	Physics (minor: Music Technology)

Appointments and Positions

2024 - present Associate Professor of Physics, The Ohio State University, Department of Physics, Columbus, Ohio, United States

2020 - 2024 Associate Professor of Physics, University of Central Florida, tenured appointment, Orlando, Florida, United States

2015 - 2020 Assistant Professor of Physics, University of Central Florida, tenure-track appointment, Orlando, Florida, United States

2014 - 2015 Senior Research Scientist, University of Central Florida, CREOL, the College of Optics and Photonics, research focus on laser development and laser filamentation, Orlando, Florida, United States

2012 - 2014 Postdoctoral Scholar, University of Central Florida, Department of Physics, research focus on attosecond spectroscopy, Orlando, Florida, United States

Products

Products Most Closely Related to the Proposed Project

1. Beetar JE, Nrisimhamurty M, Truong TC, Nagar GC, Liu Y, Nesper J, Suarez O, Rivas F, Wu Y, Shim B, Chini M. Multioctave supercontinuum generation and frequency conversion based on rotational nonlinearity. Sci Adv. 2020 Aug;6(34) PubMed Central PMCID: PMC7442354.
2. Jeong YG, Piccoli R, Ferachou D, Cardin V, Chini M, Hädrich S, Limpert J, Morandotti R, Légaré F, Schmidt BE, Razzari L. Direct compression of 170-fs 50-cycle pulses down to 1.5 cycles with 70% transmission. Sci Rep. 2018 Aug 7;8(1):11794. PubMed Central PMCID:

PMC6081375.

3. Li J, Ren X, Yin Y, Zhao K, Chew A, Cheng Y, Cunningham E, Wang Y, Hu S, Wu Y, Chini M, Chang Z. 53-attosecond X-ray pulses reach the carbon K-edge. Nat Commun. 2017 Aug 4;8(1):186. PubMed Central PMCID: PMC5543167.
4. Beetar JE, Nrisimhamurty M, Truong TC, Liu Y, Chini M. Thermal effects in molecular gas-filled hollow-core fibers. Opt Lett. 2021 May 15;46(10):2437-2440. PubMed PMID: 33988603.
5. Chini M, Zhao K, Chang Z. The generation, characterization and applications of broadband isolated attosecond pulses. Nature Photonics. 2014; 8(3):178-186. issn: 1749-4893

Other Significant Products, Whether or Not Related to the Proposed Project

1. Beetar J, Gholam-Mirzaei S, Chini M. Spectral broadening and pulse compression of a 400 μ J, 20 W Yb: KGW laser using a multi-plate medium. Applied Physics Letters. 2018; 112(5):051102. issn: 0003-6951
2. Jiang S, Gholam-Mirzaei S, Crites E, Beetar J, Singh M, Lu R, Chini M, Lin C. Crystal symmetry and polarization of high-order harmonics in ZnO. Journal of Physics B: Atomic, Molecular and Optical Physics. 2019; 52(22):225601. issn: 0953-4075
3. Truong Tran-Chau, Beetar John E, Chini Michael. Light-field synthesizer based on multidimensional solitary states in hollow-core fibers. Optics Letters. 2023; 48(9):2397--2400.
4. Liu Yangyang, Beetar John E, Nesper Jonathan, Gholam-Mirzaei Shima, Chini Michael. Single-shot measurement of few-cycle optical waveforms on a chip. Nature Photonics. 2022; 16(2):109--112.
5. Beetar J, Rivas F, Gholam-Mirzaei S, Liu Y, Chini M. Hollow-core fiber compression of a commercial Yb: KGW laser amplifier. JOSA B. 2019; 36(2):A33-A37. issn: 1520-8540

Synergistic Activities

1. iFAST Point of Contact, LaserNetUS
2. Member-at-large, APS Division of Laser Science (2022-present)
3. Co-chair, 8th International Conference on Attosecond Physics, Orlando FL, July 2022
4. Member, APS DAMOP committee on ultrafast science (2019-2021)
5. Member of the UCF Physics Bridge Program site team (2015-present)

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

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Enam A. Chowdhury

Assistant Professor
Material Science and Engineering
Electrical and Computer Engineering
Physics
The Ohio State University
2041 N College Rd
Columbus, OH 43210
(614) 247-8392
Chowdhury.24@osu.edu

Present Position

Assistant Professor of Material Science and Engineering, Electrical and Computer Engineering and Physics, The Ohio State University

Education and Training:

A. B. Physics, Wabash College, IN 1995
M. S. Electrical and Computer Engineering, University of Delaware, DE 1999
Ph. D. Physics, University of Delaware, DE 2004
Postdoctoral Researcher, The Ohio State University, 2004 – 2006

Research and Professional Experience:

Assistant Professor, Department of Material Science and Engineering, The Ohio State University, 2019 – Present
Research Associate Professor of Physics, OSU 08/18-08/19
Research Assistant Professor of Physics, OSU, 03/13-08/18
Consultant for the Air Force Institute of Technology/Air Force Research Laboratory, WPAFB 2013-present
Senior Research Associate, OSU Physics. 12/06-02/13

Selected Publications:

1. A. Mushtaq, M. Y. Noor, R. Siebenaller, E. DeAngelis, A. Fisher, L. Clink, J. Twardowski, G. K. Salman, R. C. Myers, E. Rowe, B. S. Conner, M. A. Susner, and E. Chowdhury, "AgScP2S6 van der Waals Layered Crystal: A Material with a Unique Combination of Extreme Nonlinear Optical Properties," J. Phys. Chem. Lett. **14**, 3527–3534 (2023).
2. A. Mushtaq, L. Clink, M. Y. Noor, C. Kuz, E. Deangelis, R. Siebenaller, A. Fisher, D. Verma, R. C. Myers, B. S. Conner, M. A. Susner, and E. Chowdhury, "Ultrafast Nonlinear Absorption and Second Harmonic Generation in $Cu_{0.33}In_{1.30}P_2S_6$ van der Waals Layered Crystals," J. Phys. Chem. Lett. **13**, 10513 (2022).
3. D. Hui, H. Alqattan, S. Zhang, V. Pervak, E. Chowdhury, and M. T. Hassan, "Ultrafast optical switching and data encoding on synthesized light fields," Sci. Adv. 9(8), eadf1015 (2023). (Cover of Science Advance)
4. K. Werner, V. Gruzdev, N. Talisa, K. Kafka, D. Austin, C. M. Liebig, and E. Chowdhury, "Single-Shot Multi-Stage Damage and Ablation of Silicon by Femtosecond Mid-infrared Laser Pulses," Sci. Rep. 9, 1–13 (2019).
5. D. R. Austin, K. R. P. Kafka, Y. H. Lai, Z. Wang, C. I. Blaga, and E. A. Chowdhury, "Femtosecond laser damage of germanium from near- to mid-IR wavelengths," Opt. Lett. 43(15), 3702–3705 (2018).
6. M. R. Shcherbakov, K. Werner, Z. Fan, N. Talisa, **E. Chowdhury**, and G. Shvets, “Nonlinear manifestations of photon acceleration in time-dependent metasurfaces: tunable broadband harmonics generation,” Nat. Commun. 10(1345), 1–15 (2019) (https://doi.org/10.1038/s41467-019-09313-8)
7. M. R. Shcherbakov, H. Zhang, M. Tripepi, G. Sartorello, N. Talisa, A. Alshafey, Z. Fan, J. Twardowski, L. A. Krivitsky, A. I. Kuznetsov, **E. Chowdhury**, and G. Shvets, "Generation of even and odd high harmonics in resonant metasurfaces using single and multiple ultra-intense laser pulses," Nat. Commun. 12(1), 4185 (2021).
8. K. Werner, M. Hastings, A. S. Schweinsberg, B. Wilmer, D. R. Austin, C. Wolfe, M. Kolesik, T. R. E. Ensley, L. Vanderhoef, A. Valenzuela, and E. A. Chowdhury, "Ultrafast mid-infrared high harmonic and supercontinuum generation with n_2 characterization in zinc selenide," Opt. Express 27(3), 2867 (2019).

9. D. R. Austin, K. R. P. Kafka, S. Trendafilov, G. Shvets, H. Li, A. Y. Yi, U. B. Szafruga, Z. Wang, Y. H. Lai, C. I. Blaga, L. F. DiMauro, and E. a. Chowdhury, "Laser induced periodic surface structure formation in germanium by strong field mid IR laser solid interaction at oblique incidence," Opt. Express 23(15), 19522 (2015).
10. P. L. Poole, C. Willis, R. L. Daskalova, K. M. George, S. Feister, S. Jiang, J. Snyder, J. Marketon, D. W. Schumacher, K. U. Akli, L. Van Woerkom, R. R. Freeman, and **E. A. Chowdhury**, "Experimental capabilities of 0.4 PW, 1 shot/min Scarlet laser facility for high energy density science", Applied Optics Vol. 55, pp. 4713-4719 (2016)

Research Experience

Prof. Chowdhury is a leading expert in the field of short pulse lasers and laser damage, nonlinear optics, ultra-intense and high energy density laser matter interaction, and laser generated extreme materials. He led the design and construction of the 400 TW SCARLET laser system at the OSU High Energy Density Physics (HEDP) Laboratory, which was completed in 2012 [Laser focus world cover June 2012]. Along with development of SCARLET, he concentrated on research on intense laser accelerated multi-MeV particles from liquid targets in kHz repetition rate. In 2012, he established a new AFOSR funded laboratory devoted to studying femtoseconed laser matter interaction near material damage threshold, which has concentrated on how laser damage mechanisms evolve from traditional near IR to mid IR wavelengths. His ongoing experimental efforts on various few cycle pulse and multi-pulse effects already show traditional models like Two Temperature Model (TTM) developed for near IR laser solid interaction may not be adequate, and new wavelength scaled paradigm may be necessary to explain intense laser solid interaction at longer wavelengths. He is well-known for his work on laser damage testing and modeling of high damage threshold optics used in high power ultrashort pulse lasers. He is also currently exploring strong optical nonlinearity and laser damage of van der Waals 2D MTP (metal thio-phosphate) materials, and how these nonlinearities vary with temperature.

Selected Synergistic Activities:

1. Served at panel for Basic Research Needs on Laser technology: Organized by DoE, DoD and NSF to chart out high power intense laser technology needs in the coming decade. A Basic Research Need report will come out soon. July 2023
2. Served on the proposal review Panel member for the National Science Foundation Plasma Physics for the 2022-2023 cycle.
3. Optica Incubator Panelist on On Chip High Field Nano-photonics, July 2022.
4. Serving on the Peer revew panel for the European Extreme Light Infrastructure (ELI): A billion+ dollar three pan-European extreme laser facilities.
5. Organizer and co-Chair, FIERO (Frontiers In Extreme Relativistic Optics) AFOSR funded Workshop, Columbus OH, 2013,
6. Track co-Chair, High power laser science and engineering technology, IEEE RAPID (Research in Applications of Photonics in Defense)
7. Member SPIE Laser Damage Program Committee, Member IEEE RAPID Program Committee, former member CLEO Science and Innovation program committee (2019-2022)
8. Topical Editor, High Power Laser Science and Engineering Technology, Cambridge University Press
9. Reviewer for Journals and Funding Agencies including: OSA family, Nature family, Physics of Plasmas and others; Department of Energy, Department of Defense, National Science Foundation, ELI ERIC Proposal Review panel.

Collaborators and Co-editors (last 48 months):

LaserNetUS PIs (www.lasernetus.org) and senior personnel, Colin Danson (Imperial College), D. W. Schumacher (OSU), Roberto Myers (OSU), Jinwoo Hwang (OSU), L. Brillson (OSU), Michael Chini (UCF), Zenghu Chang (UCF), L. F. Dimauro (OSU), Anil Patnaik (AFIT), Michael Dexter (AFIT), Michael Susner (AFRL/RX), Carl Liebig (AFRL/RX), Miro Kolesik (U Arizona), Carmen Menoni (Colorado State), Emily Link (LLNL), Maxim Shcherbakov (UC Irvine), Gennady Shvets (Cornell), Laura Vanderhoef (ARL/APG), Glenn Daehn (OSU), Alok Sutradhar (OSU), Jay Gupta (OSU), P.

Agostini (The Ohio State University), Anthony Valenzuela (SMDC), Miro Kolesik (U Arizona), J. T. Morrison (Contractor), C. Orban (The Ohio State University), J. Bromage (Laboratory for Laser Energetics), R. R. Freeman (The Ohio State University – Emeritus), V. Gruzdev (University of New Mexico), C. I. Blaga (Kansas State University), Brendan Reagan (Lawrence Livermore National Lab).

Graduate and Postdoctoral Advisors:
Barry C. Walker (University of Delaware), PhD adviser
Richard R. Freeman (The Ohio State University), Postdoc adviser

Graduate and Postdoctoral Advisees (Last Five Years):
Advisees within last 5 years: Kyle Kafka (OSU PhD 2017, Laboratory for Laser Energetics, U Rochester), Drake Austin (OSU PhD 2017, AFRL), Kevin Werner (OSU PhD 2019, BAE Systems), Noah Talisa (OSU PhD 2020, APL Johns Hopkins), Brandon Harris (OSU MS 2019), Michael Tripepi (OSU PhD 2022, Hillsdale College), Simin Zhang (OSU PhD 2023, KLA Corp.), Liam Clink, Ryan Siebenaller, Emma DeAngelis, Mohamed Noor, Milo Eder, Conrad Kuz, Ziyao Su, Gulsum Salman, Md. Adnan, Justin Twardowski. Postdoctoral Advisee: Aamir Mushtaq, Joseph Smith (Asst. Prof. Marietta College), Hantian Gao (Applied Materials).

Courses Taught:

Autumn 2023: MATSCEN 7575-5575 Ultrashort pulse laser materials processing: a new senior undergraduate (5575) and graduate level (7575) course developed by me, based on previous MSE5193 (Independent study) developed and taught by me. The course covers basic optics, electromagnetics, deriving optical laws and effects from Maxwell's equations, laser physics, non-linear optics, ultrashort pulse laser physics, ultrashort pulse (USPL) laser damage physics, USPL surface engineering, USPL machining, USPL applications in surgery. Class also includes three labs, an optics lab, an ultrashort pulse laser optics lab, and a USPL materials interaction lab where students analyze USPL modified surfaces with scanning electron microscopy (SEM).

Spring 2023: MATSCEN 2331 Structure and Characterization Lab. Companion laboratory course to MatScEn 2241. Experiments on X-ray diffraction, scanning electron microscopy, optical microscopy, and stereology with applications. Statistical treatment of data and technical reporting. I teach the lab portion of the class. All sophomore majors of Materials Science and Engineering must take this class.

Autumn 2022: MATSCEN 5193.02 Ultrashort pulse laser materials processing (independent study): described earlier.

Spring 2022: MATSCEN 2331 Structure and Characterization Lab.

Autumn 2021: MATSCEN 5193.02 Ultrashort pulse laser materials processing (independent study): described earlier.

Spring 2021: MATSCEN 2331 Structure and Characterization Lab.

Autumn 2020: MATSCEN 5193.02 Ultrashort pulse laser materials processing (independent study): described earlier. Designed and taught first time.

Autumn 2019: MATSCEN 5605 Quantitative Introduction to Materials Science: beginning graduate level course, geared towards introducing the general concepts in a quantitative way to incoming graduate students from other disciplines.

Senior Design/Capstone: Besides traditional courses, I have taught several Senior design courses where 1-3 senior undergraduate students pursue a research project topic (e.g. USLP laser glass-metal welding) for the entire year (two semesters) under the guidance of the topic adviser.

Geraldine L. Cochran, Ph.D.

Cellular Phone: 919-802-0884 ⬤ E-Mail: moniegeraldine@gmail.com

Education

Degrees

Ph.D. in Curriculum and Instruction Conferred December of 2013
Florida International University
Specialization: Science Education
Cognate: Physics
Dissertation: Cochran , G.L. (2013). A Q Methodology Approach to Investigating the Relationship Between Level of Reflection and Typologies Among Prospective Teachers in the Physics Learning Assistant Program at Florida International University. *FIU Electronic Thesis and Dissertations.* 1000
doi: 10.25148/etd.FI13120618

Ed.S. in Science Education Conferred May of 2013
Florida International University
Specialization: Science Teacher Preparation
Project Title: Assessing the Reflective Practice of Prospective Teachers Through Written Reflections Using Nonparametric Statistics.

M.A.T. in Secondary Education Conferred December of 2009
Chicago State University
Specialization: Secondary School Physics
Thesis Title: Understanding and Encouraging Effective Collaboration in Introductory Physics Courses.

B.S. in Mathematics Conferred December of 2004
B.S. in Physics
Chicago State University

Professional Experience (2019 – present)

Associate Professor The Ohio State University (2023 - present)
Department of Physics

Associate Professor of Professional Practice Rutgers University (2021 – 2023)
Assistant Professor of Professional Practice Rutgers University (2017 – 2021)
Office of STEM Education | Department of Physics and Astronomy

- facilitates 2 faculty learning communities focused on STEM Education Research
- supports course transformation, evaluation, and micro-research across STEM disciplines
- teachers the introductory physics sequence for engineering majors (P115/P116)
- serves as the administration overseeing the recitations for P115/116

INSIGHT Program Manager (Consultant) Michigan State University (2021 – 2022)
Facility for Rare Isotope Beams

- assisted principle investigator and co-investigators in implementing Department of Energy funded program to broaden participation in nuclear physics
- supported coordination and organization of INSIGHT program evaluation
- supported development and coordination of national initiative to broaden participation in nuclear physics

Acting Head of Diversity (Contractor) American Physical Society (APS)(2021 - 2022)

- supported strategic planning for the Programs Department
- oversaw enhancement of the APS National Mentoring Community (NMC) and completed strategic planning
- oversaw diversity related areas including the APS NMC, the APS Bridge Program, and the DELTA PHY Initiative, the HBCU/BSI Summit, and the APS Committee on Minorities
- developed organizational procedures and policies to support new initiatives, personnel transitions, and new personnel onboarding within the department.
- served on the departmental management team
- designed and oversaw a research study on the role of master's granting institutions in the APS bridge program

The College Board
AP Physics 2 Development Committee Member/Consultant College Board (2019 – 2022)

- evaluated and developed questions for the AP Physics 2 Exam
- developed and delivered virtual lectures for the high school physics classroom

Honors, Awards, and Media Mention (2019 – Present)

1. Received the Rutgers Chancellor-Provost Award for Excellence in STEM Diversity in 2022.
2. Elected a Fellow of the American Association of Physics Teacher in 2022.
3. Elected a Fellow of the American Physical Society in 2020 through the Forum on Education.
4. 2019 recipient of the Homer L. Dodge Citation for Distinguished Service to AAPT by the America Association of Physics Teachers.
5. Cited by Erica Hunzinger in Major league baseball is trying to bring more women into front offices and fields (April 18, 2019), NPR.

Grants Awarded (2021 – Present)

1. Bennett Goldberg P(PI), Michael Wittmann (Co-PI), Diana Schmpazidi (Co-PI), Charles Henderson (Co-PI), and **Geraldine Cochran (Co-PI).** Inclusive Graduate Programs: An AGEP Pilot in Physics, National Science Foundation, $570,185. Awarded August 2023.
2. **G. Cochran (PI).** Conference: Coordination, Evaluation, and Support for Astronomy REU Sites (CEASARS), National Science Foundation, **$90,123**. Awarded February 2023.
3. **G. Cochran (PI)** and R. Gilman. REU Site: Physics and Astronomy Research at Rutgers University, National Science Foundation, **$336, 613**. Awarded May 2021.

Publications (2024 only)

1. McDermott L., Mosley, N., & Cochran G.L. (2024). Diverging nonlocal fields: Operationalizing critical disability physics identity with neurodivergent physicists outside academia, *Physical Review – Physics Education Research* (20)*,* 010111. https://doi.org/10.1103/PhysRevPhysEducRes.20.010111

Daniel J. Gauthier

The Ohio State University	(614) 247-8477
Department of Physics	gauthier.51@osu.edu
191 West Woodruff Ave.	http://www.researcherid.com/rid/G-1336-2011
Columbus, OH 43235	http://scholar.google.com/citations?user=tXYIYJsAAAAJ

Education

University of Rochester	1989	Ph.D. in Optics
University of Rochester	1983	M.S. in Optics
University of Rochester	1982	B.S. in Optics

Selected Professional Experiences

2021 -	Co-Founder, Verilock, Inc., Partnership and license with Codasip, Inc.
2020 -	Co-Founder and Senior Developer, ResCon Technologies, LLC
2019 -	Professor of Electrical and Computer Engineering, The Oho State University
2016 -	Professor of Physics, The Ohio State University
2015	Interim Chair, Department of Physics, Duke University
2013 - 2015	Professor of Electrical and Computer Engineering, Duke University
2011 - 2015	Robert C. Richardson Professor of Physics, Duke University
2007 - 2011	Professor of Physics, Duke University
2005 - 2011	Chair, Department of Physics, Duke University
2004 -2007	Anne T. and Robert M. Bass Professor of Physics
2004 -2011	Professor of Biomedical Engineering, Duke University
2002 -2004	Anne T. and Robert M. Bass Associate Professor of Physics, Duke University
2001 - 2002	Director of Undergraduate Studies, Physics Department, Duke University
1997 - 1999	
2000 - 2004	Associate Professor of Biomedical Engineering, Duke University
1999 - 2002	Associate Professor of Physics, Duke University
1995 - 2000	Assistant Research Professor of Biomedical Engineering, Duke University
1992 - 1998	Assistant Professor of Physics, Duke University
1989 -1991	Research Associate, University of Oregon, Mentor: Thomas W. Mossberg
1982 -1989	Research Assistant, University of Rochester, Advisor: Robert W. Boyd

Selected Awards

2009 Outstanding Referee of the Physical Review and Physical Review Letters

2006 Fellow of Optica (formerly Optical Society of America)

2002 Fellow of the American Physical Society

1993 National Science Foundation Youn Investigator

1992 U.S. Army Research Office Young Investigator

Ph.D Students Mentored: 5 current, 23 past, **Post-Doctoral Research Associates Mentored**: 20 past

External funding: Pending: $1.4M, **Last 10 years**: $8.7M, **Total**: $34.9M

Presentations: Total: 246, **Last 10 years:** 62 invited, 1 contributed, **Patents**: 12

Publications: Total Scholarly Works: 253**, Citations (Google Scholar):** 16,993**, h-index:** 67

Synergistic Activities

2022	Co-Organizer, National Science Foundation Project Scoping Workshop on Accelerating Progress Toward Practical Quantum Advantage
2018 - 2019	Member, National Science Foundation, Review of the Physics Frontiers Center Program
2016 - 2019	Deputy Editor, *Optica*, Optical Society of America
2015 – 2020	Member, Strategic Advisory Board for QuantIC, the Quantum Enhanced Imagine Hub, Glasgow, UK
2015 – 2020	Member, Editorial Board, *Physical Review E*

Selected Publications

P. Alsing, P. Battle, J. C. Bienfang, T. Borders, T. Brower-Thomas, L. Carr, F. Chong, S. Dadras, B. DeMarco, I. Deutsch, E. Figueroa, D. Freedman, H. Everitt, D. Gauthier, E. Johnston-Halperin, J. Kim, M. Kira, P. Kumar, P. Kwiat, J. Lekki, A. Loiacono, M. Loncar, J. R. Lowell, M. Lukin, C. Merzbacher, A. Miller, C. Monroe, J. Pollanen, D. Pappas, M. Raymer, R. Reano, B. Rodenburg, M. Savage, T. Searles, and J. Ye, 'Accelerating Progress Towards Practical Quantum Advantage: The Quantum Technology Demonstration Project Roadmap,' submitted for publication (2023).

A. Conrad, S. Isaac, R. Cochran, D. Sanchez-Rosales, T. Rezaei, T. Javid, A. J. Schroeder, G. Golba, D. Gauthier, P. Kwiat, 'Drone-based quantum communication links,' Proc. SPIE, Quantum Computing, Communication, and Simulation III **12446**, 124460H (2023).

R. D. Cochran and D. J. Gauthier, 'Qubit-based clock synchronization for QKD systems using a Bayesian approach,' Entropy **23**, 988 (2021).

M. E. Shea, P. M. Baker, J. A. Joseph, J. Kim, D. J. Gauthier, 'Submillisecond, nondestructive, time-resolved quantum-state readout of a single, trapped neutral atom,' Phys. Rev. A **102**, 053101 (2020).

C. Cahall, N. T. Islam, D. J. Gauthier, and J. Kim, 'Multi-mode Time-delay Interferometer for Free-space Quantum Communication,' Phys. Rev. Appl. **13**, 024047 (2020).

N.T. Islam, C.C.W. Lim, C. Cahall, J. Kim, and D.J. Gauthier, 'Securing quantum key distribution systems using fewer states,' Phys. Rev. A **97**, 042347 (2018).

K.L. Nicolich, C. Cahall, N.T. Islam, G.P. Lafyatis, J. Kim, A.J. Miller, and D.J. Gauthier, 'Universal model for the turn-on dynamics of superconducting nanowire single-photon detectors,' Phys. Rev. Appl. **12**, 034020 (2019).

N. T. Islam, C. C. W. Lim, C. Cahall, B. Qi, J. Kim, and D. J. Gauthier, 'Scalable high-rate, high-dimensional quantum key distribution,' Quantum Sci. Technol. **4**, 035008 (2019).

C. Cahall, K.L. Nicolich, T. Islam, G.P. Lafyatis, A.J. Miller, D.J. Gauthier, J. Kim, 'Multi-Photon Detection using a Conventional Superconducting Nanowire Single-Photon Detector,' Optica **4**, 1534 (2017).

N.T. Islam, C.C.W. Lim, C. Cahall, J. Kim, and D.J. Gauthier, 'Provably-secure and high-rate quantum key distribution with time-bin qudits,' Sci. Adv. **3**, e1701491 (2017).

T. Brougham, C.F. Wildfeuer, S.M. Barnett and D.J. Gauthier, 'The information of high-dimensional time-bin encoded photons,' European Phys. J. D **70**, 214 (2016).

M. Mirhosseini, O.S. Magaña-Loaiza, N.N. O'Sullivan, B. Rodenburg, M. Malik, M.P.J. Lavery, M.J. Padgett, D.J. Gauthier, and R.W. Boyd, 'High-dimensional quantum cryptography with twisted light,' New J. Phys. **17**, 033033 (2015).

IDENTIFYING INFORMATION:

NAME: Ghazisaeidi, Maryam

ORCID iD: https://orcid.org/0000-0001-7949-2930

POSITION TITLE: Associate Professor of Materials Science and Engineering

PRIMARY ORGANIZATION AND LOCATION: The Ohio State University, Columbus, Ohio, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of Illinois at Urbana-Champaign, Urbana, Illinois, United States	PHD	12/2011	Theoretical and Applied Mechanics
Sharif University of Technology, Tehran, Not Applicable, N/A, Iran	MS	06/2005	Mechanics of Solids and Structures
Sharif University of Technology, Tehran, Not Applicable, N/A, Iran	BS	06/2003	Civil Engineering

Appointments and Positions

2024 - present	Professor, The Ohio State University, Columbus, Ohio, United States
2021 - 2022	Visiting Professor, EPFL, Lausanne, Not Applicable, N/A, Switzerland
2019 - 2024	Associate Professor of Materials Science and Engineering, The Ohio State University, Columbus, Ohio, United States
2013 - 2019	Assistant Professor, The Ohio State University, Columbus, Ohio, United States
2011 - 2013	Postdoctoral Research Associate, Brown University, Providence, Rhode Island, United States

Products

Products Most Closely Related to the Proposed Project

1. Shih M, Miao J, Mills M, Ghazisaeidi M. Stacking fault energy in concentrated alloys. Nat Commun. 2021 Jun 11;12(1):3590. PubMed Central PMCID: PMC8196205.
2. Antillon E, Ghazisaeidi M. Efficient determination of solid-state phase equilibrium with the multicell Monte Carlo method. Phys Rev E. 2020 Jun;101(6-1):063306. PubMed PMID: 32688575.
3. Niu C, LaRosa CR, Miao J, Mills MJ, Ghazisaeidi M. Magnetically-driven phase transformation strengthening in high entropy alloys. Nat Commun. 2018 Apr 10;9(1):1363. PubMed Central PMCID: PMC5893566.
4. Niu C, Rao Y, Windl W, Ghazisaeidi M. Multi-cell Monte Carlo method for phase prediction. npj Computational Materials. 2019 December 10; 5(1):120. Available from: https://doi.org/10.1038/s41524-019-0259-z DOI: 10.1038/s41524-019-0259-z
5. Niu C, Windl W, Ghazisaeidi M. Multi-Cell Monte Carlo Relaxation method for predicting

phase stability of alloys. Scripta Materialia. 2017 April 15; 132:9-12. Available from: https://www.sciencedirect.com/science/article/pii/S1359646217300015 issn: 1359-6462

Other Significant Products, Whether or Not Related to the Proposed Project

1. LaRosa C, Ghazisaeidi M. A “local” stacking fault energy model for concentrated alloys. Acta Materialia. 2022 July 01; 238:118165. DOI: 10.1016/j.actamat.2022.118165
2. Myers R, Ghazisaeidi M, Polat Genlik S. Dislocations as natural quantum wires in diamond. 2023 February 13; 7(2):024601. Available from: https://link.aps.org/doi/10.1103/PhysRevMaterials.7.024601 DOI: 10.1103/PhysRevMaterials.7.024601
3. Feng L, Kannan S, Egan A, Smith T, Mills M, Ghazisaeidi M, Wang Y. Localized phase transformation at stacking faults and mechanism-based alloy design. Acta Materialia. 2022 November 1; 240:118287. Available from: https://ui.adsabs.harvard.edu/abs/2022AcMat.24018287F DOI: 10.1016/j.actamat.2022.118287
4. Couzinié J, Heczko M, Mazánová V, Senkov O, Ghazisaeidi M, Banerjee R, Mills M. High-temperature deformation mechanisms in a BCC+B2 refractory complex concentrated alloy. Acta Materialia. 2022 July 01; 233:117995. Available from: https://www.sciencedirect.com/science/article/pii/S1359645422003767 issn: 1359-6454
5. Ghazisaeidi M. Alloy thermodynamics via the Multi-cell Monte Carlo (MC)2 method. Computational Materials Science. 2021 February 01; 193:110322. DOI: 10.1016/j.commatsci.2021.110322

Synergistic Activities

1. Elected vice chair of the 2025 Physical Metallurgy Gordon Research Conference.
2. Associate Editor: Acta Materialia and Scripta Materialia (2021-Present)
3. Editorial Advisory Board Member: Computational Materials Science (2023-Present), High Entropy Alloys and Materials (2021-Present).
4. Outstanding Reviewer: Acta Materialia and Scripta Materialia (2019)
5. Faculty Mentor: 2019 Physical Metallurgy Gordon Research Seminar, Manchester, NH

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Ghazisaeidi, Maryam in SciENcv on 2024-08-30 20:09:10

Tyler J. Grassman

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The Ohio State University
Dept. of Materials Science & Engineering
Dept. of Electrical & Computer Engineering
4012 Fontana Lab, 140 W 19th Ave
Columbus, OH 43210

EDUCATION

University of California, San Diego
Jacobs School of Engineering and Dept. of Chemistry & Biochemistry
Ph.D. Materials Science & Engineering — 2007
M.S. Materials Science & Engineering — 2001

University of Oregon
Dept. of Chemistry and Robert D. Clark Honors College
B.A. Chemistry (Minor: Mathematics) — 2000

PROFESSIONAL APPOINTMENTS

Associate Professor, *The Ohio State University* — 2021 – Present
Depts. of Materials Science & Engineering, Electrical & Computer Engineering

Assistant Professor, *The Ohio State University* — 2015 – 2021
Depts. of Materials Science & Engineering, Electrical & Computer Engineering

Research Assistant Professor, *The Ohio State University* — 2012 – 2015
Depts. of Materials Science & Engineering, Electrical & Computer Engineering

Research Staff, *The Ohio State University* — 2010 – 2012
Institute for Materials Research

Postdoctoral Researcher, *The Ohio State University* — 2007 – 2010
Dept. of Electrical & Computer Engineering

RESEARCH INTERESTS

Synthesis and characterization of electronic and photonic materials; optoelectronics (e.g. photovoltaics and photodetectors); epitaxy science; microstructure and defect characterization and engineering; surface and interface science; semiconductor heteroepitaxy and dissimilar materials integration; metamorphic materials; materials characterization and analysis methodolgy and techniques; electron microscopy; first-principles (ab-initio) materials modeling; multi-scale integrated computational/experimental materials science and engineering.

TEACHING

The Ohio State University — 2015 – Present
- Courses taught (**development of new or significant redevelopment of existing course/lab*):
  - MSE 2241 (Structure and Characterization of Materials)
  - *MSE 3331 (Materials Science and Engineering Lab I)

  - *MSE 5532 (Electronic and Optical Materials Properties Lab)
  - *MSE 5572 (Materials for a Sustainable Energy Future)
  - *ECE/MSE 5237 (Photovoltaics Processing and Characterization Lab)
  - MSE 7895 (Graduate Seminar in Materials Science and Engineering)

ACADEMIC / UNIVERSITY SERVICE

- Chair of OSU Semiconductor Curriculum Development committee (created via Intel SERP funded education project)
  - Led and/or assistant in development of new semiconductor-focused academic certificates at OSU and course frameworks at state-level (ODHE); leading/co-leading development of new semiconductor courses and experiential opportunities
- Advocate in OSU "Advocates & Allies for Equity) program
- Unit representative in College of Engineering "Justice, Equity, Diversity, and Inclusivity Council"

PROFESSIONAL SERVICE

- IEEE Photovoltaic Specialists Conference, organizing committee: Conference General Chair (2024), Conference Deputy Chair (2024), Operations Chair (2023), Treasurer (2022); Diversity & Inclusion subcommittee, founding and active member (2019 – Present); Publications Chair (2017, 2018); Graduate Student Assistant program Chair (2014 – 2017)
- IEEE Photovoltaic Specialists Conference, program committee: Program Chair (2021), Deputy Program Chair (2020); Chair/Co-Chair for "Area 3: III-Vs and CPV" technical area (2017 – 2019); Sub-Area Chair (founder) of "Hybrid Tandems" and "Low-Cost III-Vs" cross-cutting areas (2015 – 2017)
- Microscopy & Microanalysis Conference: Co-Organizer "Defects in Materials: How We See and Understand Them" symposium (2021)
- OSU IMR Materials Week: Co-Chair "Sustainable Energy Harvesting and Storage" session (2015, 2016); Co-Chair "Infrared Materials and Technologies" (2018)
- ACCGE/OMVPE Workshop: Co-Chair "III/Vs on Silicon" symposium (2015)
- Editorial Board member for *IOP Journal of Physics D* (2020 – 2022)
- Associate Editor for *Frontier in Materials*, semiconductor materials and devices section (2023 – Present)
- Proposal referee for NSF, DOE, ARO, DTRA, various international funding agencies
- Journal referee for multiple high-impact journals in the topics of semiconductors, photovoltaics, epitaxy, and electron microscopy.

PUBLICATIONS

- Publication of >110 scholarly journal articles and conference papers, 2 book chapters.
- *h*-index: 25

IDENTIFYING INFORMATION:

NAME: Gupta, Jay

ORCID iD: https://orcid.org/0000-0002-3908-7719

POSITION TITLE: Professor of Physics

PRIMARY ORGANIZATION AND LOCATION: The Ohio State University, Columbus, Ohio, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of California, Santa Barbara, California, United States	PHD	02/2022	Physics
University of California, Santa Barbara, California, United States	PHD	05/1999	Physics
University of Illinois, Urbana Champaign, Illinois, United States	BS	01/1996	Chemistry
University of Illinois, Urbana Champaign, Illinois, United States	BS	01/1996	Physics

Appointments and Positions

2020 - present	Professor of Physics, The Ohio State University, Columbus, Ohio, United States
2007 - present	Member, Chemical Physics Program, The Ohio State University, Columbus, Ohio, United States
2012 - 2020	Associate Professor of Physics, The Ohio State University, Columbus, Ohio, United States
2004 - 2012	Assistant Professor of Physics, The Ohio State University, Columbus, Ohio, United States
2002 - 2004	Postdoctoral Researcher, IBM Almaden Research, San Jose, California, United States

Products

Products Most Closely Related to the Proposed Project

1. Wang P, Lee W, Corbett JP, Koll WH, Vu NM, Laleyan DA, Wen Q, Wu Y, Pandey A, Gim J, Wang D, Qiu DY, Hovden R, Kira M, Heron JT, Gupta JA, Kioupakis E, Mi Z. Scalable Synthesis of Monolayer Hexagonal Boron Nitride on Graphene with Giant Bandgap Renormalization. Adv Mater. 2022 May;34(21):e2201387. PubMed PMID: 35355349.
2. Zhu T, O'Hara D, Noesges B, Zhu M, Repicky J, Brenner M, Brillson L, Hwang J, Gupta J, Kawakami R. Coherent growth and characterization of van der Waals 1T-VSe2 layers on GaAs(111)B using molecular beam epitaxy. PHYSICAL REVIEW MATERIALS. AUG; 4(8). DOI: 10.1103/PhysRevMaterials.4.084002
3. Young J, Chilcote M, Barone M, Xu J, Katoch J, Luo Y, Mueller S, Asel T, Fullerton-Shirey S, Kawakami R, Gupta J, Brillson L, Johnston-Halperin E. Uniform large-area growth of nanotemplated high-quality monolayer MoS2. APPLIED PHYSICS LETTERS. JUN; 110(26). DOI: 10.1063/1.4989851

4. Lee D, Gupta JA. Perspectives on deterministic control of quantum point defects by scanned probes. Nanophotonics. 2019 November; 8(11):2033. DOI: 10.1515/nanoph-2019-0212
5. Lee DH, Gupta JA. Tunable field control over the binding energy of single dopants by a charged vacancy in GaAs. Science. 2010 Dec 24;330(6012):1807-10. PubMed PMID: 21148345.

Other Significant Products, Whether or Not Related to the Proposed Project

Synergistic Activities

1. Director, NSF NRT-QUGIP: Quantum Graduate Interdisciplinary Program (2023-present): This NRT training grant is to help launch a new MS/PHD graduate program in quantum information science and engineering (QISE) at Ohio State University. QuGIP will be a standalone degree program to address structural disincentives for interdisciplinary graduate education such as tensions for disciplinary specialization, student assistantship funding, and academic vs. industry workforce preparation. The launch phase of this program will directly fund 25 trainees, along with 10-20 additional degree students funded from other sources such as assistantships and competitively awarded university fellowships.
2. Ohio State Physics Bridge Program (co-Director 2014-22, Director 2022-present) – This program is a 1-2 year post-baccalaureate program designed to help promising students from underrepresented groups who weren't accepted into graduate programs due to factors such as mixed grades or lack of research experience. The program emphasizes an individualized curriculum, academic and fellowship support and close academic / research mentorship. OSU Physics is helping the American Physical Society extend the Bridge program model through partnership with other professional societies such as the American Chemical Society, American Astronomical Society, Materials Research Society and the American Geophysical Union.
3. Co-Director, NSF Partnership in Research and Education in Materials (NSF-PREM) (seed award 2021-present). This partnership with Hispanic-serving California State University, Long Beach, leverages the research infrastructure associated with Ohio State's NSF MRSEC: Center for Emergent Materials, with a goal to increase opportunities toward the PhD for underrepresented students. PREM activities include research visits, summer opportunities for undergraduates, and joint professional development opportunities.
4. Member, RAISIN network (2021-present): The Roadmap for Applications of Implanted Single Impurities Network was formed in 2021 to facilitate collaborations between groups worldwide that are developing fabrication processes using implanted single impurities for quantum science and technology. In addition to a quarterly webinar series, RAISIN hosts international workshops and supports travel grants for international research experiences.
5. Professional and public service: Review: (panels) NSF Chemical Catalysis (2022), SLAC SIMES program review (2018), NSF CMP (2010), NSF MRI (2008) , (proposals) PRF, NSF (CAREER, DMR); U.S. Civilian Research and Development Foundation, DOE, Netherlands FOM, Germany DFG, RCSA, Alberta CANADA, Beckman Foundation, Cy-Terra (Cyprus); (journals): PRL, Science, Nature, Nature Nanotech, Nanoletters, APL, RSI, MRS proceedings, J. Physical Chemistry, ACS Nano, Physica E, JACS, Surface Science, J.Phys.ChemB., Organizer, 2023 Conference on spin polarized STM.

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Gupta, Jay in SciENcv on 2024-01-16 17:20:47

Andrew F. Heckler

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191 West Woodruff Ave., Columbus, OH 43210
614-688-3048; heckler.6@osu.edu

Professional preparation

Ohio State University	Cosmology/Astrophysics	Post-doc 1996-99
Fermi National Accelerator Lab	Cosmology/Astrophysics	Post-doc 1994-96
University of Washington	Physics	Ph.D., 1994
Peace Corps, Gabon, Africa	H.S. Science Teacher	1986-88
Ohio State University	Physics	B.S., 1986

Appointments

Assistant Dean, College of Mathematical and Physical Sciences, Ohio State Univ. 1998-2005.
Assistant Professor, Department of Physics, Ohio State University. 2005-2011.
Associate Professor, Department of Physics, Ohio State University. 2011-2017.
Professor, Department of Physics, Ohio State University. 2017-present.

Grant Funding

Current:

"STEM Fluency: Expanding the Effectiveness, Relevance, Equity, and Accessibility of Online Learning of Essential STEM Skills" PI: A. Heckler, Co-PI Don Walters 10/1/2023-9/30/2026, $599,542.

"Constructing Valid, Equitable, and Flexible Kinematics and Dynamics Assessment Scales with Evidence-Centered Design" Collaborative Project: Lead PI (MSU): R. Henderson ($240,000), WVU PI: J. Stewart ($160,000), OSU PI: A. Heckler ($196,959) 10/1/2023-9/30/2026

"QuSTEAM: Convergent undergraduate education in Quantum Science, Technology, Engineering, Arts, and Mathematics," PI: E. Johnston-Halperin. Co-PI A. Heckler. NSF Accelerator Grant, 10/2021-8/2024 $5M

Previous: Over $4M from 9 grants since 2004 (Lead PI on 5), from NSF IUSE, NSF NRT-IGE, NSF REESE, NSF MRSEC, Institute for Education Sciences, Ohio Department of Education

Awards

1) Fellow of the American Physical Society, 2021
2) University Distinguished Teaching Award, Ohio State University, 2018
3) Outstanding Referee Award, American Physical Society, 2016
4) Outstanding Teaching Award, Physics Department, Ohio State University, 2016

Publications (77 publications, Google Scholar: >2700 Citations, h-index = 26)

- Physics Education and Cognition Research: 30 Publications in peer-reviewed journals
- Astrophysics and Cosmology: 9 Publications in peer-reviewed journals
- Book Chapters: 2 publications
- Peer-Reviewed Conference Proceedings: 36 peer-reviewed publications

Invited and Peer-reviewed Presentations (> 60 since 2005)

Other Products:

- STEMfluency.org: research-based online learning application used by over 35,000 students.
- Graduate group work tutorials in quantum mechanics, on Physport.org
- Group work tutorials for introductory material science.

IDENTIFYING INFORMATION:

NAME: Johnston-Halperin, Ezekiel

ORCID iD: https://orcid.org/0000-0002-6240-3505

POSITION TITLE: Professor of Physics

PRIMARY ORGANIZATION AND LOCATION: Ohio State University, Columbus, OH, USA

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
California Institute of Technology, Pasadena, CA, USA	Postdoctoral Fellow	06/2003 - 06/2006	Division of Chemistry and Chemical Engineering
University of California at Santa Barbara, Santa Barbara, CA, USA	PHD	05/2003	Physics
Case Western Reserve University, Cleveland, OH, USA	BS	05/1996	Physics
University of California at Santa Barbara, Santa Barbara, CA, USA	MS	06/2000	Physics

Appointments and Positions

2019 - present Professor of Physics, Ohio State University, Columbus, OH, USA

2012 - 2019 Associate Professor of Physics, Ohio State University, Physics, Columbus, OH, USA

2011 - 2017 Director, Center for the Exploration of Novel Complex Materials (ENCOMM), Columbus, OH, USA

2006 - 2012 Assistant Professor of Physics, Ohio State University, Columbus, OH, USA

Products

Products Most Closely Related to the Proposed Project

1. Asfaw A, Blais A, Brown K, Candelaria J, Cantwell C, Carr L, Combes J, Debroy D, Donohue J, Economou S, Edwards E, Fox M, Girvin S, Ho A, Hurst H, Jacob Z, Johnson B, Johnston-Halperin E, Joynt R, Kapit E, Klein-Seetharaman J, Laforest M, Lewandowski H, Lynn T, McRae C, Merzbacher C, Michalakis S, Narang P, Oliver W, Palsberg J, Pappas D, Raymer M, Reilly D, Saffman M, Searles T, Shapiro J, Singh C. Building a Quantum Engineering Undergraduate Program. IEEE Transactions on Education. 2022; 65(2):220-242. Available from: https://ieeexplore.ieee.org/document/9705217/ DOI: 10.1109/TE.2022.3144943
2. Candido D, Fuchs G, Johnston-Halperin E, Flatté M. Predicted strong coupling of solid-state spins via a single magnon mode. Materials for Quantum Technology. 2020 December 30; 1(1):011001-. Available from: https://iopscience.iop.org/article/10.1088/2633-4356/ab9a55 DOI: 10.1088/2633-4356/ab9a55
3. McCullian B, Chilcote M, Bhallamudi V, Purser C, Johnston-Halperin E, Hammel P. Broadband Optical Detection of Ferromagnetic Resonance From the Organic-Based Ferrimagnet V[TCNE]$_x$ Using N-V Centers in Diamond. Physical Review Applied. 2020; 14(2):-. Available from: https://link.aps.org/doi/10.1103/PhysRevApplied.14.024033 DOI:

10.1103/PhysRevApplied.14.024033

4. Pu Y, Odenthal P, Adur R, Beardsley J, Swartz A, Pelekhov D, Flatté M, Kawakami R, Pelz J, Hammel P, Johnston-Halperin E. Ferromagnetic Resonance Spin Pumping and Electrical Spin Injection in Silicon-Based Metal-Oxide-Semiconductor Heterostructures. Physical Review Letters. 2015 December 10; 115(24):-. Available from: https://link.aps.org/doi/10.1103/PhysRevLett.115.246602 DOI: 10.1103/PhysRevLett.115.246602
5. Pu Y, Beardsley J, Odenthal P, Swartz A, Kawakami R, Hammel P, Johnston-Halperin E, Sinova J, Pelz J. Correlation of electrical spin injection and non-linear charge-transport in Fe/MgO/Si. Applied Physics Letters. 2013 July; 103(1):012402-. Available from: http://aip.scitation.org/doi/10.1063/1.4812980 DOI: 10.1063/1.4812980

Other Significant Products, Whether or Not Related to the Proposed Project

1. Chilcote M, Lu Y, Johnston-Halperin E. Organic-based magnetically ordered films. Miller J, Vardeny Z, Wohlgennant M, editors. World Scientific; 2018///. 125-168p. DOI: 10.1142/9789813230200_0003
2. Tjung S, Hollen S, Gambrel G, Santagata N, Johnston-Halperin E, Gupta J. Crystalline hydrogenation of graphene by scanning tunneling microscope tip-induced field dissociation of H2. Carbon. 2017 November; 124:97-104. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0008622317307261 DOI: 10.1016/j.carbon.2017.07.044
3. Young J, Chilcote M, Barone M, Xu J, Katoch J, Luo Y, Mueller S, Asel T, Fullerton-Shirey S, Kawakami R, Gupta J, Brillson L, Johnston-Halperin E. Uniform large-area growth of nanotemplated high-quality monolayer MoS_2. Applied Physics Letters. 2017 June 26; 110(26):263103-. Available from: http://aip.scitation.org/doi/10.1063/1.4989851 DOI: 10.1063/1.4989851
4. Jaworski C, Myers R, Johnston-Halperin E, Heremans J. Giant spin Seebeck effect in a non-magnetic material. Nature. 2012; 487(7406):210-213. Available from: http://www.nature.com/articles/nature11221 DOI: 10.1038/nature11221
5. Beckman R, Johnston-Halperin E, Luo Y, Green J, Heath J. Bridging Dimensions: Demultiplexing Ultrahigh-Density Nanowire Circuits. Science. 2005 October 21; 310(5747):465-468. Available from: https://www.science.org/doi/10.1126/science.1114757 DOI: 10.1126/science.1114757

Synergistic Activities

1. Inaugural co-Director of the Center for Quantum Information Science and Engineering at The Ohio State University (2022-present). Role includes coordination of 40+ faculty across 2 colleges and 6 departments, building bridges between academia and industry, and developing research infrastructure for QISE.
2. Broadening the STEM pipeline through innovations in pedagogy: Johnston-Halperin is a founding member of the Ohio State University Masters to PhD Bridge Program (2014-present) and is the PI of the NSF funded QuSTEAM initiative (2020-present), a national network of colleges and universities targeting the development of undergraduate curricula in quantum information.

3. Co-lead of IRG-1: “Towards Spin-Preserving, Heterogeneous Spin Networks” within Ohio State's MRSEC the Center for Emergent Materials (2008 - 2014).

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Johnston-Halperin, Ezekiel in SciENcv on 2023-11-29 16:39:10

Curriculum Vitae

Thomas Kerler

Employment

2014 - present: The Ohio State University. Professor of Mathematics.

2002 - 2014 : The Ohio State University. Associate Professor of Mathematics. (with tenure)

1996 - 2002: The Ohio State University. Assistant Professor of Mathematics

5/96-9/96: UC Berkeley, Berkeley, CA. Research Fellow.

1995 - 1996: Institute for Advanced Studies, Princeton. School of Mathematics. Member.

1992 - 1995: Harvard University, Cambridge, MA.
Benjamin Peirce Lecturer, Assistant Professor of Mathematics.

1986-1992: ETH Zürich, Theoretical Physics & Mathematics. Teaching Assistant.

Education

1992: Doctoral Degree (with distinction) in Mathematical Physics
Eidgenössische Technische Hochschule , Zürich. Advisor: Jürg Fröhlich.

1989: Diplom in Theoretical Physics.
Eidgenössische Technische Hochschule , Zürich. Advisor: Jürg Fröhlich.

Oct. 1985: Vordiplome in Mathematics and Physics.
University of Heidelberg.

Selected Publications

- "Non-semisimple Topological Quantum Field Theories for 3-Manifolds with Corners". *Lecture Notes in Mathematics* **1765** Springer-Verlag, 2001. xi + 375 pages. (with V. Lyubashenko)
- "Quantumgroups, Quantumcategories and Quantumfieldtheory" *Lecture Notes in Mathematics* **1542**, Springer Verlag, 1993. xiii + 436 pages (Second Edition, 1995). (with J.Fröhlich)
- "The Lawrence-Krammer-Bigelow representations of the braid groups via Uq(sl2)". *Adv. Math.* **228** (2011) 1689-1717.
- "Bridged Links and Tangle Presentations of Cobordism Categories". *Adv. Math.* **141** (1999) 207-281.
- "On the Connectivity of Cobordisms and Half-Projective TQFT's". *Commun. Math. Phys.* **198** (1998) 535-590.
- "Structuring the Set of Incompressible Quantum Hall Fluids", *Nucl. Phys.B* **453** (1995) 670-704. (with J.Fröhlich, U.Studer, E.Thiran)
- "Mapping Class Group Actions on Quantum Doubles". *Commun. Math. Phys.* **168** (1994) 353-388.
- "Universality in Quantum Hall Systems" *Nucl. Phys.B* **354** (1991) 369-417. (with J.Fröhlich)

Mentoring

Graduated Students

- Matthew Harper, **PhD 2021** (Jobs: VAP at UC Riverside; Post-doc at Michigan State)
- Yilong Wang, **PhD 2018** (Jobs: VAP Louisiana State, Assist Prof - tenure-track at BIMSA)
- Alexander Borland, **PhD 2017** (Job: OSU Lecturer)
- Jennifer (George) Sheldon, **PhD 2013** (Jobs: Assist Prof – clinical at OSU)
- Matthew Sequin, **PhD 2012** (Jobs: Assist Prof – tenure-track at St Peter's Univ; Assoc Prof – teaching at Rutgers)
- Thomas Johnson, **MS Thesis 2007** (Jobs: Software industry).
- Craig Jackson, **MS Thesis 2001** (PhD Univ Chicago; Prof tenured at Ohio Wesleyan)

Post-Doctoral

- *Principal Mentor:* Qi Chen (Prof tenured at Winston Salem State); Craig Jackson (Prof tenured at Ohio Wesleyan); Ahn Tran: (Assoc Proftenured at Univ of Texas – Dallas); Yu Tsumura (Data Analyst, Japan).
- *Co-Mentor:* Alissa Crans (Prof tenured at Loyola Marymount); Christopher Davis (Assoc Prof tenured at Univ Wisconsin – Eau Claire); Sujoy Mukherjee (VAP University of Denver)

Administrative Positions & University or College Service

- Vice-Chair for Graduate Studies, 2008-2023.
- Graduate School Council, 2021-2024.
- Graduate Curriculum Committees: ASC 2012-2015; GS/CAA: 2021-2023.
- ASC Committee for Fellowships & Grad Studies: 2014, 2021
- Freshmen Calculus Coordinator (Math 151, ~2500 students/year) 2004-2008.

Synergistic Activities

- *National Math Alliance:* 2014-pres Doctoral Program Group Lead, establish on-boarding mentoring program, F-GAP Facilitator, Alliance Member/Partner Liaison.
- *Sampling Advanced Mathematics for Minority Students* (SAMMS) 2011-2019 (annual). Collaboration on program design, organization, and graduate events.
- *Young Mathematicians Conference*: 2003-2007, 2009-2012. Organization, funding opportunities, design of event and evaluation process, technology development, training of new organizers.
- Numerous talks and consultations about graduate school with undergraduates at universities across the US and national conferences.
- Development of graduate program management software. Design and coding of various stand-alone applications, and directing of *GradCentral* software development through ASC. Development of *Simply Connected @ OSU Math* after abandoning GradCentral in 2016.

BERN KOHLER

Professor and Ohio Eminent Scholar
Department of Chemistry and Biochemistry
The Ohio State University
100 W 18th Ave
Columbus, OH 43210 USA

E-mail: kohler.40@osu.edu
Telephone (614) 688-2635
Fax (614) 292-1685
http://orcid.org/0000-0001-5353-1655

Education

B.S.	1985	Chemistry	*Stanford University*
Ph.D.	1990	Physical Chemistry	*Massachusetts Institute of Technology* Advisor: Prof. Keith A. Nelson

Thesis: Ultrafast Dynamics of Molecular Liquids Investigated by Femtosecond Light Scattering

Appointments

July 2016 – present	**Professor and Ohio Eminent Scholar**, Department of Chemistry and Biochemistry, The Ohio State University
2009 – 2016	**Professor of Chemistry**, Montana State University
2011 – 2012	**Interim Department Head**, Department of Chemistry and Biochemistry, Montana State University
Summer 2008	**Visiting Professor of Physics**, Aarhus University
1995 – 2009	**Assistant, Associate, Full Professor**, Department of Chemistry, *The Ohio State University*

Honors and Awards

ERUDITE Scholar-in-Residence, Kerala State Higher Education Council, India, 2019.
Inter-American Photochemical Society (I-APS) Award in Photochemistry, 2017.
AAAS Fellow, 2015.
Cox Award for Creative Scholarship and Teaching, MSU, 2015.
Charles and Nora L. Wiley Faculty Award for Meritorious Research, Montana State University, 2010.
Arts and Sciences Outstanding Teaching Award Finalist, The Ohio State University, 2009.
Visiting Professor Fellowship, University of Aarhus, Denmark, summer 2008.
Research Fellow of the Alexander von Humboldt Foundation, 2004-2005.
Associate Editor, *Photochemistry and Photobiology*, 2004-present.

Research Interests

Ultrafast excited state dynamics in biomolecules (DNA, melanin) and nanomaterials; electronic and vibrational spectroscopy in the condensed phase; exciton and charge transport dynamics in self-assembled nanomaterials for photocatalysis and solar energy conversion; photophysics of disordered carbon nanomaterials and non-stoichiometric metal oxides

Recent Research Grants

1. National Science Foundation, Dynamics of Excited Electronic States in DNA Strands and DNA-Silver Nanoclusters, 8/1/18 – 7/31/23, $466,789. *Photophysics of DNA-metal nanoassemblies.*
2. ACS Petroleum Research Fund, Probing Elementary Photochemical Events in Cerium Oxide by Steady-State and Ultrafast Spectroscopy, 7/1/16 – 8/31/19, $110,000. *Investigating carrier dynamics and the interfacial photochemistry of ceria nanoparticles.*
3. National Science Foundation, Dynamics of Excited Electronic States in DNA Strands, 8/1/15 – 7/31/18, $433,300. *Study of proton-coupled electron transfer in DNA strands in water and in ionic liquids by femtosecond TRIR spectroscopy.*
4. NASA, *A Bottom-up Approach to Understanding UV Hardiness in Prebiotic Nucleic Acids*, 1/17/12 – 6/30/16, $281,658 (MSU portion), co-PI. *Investigated photostability mechanisms of DNA and related prebiotic compounds using time-resolved spectroscopy.*

Professional Service

American Chemical Society, Physical Chemistry Division, Vice-Chair Elect, 2024
President and Past-President, Telluride Science Research Center (2021-2022)
Alternate Councilor, Physical Division of the American Chemical Society (2020-2022)
Co-Vice Chair (2009) and Co-Chair (2012) of Electronic Spectroscopy & Dynamics Gordon Conference.
Co-Vice Chair (2011) and Co-Chair (2013) of Photochemistry Gordon Research Conference.

Current Graduate Students and Postdocs

Alex Hanes, Lily Kinziabulatova, Bach Pham, Meera Madhu, Bárbara Fornaciari, Rayne Pozza, Zachary Hunchuk

Recent and Selected Publications (>8,000 citations, *h*-index = 44)

138. Martínez-Fernández, Lara; Kohl, Forrest R.; Zhang, Yuyuan; Ghosh, Supriya; Saks, Andrew J.; Kohler, Bern "Triplet excimer formation in a DNA duplex with silver ion-mediated base pairs," *J. Am. Chem. Soc.*, **2024**, *146*, 1914-1925. DOI: 10.1021/jacs.3c08793.

137. Wang, Xueli; Martinez-Fernandez, Lara; Zhang, Yuyuan; Wu, Pecong; Kohler, Bern; Improta, Roberto; Chen, Jinquan, "Ultrafast Formation of a Delocalized Triplet Excited State in an Epigenetically Modified DNA Duplex under Direct UV Excitation," *J. Am. Chem. Soc.* **2024**, *146*, 1839-1848. DOI: 10.1021/jacs.3c04567.

136. Ghosh, Supriya; Pham, Bach; Madhu, Meera; Kohler, Bern "Interband and Intraband Induced Hot Electron Transfer in Plasmonic Gold-Cerium Oxide Core-Shell Nanoparticles," *J. Phys. Chem. C*, **2023**, *127*, 21593-21602. DOI: 10.1021/acs.jpcc.3c03856.

135. Wang, Xueqing; Kinziabulatova, Lilia; Bortoli, Marco; Manickoth, Anju; Barilla, Marisa A.; Huang, Haiyan; Blancafort, Lluís; Kohler, Bern; Lumb, Jean-Philip Lumb "Indole-5, 6-quinones mimic the optical and electronic properties of eumelanin," *Nature Chem.* **2023**, *15*, 787-793. DOI: 10.1038/s41557-023-01175-4.

134. Hanes, Alex T; Grieco, Christopher; Lalisse, Remy F.; Hadad, Christopher M.; Kohler, Bern "Vibrational Relaxation by Methylated Xanthines in Solution: Insights from 2D-IR Spectroscopy and Calculations," *J. Chem. Phys.* **2023**, *158*, 044302 (16 pages). DOI: 10.1063/5.0135412.

133. Grieco, C.; Kohl, F. R.; Kohler, B. "Ultrafast Radical Photogeneration Pathways in Eumelanin", *Photochem. Photobiol.* **2023**, *99*, 680-692. DOI: 10.1111/php.13731.

126. Grieco, C.; Kohl, F. R.; Hanes, A. T.; Kohler, B. "Probing the Heterogeneous Structure of Eumelanin using Ultrafast Vibrational Fingerprinting," *Nature Commun.* **2020**, *11*, 4569 (9 pages). DOI: 10.1038/s41467-020-18393-w.

96. Zhang, Y.; de La Harpe, K.; Beckstead, A. A.; Improta, R.; Kohler, B. "UV-induced Proton Transfer Between DNA Strands," *J. Am. Chem. Soc.* **2015**, *137*, 7059-7062. **Selected for a *JACS* spotlight and cover of issue 27, volume 137 (July 15, 2015).**

62. Schreier, W. J.; Schrader, T. E.; Koller, F. O.; Gilch, P.; Crespo-Hernández, C. E.; Swaminathan, V. N.; Carell, T.; Zinth, W.; Kohler, B. "Thymine Dimerization in DNA is an Ultrafast Photoreaction," *Science* **2007**, *315*, 625-629.

58. Crespo-Hernández, C. E.; Cohen, B.; Kohler, B. "Base stacking controls excited-state dynamics in A·T DNA," *Nature* **2005**, *436*, 1141-1144. DOI: 10.1038/nature03933

Invited Seminar and Colloquium Presentations

100+ invited lectures at universities and international conferences since 2010.

Research Capabilities

The Kohler group has state-of-the-art instrumentation for measuring absorption and emission from femtosecond to millisecond time scales. Probing of electronic and vibrational transitions is possible using femtosecond laser pulses with wavelengths that span the UV (200 – 400 nm) to the mid-IR (2 – 10 μm). A full suite of instrumentation for steady-state spectroscopy (CD, UV/vis, FTIR, fluorescence) is also available for comprehensive photochemical investigations.

ALEXANDRA S. LANDSMAN

EDUCATION

Princeton University, Ph.D. in Plasma Physics, 2005
Dartmouth College, B.A., High Honors in Physics, 1998

PROFESSIONAL EMPLOYMENT

Department of Physics, Ohio State University
Associate Professor, 2019-present

Max Planck Institute for the Physics of Complex Systems (MPIPKS/MPK)
Group Leader of Ultrafast Laser-Matter Interaction Group, 2015 – 2019
Partial employment at the Seminar of Applied Math, ETH Zurich, 2015-2017

Department of Physics, ETH Zürich
Senior Scientist (Marie Curie, Ultrafast Laser Physics group), 2011 – 2014

Department of Physics, ETH Zürich
Research Scientist, 2010 – 2011

James Madison University
Tenure-track assistant professor, 2008- 2009

National Academy of Sciences
National Research Council Postdoctoral Fellow (NRL), 2005-2008

TEACHING EXPERIENCE

- Honors Intermediate E&M (Physics 5400H), Fall 2021, 2022, 2023
- Honors Advanced E&M (Physics 5401H), Spring 2022, 2023, 2024
- Condensed Matter Physics (Physics 6806), Spring 2020, 2021
- Ionization of Atomic Systems (Master-level course), Autumn 2013
- Ultrafast Dynamics in Atoms, Molecules, and Plasmas (Master-level course), Spring 2013
- Topics in Attosecond Science (Master-level course), Fall 2012
- Strong Field Laser Ionization (Master-level course), Spring 2012
- Laser-Atom Interaction (Master-level course), Spring 2011
- Nonlinear Dynamics (elective upper-level undergraduate course), Spring 2009
- Modern Physics (required course for majors), Autumn 2008

STUDENTS AT OSU

- Graduate student (A. Schmoller), June 2022-present
- Graduate student (B. Grafstrom), June 2021-present
- Graduate student (A. AlShafey), June 2020 – present
- Undergraduate student (L. McHale), Summer 2023
- Undergraduate student (H. Pasquinilli), April 2022-present

- Undergraduate student (Steven Speck), December 2022-May 2023

FUNDING at OSU

- NSF PI-grant, $200K, funding period 2022-2025
- DOE PI-grant, $402K, funding period 2021-2024
- NSF-MRSEC, $18M funding for 2020-2026 (one of 20 co-PIs)
- OSU Materials Research Seed Grant, $45K (PI with Mohit Randeria co-PI), 2021

EXTERNAL SERVICE

- NSF review panel (2-day virtual site visit), Plasma Physics Division, 2022-2023
- NSF review panel (2-day virtual site visit), AMO Theory Division, 2022-2023
- Chair of XFEL and High-field Laser Science subcommittee of FiO+LS 2023 (organized by Optica)
- APS DAMOP organizing committee, 2022-2023
- DFG proposal reviewer, 2022-2023
- Chaired a Session at FiO+LS, October 18th, 2022
- DOE review panel (2-day virtual site visit), December 13-14, 2021
- Reviewer of DOE PI proposals, 2021, 2023
- Editorial Board Member for New Journal of Physics, June 2020 - present
- Chair of Focus Session at APS DAMOP meeting, June 2021
- Committee member for CLEO for selecting contributed and invited talks for CLEO, 2019-2021

OUTREACH

- Interviewed for *Wired* magazine story: "How to use a laser to kick an electron out of a molecule", November 2022
- Interviewed for *Wired* magazine story: "How quickly can atoms slip ghostlike through barriers?", July 2020
- Interviewed for *SPIE* News, Photonics Focus: "What exactly is a photon?", November 2020
- Speaker at CUWiP (APS Virtual Conference for Undergraduate Women in Physics), 2021

JOURNAL REFEREEING

Science, Nature, PNAS, Nature Physics, Nature Communications, Nature Communications Physics, Physical Review Letters, Phys. Rev. A, Phys. Rev. B, Journal of Physics B, Scientific Reports, Physics Letters A, Physica D, Physica A, Chaos, IEEE Photonics, IEEE Transactions on Circuits and Systems, Fluctuations and Noise Letters, Communications in Numerical Methods in Engineering, Discrete and Continuous Dynamical Systems, Optics Letters, Optics Express, ACS Photonics, New Journal of Physics, Physics of Plasmas,

ORGANIZED EVENTS

- Program Committee member at APS DAMOP (APS Division of Atomic, Molecular and Optical Physics), 2022-23
- One of the organizers for the Frontiers in Chemical Physics Lecture Series, Spring 2023
- Committee member for CLEO, FS7 High-Field Physics and Attosecond Science Subcommittee, 2019-2021.
- On Scientific Advisory Board for *Time and Fundamentals of Quantum Mechanics*, Weizmann Institute, January 28-31, 2019

NSF BIOGRAPHICAL SKETCH

Provide the following information for the Senior personnel.
Follow this format for each person. **DO NOT EXCEED 3 PAGES.**

IDENTIFYING INFORMATION:

NAME: Lu, Yuan-Ming

ORCID: 0000-0001-6275-739X

POSITION TITLE: Associate Professor

ORGANIZATION AND LOCATION: The Ohio State University, Columbus, OH, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	DATE RECEIVED	FIELD OF STUDY
Boston College, Chestnut Hill, MA, United States	PHD	09/2011	Physics
Tsinghua University, Beijing, China	BS	07/2007	Physics

Appointments and Positions

2019 - present Associate Professor, The Ohio State University, Department of Physics, Columbus, OH, United States

2015 - 2019 Assistant Professor, The Ohio State University, Department of Physics, Columbus, OH, United States

2011 - 2014 Postdoctoral Fellow, Lawrence Berkeley National Laboratory , Material Sciences Division, Berkeley, CA, United States

Products

Products Most Closely Related to the Proposed Project

1. Yan-Qi Wang, Chunxiao Liu, Yuan-Ming Lu. Theory of topological defects and textures in two-dimensional quantum orders with spontaneous symmetry breaking. 2022 November. Available from: https://arxiv.org/abs/2211.13207 DOI: 10.48550/ARXIV.2211.13207
2. Vijayvargia A, Nica E, Moessner R, Lu Y, Erten O. Magnetic fragmentation and fractionalized Goldstone modes in a bilayer quantum spin liquid. Physical Review Research. 2023; 5(2):-. Available from: https://link.aps.org/doi/10.1103/PhysRevResearch.5.L022062 DOI: 10.1103/PhysRevResearch.5.L022062
3. Bischoff M, Jones C, Lu Y, Penneys D. Spontaneous symmetry breaking from anyon condensation. Journal of High Energy Physics. 2019 February 12; 2019(2):-. Available from: https://link.springer.com/10.1007/JHEP02(2019)062 DOI: 10.1007/JHEP02(2019)062
4. Rasmussen A, Lu Y. Classification and construction of higher-order symmetry-protected topological phases of interacting bosons. Physical Review B. 2020; 101(8):-. Available from: https://link.aps.org/doi/10.1103/PhysRevB.101.085137 DOI: 10.1103/PhysRevB.101.085137
5. Lu Y, Ran Y. Symmetry-protected fractional Chern insulators and fractional topological insulators. Physical Review B. 2012; 85(16):-. Available from:

https://link.aps.org/doi/10.1103/PhysRevB.85.165134 DOI: 10.1103/PhysRevB.85.165134

Other Significant Products, Whether or Not Related to the Proposed Project

1. Manjunath N, Prem A, Lu Y. Rotational symmetry protected edge and corner states in Abelian topological phases. Physical Review B. 2023; 107(19):-. Available from: https://link.aps.org/doi/10.1103/PhysRevB.107.195130 DOI: 10.1103/PhysRevB.107.195130
2. Lee C, Sun Y, Ye L, Rathi S, Wang K, Lu Y, Moore J, Checkelsky J, Orenstein J. Spin wavepackets in the Kagome ferromagnet Fe_3Sn_2 : Propagation and precursors. Proceedings of the National Academy of Sciences. 2023 May 15; 120(21):-. Available from: https://pnas.org/doi/10.1073/pnas.2220589120 DOI: 10.1073/pnas.2220589120
3. Karaki M, Yang X, Williams A, Nawwar M, Doan-Nguyen V, Goldberger J, Lu Y. An efficient material search for room-temperature topological magnons. Science Advances. 2023 February 17; 9(7):-. Available from: https://www.science.org/doi/10.1126/sciadv.ade7731 DOI: 10.1126/sciadv.ade7731
4. Lu Y, Ran Y, Oshikawa M. Filling-enforced constraint on the quantized Hall conductivity on a periodic lattice. Annals of Physics. 2020 February; 413:168060-. Available from: https://linkinghub.elsevier.com/retrieve/pii/S000349161930315X DOI: 10.1016/j.aop.2019.168060
5. Wang Q, Liu C, Lu Y, Zhang F. High-Temperature Majorana Corner States. Physical Review Letters. 2018 October 30; 121(18):-. Available from: https://link.aps.org/doi/10.1103/PhysRevLett.121.186801 DOI: 10.1103/PhysRevLett.121.186801

Synergistic Activities

1. Service as an organizer of international workshops, the latest example being "TopoMag23 - Topology and Fractionalization in Magnetic Materials" workshop at OSU in May 15-20, 2023.
2. Service as a tutorial lecturer in international workshops and schools, the latest example being 3 invited tutorials at "Novel Quantum States in Condensed Matter 2022" workshop at YITP, Kyoto University in Oct. 2022.
3. Service as a member of guest editorial board, the latest example being "Focus Issue on Topological Physics: From Condensed Matter to Cold Atoms and Optics", New Journal of Physics, 2015-2016.
4. Broader impacts: faculty lecturer in the Scientific Thinkers program at OSU, aimed at high-poverty, underrepresented minority population of elementary school students in the Columbus area, since 2019.
5. Education: developments of new special topic courses for graduate students at OSU, the latest example being "Topological phenomena in condensed matters" in Autumn semester, 2020.

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Lu, Yuan-Ming in SciENcv on 2023-07-12 08:35:13

IDENTIFYING INFORMATION:

NAME: Myers, Roberto

ORCID iD: https://orcid.org/0000-0002-3695-2244

POSITION TITLE: Professor

PRIMARY ORGANIZATION AND LOCATION: Ohio State University, Materials Science and Engineering, Electrical and Computer Engineering, Physics, Columbus, Ohio, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of California, Santa Barbara, California, United States	Postdoctoral Fellow	10/2006 - 08/2008	California NanoSystems Institute
University of California, Santa Barbara, California, United States	PHD	10/2006	Materials
University of Pennsylvania, Philadelphia, Pennsylvania, United States	BS	05/2001	Materials Science and Engineering
University of Pennslyvania, Philadelphia, Pennsylvania, United States	BA	05/2001	Philosophy of Science

Appointments and Positions

2017 - present Professor, Ohio State University, Materials Science and Engineering, Electrical and Computer Engineering, Physics, Columbus, Ohio, United States

2013 - 2017 Associate Professor, Ohio State University, Materials Science and Engineering, Electrical and Computer Engineering, Physics, Columbus, Ohio, United States

2008 - 2013 Assistant Professor, Ohio State University, Materials Science and Engineering, Electrical and Computer Engineering, Physics, Columbus, Ohio, United States

Products

Products Most Closely Related to the Proposed Project

1. Fonseca Montenegro A, Baan M, Ghazisaeidi M, Grassman T, Myers R. Log-Normal Glide and the Formation of Misfit Dislocation Networks in Heteroepitaxial ZnS on GaP. Crystal Growth & Design. 2024 July 03; 24(14):6007-6016. Available from: https://pubs.acs.org/doi/10.1021/acs.cgd.4c00559 DOI: 10.1021/acs.cgd.4c00559
2. Verma D, Adnan M, Dhara S, Sturm C, Rajan S, Myers R. Anisotropic excitonic photocurrent in β − Ga 2 O 3 . Physical Review Materials. 2023; 7(6):-. Available from: https://link.aps.org/doi/10.1103/PhysRevMaterials.7.L061601 DOI: 10.1103/PhysRevMaterials.7.L061601
3. Giles B, Yang Z, Jamison J, Gomez-Perez J, Vélez S, Hueso L, Casanova F, Myers R. Thermally driven long-range magnon spin currents in yttrium iron garnet due to intrinsic spin Seebeck effect. Physical Review B. 2017 November 22; 96(18):-. Available from: https://link.aps.org/doi/10.1103/PhysRevB.96.180412 DOI: 10.1103/PhysRevB.96.180412
4. Giles B, Yang Z, Jamison J, Myers R. Long-range pure magnon spin diffusion observed in a

nonlocal spin-Seebeck geometry. Physical Review B. 2015 December 11; 92(22):-. Available from: https://link.aps.org/doi/10.1103/PhysRevB.92.224415 DOI: 10.1103/PhysRevB.92.224415

5. Jin H, Restrepo O, Antolin N, Boona S, Windl W, Myers R, Heremans J. Phonon-induced diamagnetic force and its effect on the lattice thermal conductivity. Nature Materials. 2015 March 23; 14(6):601-606. Available from: https://www.nature.com/articles/nmat4247 DOI: 10.1038/nmat4247

Other Significant Products, Whether or Not Related to the Proposed Project

1. Golam Sarwar A, Carnevale S, Kent T, Yang F, McComb D, Myers R. Tuning the polarization-induced free hole density in nanowires graded from GaN to AlN. Applied Physics Letters. 2015 January 19; 106(3):-. Available from: https://pubs.aip.org/apl/article/106/3/032102/240038/Tuning-the-polarization-induced-free-hole-density DOI: 10.1063/1.4906449
2. Boona S, Myers R, Heremans J. Spin caloritronics. Energy & Environmental Science. 2014; 7(3):885-. Available from: https://xlink.rsc.org/?DOI=c3ee43299h DOI: 10.1039/c3ee43299h
3. Carnevale SD, Kent TF, Phillips PJ, Sarwar AT, Selcu C, Klie RF, Myers RC. Mixed polarity in polarization-induced p-n junction nanowire light-emitting diodes. Nano Lett. 2013 Jul 10;13(7):3029-35. PubMed PMID: 23756087.
4. Jaworski C, Myers R, Johnston-Halperin E, Heremans J. Giant spin Seebeck effect in a non-magnetic material. Nature. 2012; 487(7406):210-213. Available from: https://www.nature.com/articles/nature11221 DOI: 10.1038/nature11221
5. Carnevale S, Marginean C, Phillips P, Kent T, Sarwar A, Mills M, Myers R. Coaxial nanowire resonant tunneling diodes from non-polar AlN/GaN on silicon. Applied Physics Letters. 2012 April 02; 100(14):-. Available from: https://pubs.aip.org/apl/article/100/14/142115/151434/Coaxial-nanowire-resonant-tunneling-diodes-from DOI: 10.1063/1.3701586

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Myers, Roberto in SciENcv on 2024-08-22 11:51:24

Employment/Education:

2020–Present	**The Ohio State University**, Ohio, USA. Associate professor
2016–2020	**The Ohio State University**, Ohio, USA. Assistant professor
2014-16	**University of California, Los Angeles**, California, USA. Assistant adjunct professor (postdoc) Postdoctoral supervisors: Sorin Popa and Dmitri Shlyakhtenko
2012-14	**University of Toronto**, Ontario, Canada. Mathematics postdoctoral fellow Postdoctoral supervisors: Dror Bar-Natan and George Elliott
2005-12	**University of California, Berkeley**, California, USA. Mathematics Ph.D. Advisor: Vaughan F.R. Jones Dissertation: "Planar structure for inclusions of finite von Neumann algebras"
2001-5	**The George Washington University**, Washington, D.C., USA, Mathematics, B.A., Ruggles Prize 2003 and 2005 Physics, B.S., Howard Hughes Fellow in Bioinformatics 2004 Chemistry, B.S., George Gamow Fellow 2003 Columbian School Distinguished Scholar, Summa Cum Laude, Phi Beta Kappa.

Selected Scientific/Academic Honors and Grants:

- Co-PI on NSF NRT grant 2244045 "NRT-QISE: QuGIP: a new interdisciplinary degree program for convergent research and graduate training in quantum information science and engineering 2023-28 (with PI Gupta and Co-PIs Myers, Reano, and Shafaat)
- NSF DMS grant 2154389 "Quantum Symmetries: Subfactors, Topological Phases, and Higher Categories" 2022-25
- Senior Participant on OSU's NSF QuSTEAM C-ACCEL grant 2040581. I am course lead for Course 3: Mathematical Methods for Quantum Information Science
- OSU 2020 ASC Early-Career Faculty Excellence Award
- NSF CAREER grant DMS 1654159 2017-2022 "Representing and classifying enriched quantum symmetry", with 2019 supplement DMS 1927098 and 2021 supplement DMS 2051170.
- NSF DMS grant 1500387 2015-16 "Classifying subfactors and fusion categories", transferred to OSU as NSF DMS grant 1655912 2016-18

Selected Peer reviewed journal articles:

1. *Enriched string-net models and their excitations* (with David Green, Peter Huston, Kyle Kawagoe, Anup Poudel, and Sean Sanford). To appear **Quantum** `arXiv:2305.14068`
2. *A categorical Connes' $\chi(M)$* (with Quan Chen and Corey Jones). To appear **Math. Ann.** `arXiv:2111.06378`
3. *Composing topological domain walls and anyon mobility.* (with Peter Huston, Fiona Burnell, and Corey Jones). **SciPost Phys.** 15, 076 (2023). `arXiv:2208.14018`
4. *The Extended Haagerup fusion categories* (with Pinhas Grossman, Scott Morrison, Emily Peters, and Noah Snyder). **Ann. Sci. Éc. Norm. Supér.** (4) 56 (2023), no. 2, 589–664 `arXiv:1810.06076`
5. *The classification of subfactors with index at most* $5\frac{1}{4}$ (with Narjess Afzaly and Scott Morrison). **Mem. Amer. Math. Soc.** 284 (2023), no. 1405. `arXiv:1509.00038`
6. *A 3-categorical perspective on G-crossed braided categories* (with Corey Jones and David Reutter). **J. Lond. Math. Soc.** (2) 107 (2023), no. 1, 333–406. `arXiv:2009.00405`
7. *Planar algebras in braided tensor categories* (with André Henriques and James Tener). **Mem. Amer. Math. Soc.** 282 (2023), no. 1392. `arXiv:1607.06041`

8. *Unitary dual functors for unitary multitensor categories.* **Higher Structures** 4(2):22-56, 2020. arXiv:1808.00323
9. *Realizations of algebra objects and discrete subfactors* (with Corey Jones). **Adv. Math.** 350 (2019), p 588-661 arXiv:1704.02035
10. Spontaneous symmetry breaking from anyon condensation (with Marcel Bischoff, Corey Jones, and Yuan-Ming Lu). **J. High Energy Phys.** (2019) 2019: 62. arXiv:1811.00434
11. *Operator algebras in rigid C*-tensor categories* (with Corey Jones). **Comm. Math. Phys.** 355 (2017), no. 3, 1121–1188, arXiv:1611.04620
12. *Bicommutant categories from fusion categories* (with André Henriques). **Selecta Math. (N.S.)** 23 (2017), no. 3, 1669–1708, arXiv:1511.05226.
13. *Categorified trace for module tensor categories over braided tensor categories* (with André Henriques and James Tener). **Documenta Math.** 21 (2016) 1089–1149 arXiv:1509.02937
14. *Chirality and principal graph obstructions.* **Adv. Math.** 273 (2015), no. 19, 32–55. arXiv:1307.5890
15. *Principal graph stability and the jellyfish algorithm* (with Stephen Bigelow). **Math. Ann.** 358 (2014), no. 1-2, 1-24. arXiv:1208.1564
16. *A planar calculus for infinite index subfactors.* **Comm. Math. Phys.** 319 (2013), no. 3, 595-648, arXiv:1110.3504
17. *The embedding theorem for finite depth subfactor planar algebras* (with Vaughan F. R. Jones). **Quantum Topol.** 2 (2011), no. 3, 301–337. arXiv:1007.3173

Selected academic service:

- Organized many national and international conferences, including conferences at AIM (2021, 2022), BIRS (2014, 2018, 2023), Fields (2023), IPAM (2021), and OSU (ECOAS 2019, OSU Quantum Symmetries 2019, GPOTS 2023)
- Served on several NSF panels.
- Served on OSU's Quantum Task Force in Spring 2020 and Autumn 2021, leading to the formation of OSU's Center for Quantum Information Science and Engineering (CQISE)
- Member of Advisory Board for OSU's CQISE 2022-25
- Co-PI for interdepartmental graduate program QuGIP at OSU

Mentoring of faculty, postdocs, PhD students, and undergraduate researchers:

- Postdocs: Kyle Kawagoe, Chian Yeong Chuah, Anup Poudel, Sean Sanford, Corey Jones
- PhD students: Anupama Bhardwaj, Chumeng Di, Brett Hungar, Giovanni Ferrer, Daniel Wallick, David Green, Quan Chen, Zachary Dell, Peter Huston, Roberto Hernandez Palomares
- Supervised 13 undergraduate researchers in at least 10 projects over 6 years
- I am an NRMN-CAM Trained Facilitator for mentor training, and I am part of OSU's NRMN-CAM mentor training team https://u.osu.edu/osupac/mentoring-training/.
- Senior Mentor for the Operator Algebra Mentor Network.

Selected Teaching at OSU:

- Developed multiple graduate topics classes, including Higher Linear Algebra (8110), Topological Phases of Matter (8800), and Quantum Algebra (8160)
- Developed undergraduate course Mathematical Methods for Quantum Information Science (Group Studies 2194) for QuSTEAM

Biographical Sketch

Ronald M. Reano

Professor, Department of Electrical and Computer Engineering
Co-Director, Center for Quantum Information Science and Engineering
The Ohio State University, Columbus, 205 Dreese Laboratory, 2015 Neil Avenue
Columbus, Ohio 43210, Tel: 614-247-7204, reano.1@osu.edu
u.osu.edu/reano.1
quantum.osu.edu

RESEARCH INTERESTS

Waveguide integrated optics, nonlinear optics in waveguides, and integrated optical devices to drive innovation in sensors, communications systems, and computing in the classical and quantum domains.

Integrated optics involves the manipulation of light at the micrometer and nanometer scale. It is analogous to integrated electronics. Instead of electrons, however, photons are guided and controlled on the surface of an optical chip. The use of light provides a route to miniaturized high-speed devices enabling revolutionary innovation.

DEGREES

- Ph.D., Electrical Engineering, University of Michigan, Ann Arbor, 2004
- M.S., Electrical Engineering, University of Michigan, Ann Arbor, 2000
- B.S., Electrical Engineering, University of New Mexico, 1996
- B.S., Physics, University of California, Los Angeles 1991

PROFESSIONAL EXPERIENCE

- 2022-Present: Co-Director, Center for Quantum Information Science and Engineering, The Ohio State University, Columbus, OH.
- 2017-Present: Professor of Electrical and Computer Engineering, The Ohio State University, Columbus, OH.
- 2011-2017: Associate Professor of Electrical and Computer Engineering, The Ohio State University, Columbus, OH.
- 2005-2011: Assistant Professor of Electrical and Computer Engineering, The Ohio State University, Columbus, OH.
- 2004-2005: Post-Doctoral Research Fellow with Professor Stella W. Pang in the area of nanotechnology, Solid State Electronics Laboratory, University of Michigan, Ann Arbor, MI.
- 1999-2004: Graduate Student Research Assistant with Professor Linda P. B. Katehi and John F. Whitaker, Radiation Laboratory and Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, MI.
- 1998-1999: Graduate Student Instructor, University of Michigan, Ann Arbor, MI.
- 1996-1998: Research Assistant, Microelectronics Research Center, University of New Mexico, Albuquerque, NM.
- 1992-1996: Aircraft Systems Reliability Analyst (US Air Force Active Duty), Systems Analysis Division, Headquarters Air Force Operational Test and Evaluation Center, Kirtland Air Force Base, New Mexico.

RECENT JOURNAL PUBLICATIONS

1. Karan Prabhakar and Ronald M. Reano, "Fabrication of Low Loss Lithium Niobate Rib Waveguides Through Photoresist Reflow," IEEE Photonics Journal 14, 1-8 (2022).

2. Karan Prabhakar, Ryan J. Patton, and Ronald M. Reano, “Stress reduction and wafer bow accomodation for the fabrication of thin film lithium niobate on oxidized silicon,” Journal of Vacuum Science and Technology B **39**, 062208 (2021).

3. Ryan J. Patton and Ronald M. Reano, “Higher Order Mode Conversion from Berry’s Phase in Silicon Optical Waveguides,” IEEE Photonics Journal doi: 10.1109/JPHOT.2021.3104180.

4. R. J. Patton and R. M. Reano, “Framework for tunable polarization state generation using Berry’s phase in silicon waveguides,” Optics Express **28**, 20845-20857 (2020).

5. J. T. Nagy and R. M. Reano, “Submicrometer periodic poling of lithium niobate thin films with bipolar preconditioning pulses,” Optical Materials Express **10**, 1911-1920 (2020).

6. J. Nagy and R. M. Reano, “Reducing leakage current during periodic poling of ion-sliced x-cut MgO doped lithium niobate thin films,” Optical Materials Express **9**, 3146-3155 (2019).

TEACHING ACTIVITIES (SEMESTER-LENGTH COURSES)

- ECE 6511: Nonlinear Optics (Senior Undergraduate and Graduate Students)
- ECE 5012: Integrated Optics (Undergraduate and Graduate Students)
- ECE 3050: Signals and Systems (Undergraduate Students)
- ECE 3010: Intro to Radio Frequency and Optical Engineering (Undergraduate Students)

HONORS AND AWARDS

- 2015 David C. McCarthy Engineering Teaching Award, College of Engineering, The Ohio State University. Citation: For outstanding teaching and creation of innovative optics and photonics undergraduate and graduate program.
- 2010: National Science Foundation (NSF) CAREER Award
- 2009: Army Research Office (ARO) Young Investigator Award
- 2009: Lumley Research Award, College of Engineering, The Ohio State University
- 2008: Defense Advanced Research Projects Agency (DARPA) Young Faculty Award
- 2006: Elevated to Senior Member IEEE.

SERVICE TO PROFESSIONAL SOCIETIES

- 2015 - April 2022: Associate Editor for Optics Express
- 2015: Program Co-Chair, Frontier in Optics Conference (OSA Annual Meeting)
- 2013 - 2014: Chair, Subcommittee on Integrated Photonics, Frontiers in Optics Conference (OSA Annual Meeting)
- 2013 – Present: Faculty advisor, Student Chapter of the Optical Society (OSA) at Ohio State University (chapter established in 2013 under the direction of Reano)
- 2012 - 2014: Member, Subcommittee on Optical Interconnects, IEEE Photonics Society Annual Meeting
- 2011 - 2012: Member, Subcommittee on Integrated Photonics, Frontiers in Optics Conference (OSA Annual Meeting)
- 2011 - 2014: Member, Conference Program Committee, International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication (EIPBN).

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Research Vision

To develop synthesis and atomic-scale manipulation techniques of thin films and heterostructures, leading to fundamental understanding and control of structure–composition–property relationships.To reveal hidden quantum states at the atomic scale and exploit structure-property relationships for the atom-by-atom design of multifunctional materials.

Appointment

Assistant Professor, Materials Science Department, Ohio State Univeirisity, Columbus, USA, August 2023-Present

Kavli Postdoctoral Fellow, Applied Engineering Physics, Cornell University, Ithaca, USA (with David Muller) September 2021-August 2023

Education

Ph.D. in materials, University of California, Santa Barbara, USA, 2016-2021 (with Susanne Stemmer) Thesis titled *Atomic Scale Understanding of Ferroelectricity and Superconductivity in* $SrTiO_3$

M.Sc in materials, University of Alberta, Edmonton, Canada, 2013-2016 (with Carlo Montemagno) Thesis titled *Organic electrochemical transistor understanding and modifying for sensing applications*

M.Sc in materials, Sharif University of Technology, Tehran, Iran, 2009-2011 (with Abolghasem Dolati) Thesis titled *Investigation of sensory behavior of aligned carbon nanotubes modified by platinum nanoparticles for hydrogen sulfide detection*

B.Sc in materials, Sahand University of Technology, Tabriz, Iran, 2005-2009 (with Alireza Akbari) Thesis titled *Ni-SiC nanocomposite coating and its mechanical properties*

Awards and Honors

- Kavli Postdoctoral Fellowship, Cornell University (2021)
- Young Investigators Lecture Series (YILS) Caltech (2021)
- DCMP student travel award, APS March meeting, Denver (2020)
- Graduate Students Association of University of Alberta Professional Development Grant (2015)

Membership in Professional Societies

- Materials Research Society (MRS), 2015-present
- American Physical Society (APS), 2018-present
- Microanalysis Society (MAS), 2019-present
- Microscopy Society of America (MSA), 2019-present

Relevant Publications

17) **S.Salmani-Rezaie**, B.Faeth, C.Mowers, Y.Tarn, P.Malinowski, K.Shen and D.A.Muller, *Understanding the interplay between superconductivity and atomic-scale interface structure of multilayer FeSe /$SrTiO_3$ (under review)*
16) T. Schwaigert*, **S.Salmani-Rezaie***,S.Hazra*, B.Pamuk, D.Muller,D.Schlom,V. Gopalan, and K. Ahadi, *Strain Engineering of $KTaO_3$:Route to Stabilize Cooperative Polar Orders (under review)*
15) A.Llanos, **S.Salmani-Rezaie**, J.Kim, N. Kioussis, D. A. Muller, and J. Falson, *Supercell formation in epitaxial rare-earth ditelluride thin films*, Cryst. Growth, 1, 115-121 (2024) [DOI] arXiv
14) A. H. Al-Tawhid, S. J. Poage, **S. Salmani-Rezaie**, A. Gonzalez, S. Chikara, D. A. Muller, D. P. Kumah, M.N. Gastiasoro, J. Lorenzana, and K. Ahadi, *Enhanced critical field of superconductivity at an oxide interface*, Nano Lett. 23,15,6944-6950 (2023) [DOI]
13) E.G. Arnault, A.H. Al-Tawhid,**S. Salmani-Rezaie**, D.A. Muller, D.P. Kumah, M.S. Bahramy, G. Finkelstein, and K. Ahadi, *Anisotropic Superconductivity at $KTaO_3$(111) interfaces*, Science Advances,9, eadf141 (2023)[DOI]
12) T. Schwagiert, **S. Salmani-Rezaie**, M. R. Barone, H. Paik, E.Ray, M.D.Williams, D. A. Muller, D.G. Schlom, and K. Ahadi, *Molecular Beam Epitaxy of $KTaO_3$*, JVST, A, 41 (2), 022703 (2023)[DOI]
11) **S. Salmani-Rezaie**, H. Jeong, R. Russell, J.Harter, and S. Stemmer, *Role of locally polar regions in the superconductivity of $SrTiO_3$* , Phys. Rev. Materials 5,104801 (2021) [DOI]
10) **S. Salmani-Rezaie***, L. Galletti*, R. Russell, T. Schumann, H. Jeong, Y. Li, J. Harter and S. Stemmer, *Superconductivity in Magnetically Doped $SrTiO_3$* Appl. Phys. Lett. 118, 202602 (2021) [DOI]
9) **S. Salmani-Rezaie**, K. Ahadi, and S. Stemmer, *Polar nanodomains in a ferroelectric superconductor*, Nano Lett. 20,9,6542-6547 (2020) [DOI]
8) **S. Salmani-Rezaie**, K. Ahadi, W. Strickland, and S. Stemmer, *Order-disorder ferroelectric phase transition of strained $SrTiO_3$ films*, Phys. Rev. Lett. ,125,8, 087601, (2020) [DOI] ArXiv
7) M. Goyal*, **S. Salmani-Rezaie** *, T.N. Pardue, B. Guo, D.A. Kealhofer, and S. Stemmer, *Carrier mobilities of (001) cadmium arsenide films*, APL Mater. 8,051106 (2020), * equal contribution[DOI]
6) T. Schumann, L. Galletti, H. Jeong, K. Ahadi, W.M. Strickland, **S. Salmani-Rezaie,** and S. Stemmer, *Possible signature of mixed-parity superconductivity in doped $SrTiO_3$ film*, Phys. Rev. B. 101, 100503 (R) (2020), * equal contribution[DOI] ArXiv
5) **S. Salmani-Rezaie**, H. Kim, K. Ahadi, and S. Stemmer, *Lattice relaxations around individual dopant atoms in $SrTiO_3$*, Phys. Rev. Mater 3, 114404 (2019) [DOI]
4) H. Kim, M. Goyal, **S. Salmani-Rezaie**, T. Schumann, T.N. Pardue, J-M. Zuo, and S. Stemmer, *Point group symmetry of cadmium arsenide thin films determined by convergent beam electron diffraction*, Phys. Rev. Mater 3, 084202 (2019) [DOI] ArXiv
3) K. Ahadi, L. Galletti, Y. Li, **S. Salmani-Rezaie**, W. Wu, and S. Stemmer, *Enhancing superconductivity with strain in $SrTiO_3$*, Science Adv., 5 120 (2019) [DOI]
2) H. Kim, M. Goyal, **S. Salmani-Rezaie**, T. Schumann, T.N. Pardue, J-M. Zuo, and S. Stemmer, *Point group symmetry of cadmium arsenide thin films determined by convergent beam electron diffraction*, Phys. Rev. Mater 3, 084202 (2019) [DOI] ArXiv
1) K. Ahadi, X. Lu, **S. Salmani-Rezaie**, P.B. Marshall, J.M. Rondinelli, and S. Stemmer, *Anisotropic magnetoresistance in itinerant, antiferromagnetic $EuTiO_3$*, Phys. Rev. B. 99, 041106(R) (2019) [DOI]

Invited Talks

- Yound Research Leaders Group Workshop, Correlation and Topology in magnetic materials, Ingelheim, Germany (Jul. 2024)
- PennState, Department of Materials Science and Engineering Seminar (Dec. 2023)
- Women in Microscopy conference, NUANCE (Mar. 2023)
- Arizona State University, Materials Department Seminar (Mar. 2022)
- University of Southern California, Materials Department Seminar (Mar. 2022)
- Yale University, Materials Department Seminar (Feb. 2022)
- California Institute of Technology, Materials Department Seminar (Feb. 2022)
- Ohio State University, Materials Department Seminar (Nov. 2021)
- University of Tennesse Knoxville Physics Department's condensed matter seminar (Aug. 2021)
- North Carolina State University, Early carrier lecture series, Materials Department (Feb.2021)
- Caltech's Young Investigators Lecture Series (YILS) in Engineering and Applied Science (Jan.2021)
- Cornell University, Applied and Engineering Physics, Kavli candidate seminar (Jan. 2021)
- University of California Irvine, Materials Department Seminar (June 2020)

Selected Conference Presentations

- Revealing the Short and Long-range Structural Distortions at Nb-doped $KTaO_3$, Microscopy and Microanalysis, Minneapolis, (2023)
- Strain Engineering of $KTaO_3$: route to Stablizie Polar Orders, MRS spring meeting, San Fransisco, (2023)
- Understanding the Interplay between Superconductivity and Atomic-Scale Interface Structure of Multilayer $FeSe/SrTiO_3$, APS March Meeting, Las Vegas (2023)
- Interplay between Polar Distortions and Superconductivity in $SrTiO_3$, Microscopy and Microanalysis, virtual (2021)
- Competition between doping and the polar instability in a ferroelectric superconductor, MRS fall meeting virtual (2020)
- Probing the polar instability of strained $SrTiO_3$ with HAADF-STEM, Microscopy and Microanalysis, Milwaukee (2020)
- Polar domains in strained $SrTiO_3$ films, APS March meeting, Denver (2020)

Teaching Experience

At OSU

- MATSCEN 5532:Electronic, Optical, and Magnetic Properties Laboratory (Fall 2023)
- MATSCEN 5572 *Materials for Energy Technology* (Fall 2023)

Before OSU

- Teacher assistant, MATRL 226, Symmetry and tensor properties of materials (Spring 2021)
- Teacher assistant, MATRL 286D, Advanced TEM, UCSB (Spring 2020)
- Teacher assistant, MATRL 200C, Structural evolution, UCSB (Spring 2019)
- Teacher assistant, MATE 202, Materials Science II, University of Alberta (Winter 2015)

Journal Reviews

Physical Review Letters, Physical Review B, Nano Letters, and Ultramicroscopy

Kevin Singh

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EMPLOYMENT

Assistant Professor — Starting 2025
Department of Physics, The Ohio State University

Postdoctoral Fellow — 2019 - 2024
Pritzker School of Molecular Engineering, University of Chicago

Intelligence Community Postdoctoral Research Fellow — 2020 - 2022
Pritzker School of Molecular Engineering, University of Chicago

EDUCATION

Ph.D. in Physics, University of California, Santa Barbara — March 2019
Thesis: *Floquet Engineering with Ultracold Lithium in Optical Lattices*
Thesis Advisor: Dr. David Weld

M.A. in Physics, University of California, Santa Barbara — June 2016

S.B. in Physics, Massachusetts Institute of Technology — June 2013
Thesis: *Search for the standard model Higgs boson in the Z gamma channel*
Thesis Advisor: Dr. Christoph Paus

AWARDS AND HONORS

Quantum Creators Prize (Chicago Quantum Exchange) — 2023
The Maria Lastra Excellence in Mentoring Award (Pritzker School of Molecular Engineering, University of Chicago) — 2021
Best Poster Award: MPQ 2021 (Machine Learning for Quantum 2021) — 2021
Intelligence Community Postdoctoral Fellowship (Office of the Director of National Intelligence) — 2020
Philip and Aida Siff Educational Foundation Scholarship (The Philip and Aida Siff Educational Foundation) — 2015
MIT Joel Matthew Orloff Award in Service (MIT Department of Physics) — 2013
MIT QuestBridge Scholar (Massachusetts Institute of Technology) — 2009 - 2013

PUBLICATIONS

12. S. Anand, C. E. Bradley, R. White, V. Ramesh, **K. Singh**, and H. Bernien. *A dual-species Rydberg array.* arXiv:2401.10325 (2024) (To appear in Nature Physics)
11. **K. Singh**, C. E. Bradley, S. Anand, V. Ramesh, R. White, and H. Bernien. *Mid-circuit correction of correlated phase errors using an array of spectator qubits.* Science **380**, 1265-1269 (2023)
10. **K. Singh**, S. Anand, A. Pocklington, J. T. Kemp, and H. Bernien. *A dual-element, two-dimensional atom array with continuous mode operation.* Phys. Rev. X. **12**, 011040 (2022) **(Featured in APS *Physics Magazine*)**
9. S. Menon, **K. Singh**, J. Borregaard, and H. Bernien. *Nanophotonic quantum network node with neutral atoms and an integrated telecom interface.* New Journal of Physics **22,** 073033 (2020)
8. **K. Singh**, C. J. Fujiwara, Z. A. Geiger, E. Q. Simmons, M. Lipatov, A. Cao, P. Dotti, S. V. Rajagopal, R. Senaratne, T. Shimasaki, M. Heyl, A. Eckardt, and D. M. Weld. *Quantifying and Controlling Prethermal Nonergodicity in Interacting Floquet Matter.* Phys. Rev. X. **9**, 041021 (2019)
7. K. M. Fujiwara, **K. Singh**, Z.A. Geiger, R. Senaratne, S. V. Rajagopal, M. Lipatov, and D.M. Weld. *Transport in Floquet-Bloch bands.* Phys. Rev. Lett. **122**, 010402 (2019)
6. Z. Geiger, K. M. Fujiwara, **K. Singh**, R. Senaratne, S. V. Rajagopal, M. Lipatov, T. Shimasaki, R. Driben, V. V. Konotop, T. Meier, and D. M. Weld. *Observation and Uses of Position-space Bloch Oscillations in an Ultracold Gas.* Phys. Rev. Lett. **120**, 213201 (2018) **(Featured in APS *Physics Magazine* and selected for an Editor's Viewpoint)**

5. R. Senaratne, S. V. Rajagopal, T. Shimasaki, P. E. Dotti, K. M. Fujiwara, **K. Singh**, Z.A. Geiger, and D.M. Weld. *Quantum Simulation of Ultrafast Dynamics Using Trapped Ultracold Atoms.* Nature Communications **9**, 2065 (2018)
4. K.M. Fujiwara, Z.A. Geiger, **K. Singh**, R. Senaratne, S.V. Rajagopal, M. Lipatov, T. Shimasaki, and D.M. Weld. *Experimental Realization of a Relativistic Harmonic Oscillator.* New J. Phys. **20**, 063027 (2018)
3. S.V. Rajagopal, K.M. Fujiwara, R. Senaratne, **K. Singh**, Z.A. Geiger, and D.M. Weld. *Quantum Emulation of Extreme Non-equilibrium Phenomena with Trapped Atoms.* Annalen Der Physik. **529**, 1700008 (2017)
2. **K. Singh**, K. Saha, S.A. Parameswaran, and D. M. Weld. *Fibonacci Optical Lattices for Tunable Quantum Quasicrystals.* Phys. Rev. A **92**, 063426 (2015)
1. Bornheim, A. et al. *Search for a Light Higgs boson in the Z boson plus a Photon Decay Channel*. CMS Physics Analysis Summary, CMS PAS HIG-12-049 (2012)

PRESENTATIONS

Since 2018: more than 25 talks at symposiums and international conferences (14 invited)

TEACHING EXPERIENCE

Nominated in 2014 and in 2017 for Graduate Student Association Excellence in Teaching Award (UCSB)

Teaching Assistant

Lead TA for UCSB Physics 20 (classical mechanics for physics majors) — Fall 2016
Coordinated homework, reviews, and activities of all TAs and graders.

UCSB Physics 210A (graduate electromagnetic theory) — Winter 2015

Laboratory Instructor and Teaching Assistant:

UCSB Physics 127AL (analog electronics) — Summer 2014

UCSB Physics 6C (optics) — Spring 2014

UCSB Physics 6A (classical mechanics for life-science majors) — Winter 2014

UCSB Physics 3 (waves and vibrations) — Fall 2013

LEADERSHIP AND OUTREACH

Member of PME Equity, Diversity, and Inclusion Committee — 2022- 2024
Engage with EDI issues at all levels. Personal efforts include new postdoc onboarding, outreach events for first-generation college students, design and staffing of two demos for annual UChicago South Side Science Festival

Condensed Matters Seminar Series — 2019 - 2020
Created and organized a monthly seminar series to bring together and encourage collaboration among the various physical science departments at UChicago

Educational Outreach with UCSB Women in Physics — 2014 - 2016
Visited local high schools with the UCSB Women in Physics program to teach students about superfluidity, Bose-Einstein condensation, and pursuing careers in physics

President of MIT Society of Physics Students — 2012 - 2013

MIT-China Development Initiative – Service Leadership Program — 2012
Mentored Chinese middle school and high school students on subjects of leadership, service, and educational opportunities in the US – Shenzhen, CN

Boston Let's Get Ready Program — 2011
Taught free SAT prep class for high school students in the Boston area, targeting students from low-income areas

PROFESSIONAL SERVICE

Referee
Physical Review, Physical Review Letters, Physical Review X

Conference Session Chair
APS March Meeting, APS Division of Atomic, Molecular, and Optical Physics

Brian J. Skinner

Contact Information

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191 West Woodruff Ave
Columbus OH, 43210 USA

Phone: +1-540-257-3236
E-mail: skinner352@osu.edu
WWW: physics.osu.edu/people/skinner.352

Employment History

Ohio State University, Columbus, OH USA
Assistant Professor, Department of Physics — January 2020 – present

Massachusetts Institute of Technology, Cambridge, MA USA
Postdoctoral Associate — August 2015 – July 2019
Supervisors: Liang Fu, Leonid Levitov

Argonne National Laboratory Materials Science Division, Argonne, IL USA
Eugene Wigner Postdoctoral Fellow — August 2013 – August 2015
Supervisor: K. A. Matveev

University of Minnesota Physics Department, Minneapolis, MN USA
Research Associate — September 2011 – August 2013
Advisors: B. I. Shklovskii and Alexander L. Efros

Education

University of Minnesota, Minneapolis, MN USA
Ph.D., Physics, August 2011
Dissertation: *Microscopic Theory of Supercapacitors*
Advisor: Boris I. Shklovskii

Virginia Polytechnic Institute & State University (Virginia Tech), Blacksburg, VA USA
B.S., Physics and B.S., Mechanical Engineering, May 2007
Summa cum Laude, Honors Baccalaureate diploma
Minors in Mathematics and Spanish

Summary of Research Interests

I am a theorist focusing mostly on dynamical and transport phenomena in quantum many-body systems.

Selected Awards

Frontiers of Science Award, 2023

Provost's Early Career Scholar, 2022

NSF CAREER Award, 2021

Eugene Wigner Postdoctoral Fellowship, 2013

National Science Foundation Graduate Research Fellowship, 2007

Rhodes Scholarship finalist, 2007

Publications

See Google Scholar or the arXiv

Teaching

Physics 8806.01 - 8806.02: Topics in Condensed Matter Physics 1 & 2 (Fall 2023, Spring 2024)
Two-semester sequence of advanced graduate-level courses in condensed matter physics.

Physics 1251: E & M, Optics, Modern Physics (Spring 2022, Fall 2022, Spring 2023)
Large, introductory-level course for engineering students.

Other teaching activities:

- Lecturer at the *Condensed Matter Summer School: Dynamics and Quantum Information in Many-body Systems*, University of Minnesota, June 2023.
- Graduate of the MIT Kaufman Teaching Certificate Program (Summer 2018)
- Instructor/course creator for the annual "MIT Splash" event for high school students (November 2015, 2016, 2017, 2018)

ADVISING

PhD advisor to five students at Ohio State University:

- Xiaozhou Feng, graduated spring 2023: now a postdoc in Physics at UT Austin
- Sandeep Joy, anticipated graduation summer 2024
- Calvin Pozderac, anticipated graduation summer 2024
- Poulomi Chakraborty, anticipated graduation summer 2026
- Joshua Scales, anticipated graduation summer 2027

Primary advisor to one postdoctoral researcher:

- Aaron Hui (2021 - 2024): now an Assistant Professor of Physics at Brown University

Co-advisor to three other postdoctoral researchers:

- Xu Yang (2021 - present)
- Kyle Kawagoe (2022 - present)
- Penghao Zhu (2023 - present)

SELECTED OUTREACH

Mentor for students in the APS Bridge Program.

Member of the coaching staff for the US team of the International Physics Olympiad (2018 - 2022). I continue to write problems for training and selection of the US Team.

Author of a popular physics blog, Gravity and Levity, that explains upper-level concepts in physics and has been viewed > 1.5 million times (2009 - 2020).

Speaker at the 2016 USA Science and Engineering Festival in Washington DC.

SELECTED POPULAR PRESS COVERAGE

Quanta Magazine, "Physicists Observe 'Unobservable' Quantum Phase Transition", September 2023.

Phys.org, "Measurements induce a phase transition in entangled systems", August 2019.

MIT News, "Turning up the heat on thermoelectrics", May 2018.

Phys.org, "Electrons 'puddle' under high magnetic fields, study reveals", January 2017.

Inside Science, "Electrons in Semiconductors Don't Follow Random Routes", August 2016.

Boston Globe, "In crowds, human 'particles' follow laws of movement", December 2014.

Nature News and *Scientific American*, "Mathematical Time Law Governs Crowd Flow", November 2014.

Wired Magazine, "NBA Players Scoff at Mathematical Model Suggesting When to Shoot", February 2012.

Science Magazine, "The Mathematics of Basketball", August 2011.

Alexander Yu. Sokolov

The Ohio State University
Department of Chemistry & Biochemistry
100 W. 18th. Ave., Columbus, OH 43210

E-mail: sokolov.8@osu.edu
Web: research.cbc.osu.edu/sokolov.8
Phone: (614) 688-3636

Education:

2009 – 2014	**University of Georgia**, Center for Computational Quantum Chemistry Ph.D., Chemistry Advisor: Professor Henry F. Schaefer III Thesis: "Development of density cumulant functional theory"
2004 – 2009	**St. Petersburg State University**, Russia Specialist Degree (M.S.), Chemistry, Diploma with Distinction Advisor: Professor Olga V. Sizova Thesis: "Valence structure analysis of heavy transition metal complexes with electronic configurations d^6, d^7, d^8, and d^{10}"

Professional Experience:

2023 – present	**Associate Professor**, The Ohio State University Department of Chemistry & Biochemistry
2017 – 2023	**Assistant Professor**, The Ohio State University Department of Chemistry & Biochemistry
2016 – 2017	**Postdoctoral Scholar**, California Institute of Technology Advisor: Professor Garnet K.-L. Chan
2014 – 2016	**Postdoctoral Research Associate**, Princeton University Advisor: Professor Garnet K.-L. Chan

Scholarships, Honors, and Awards:

2023	OpenEye Outstanding Junior Faculty Award in Computational Chemistry
2021	National Science Foundation CAREER Award
2016	American Chemical Society Physical Chemistry Division Postdoctoral Award
2015	IBM-Löwdin Award for Postdoctoral Associates, 55^{th} Sanibel Symposium
2014	Martin Reynolds Smith Award, The University of Georgia
2013	Dissertation Completion Award, The University of Georgia
2013	Best Graduate Student Poster Award, 53^{rd} Sanibel Symposium
2012	James L. Carmon Award, The University of Georgia
2009	Best Alumnus of St. Petersburg 2009 Award, St. Petersburg (Russia)
2008 – 2009	Special Scholarship of the Government of Russian Federation (Russia)
2004 – 2009	Full Scholarship, St. Petersburg State University (Russia)

University Service:

2023 – 2024	Search committee for experimental physical chemistry junior faculty search
2022 – present	CQISE advisory committee
2020 – present	Physical division seminar coodinator
2019 – present	Graduate student admissions committee
2018 – 2019	Graduate student recruitment committee

Professional Service, Activities & Affiliations:

2019 – present	Member, PySCF Board of Directors
2018 – present	Member, Institute for Optical Science at the Ohio State University
2017 – present	Reviewer for the following organizations: National Science Foundation, Department of Energy, American Chemical Society Petroleum Research Fund, Swiss National Science Foundation, German Research Foundation
2014 – present	Reviewer for the following journals: Journal of Chemical Theory and Computation, Journal of Chemical Physics, Journal of American Chemical Society, Nature Chemistry, Physical Chemistry Chemical Physics, International Journal of Quantum Chemistry, Dalton Transactions, WIREs Computational Molecular Science, Theoretical Chemistry Accounts, New Journal of Chemistry, Acta Physica Polonica A
2012 – present	Member, American Chemical Society

Teaching Experience:

2023 – present	Quantum Chemistry and Spectroscopy (CHEM 6510), Instructor, OSU
2019 – present	Physical Chemistry I (CHEM 4300), Instructor, OSU
2018 – 2021	Advanced Quantum Chemistry and Spectroscopy (CHEM 7520), Instructor, OSU
2011 – 2014	Advanced Quantum Chemistry (CHEM 8950), Teaching Assistant, UGA
2011 – 2012	Summer Undergraduate Fellowship Program, Instructor and Mentor, UGA
2010 – 2011	General Chemistry Laboratory I and II, Teaching Assistant, UGA
2008	General and Inorganic Chemistry, Teaching Assistant, St. Petersburg State University (Russia)

Selected Invited Talks:

06/2023	Quantum International Frontiers conference, Lodz (Poland)
06/2023	Symposium “Advances in Theoretical and Computational Chemistry”, Vancouver (Canada)
04/2023	Workshop on Excited-State Methods, Toulouse (France)
03/2023	COMP Award Symposium, ACS National Meeting, Indianapolis, IN (USA)
06/2022	10^{th} Molecular Quantum Mechanics (MQM) Congress, Blacksburg, VA (USA)
06/2022	International Workshop on Reduced Density Matrix Theory for Quantum Many-Fermion Systems, San Sebastian (Spain)
02/2022	Sanibel Symposium, St. Simon’s Island, GA (USA)
12/2021	Symposium “Computational Quantum Chemistry: Synergism Between Theory and Experiment”, Pacifichem 2020, Honolulu, HI (USA)
07/2021	Workshop “New Developments in Coupled-Cluster Theory”, Telluride, CO (USA)
06/2021	“New Frontiers in Electron Correlation” Conference, Telluride, CO (USA)
06/2020	“Low-scaling and Unconventional Electronic Structure Techniques” (LUEST) Conference, Telluride, CO (USA)
08/2019	Symposium “Computational Quantum Chemistry: From Promise to Prominence”, 258^{th} ACS National Meeting, San Diego, CA (USA)
07/2019	32^{nd} Midwest Undergraduate Computational Chemistry Consortium Conference, Columbus, OH (USA)
06/2019	Workshop “Fundamental Challenges of Electron-Density-Based Approaches to Time-Dependent Processes and Open Quantum Systems”, ETH Zürich (Switzerland)
03/2019	Symposium “Quantum Mechanics: Strong Correlation”, 257^{th} ACS National Meeting, Orlando, FL (USA)

Publications:

Google Scholar http://scholar.google.com/citations?user=RlJQsC8AAAAJ&hl=en

BIOGRAPHICAL SKETCH
Fernando Lisboa Teixeira

PROFESSIONAL PREPARATION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, MA
Postdoc, Electrical Engineering, 1999–2000
UNIVERSITY OF ILLINOIS, Urbana-Champaign, IL
Electrical Engineering, Ph.D., 1999
PONTIFICAL CATHOLIC UNIVERSITY, Rio de Janeiro, Brazil
Electrical Engineering, B.S., 1991, M. S., 1995

ACADEMIC APPOINTMENTS

THE OHIO STATE UNIVERSITY, Columbus, OH
Professor, Electrical Engineering, 2011–present
Associate Professor, 2006–2011
Assistant Professor, 2000–2006
MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, MA
Postodoctoral Research Associate, Research Laboratory of Electronics, 1999–2000
UNIVERSITY OF ILLINOIS, Urbana-Champaign, IL
Research Assistant, Department of Electrical and Computer Engineering, 1996–1999

SELECTED PUBLICATIONS

- Nayak, M. Kumar, and F. L. Teixeira, “Koopman autoencoders for reduced-order modeling of kinetic plasmas,” in: *Advances in Electromagnetics Empowered by Artificial Intelligence and Deep Learning*, S. D. Campbell and D. H. Werner (eds.) Wiley-IEEE Press, 2023, to appear.
- Nayak, M. Kumar, and F. L. Teixeira, “Detection and prediction of equilibrium states in kinetic plasma simulations via mode tracking using reduced-order dynamic mode decomposition,” *J. Comp. Phys.*, vol. 447, 110671, 2021.
- D. Y. Na, J. Zhu, W. C. Chew, and F. L. Teixeira, “Quantum information preserving computational electromagnetics,” *Phys. Rev. A*, vol. 102, 013711, 2020.
- D.-Y. Na, J. L. Nicolini, R. Lee, B.-H. V. Borges, Y. A. Omelchenko, F. L. Teixeira, “Diagnosing numerical herenkov instabilities in relativistic plasma simulations based on general meshes,” *J. Comp. Phys*, vol. 402, 108880, 2020.
- A. F. Mota, A. Martins, V. Pepino, H. Ottevaere, W. Meulebroeck, F. L. Teixeira, and B.-H. V. Borges, “Semi-analytical modeling of arbitrarily distributed quantum emitters embedded in nano-patterned hyperbolic metamaterials,” *J. Opt. Soc. Am. B*, vol. 36, no. 5, pp. 1273-1287, 2019.
- D. Y. Na and F. L. Teixeira, “Analysis of multipactor effects by a particle-in-cell algorithm integrated with secondary electron emission model on irregular grids*,” IEEE Trans. Plasma Sci.*, vol. 47, no. 2, pp. 1269-1278, 2019.
- J. L. Nicolini, D.-Y. Na, and F. L. Teixeira, “Model order reduction of electromagnetic particle-in-cell kinetic plasma simulations via proper orthogonal decomposition,” *IEEE Trans. Plasma Sci.*, vol. 47, pp. 5239-5250, 2019.

- A.F. Mota, A. Martins, H. Ottevaere, W. Meulebroeck, E. R. Martins, J. Weiner, F. L. Teixeira, and B.-H. Borges, "Semi-analytical model for design and analysis of grating-assisted radiation emission of quantum emitters in hyperbolic metamaterials," *ACS Photonics*, vol. 5, no. 5, pp. 1951-1959, 2018.
- D.-Y. Na, H. Moon, Y. A. Omelchenko, and F. L. Teixeira, "Relativistic extension of a charge-conservative finite element solver for time-dependent Maxwell-Vlasov equations," *Phys. Plasmas*, vol. 25, 013109, 2018.
- D.-Y. Na, Y. A. Omelchenko, H. Moon, B.-H. V. Borges and F. L. Teixeira, `Axisymmetric charge-conservative electromagnetic particle simulation algorithm on unstructured grids: Application to microwave vacuum electronic devices,' *J. Comp. Phys*., vol. 346, pp. 295-317, 2017.
- D. Y. Na, H. Moon, Y. A. Omelchenko, and F. L. Teixeira, `Local, explicit, and charge-conserving electromagnetic particle-in-cell algorithm on unstructured grids,' *IEEE Trans. Plasma Sci*., vol. 44, no. 8, pp. 1353-1362, 2016.
- H. Moon, F. L. Teixeira, and Y. A. Omelchenko, 'Exact charge-conserving scatter-gather algorithm for particle-in-cell simulations on unstructured grids: A geometric perspective,' *Comp. Phys. Comm*., vol. 194, pp. 43-53, 2015.

SYNERGISTIC ACTIVITIES

Editorial and Reviewer Activities

Associated Editor, *IET Microwaves, Antennas and Propagation*, 2014-present; Associate Editor, *IEEE Antennas and Wireless Propagation Letters*, 2008–2014; Guest Editor, *Remote Sensing*, 2018; Guest Editor, *IEEE Antennas and Wireless Propagation Letters*, 2015; Guest Editor, *Progress in Electromagnetics Research* (PIER), 2001; Production Editor, *Journal of Electromagnetic Waves and Applications*, 2000-2005; Reviewer for NSF panels, DoD, NASA, several international agencies (Belgium, Canada, France, Georgia, Hong Kong, Israel, Kuwait, Netherlands, Qatar, Poland, S. Africa, Turkey). Referee for 100+ journals (APS, IOP, IMA, IEEE, OSA, SIAM etc.).

Student Advising

PhD advisor to completion for 25+ students. Dissertation committee member for 110+ PhD students.

Professional Service

Fellow IEEE. Elected Member URSI Commissions B and F. Secretary, Vice-Chairman, and Chairman of the IEEE Columbus AP/MTT Joint Chapter, 2002-2006. TPC PIERS 00, Cambridge, MA. AdCom and session organizer: PIERS '00, '02, '08; ICEAA 01, APS/URSI '02. TPC member: IEEE APS/URSI '03–'22; IEEE FEM Workshop '04, '08,'10, '12; GPR '06; EuCAP '14, '15, '16, '17, '18; IEEE VTC '17; SBMO '21. ICERM 2018 Workshop Organizer. ICCEM '20 Advisory Committee member. Session chair in numerous conferences.

Other

NSF CAREER awardee. Oberwolfach Institute Fellow. OSU Harrison Faculty Award for Excellence in Engineering Education. NASA Certificate of Appreciation (twice). OSU Lumley Research Award (twice). OSU Commercialization Achievement Award,

Nandini Trivedi

Professional Preparation

Indian Institute of Technology, Delhi, India	Physics	B.S.-M.S. 1981
Cornell University, Ithaca, NY	Physics	Ph.D., 1987
University of Illinois at Urbana-Champaign, IL	Post-doctoral research associate	1987-1989
SUNY at Stony Brook, NY	Post-doctoral research associate	1989-1991

Appointments

Professor, Department of Physics	The Ohio State University	2004-
Visiting Professor, Physics	MIT	Spring 2016
Visiting Professor, Physics	UC Berkeley	Fall 2016
Visiting Professor	University of Illinois at Urbana-Champaign	2002-2003
Reader, Associate Professor, Professor	Tata Institute of Fundamental Research	1995-2004
Assistant Scientist, Scientist	Argonne National Laboratory	1991-1995

Honors and Awards:

2022	College of Arts and Sciences Distinguished Professor of Physics, Ohio State University
2021	Distinguished Alumni Award, Indian Institute of Technology, Delhi,
2020	Fellow, American Association for Advancement of Science
2019	Distinguished Scholar, The Ohio State University
2018	Fellow, Institute of Science of Origins, Case Western Reserve University
2015-2016	Simons Fellow
2010	Fellow, American Physical Society

Total Publications: 137 (refereed); Review articles: 9; Books edited: 1

h-index: 61; 38 papers with over 100 citations (Google Scholar)

Patent No: US 11,011,692 B2 May 18, 2021, *Thermoelectric Device Utilizing Non-Berry Curvature*

Synergistic Activities

- Member, International Scientific Advisory Board, Max Planck Institute for Solid State Research, 2023-2028.
- Member (2015 - present), Editorial Board, Reports on Progress in Physics [Impact Factor 18], Institute of Physics (IOP), United Kingdom
- Chair (2020), Gordon Research Conference, Strongly Correlated Systems
- Chair (2020), Vice Chair (2019), APS Buckley Prize Committee
- Chair (2018), Vice Chair (2017), APS Onsager Prize Committee
- Kavli Institute of Theoretical Physics, Member, Advisory Board, 2016-2019; Chair, CMT Advisory Committee 2017-2018.
- Editorial board, Reports on Progress in Physics, 2015-
- Co-organizer, "Spin-Orbit Coupling and Magnetism in Correlated Transition Metal Oxides", OSU, May 3-7, 2015.
- Member-at-large, Condensed Matter Physics (DCMP), American Physical Society (2011-2014)
- Member, DOE Panel on "Grand Challenges at the Interface of Condensed Matter Physics and High Energy Physics" chaired by Juan Maldacena (Princeton), Eduardo Fradkin (UIUC) (2014)

- Co-organizer, Aspen summer program on "Disorder, Dynamics, Frustration and Topology in Quantum Condensed Matter", Aspen Center of Physics, (2013).
- Member, DOE-BES review panel for Oak Ridge National Laboratory (2011)
- Founder-Director, "Scientific Thinkers", an inquiry-based science outreach program started in 2012 at Innis Elementary School, Columbus, Ohio, a largely minority school. The program brings STEM undergraduate and graduate students to the classroom to teach hands-on experiments and critical thinking to elementary school students.
- Director and organizer of 3 "Festivals of Physics" (2007, 2009, 2011) in partnership with Columbus Science Museum COSI with participation by ~80 undergraduate and graduate students engaging with the public in each event.

Graduate Advisor:
Neil W. Ashcroft, Cornell University

Postdoctoral advisors:
David M. Ceperley, University of Illinois, Urbana-Champaign
Philip B. Allen, SUNY Stony Brook

Total Number of Graduate Students Supervised: 26
Total Number of Postdocs Supervised: 18
Total Number of Undergraduate Students Supervised: 27

Post-Doctoral Advisees

Current: Abhisek Samanta (PhD: TIFR, Mumbai), Xu Yang (PhD: Boston College), Penghao Zhu (PhD: UIUC)

Past: Zachariah Addison (Asst. Prof. Wellesley College, Boston, PhD: U. Penn), Oscar Avalos Ovando, Kyungmin Lee, Niravkumar D. Patel, Subhasree Pradhan, Kyusung Hwang, Karim Bouadim, Soon-Yong Chang, Mehdi Kargarian, Yen-Lee Loh, Anamitra Mukherjee, David Nozadze, Prasenjit SenSarma, Salman Ullah, Shizhong Zhang

Graduate students

Current: Shi Feng (Presidential Fellow 2023), Sayantan Roy, Ryan Buechele, Oleksandr Molchanov, Arkaprava Mukherjee, Carter Swift, Nagananda Krishnamurthy

Past: Joseph Szabo, Yanjun He, Wenjuan Zhang, Franz Utermohlen, David Ronquillo, Hasan Khan, Timothy McCormick (Presidential Fellow 2017), David Ronquillo, Chris Svoboda**,** William Cole (Presidential Fellow 2013), Oinam Ngamba Meetei (Presidential Fellow 2012), Onur Erten, Mason Swanson (NSF Fellow), Eric Duchon, Julia Janczak, Arun Paramekanti, Sara Rajaram, Dariush Heidarian, Amit Ghosal

Undergraduate research students

Current: Seth Cox, Salim Karimov, Luke Knull, Nigel Krekeler, Alexander Torres

Past: Lauren Clar, Boxi Song, Cullen Ganterberg, Candice King, Dhruv Prasad, Benjamin Knight, Ian Osborne**,** Robert McKay, Omar Mansour, Charles Woodrum, Ian Osbourne, Adu Vengal, Caitlin Patterson, Michael Ferrarelli, Henry Xiong, William Chuirazzi, Joseph Garrett, Robert Ivancic, Nickolas Sedblock, Nathan Turner, Natalie Zeleznick, Nathan McKee

Biographical Sketch: Dr. Wolfgang Windl

Professor
Department of Materials Science and Engineering, The Ohio State University,
2041 College Rd, Columbus, OH 43210
voice: 614-247-6900; fax: 614-292-1537
windl.1@osu.edu

Education

Institution	Major/Area	Degree/Position	Year
Los Alamos National Laboratory	Theoretical Division	Postdoc	1996-97
Arizona State University	Solid State Science Ctr.	Postdoc	1995-96
University of Regensburg, Germany	Physics	Doctor of Science	1995
University of Regensburg, Germany	Physics	Diploma (~M.S.)	1992

Positions

2010- Professor, Department of Materials Science and Engineering, The Ohio State University, Columbus, OH.

2008- Co-PI and Member of the "Center for Emergent Materials" at OSU, an NSF MRSEC

2001-2010 Associate Professor, Department of Materials Science and Engineering, The Ohio State University, Columbus, OH

1999-2001 Principal Staff Scientist, Computational Materials Group, Motorola, Austin, TX; Project Leader "Front-End Process Simulation".

1997-1999 Senior, then Technical Staff Scientist, Computational Materials Group, Motorola, Los Alamos, NM

Awards and Honors

2012 **Lumley Research Award** and two **Interdisciplinary Lumley Research Awards** from the College of Engineering, The Ohio State University, Columbus, OH.

2006 First recipient of the new **Fraunhofer-Bessel Research Award**, jointly awarded by the Fraunhofer-Society and the Humboldt Foundation "to young, top-rank academics from the USA in recognition of their achievements in applied research to date."

2006 **Mars Fontana Teaching Award** of the Department of Materials Science and Engineering, The Ohio State University, Columbus, OH.

2004 **Nano Technology Industrial Impact Award** from the *Nano Science and Technology Institute* with Prof. Gerd Duscher (UTK) for the discovery of atomically sharp „ideal" interfaces in Ge/SiO_2 devices.

2001 **Golden Quill Award** from Motorola for outstanding contribution to the publication objectives of the Motorola Semiconductor Products Sector.

1998+99 Two **Patent & Licensing Awards** from Los Alamos National Laboratory for contributions to the coding of the "CLSMAN" molecular dynamics simulation platform (with Arthur F. Voter, Joel D. Kress, and Robert B. Walker).

1992-95 **Fellow** of the postgraduate study program *"Graduiertenkolleg"* of the Deutsche Forschungsgemeinschaft at the University of Regensburg.

Selected Publications Past Five Years:

1. E. Bianco, S. Butler, S. Jiang, O. D. Restrepo, W. Windl, and J. E. Goldberger, *Stability and Exfoliation of Germanane: A Germanium Graphane Analogue*, ACS Nano **7**, 4414 (2013).
2. S. Z. Butler, S. M. Hollen, L. Cao, Y. Cui, J. A. Gupta, H. R. Gutiérrez, T. F. Heinz, S. S. Hong, J. Huang, A. F. Ismach, E. Johnston-Halperin, M. Kuno, V. V.Plashnitsa, R. D. Robinson, R. S. Ruoff, S. Salahuddin, J. Shan, L. Shi, M. G. Spencer, M. Terrones, W. Windl & J. E. Goldberger, *Progress, Challenges, and Opportunities in Two-Dimensional Materials Beyond Graphene*, ACS Nano **7**, 2898 (2013).
3. M. F. Chisholm, G. Duscher & W. Windl, *Oxidation Resistance of Reactive Atoms in Graphene*, Nano Lett. **12**, 4651 (2012).
4. P.J. Phillips, M. De Graef, L. Kovarik, A. Agrawal, W. Windl & M.J. Mills, *Atomic-resolution defect contrast in low angle annular dark-field STEM*, Ultramicroscopy **116**, 47 (2012).
5. O. D. Restrepo and W. Windl, *Full first-principles theory of spin relaxation in group-IV materials*, Phys. Rev. Lett. **109**, 166604 (2012).
6. S. C. Nagpure, S.S. Babu, B. Bhushan, A. Kumar, R. Mishra, W. Windl, L. Kovarik & M. Mills, *Local electronic structure of $LiFePO_4$ nanoparticles in aged Li-ion batteries*, Acta Materialia **59**, 6917 (2011).
7. R. Mishra, O. Restrepo, S. Rajan & W. Windl, *First principles calculation of polarization induced interfacial charges in GaN/AlN heterostructures*, Appl. Phys. Lett. **98**, 232114 (2011).
8. R. Mishra, O. D. Restrepo, P. M. Woodward, and W. Windl, *First principles study of defective and non-stoichiometric Sr_2FeMoO_6*, Chem. Mater. **22**, 6092 (2010).
9. R. Heinen, K. Hackl, W. Windl & M. F.-X. Wagner, *Microstructural evolution during multiaxial deformation of pseudoelastic NiTi studied by first principles and micromechanical modeling*, Acta Mater. **57**, 3856 (2009).
10. D. Li, W. Windl & N. P. Padture, *Towards Site-Specific Stamping of Graphene*, Adv. Mater. **21**, 1243-46 (2009).
11. M. F.-X. Wagner & W. Windl, *Mechanical stability, elastic constants and macroscopic moduli of NiTi martensites from first principles*, Acta Mater. **56**, 6232-6245 (2008).

Selected Other Scholarly & Synergistic Activities

- Associate Editor of the *Journal of Computational Electronics* (2002-2011) and the *Journal of Computational and Theoretical Nanoscience* (2002-2008).
- 25 times session organizer and co-organizer at annual meetings of professional societies (multiple times at MRS, EMRS, APS, TMS, AIChE, and NSTI); Chairman of the International Conference on Computational Nanoscience Conference Series; Co-organizer of the 10th US National Congress on Computational Mechanics, Columbus, OH July 16-19, 2009.
- Presentation of research results in more than 100 invited talks at professional meetings and colloquia.

Graduate Student and Postdoctoral Advisors: D. Strauch (U. Regensburg, ret.), O. F. Sankey (hBar Scientific, Prof. Em. ASU), A. F. Voter (LANL), J. D. Kress (LANL).

Former Advisees in the Last Five Years:

Graduate students:

W. Luo (Deform, PhD 2008), A. Bharathula (Lam Research, PhD 2010), J. Askin (Dow-Corning, PhD 2010), H. Govindarajan (Nufern, MS 2011), R. Mishra (ORNL, PhD 2012), A. Agrawal (Clemson, PhD 2012), L. Ward (Northwestern, MS 2012).

Joseph Mercer Zadrozny

The Ohio State University | Cell: 540.292.0713
Department of Chemistry and Biochemistry | Email: zadrozny.13@osu.edu
Newman and Wolfrom Lab
100 W. 18th Ave
Columbus, OH 43210

EMPLOYMENT HISTORY

Associate Professor — The Ohio State University, **2024-present**
Department of Chemistry and Biochemistry

Assistant Professor — Colorado State University, **2017-2023**
Department of Chemistry

EDUCATION

Postdoctoral Researcher — Northwestern University, **2013-2017**
Advisor: ***Prof. Danna E. Freedman***
Project: Coordination Chemistry Approaches to Molecular Electronic Spin Qubit Development

Ph.D. Inorganic Chemistry — University of California, Berkeley, **2013**
Advisor: ***Prof. Jeffrey R. Long***
Thesis: Slow Magnetic Relaxation in Multinuclear Coordination Clusters and Low-Coordinate Transition metal Complexes

B.S. *summa cum laude* in Chemistry — Virginia Polytechnic Institute and State University, **2007**
Advisor: ***Prof. Gordon T. Yee***
Project: Tunable, Three-Dimensional Magnetic Coordination Polymers

HONORS AND AWARDS

(8) Cottrell Teacher-Scholar Award — Research Corp for Scientific Advancement, **2021**
(7) NSF CAREER Award — National Science Foundation, **2020**
(6) Pre-Tenure Faculty Excellence in Teaching and Mentoring Award — Colorado State University, **2020**
(5) Doctoral New Investigator Award (PI) — ACS-Petroleum Research Fund, **2019**
(4) Trailblazer Award (PI) — National Institute of Biomedical Imaging and Bioengineering, **2018**
(3) IIN Outstanding Researcher Award (postdoc) — International Institute of Nanotechnology (IIN), **2016**
(2) SciFinder Future Leaders Award (postdoc) — Chemical Abstracts Service (CAS), **2016**
(1) Doctoral Thesis Award in Molecular Magnetism (graduate) — European Institute of Molecular Magnetism, **2016**

FUNDING

(9) National Science Foundation, QuSeC-TAQS: Noise Engineering For Enhanced Quantum Sensing (Co-PI), $1,750,000 (USD), 2023-2027, Current.
(8) National Science Foundation, *Toward High Intensity Forbidden EPR Transitions In Bimetallic Complexes* (PI), $450,000 (USD), 2023-2026, Current.
(7) National Science Foundation, *REU Site: Advancing Chemistry with Cross-Disciplinary Collaboration - Chemical Sciences at CSU* (Co-PI), $405,000 (USD), 2023-2026, Current.
(6) Research Corporation for Scientific Advancement, Cottrell Scholar Award: *Harnessing Ligand-Shell Nuclear Spins to Control Molecular Spin Coherence* (PI), $100,000 (USD), 2021-2023, Current.
(5) National Science Foundation, Early CAREER Award: *CAREER: Robust Coherence and High Sensitivity in Metal-Ion Nuclear-Spin Qubits* (PI), $658,000 (USD), 2021-2026, Current.
(4) National Institutes of Health, *A Coordination Chemistry Approach to High-Field Electron Paramagnetic Resonance Imaging* (PI), $533,905 (USD), 2018-2021, Completed – 7 publications.
(3) American Chemical Society Petroleum Research Fund, *Rare Earth Magnetic Control of Organic Reactions* (PI), $110,000 (USD), 2019-2021, Completed.
(2) US Department of Energy, *Toward a Photomagnetic Mechanism for f-Element Separations* (PI), $180,000 (USD), 2020-2021, Completed.

(1) National Science Foundation, *QLC: EAGER: Toward Magnetic Selectivity with Molecular Clock Qubits* (PI), $250,000 (USD), 2018-2020, Completed – 8 publications.

SELECT INDEPENDENT SCIENTIFIC PUBLICATIONS

(22) Üngör, Ö.; Sanchez, S.; Ozvat, T. M.; Zadrozny, J. M. "Asymmetry-Enhanced ^{59}Co NMR Thermometry in Co(III) Complexes" *Inorg. Chem. Front.* **2023**, 10, 7064-7072.

(21) Martinez, R.; Jackson, C. E.; Üngor, Ö.; van Tol, J.; Zadrozny, J. M. "Impact of Ligand Chlorination and Counterion Tuning on High-Field Spin Relaxation in a Series of V(IV) Complexes" *Dalton Trans*. **2023**, *52*, 10805-10816.

(20) Kamin, A.; Moseley, I. P.; Oh, J,; Brannan, E.; Gannon, P.; Kaminsky, W.; Zadrozny, J. M.; Xiao, D. J. "Geometry-dependent valence tautomerism, magnetic ordering, and electrical conductivity in 1D iron-tetraoxolene chains" *Chem. Sci.* **2023,** *14*, 4083-4090.

(19) Campanella, A. J.; Üngör, Ö; Zadrozny, J. M. "Quantum Mimicry With Inorganic Chemistry" *Comments Inorg. Chem.* **2023**, Online Article. DOI: 10.1080/02603594.2023.2173588

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Zhihui Zhu

The Ohio State University
Department of Computer Science and Engineering
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Email: zhu.3440@osu.edu
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Research Interests

- Machine learning, data science, signal processing, and quantum information
- Analyses and practical techniques for deep learning, generative models, and LLMs
- Statistical and algorithmic aspects of quantum information science

Education

2017	Ph.D. in Electrical Engineering (Dr. Michael Wakin, advisor)	Colorado School of Mines
2012	B.E. in Telecommunications Engineering (Dr. Gang Li, advisor), winner of Best Bachelor's Thesis Award (1/125)	Zhejiang University of Technology Jianxing Honors College

Positions

2022-	Assistant Professor	Ohio State University Department of Computer Science & Engineering
2020-2022	Assistant Professor	University of Denver Department of Electrical & Computer Engineering
2018-2019	Postdoctoral Fellow (Dr. René Vidal, advisor)	Johns Hopkins University Center for Imaging Science Mathematical Institute for Data Science

Honors

2021	Research, Scholarship, and Creative Work Faculty Recognition	Univ. Denver
2019	Finalist for the Best Student Paper Award	IEEE CAMSAP
2018	Electrical Engineering Graduate Research Award	Colorado School of Mines
2013	National Scholarship	Ministry of Education of PRC
2012	Best Bachelor's Thesis Award (1/125) for the Thesis "On The Sparse Representation of Signals in Compressive Sensing"	ZJUT
2011	Meritorious Winner in the Mathematical Contest in Modeling (MCM, sponsored by SIAM, NSA, and INFORMS)	

Research Support

2023-2026	"Collaborative Research: RI: Medium: Principles for Optimization, Generalization, and Transferability via Deep Neural Collapse," OSU PI, $400K, NSF Division of Information and Intelligent Systems (Collaborative with J. Sulam at JHU and Q. Qu at UMich)
2023	"Nonconvex Optimization for Efficiently Characterizing Quantum Network," OSU PI, $10K, CQISE Partnership Seed Award (Collaborative with B. Kirby at ARL)
2021-2025	"Collaborative Research: CIF: Medium: Structured Inference and Adaptive Measurement Design in Indirect Sensing Systems," DU PI, $344K, NSF Division of Computing and Communication Foundations (Collaborative with M. Wakin and G. Tang at Colorado School of Mines)

2020-2024 "Collaborative Research: CIF: Small: Deep Sparse Models: Analysis and Algorithms," DU PI, \$205K, NSF Division of Computing and Communication Foundations (Collaborative with J. Sulam at Johns Hopkins University)

Professional Activities

Action Editor for *Transactions on Machine Learning Research*
Area Chair for *ICML*, *NeurIPS*, and *ICASSP (MLSP)*
Co-organizer of the first *Conference on Parsimony and Learning (CPAL)*, three workshops on *Seeking Low-Dimensionality in Deep Neural Networks (SlowDNN)*, SIAM MDS22 Mini-symposium on *Deep Learning with Low-Dimensional Models.*

Teaching Experience

OSU: *Machine Learning*, *Deep Learning: Models, Theory & Application*
DU: *Machine Learning*, *Large-scale Optimization*, *Probability and Statistics for Engineers*
IEEE ICASSP: short courses on *Learning Nonlinear and Deep Low-Dimensional Representations from High-Dimensional Data: From Theory to Practice*, and *Low-Dimensional Models for High-Dimensional Data: From Linear to Nonlinear, Convex to Nonconvex, and Shallow to Deep*

Book Chapters

1. R. Vidal, Z. Zhu, and B. Haeffele, "Optimization Landscape of Neural Networks," in P. Grohs and G. Kutyniok (Eds.), *Mathematics Aspects of Deep Learning*, Cambridge University Press, 2022.

Selected Publications

1. Z. Qin, C. Jameson, Z. Gong, M. B. Wakin, and Z. Zhu, "Quantum State Tomography for Matrix Product Density Operators," to appear in *IEEE Transactions on Information Theory*, 2024.
2. Z. Zhu, J. M. Lukens, and B. T. Kirby, "On the connection between least squares, regularization, and classical shadows," arXiv preprint arXiv:2310.16921, 2023.
3. T. Chen, L. Liang, T. Ding, Z. Zhu, and I. Zharkov, "OTOv2: Automatic, Generic, User-Friendly", *International Conference on Learning Representations (ICLR)*, May 2023.
4. J. Sulam, C. You, and Z. Zhu, "Recovery and Generalization in Over-Realized Dictionary Learning," *Journal of Machine Learning Research*, vol. 23, no. 135, pp. 1-23, 2022.
5. J. Zhou, C. You, X. Li, K. Liu, S. Liu, Q. Qu, and Z. Zhu, "Are All Losses Created Equal: A Neural Collapse Perspective," *Neural Information Processing Systems (NeurIPS)*, 2022.
6. Z. Qin, A. Lidiak, Z. Gong, G. Tang, M. B. Wakin, and Z. Zhu, "Error Analysis of Tensor-Train Cross Approximation," *Neural Information Processing Systems (NeurIPS)*, December 2022.
7. C. Yaras, P. Wang, Z. Zhu, L. Balzano, and Qing Qu, "Neural Collapse with Normalized Features: A Geometric Analysis over the Riemannian Manifold," NeurIPS, December 2022.
8. X. Dai, M. Li, P. Zhai, S. Tong, X. Gao, S. Huang, Z. Zhu, C. You, and Yi Ma, "Revisiting Sparse Convolutional Model for Visual Recognition," *NeurIPS*, December 2022.
9. Jinxin Zhou*, Xiao Li*, Tianyu Ding, Chong You, Qing Qu, and Zhihui Zhu, "On the Optimization Landscape of Neural Collapse under MSE Loss: Global Optimality with Unconstrained Features," *International Conference in Machine Learning (ICML)*, 2022.
10. Z. Zhu*, T. Ding*, J. Zhou, X. Li, C. You, J. Sulam, and Q. Qu, "A Geometric Analysis of Neural Collapse with Unconstrained Features," *Neural Information Processing Systems (NeurIPS)*, 2021.
11. Z. Zhu, Q. Li, G. Tang, and M. B. Wakin, "The Global Optimization Geometry of Low-Rank Matrix Optimization," *IEEE Transactions on Information Theory*, vol. 67, no. 2, pp. 1308-1331, 2021.

Letters of Support

Included here are concurrence letters from:

1. Department of Chemistry and Biochemistry
2. Department of Computer Science Engineering
3. Department of Electrical and Computer Engineering
4. Department of Materials Science Engineering
5. Department of Mathematics
6. Department of Physics

THE OHIO STATE UNIVERSITY

College of Arts and Sciences

Claudia Turro
Dr. Melvin L. Morris Endowed Professor and Department Chair

Department of Chemistry and Biochemistry
151 West Woodruff Avenue, Columbus, OH 43210
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http://chemistry.osu.edu

May 3, 2024

Professor Jay Gupta
Department of Physics
College of Arts and Sciences

Dear Jay

As Chair of the Department of Chemistry and Biochemistry, I strongly support your effort to establish a new interdisciplinary graduate program in QISE. As you know, QISE is a broad and rapidly developing field that spans fundamental science and engineering, including for example, research by our faculty into designing molecular complexes that can serve as spin qubits. We look forward to the increased opportunities for collaborative education and research that this program will help foster at OSU.

We concur that the new graduate courses to be developed as part of this program (see table below) can be cross-listed in our department and will be of interest to students as well as those in the new program. When or if our faculty teach these courses, students will enroll in our Departmental cross-listed course (e.g. CHEM 7100 for the Foundations course). Graduate students in the new program can also take our courses as electives, assuming the necessary prerequisites are met, or with permission of the instructor.

QISE 7100 (cross-lists: CHEM 7100, CSE7100, ECE 7100, MATH 7100, MATSCEN 7100, PHY7100)	Foundations in QISE
QISE 7101 (and cross lists)	Quantum Circuits and Algorithms
QISE 7102 (and cross lists)	Grand Challenges in QISE
QISE 7110 (and cross lists)	Modular content

Sincerely,

Claudia Turro
Dr. Melvin L. Morris Endowed Professor and Chair
Department of Chemistry and Biochemistry

THE OHIO STATE UNIVERSITY

College of Engineering

Department of Computer Science and Engineering

395 Dreese Labs
2015 Neil Avenue
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September 4, 2024

Dear Dr. Gupta,

As Chair of the Department of Computer Science Engineering, I strongly support your effort to establish a new interdisciplinary graduate program in QISE. As you know, QISE is a broad and rapidly developing field that spans fundamental science and engineering, including for example, research by our faculty into quantum computing that demonstrate advantage over classical computing. We look forward to the increased opportunities for collaborative education and research that this program will help foster at OSU.

We concur that the new graduate courses to be developed as part of this program (see table below) be cross listed in our department and will be of interest to students as well as those in the new program. When or if our faculty teach these courses, students will enroll in our Departmental cross-listed course (e.g. CSE 7100 for the Foundations course). Graduate students in the new program can also take our courses as electives, assuming the necessary prerequisites are met, or with permission of the instructor.

Required core courses for degree: MS			
Course #	**Course Title**	**Credits for course based**	**Credits for thesis based**
QISE 7100 (and cross-lists)	Foundations in QISE	4	4
QISE 7101 (and cross lists)	Quantum Circuits and Algorithms	4	4
QISE 7102 (and cross lists)	Grand Challenges in QISE	3	3
PHY 6810, CHEM 6540, MATSCEN 6756.72, CSE 6321, ECE 5510, MATH 6601	Computational/Numerical Methods	1+	1+
QISE 7111	Journal Club	2	2+

QISE 7112	Professional development seminar	2	2
QISE 7113	1st year Research Rotations	9+	9+
XXXX-7999	Thesis research	0	10+

With best regards,

Anish Arora
Distinguished Professor of Engineering and Chair
Faculty Director, 5G-OH Center
Department of Computer Science and Engineering

ECE Concurrence on QISE Gradaute Program

Anderson, Betty Lise <anderson.67@osu.edu>

Tue 8/27/2024 9:52 AM

To:Gupta, Jay <gupta.208@osu.edu>
Cc:Reano, Ronald <reano.1@osu.edu>;Teixeira, Fernando <teixeira.5@osu.edu>;Arafin, Shamsul <arafin.1@osu.edu>;Shanker, Balasubramaniam <shanker@ece.osu.edu>;Quinzon-Bonello, Rosario <quinzon-bonello.1@osu.edu>;Anderson, Betty Lise <anderson.67@osu.edu>

Dear Prof Gupta,

The Department of Electrical and Computer Engineering is pleased to offer its concurrence for the proposed Interdisciplinary Graduate Program in Quantum Information Science and Engineering. This is subject to the understanding that ECE faculty may teach core courses in the new program, but it will be on an as-available basis, subject to teaching loads and demands in ECE. ECE will continue to offer the three ECE elective courses mentioned in the proposal (ECE 5012, 5510, and 6511), at a frequency determined by enrollments and availability of instructors.

Betty Lise

Betty Lise Anderson, PhD, Professor and Associate Chair
Electrical and Computer Engineering
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THE OHIO STATE UNIVERSITY

Department of Mathematics

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Web www.math.osu.edu

April 16, 2024

Dear Dr. Gupta,

As the Chair of the Department of Mathematics, I am writing to offer our strong support for your efforts to establish a new interdisciplinary graduate program in QISE. As you know, QISE is a broad and rapidly developing field that spans fundamental science and engineering, including for example, research by our faculty into the properties of topological qubits. We look forward to the increased opportunity for collaborative education and research that this program will help foster at Ohio State.

We concur that the new graduate courses to be developed as part of this program (see table below) can be cross-listed in our department and will be of interest to students as well as those in the new program. When or if our faculty teach these courses, students will enroll in our departmental cross-listed courses (e.g., MATH 7100 for the Foundations in QISE course). Graduate students in the new program can also take our courses as electives, assuming the necessary prerequisites are met, or with permission from the instructor.

QISE 7100 (cross-lists: CHEM 7100, CSE7100, ECE 7100, MATH 7100, MATSCEN 7100, PHY7100)	Foundations in QISE
QISE 7101 (and cross lists)	Quantum Circuits and Algorithms
QISE 7102 (and cross lists)	Grand Challenges in QISE
QISE 7110 (and cross lists)	Modular content

Sincerely,

Dongbin Xiu
Professor and Chair

e-mail: xiu.16@math.osu.edu

Department of Materials Science and Engineering

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April 14, 2024

Jay Gupta, PhD
Professor
Department of Physics
Director, NSF NRT - QuGIP

Re: Interdisciplinary Graduate Program in Quantum Information Science and Engineering

Dear Dr. Gupta,

As Chair of the Department of Materials Science Engineering, I strongly support your effort to establish a new interdisciplinary graduate program in QISE. As you know, QISE is a broad and rapidly developing field that spans fundamental science and engineering, including for example, research by our faculty into controlling potential defect qubits in epitaxial materials. We look forward to the increased opportunities for collaborative education and research that this program will help foster at OSU.

After consideration by the MSE Graduate Studies Committee, we concur that the new graduate courses to be developed as part of this program (see table below) can be cross-listed in our department and will be of interest to students as well as those in the new program. When or if our faculty teach these courses, students will enroll in our Departmental cross-listed course (e.g. MATSCEN 7100 for the Foundations course). Graduate students in the new program can also take our courses as electives, assuming the necessary prerequisites are met, or with permission of the instructor.

QISE 7100 (cross-lists: CHEM 7100, CSE7100, ECE 7100, MATH 7100, MATSCEN 7100, PHY7100)	Foundations in QISE
QISE 7101 (and cross lists)	Quantum Circuits and Algorithms
QISE 7102 (and cross lists)	Grand Challenges in QISE

Sincerely,

Michael J. Mills

Michael J. Mills
Chair and McDougal Professor of Engineering
Department of Materials Science and Engineering
The Ohio State University

THE OHIO STATE UNIVERSITY

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Office of the Chair

1040 Physics Research Building
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physics.osu.edu

Friday, August 30, 2024

Re: Concurrence letter for proposed quantum graduate program

Dear Dr. Gupta,

As Chair of the Department of Physics, I strongly support your effort to establish a new interdisciplinary graduate program in QISE. As you know, QISE is a broad and rapidly developing field that spans fundamental science and engineering, including for example, research by our faculty into spin qubits and quantum communication. We look forward to the increased opportunities for collaborative education and research that this program will help foster at OSU.

We concur that the new graduate courses to be developed as part of this program (see table below) can be cross-listed in our department and will be of interest to students as well as those in the new program. When or if our faculty teach these courses, students will enroll in our Departmental cross-listed course (e.g. PHY 7100 for the Foundations course). Graduate students in the new program can also take our courses as electives, assuming the necessary prerequisites are met, or with permission of the instructor.

QISE 7100 (cross-lists: CHEM 7100, CSE7100, ECE 7100, MATH 7100, MATSCEN 7100, PHY7100)	Foundations in QISE
QISE 7101 (and cross lists)	Quantum Circuits and Algorithms
QISE 7102 (and cross lists)	Grand Challenges in QISE

Sincerely,

Ralf Bundschuh
Professor and Chair
Department of Physics

Course Descriptions

The quantum graduate program will include three new graduate core courses, as well as two new seminar courses and course-listings for 1st year rotations and MS thesis research. Syllabi for these courses are attached here, but a brief description of the required courses follows:

<u>New courses:</u>

1. QISE 7100: Foundations in QISE (3 cr): this course will introduce a variety of core concepts from quantum mechanics that are especially relevant for initial studies in QISE, so that students will be able to: (i) understand quantum state notation, (ii) perform linear algebra calculations and distinguish entangled from separable quantum states, and (iii) understand how quantum superposition states are realized and measured in the laboratory. Importantly, these learning goals are not stressed in traditional quantum mechanics courses, and such courses often heavily emphasize discipline-specific formalism that is a barrier to students coming from different undergraduate training backgrounds.
2. QISE 7101: Quantum Circuits and Algorithms (3 cr): This course will provide students with a deeper appreciation for scaling and complementarity of classical and quantum computing. Students will be able to describe two paradigmatic algorithms for search (Grover) and factoring (Shor) and estimate regimes and problem classes where quantum advantage is expected.
3. QISE 7102: Grand Challenges in QISE (3 cr): This course will focus on grand challenges toward realizing quantum computers, including scalable multi-qubit entanglement, long-distance networking, error correction and algorithms. On the hardware side, the content will focus on fundamentals of electromagnetic interactions with matter, starting with microwave superconducting circuits and photonic structures, but also including semiconductor point defects, atoms, and molecules. A primary learning outcome for this course is for students to articulate pros and cons of physical implementations of quantum networks and qubits, with respect to computing algorithms and other quantum applications (sensing, simulations, communication).
4. QISE 7111: Quantum journal club (1cr): this is a required interdisciplinary journal club seminar course. Students will rotate presenting a paper of current interest, followed by group discussions clarifying key points and context. Students will develop general presentation skills and learn how to communicate across disciplines.
5. QISE 7112: Professional Development Seminar (1 cr): This will be a discussion-focused seminar on aspects of professional development and ethics particularly relevant to quantum information. For example, if quantum computers can break classical encryption, what's the ramification for data security? The format will be a group discussion of current article / news story, led by the faculty instructor.
6. QISE 7113: 1st year research rotations (1.5+ cr) – This is a structured independent study course, where students complete short (~ 7 week) rotations with a faculty advisor.
7. QISE 7999: Independent research (1+ cr) – Masters thesis option students will participate in a focused, full-time research experience with a primary faculty advisor starting in their 1st summer.

Existing courses

Students must complete one course in computational and/or numerical methods, to be selected from a menu of existing courses in the participating departments:

PHY 5810 (4), MATH 6601 (4), CHEM 7470 (1.5), CHEM 7590 (3), ECE 5510 (3), ECE 7011 (3), MSE 6756 (2), CSE 6449 (3)

Students can satisfy their elective requirements by taking approved courses in the participating departments relevant for their specialization in the program. These courses will generally be PHY 6000+, MATSCEN 6000+, ECE 5000+, CHEM 6000+, CSE 5000+, MATH 6000+ and chosen in consultation with the students' advisor.

1) The *Quantum Computing* specialization is focused on the development, implementation and scaling of quantum algorithms and associated hardware for solving complex problems and error correction.

Specialization	Example electives (# cr)
Quantum Computing	CSE 6429 Advanced Computer Architecture (1-3); ECE 7005 Information Theory (3); MATH 6251 Theory of Probability (4), MATH 5801 General topology and knot theory (3), ECE 6531 Semiconductor Devices (3), ECE 7022 Advanced RF integrated circuits (3), MATSCEN 6295 Superconducting Materials and Properties (2), PHY 5680 Big Data Analysis in Physics (3),

2) The *Quantum Networking and Communication* specialization is focused on the transportation and multiplexing of quantum information using elements such as photonics and microwave cavities.

Specialization	Example electives (# cr)
Quantum Networking and Communication	ECE 6511 Nonlinear Optics (3), CSE 6469 Advanced Studies in Computer networking (1-3); CSE 6422 Advanced Computer Architecture (3), Physics 8820 Special topics: Atomic, molecular and optical physics (3), MATSCEN 6777 Electronic properties of materials (2), ECE 6010 EM Field Theory (3), ECE 6101 Computer Communication Networks (3)

3) The *Quantum Simulation* specialization is focused on quantum-enabled methods to better understand physical systems whose complexity exceeds even the best classical high performance computing algorithms.

Specialization	Example electives (# cr)
Quantum Simulation	MATH 6801 Algebraic Topology (3); MATH 6151 Commutative Algebra (3); PHY 8820 Special Topics: Quantum information theory (3), ECE 5200 Digital Signal Processing (3), ECE 5307 Machine Learning (4), MATSCEN 6756 Computational Materials Modeling (2), CSE 6521 Artificial Intelligence (3),

4) The *Quantum Materials and Sensing* specialization is focused on the physical materials (solid state and molecular) used for quantum bits, sensors and storage.

Specialization	Example electives (# cr)
Quantum Materials and Sensing	MATSCEN 7835 Point Defects in Crystalline Materials (2); PHY 8806 Topics in Condensed Matter Physics (3); CHEM 6510 Quantum Mechanics and Spectroscopy (1.5) , CHEM 6540 Electronic Structure (1.5), CHEM 7370 Nanochemistry and Nanomaterials (1.5), ECE 5033 Surfaces and Interfaces of Electronic Materials (3),

These tables are not an exhaustive list of courses, and requests for additional courses will be reviewed by the QGSC each semester.

Course Syllabi

Included here are syllabi for the three new graduate core courses (QISE 7100, 7101, 7102), as well as syllabi for the new seminar courses (QISE 7111, 7112) and first year research rotations (QISE-7113).

Syllabus
QISE 7100: Foundations in QISE

Autumn 2026

FACULTY INSTRUCTOR:
TBD (email TBD)
Office: TBD
Office hours: TBD

COURSE DESCRIPTION: This course will focus on the foundational mathematics and physics needed to describe quantum information and related phenomena. This class will ensure students are able to describe quantum systems using linear algebra, more precisely finite dimensional Hilbert spaces and operators, and conversely, describe the physical meaning of a linear algebraic expression.

Prerequisites: For graduate students admitted to the QISE program or any QISE related discipline (Chemistry, Mathematics, Physics, Computer Science Engineering, Electrical Engineering, or Materials Science Engineering), there are no prerequisites. All other graduate students must have prior approval of the instructor to enroll in this course.

COURSE LEARNING OBJECTIVES:

A. Describe and apply both mathematically and conceptually the idea of fundamental randomness and its connection to physical states. Describe and apply probability distributions using words, graphical and mathematical-symbolic representations.
B. Students will be able to describe the relationship between physical properties and linear algebra. In particular, students will be able to:
    a. describe quantum physical phenomena using linear algebra, and
    b. conversely, explain the physical meaning of linear algebra expressions.
C. Describe quantum entangled states conceptually, and represent mathematically. Students will be able to explain how to exploit entangelement for computation
D. Students will be able to describe quantum protocols for information processing, and explain the advantage compared to classical protocols.

HOW THIS COURSE WORKS

FORMAT OF INSTRUCTION: In person lectures by the instructor. Pauses will be given during the class period for students to work on exercises along the way.

MODE OF DELIVERY: In person

NUMBER OF CONTACT HOURS PER WEEK: 3 x 55min classes each week

CREDIT HOURS AND WORK EXPECTATIONS: This is a 3-credit-hour course. According to Ohio State policy (go.osu.edu/credithours), students should expect around 3 hours per week of time spent on direct instruction (instructor content and Carmen activities, for example) in addition to 6 hours of homework (reading and assignment preparation, for example) to receive a grade of (C) average.

COURSE TECHNOLOGY:
For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. In-person support information is available at https://it.osu.edu/help, and support via phone or email is available 24/7.

- **Self-Service and Chat support:** go.osu.edu/IT
- **Phone:** 614-688-4357(HELP)
- **Email:** servicedesk@osu.edu

BASELINE TECHNICAL SKILLS FOR COURSES

- Basic computer and web browsing skills
- Navigating Carmen: for questions about specific functionality, see the Canvas Student Guide.

REQUIRED TEXTBOOK

- Nielsen, M. A., & Chuang, I. L. (2001). Quantum computation and quantum information (Vol. 2). Cambridge: Cambridge university press.
    - Chapters covered: 1-2, 5, 9, 11-12
- Instructor notes (to be provided)

REQUIRED EQUIPMENT

- Personal computer (laptop): current Mac (OS X) or PC (Windows 7+) with high-speed internet connection.
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication should such a necessity arise

REQUIRED SOFTWARE

- None

CARMEN ACCESS

You will need to use BuckeyePass multi-factor authentication to access your courses in Carmen. To ensure that you are able to connect to Carmen at all times, it is recommended that you take the following steps:

- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass - Adding a Device help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Download the Duo Mobile application to all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service.

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

GRADING

The grades for the course will be based on homework, exams, and a semester-long project.

HOMEWORK. Students will be assigned about 5 written/typed homework problems each week pertaining to the class material. Problems will be taken from the required text and the instructor's problem sets. Written homework solutions will be due at the beginning of the lecture on which it is due. The assigned problems are a lower bound of what the student is expected to do. Students may work together to solve the problems, but each student is responsible for their own solutions. In particular, students must write up solutions separately, and any copying will be regarded as academic misconduct/plagiarism. Students may use whatever resources they want for their homework, but they must cite all resources.

EXAMS. There are two midterms and a final exam. All exams will be delivered in-person. The midterms will cover blocks of the course content as indicated on the syllabus below, while the final exam will be comprehensive.
Midterm 1: TBD, during lecture
Midterm 2: TBD, during lecture
Final exam: TBD, during the period set by the registrar
There will be no makeup exams. A missed exam will count for a zero for that test. (See grading option (2).)

SEMESTER-LONG PROJECT. Students will work on a semester-long project whose aim is to look in detail at an area of quantum information science in which the techniques of this class are used extensively.

Semester-Long Project Components:
Students will complete a final (at least) 5 page paper (plus citations which can go longer) which discusses an active area of research in quantum information science which uses the material discussed in this course. Students will also give a 10 minute final slide presentation presenting their research and findings along with discussing concrete applications. Both the 5 page paper and the presentation will each contribute 10 percentage points to the final grade.

Topics for the project will be suggested on the Carmen course site with initial sources provided, or students can select their own topic and initial sources with approval by the instructor/teaching assistant at one of the intermediate “touch points” of the project described next.

The project will have major “touch points” to verify that they are keeping on track with the project and undertaking a substantial project. The touch points will only be graded on the basis of meeting deadlines, that is, 1 or 0 points will be awarded for meeting the deadline for said touch point. These touch points will account for only 1 out of 10 percentage points for each of the final paper and final presentation.
paper.

The touch points include (feedback will be provided to each student):

End of week 4: A one-paragraph description of their research topic proposal summarizing their topic, together with a minimum of three initial sources.

End of week 8: A one-paragraph summary of their topic which clearly explains its applications in quantum information science.

End of week 12: Final 5 page paper submitted.

PRESENTATION GRADING RUBRIC:
Students will work with the instructor to develop a grading rubric for the presentations. Some sample grading considerations will be supplied by the instructor, but the class will agree on 5 main areas which will be assessed for the presentations. Students will also implement their rubric by evaluating each talk. The rubrics, which will not be anonymous to the professor, will be collected and used to assess the final presentation grade. The feedback from the student rubrics will be anonymized and then given to the presenter.

GRADING. There are two grading options for each student:

(1)

ASSIGNMENT CATEGORY	PERCENTAGE
HOMEWORK	20
EXAM 1	20
EXAM 2	20
SEMESETER PROJECT PAPER	10
SEMESETER PROJECT PRESENTATION	10
FINAL EXAM	20

(2)

ASSIGNMENT CATEGORY	PERCENTAGE
HOMEWORK	20
HIGHER EXAM	20
SEMESETER PROJECT PAPER	10
SEMESETER PROJECT PRESENTATION	10
FINAL EXAM	40

The instructor will automatically pick the option that results in a higher grade. If a student must miss more than one test for reasons beyond their control, in extremely rare circumstances, with prior consent from the instructor, the final will count for a higher percent of their grade.

The instructor may curve the final distribution to the students' benefit, but the following scale will ensure the following grades:
>93% = A 90-92.99% = A- 87-89.99% = B+ 83-86.99% = B 80-82.99% = B-
77-79.99% = C+ 73-76.99% = C 70-72.99% = C- 67-69.99% = D+ 60-66.99% = D
<60% = E

GRADE REVISIONS. You may request that exams be regraded. This request must be in writing and be turned in by the end of the class or office hour during which your exam was returned. If you leave class or office hours with your exam for any reason, your grade revision request will not be accepted.

COURSE SCHEDULE

Week	Date	Class #	Broad Theme	Topic
1	8/24			
	8/26	1	General overview	Stern-Gerlach experiment, complex numbers
	8/28	2	Qubits	Hilbert space, computational basis, vector space geometry, superposition
2	8/31	3	Observables	M2(ℂ): operators on a single qubit
	9/2	4	States	State vectors and vector states; Bloch sphere
	9/4	5	Linear algebra 1	Eigenvalues and eigenvectors
3	9/7	NO CLASSES - LABOR DAY		
	9/9	6	Linear algebra 2	Spectral theorem
	9/11	7	Measurement	Born rule, spectral projections
4	9/14	8	Expectation value	Expectation values of random variables; uncertainty principle; commuting variables
	9/16	9	Mutually unbiased bases	mutually unbiased bases; interpretation of Stern Gerlach experiment; polarizers as projectors
	9/18	10	mixed states	classical finite probability spaces; mixed states as ensembles of pure states; density matrices; the trace Tr on M2(ℂ)
5	9/21	11	quantum state tomography	convex combinations of states; Bloch vectors; tomography
	9/23	12	Entropy 1	Shannon entropy of a finite probability distribution
	9/25	13	Entropy 2	Von Neumann entropy of a mixed state; entropic characterization of pure states
6	9/28	14	Tensor products	the 2-qubit Hilbert space ℂ2 ⨂ ℂ2 ; Kronecker product of matrices; computational basis; Bell basis
	9/30	15	Tensor products of operators	Kronecker product of matrices revisited; exchange relation; No cloning theorem
	10/2	16	MIDTERM EXAM 1 (content: Lectures 1-13)	
7	10/5	17	Tensor product states	pure states: entangled vs. product states; singlet state; EPR paradox "spooky action at a distance"

	10/7	18	Measurement	global vs. local measurement; spectral projections and spectral decomposition of a self-adjoint operator
	10/9	19	Local realism	local realism; hidden variable theories; violations of the CHSH inequality
8	10/12	20	Hidden variables	GHZ inequality
	10/14	21	Density matrices	Density matrices in M4(ℂ); product states, separable states, and entangled states
	10/16	NO CLASSES - AUTUMN BREAK		
9	10/19	22	Partial traces	partial traces
	10/21	23	Reduced densities	reduced density matrices
	10/23	24	Von Neumann entropy	quantum state purification
10	10/26	25	Von Neumann entropy	entropic characterization of pure states
	10/28	26	Von Neumann entropy	bipartitie entanglement entropy
	10/30	27	Multiple qudit spaces	The n-qubit Hilbert space $\mathbb{C}2 \otimes \ldots \otimes \mathbb{C}2$; The qudit space and the n-qudit space
11	11/2	28	Graphical calculus 1	graphical calculus for n-qubits; graphical calculus for Bell states
	11/4	29	MIDTERM EXAM 2(content: Lectures 14-26)	
	11/6	30	Graphical calculus 2	graphical calculus for operators; rotation=transpose; zig-zag relation; trace as capping off
12	11/9	31	Graphical calculus 3	quantum circuits
	11/11	NO CLASSES - VETS DAY		
	11/13	32	Graphical calculus 4	graphical calculus for partial traces
13	11/16	33	Quantum teleportation	quantum teleportation protocol
	11/18	34	Superdense coding	superdense coding protocol
	11/20	35	Quantum teleportation and superdense coding	connection between QT and SDC
14	11/23	36	Quantum key distribution 1	BB84 protocol
	11/25	NO CLASSES - THANKSGIVING		

	11/27			
15	11/30	37	QKD 2	E91 protocol
	12/2	38	REVIEW DAY	
	12/4	39	Final project presentations	
16	12/7	40	Final project presentations	
	12/9	41	Final project presentations	
	TBD	COMPREHENSIVE FINAL EXAM		

OTHER COURSE POLICIES

INCOMPLETE GRADE POLICY

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ACADEMIC MISCONDUCT POLICY

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-48.7 (B)). For additional information, see the Code of Student Conduct.

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If you are ill and need to miss class, including if you are staying home and away from others while experiencing symptoms of a viral infection or fever, please let me know immediately. In cases where illness interacts with an underlying medical condition, please consult with Student Life Disability

Services to request reasonable accommodations. You can connect with them at slds@osu.edu; 614-292-3307; or slds.osu.edu.

STATEMENT ON RELIGIOUS ACCOMMODATIONS

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If students have questions or disputes related to academic accommodations, they should contact their course instructor, and then their department or college office. For questions or to report discrimination or harassment based on religion, individuals should contact the Office of Institutional Equity. (Policy: Religious Holidays, Holy Days and Observances).

MENTAL HEALTH STATEMENT

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and Consultation Service (CCS) by visiting ccs.osu.edu or calling 614-292-5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on call counselor when CCS is closed at 614-292-5766 and 24 hour emergency help is also available 24/7 **by dialing 988 to reach the Suicide and Crisis Lifeline**.

STATEMENT ON TITLE IX

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu.

DIVERSITY STATEMENT

The Ohio State University affirms the importance and value of diversity of people and ideas. We believe in creating equitable research opportunities for all students and to providing programs and curricula that allow our students to understand critical societal challenges from diverse perspectives and aspire to use research to promote sustainable solutions for all. We are committed to maintaining an inclusive community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among all members; and encourages each individual to strive to reach their own potential. The Ohio State University does not discriminate on the basis of age, ancestry, color, disability, gender identity or expression, genetic information, HIV/AIDS status, military status, national origin, race, religion, sex, gender, sexual orientation, pregnancy, protected veteran status, or any other bases under the law, in its activities, academic programs, admission, and employment. (To learn more about diversity, equity, and inclusion and for opportunities to get involved, please visit: https://odi.osu.edu/ or https://cbsc.osu.edu).

Syllabus
QISE 7101: Quantum Circuits and Algorithms

Spring 2027

FACULTY INSTRUCTOR:
TBD (email TBD)
Office: TBD
Office hours: TBD

COURSE DESCRIPTION: "Quantum Circuits and Algorithms" is designed to provide students with a broad introduction to quantum computing. Using various tools such as IBM Quantum Composer and QISKIT, students will learn and visualize quantum computing concepts, and compare them with classical computing models. This will enable the comparison of quantum algorithms and their advantages over corresponding classical algorithms. Students will also understand research papers in the field and explain these concepts to the class as a team.

Prerequisites: For graduate students admitted to the QISE program or any QISE related discipline (Chemistry, Mathematics, Physics, Computer Science Engineering, Electrical Engineering, or Materials Science Engineering), there are no prerequisites. All other graduate and undergraduate students must have prior approval of the instructor to enroll in this course.

COURSE LEARNING OBJECTIVES:

By the end of this course, students should successfully be able to:

- Explain how qubits are structured and how they differ from classical bits.
- Develop quantum circuits and distinguish them from classical digital circuits.
- Explain how a quantum algorithm has an advantage over a classical algorithm.
- Explain and distinguish different approaches to error correction.
- Be able to use analytical and computational methods (e.g., Python, Qiskit, IBM Composer) to solve quantum computing problems.
- Be able to describe and explain peer-reviewed research papers related to quantum computing to peers with different disciplinary backgrounds.
- Productively engage in interdisciplinary teams to learn course content and contribute to interdisciplinary research projects.

HOW THIS COURSE WORKS

FORMAT OF INSTRUCTION: In person lectures by the instructor. Pauses will be given during the class period for students to work on exercises along the way.

MODE OF DELIVERY: In person

NUMBER OF CONTACT HOURS PER WEEK: 3 x 55 min classes each week

CREDIT HOURS AND WORK EXPECTATIONS: This is a 3-credit-hour course. According to Ohio State policy (go.osu.edu/credithours), students should expect around 3 hours per week of time spent on direct instruction (instructor content and Carmen activities, for example) in addition to 6 hours of homework (reading and assignment preparation, for example) to receive a grade of (C) average.

Pace of activities: This course is divided into **weekly modules** that are released one week ahead of time. Students are expected to keep pace with weekly deadlines but may schedule their efforts freely within that time frame.

Attendance and participation requirements: Research shows regular participation is one of the highest predictors of success. With that in mind, I have the following expectations for everyone's participation:

- **Participating in in-class activities for attendance**: **at least 1 – 2 per week** You are expected to attend class because there will be in-class activities interleaved with lectures. These in-class activities could be paper-based or could require you to log into a computer and write code. You are encouraged to work with your peers to complete these activities. However, you are required to submit your own work for every in-class assignment.
- **Weekly Reflections**: **once a week** You are required to post weekly reflections about your experience and engagement with the course materials on carmen. The general prompts for reflection centers around what worked for you and what are some concepts of the course that you found challenging. There could be weeks when I might have reflection prompts specific to the content from that week.

COURSE TECHNOLOGY:

For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. In-person support information is available at https://it.osu.edu/help, and support via phone or email is available 24/7.

- **Self-Service and Chat support:** go.osu.edu/IT
- **Phone:** 614-688-4357(HELP)
- **Email:** servicedesk@osu.edu

BASELINE TECHNICAL SKILLS FOR COURSES

- Basic computer and web browsing skills
- Navigating Carmen: for questions about specific functionality, see the Canvas Student Guide.

REQUIRED TEXTBOOK

- Nielsen, M. A., & Chuang, I. L. (2001). Quantum computation and quantum information (Vol. 2). Cambridge: Cambridge university press.
  - Chapters covered: 3-4, 6, 10

REQUIRED EQUIPMENT

- Personal computer (laptop): current Mac (OS X) or PC (Windows 7+) with high-speed internet connection.
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication should such a necessity arise

REQUIRED SOFTWARE

- **IBM Composer:** https://quantum.ibm.com/composer/files/new
- **Qiskit:** https://www.ibm.com/quantum/qiskit

CARMEN ACCESS

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- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass - Adding a Device help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Download the Duo Mobile application to all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service.

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

GRADING:

Your grade will be calculated based on the following course components:

Assignment Category
In-class activities (1-2 per week) – 25%
Homework – 25%
Weekly Reflections – 10%
Final Research Project (multiple components) – 40%

In-Class Activities

Description: This course adopts active learning in the class. Students will engage with at least 1 – 2 in-class activities per week in the class. These activities could be paper-based or could involve writing code on the computer. These activities can be done in collaboration with other students, but each student is required to submit their own work. Students with a valid excused absence can make arrangements with the instructor for make up activities.

Homework

Description: Homework assignments will be like the in-class activities and will be given to make sure that the students understand the concepts covered in the class. Homework can be done in collaboration with other students, but each student is required to submit their own work. Please view the academic integrity policy for more details.

Weekly Reflections

Description: You are required to post short (100 word) weekly reflections about your experience and engagement with the course materials on carmen. The general prompts for reflection center around what worked for you and what are some concepts of the course that you found challenging. There could be weeks when I might have reflection prompts specific to the content from that week. These are graded for completion only.

Final Research Project

Description: For the research project, students will work in teams (~ 3 students), and will be graded on the team result as well as their individual contributions. First, the team will find a research paper related to the quantum computing concepts they have studied in the class. They are then required to understand the paper and create a didactic presentation to be presented to the class. Peer review of the presentation for clarity and accessibility across disciplines will be a component of the grade for this part of the project. Students will also be graded on their individual contributions to a written report (~ 20 pages in length) comprising multiple sections including an introduction with background material and literature review, a results section focused on the selected paper, and a discussion section putting the results in context and outlining possible future steps. Division of tasks will be documented as part of the report appendix.

Academic integrity and collaboration: Your assignments should be your own original work. However, you are encouraged to have discussions with the instructor and peers about all the assignments. For example, if you are stuck on a step in a homework problem, you are free to discuss with your peers, but the final worked solution should be your own.

Late Assignments

Please refer to Carmen for due dates. Due dates are set to help you stay on pace and to allow timely feedback that will help you complete subsequent assignments. However, in certain instances where documented excuse is presented, the deadlines may be extended at the discretion of the instructor.

The following scale will ensure the following grades:

>93% = A
90-92.99% = A-
87-89.99% = B+
83-86.99% = B
80-82.99% = B-
77-79.99% = C+
73-76.99% = C
70-72.99% = C-
67-69.99% = D+
60-66.99% = D
<60% = E

COURSE SCHEDULE

Week	Date	Class #	Broad Theme	Topic
1	01/11/27	1	Course introduction and fundamentals	Overview
	01/13/27	2		Numbering systems - binary and others
	01/15/27	3		Classical Logic and Gates
2	01/18/27	MLK day	Review: quantum state mathematics	Vectors and complex numbers
	01/20/27	4		Superpositions
	01/22/27	5		Probabilistic interpretation
3	01/25/27	6	quantum gates I	Measurements of quantum states
	01/27/27	7		quantum logic and gates
	01/29/27	8		reversible/irreversible quantum gates and operations
4	02/01/27	9	quantum gates II	matrix representation of quantum gates
	02/03/27	10		discussions: select project team for final project
	02/05/27	11		
5	02/08/27	12	Entanglement	multiple qubit systems
	02/10/27	13		entangled states I
	02/12/27	14		entangled states II
6	02/15/27	15	applications of entanglement	quantum teleportation
	02/17/27	16		superdense coding
	02/19/27	17		discussions: teams select topic for final project
7	02/22/27	18	quantum information processing	examples: no cloning, quantum key distribution, sensing
	02/24/27	19		universal computing (Turing thesis)
	02/26/27	20		computational complexity
8	03/01/27	21	quantum algorithms I	Deutsch-Josza ; Grover, Shor
	03/03/27	22		
	03/05/27	23		
9	03/08/27	24	quantum algorithms II	
	03/10/27	25		
	03/12/27	26		discussions: teams report out on the final project progress
10	03/15/27	NO CLASSES - SPRING BREAK		
	03/17/27			
	03/19/27			

11	03/22/27	27	noisy qubits	noisy quantum states and noise modeling
	03/24/27	28		NISQ quantum computing
	03/26/27	29		
12	03/29/27	30	quantum error correction	error correction methods and fault tolerant computing
	03/31/27	31		
	04/02/27	32		
13	04/05/27	33		what is the future of the field?
	04/07/27	34		course review
	04/09/27	35		~discussions: teams report out on the final project progress
14	04/12/27	36	Final project presentations	
	04/14/27	37		
	04/16/27	38		
15	04/19/27	39		
	04/21/27	40		
	04/23/27	41		
16	04/26/27	42		

OTHER COURSE POLICIES

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STATEMENT ON TITLE IX

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu.

DIVERSITY STATEMENT

The Ohio State University affirms the importance and value of diversity of people and ideas. We believe in creating equitable research opportunities for all students and to providing programs and curricula that allow our students to understand critical societal challenges from diverse perspectives and aspire to use research to promote sustainable solutions for all. We are committed to maintaining an inclusive community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among all members; and encourages each individual to strive to reach their own potential. The Ohio State University does not discriminate on the basis of age, ancestry, color, disability, gender identity or expression, genetic information, HIV/AIDS status, military status, national origin, race, religion, sex, gender, sexual orientation, pregnancy, protected veteran status, or any other bases under the law, in its activities, academic programs, admission, and employment. (To learn more about diversity, equity, and inclusion and for opportunities to get involved, please visit: https://odi.osu.edu/ or https://cbsc.osu.edu).

Syllabus
QISE 7102: Grand Challenges in Quantum Information Science and Engineering

Spring 2027

FACULTY INSTRUCTOR:
TBD (email TBD)
Office: TBD
Office hours: TBD

COURSE DESCRIPTION: This course will focus on grand challenges toward realizing quantum computers, including scalable multi-qubit entanglement, long-distance networking, error correction and algorithms.

Prerequisites: For graduate students admitted to the QISE program or any QISE related discipline (Chemistry, Mathematics, Physics, Computer Science Engineering, Electrical Engineering, or Materials Science Engineering), there are no prerequisites. All other graduate and undergraduate students must have prior approval of the instructor to enroll in this course.

COURSE LEARNING OBJECTIVES:

A. Explain the purpose and functionality of different architectures for quantum computing, networking and sensing
B. Explain how quantum superpositions are achieved in several physical platforms
C. Compare and contrast physical platforms for different quantum tasks: computing, networking, sensing, storage, error correction

FORMAT OF INSTRUCTION: In person lectures by the instructor. Pauses will be given during the class period for students to work on exercises along the way.

MODE OF DELIVERY: In person

NUMBER OF CONTACT HOURS PER WEEK: 3 hours, meaning 3 x 55min classes each week

CREDIT HOURS AND WORK EXPECTATIONS: This is a 3-credit-hour course. According to Ohio State policy (go.osu.edu/credithours), students should expect around 3 hours per week of time spent on direct instruction (instructor content and Carmen activities, for example) in addition to 6 hours of homework (reading and assignment preparation, for example) to receive a grade of (C) average.

COURSE TECHNOLOGY:
For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. In-person support information is available at https://it.osu.edu/help, and support via phone or email is available 24/7.

- **Self-Service and Chat support:** go.osu.edu/IT
- **Phone:** 614-688-4357(HELP)
- **Email:** servicedesk@osu.edu

BASELINE TECHNICAL SKILLS FOR COURSES

- Basic computer and web browsing skills
- Navigating Carmen: for questions about specific functionality, see the Canvas Student Guide.

REQUIRED TEXTBOOK

- "Building Quantum Computers" by Majidy, Wilson and Laflamme, Cambridge University Press 2024

REQUIRED EQUIPMENT

- Personal computer (laptop): current Mac (OS X) or PC (Windows 7+) with high-speed internet connection.
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication should such a necessity arise

REQUIRED SOFTWARE

- None

CARMEN ACCESS

You will need to use BuckeyePass multi-factor authentication to access your courses in Carmen. To ensure that you are able to connect to Carmen at all times, it is recommended that you take the following steps:

- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass - Adding a Device help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Download the Duo Mobile application to all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service.

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

GRADING

The grades for the course will be based on homework, exams, and a semester-long project.

HOMEWORK. Students will be assigned homework problems each week pertaining to the class material. Homework will be due at the beginning of the lecture on which it is due. The assigned problems are a lower bound of what the student is expected to do. Students may work together to solve the problems, but each student is responsible for their own solutions. In particular, students must write up solutions separately, and any copying will be regarded as academic misconduct/plagiarism. Students may use whatever resources they want for their homework, but they must cite all resources.

EXAMS. There are two midterms and a final exam. All exams will be delivered in-person. The midterms will cover blocks of the course content as indicated on the syllabus below, while the final exam will be comprehensive.

Midterm 1: TBD, during lecture
Midterm 2: TBD, during lecture
Final exam: TBD, during the period set by the registrar
There will be no makeup exams. A missed exam will count for a zero for that test. (See grading option (2).)

SEMESTER-LONG PROJECT. Students will work on a semester-long project whose aim is to look in detail at an area of quantum information science in which the techniques of this class are used extensively.

Semester-Long Project Components:

Students will complete a final (at least) 5 page paper (plus citations which can go longer) which discusses an active area of research in quantum information science which uses the material discussed in this course. Students will also give a 10 minute final slide presentation presenting their research and findings along with discussing concrete applications. Both the 5 page paper and the presentation will each contribute 10 percentage points to the final grade.

Topics for the project will be suggested on the Carmen course site with initial sources provided, or students can select their own topic and initial sources with approval by the instructor/teaching assistant at one of the intermediate “touch points” of the project described next.

The project will have major “touch points” to verify that they are keeping on track with the project and undertaking a substantial project. The touch points will only be graded on the basis of meeting deadlines, that is, 1 or 0 points will be awarded for meeting the deadline for said touch point. These touch points will account for only 1 out of 10 percentage points for each of the final paper and final presentation.
paper.

The touch points include (feedback will be provided to each student):

End of week 4: A one-paragraph description of their research topic proposal summarizing their topic, together with a minimum of three initial sources.

End of week 8: A one-paragraph summary of their topic which clearly explains its applications in quantum information science.

End of week 12: Final 5 page paper submitted.

PRESENTATION GRADING RUBRIC:
Students will work with the instructor to develop a grading rubric for the presentations. Some sample grading considerations will be supplied by the instructor, but the class will agree on 5 main areas which will be assessed for the presentations. Students will also implement their rubric by evaluating each talk. The rubrics, which will not be anonymous to the professor, will be collected and used to assess the final presentation grade. The feedback from the student rubrics will be anonymized and then given to the presenter.

GRADING. There are two grading options for each student:

(1)

ASSIGNMENT CATEGORY	PERCENTAGE
HOMEWORK	20
EXAM 1	20
EXAM 2	20
SEMSETER PROJECT PAPER	10
SEMSETER PROJECT PRESENTATION	10
FINAL EXAM	20

(2)

ASSIGNMENT CATEGORY	PERCENTAGE
HOMEWORK	20
HIGHER EXAM	20
SEMSETER PROJECT PAPER	10
SEMSETER PROJECT PRESENTATION	10
FINAL EXAM	40

The instructor will automatically pick the option that results in a higher grade. If a student must miss more than one test for reasons beyond their control, in extremely rare circumstances, with prior consent from the instructor, the final will count for a higher percent of their grade.

The instructor may curve the final distribution to the students’ benefit, but the following scale will ensure the following grades:
>93% = A 90-92.99% = A- 87-89.99% = B+ 83-86.99% = B 80-82.99% = B-
77-79.99% = C+ 73-76.99% = C 70-72.99% = C- 67-69.99% = D+ 60-66.99% = D
<60% = E

GRADE REVISIONS. You may request that exams be regraded. This request must be in writing and be turned in by the end of the class or office hour during which your exam was returned. If you leave class or office hours with your exam for any reason, your grade revision request will not be accepted.

COURSE SCHEDULE

Week	Date	Class #	Broad Theme	Topic
1	1/11/2027	1	Requirements for quantum computing	Scalability
	1/13/2027	2		Universal Logic
	1/15/2027	3		Correctability
2	1/18/2027	MLK day	NMR	Bloch sphere, qubit rotations
	1/20/2027	4		Spin manipulation in magnetic field
	1/22/2027	5		Spin-echoes, Ramsey sequences
3	1/25/2027	6	Spin qubits (NV centers in diamond)	Two-qubit gate via spin-spin interactions
	1/27/2027	7		2D electron gas, single dot spectroscopy, quantum dots, defect centers
	1/29/2027	8		electron-nuclear coupling, spin-photon entanglement
4	2/1/2027	9	Photons	Optical modes: waves vs photons, Fock states
	2/3/2027	10		Beamsplitters, single photon detectors
	2/5/2027	11		Long distance networking
5	2/8/2027	12	Trapped ions	Paul trap, Cooling ions in a trap
	2/10/2027	13		atom-photon entanglement
	2/12/2027	14		Geometric phase gates
6	2/15/2027	15	MIDTERM EXAM 1 (content: Lectures 1-11)	
	2/17/2027	16	Superconducting qubits	Superconductivity, Josephson junctions
	2/19/2027	17		Transmon qubits, flux qubits, and phase qubits
7	2/22/2027	18		Circuit QED
	2/24/2027	19		Superconducting Circuits
	2/26/2027	20		microwave-optical transduction
8	3/1/2027	21	Neutral atom qubits	Atomic levels, hyperfine qubits, nuclear-spin qubits
	3/3/2027	22		Laser cooling, magneto-optical traps, optical tweezers
	3/5/2027	23		Rydberg interactions/gates
9	3/8/2027	24	pros/cons	DiVincenzo's criteria, requirements for gate-based QC, measurement-based QC, and adiabatic QC
	3/10/2027	25		Study/comparison of leading platforms for quantum computing
	3/12/2027	26		Requirements for long-distance quantum networking
10	3/15/2027	NO CLASSES - SPRING BREAK		
	3/17/2027			

	3/19/2027			
11	3/22/2027	27	pros/cons	Study/comparison of leading platforms for quantum networking
	3/24/2027	28		Introduction to and requirements for quantum sensing
	3/26/2027	29		Study/comparison of leading platforms for quantum sensing
12	3/29/2027	30	MIDTERM EXAM 2 (Lectures 12-23)	
	3/31/2027	31	noisy intermediate scale quantum systems	Definition of NISQ
	4/2/2027	32		Early use cases of quantum computers
13	4/5/2027	33		Quantum advantage experiments
	4/7/2027	34	error correction schemes and implementation	Logical qubits
	4/9/2027	35		Error-correcting codes
14	4/12/2027	36		Physical implementations
	4/14/2027	37	guest speakers: national labs, industry, startups	
	4/16/2027	38		
15	4/19/2027	39	Final Project presentations	
	4/21/2027	40	Final Project presentations	
	4/23/2027	41	Final Project presentations	
16	4/26/2027	42	Review	
	TBD		COMPREHENSIVE FINAL EXAM	

OTHER COURSE POLICIES

INCOMPLETE GRADE POLICY

From http://artsandsciences.osu.edu/academics/current-students/advising/policies
An 'I' indicates that a student has completed a major portion of the work in the course in a satisfactory manner, but for reasons judged by the instructor to be legitimate, a portion of the course requirements remains to be completed. If illness or an emergency prevents you from finishing a course, you may request an 'Incomplete' from the instructor. When you receive this grade, you must consult with the instructor as soon as possible to make arrangements for completing the course requirements. Incomplete work must be completed no later than the sixth week of the following semester. If the work is not made up by the due date, the 'I' mark will be changed to the alternate grade the instructor reported.

ACADEMIC MISCONDUCT POLICY

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If you are ill and need to miss class, including if you are staying home and away from others while experiencing symptoms of a viral infection or fever, please let me know immediately. In cases where illness interacts with an underlying medical condition, please consult with Student Life Disability Services to request reasonable accommodations. You can connect with them at slds@osu.edu; 614-292-3307; or slds.osu.edu.

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Syllabus
QISE 7111: Current research in Quantum Information Science and Engineering
Autumn 2026

FACULTY INSTRUCTOR:
TBD (email TBD)
Office: TBD
Office hours: TBD

COURSE DESCRIPTION: This student-led seminar-style course will meet once weekly during the term, and will feature regular presentations by students on journal articles of current interest. Students will gain experience in presenting and discussing technical content to a multi-disciplinary audience. These discussions will be facilitated by a rotating team of faculty, chosen for disciplinary overlap with the weeks' selection.

Prerequisites: For graduate students admitted to the QISE program or any QISE related discipline (Chemistry, Mathematics, Physics, Computer Science Engineering, Electrical Engineering, or Materials Science Engineering), there are no prerequisites. All other graduate students must have prior approval of the instructor to enroll in this course.

COURSE LEARNING OBJECTIVES:
Students will be able to describe the current frontiers in the field of QISE by selecting, reading, discussing and presenting recent research papers. Students will be able to effectively use various literature searching tools such as Google Scholar, Web of Science, ARXIV and other indices. Students will be able to describe and explain the utility of journal reputation, citation counts and other metrics to assess novelty and impact of research papers. Students will be able to prepare and effectively present technical content in their selected papers to a multi-disciplinary audience.

HOW THIS COURSE WORKS

FORMAT OF INSTRUCTION: Weekly presentations and discussion of current topics / papers

MODE OF DELIVERY: In person

NUMBER OF CONTACT HOURS PER WEEK: 1 x 55min class each week

CREDIT HOURS AND WORK EXPECTATIONS: This is a 1-credit-hour course. According to Ohio State policy (go.osu.edu/credithours), students should expect around 3 hours per week of time spent on preparing presentations and in-class discussions.

COURSE TECHNOLOGY:
For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. In-person support information is available at https://it.osu.edu/help, and support via phone or email is available 24/7.

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- **Phone:** 614-688-4357(HELP)
- **Email:** servicedesk@osu.edu

BASELINE TECHNICAL SKILLS FOR COURSES

- Basic computer and web browsing skills
- Navigating Carmen: for questions about specific functionality, see the Canvas Student Guide.

REQUIRED TEXTBOOK

- None

REQUIRED EQUIPMENT

- Personal computer (laptop): current Mac (OS X) or PC (Windows 7+) with high-speed internet connection recommended but not required.
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication should such a necessity arise

REQUIRED SOFTWARE

- None

CARMEN ACCESS

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- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass - Adding a Device help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
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If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

GRADING

The course will be graded on the 'Satisfactory / Unsatisfactory' basis. An Unsatisfactory grade will reflect a one or more missing (unexcused) or poorly-prepared presentation assignments, and/or missing 20% of the course meetings.

ASSIGNMENTS: Students should expect to present two papers during the term, with each presentation comprising ~ 5 slides showing the papers' main results and providing some context within the field. The presentations should be designed to last 15 minutes without interruptions, but active discussions will be encouraged during the talks. When they are not presenting, students will read the selected paper and review foundational background material.

EXAMS. None

Week	Date	Class #	Topic
1	8/24		Introductions, overview of QISE
	8/26		
	8/28	1	
2	8/31		Overview of literature searching methods: Google Scholar, ISI Web of Science, ARXIV
	9/2		
	9/4	2	
3	9/7	NO CLASSES - LABOR DAY	
	9/9		Paper presentations
	9/11	3	
4	9/14		Paper presentations
	9/16		
	9/18	4	
5	9/21		Paper presentations
	9/23		
	9/25	5	
6	9/28		Paper presentations
	9/30		
	10/2	6	
7	10/5		Paper presentations
	10/7		
	10/9	7	
8	10/12		
	10/14		
	10/16	NO CLASSES - AUTUMN BREAK	
9	10/19		Paper presentations
	10/21		
	10/23	8	
10	10/26		Paper presentations
	10/28		
	10/30	9	
11	11/2		Paper presentations
	11/4		
	11/6	10	
12	11/9		
	11/11	NO CLASSES - VETS DAY	
	11/13	11	Paper presentations
13	11/16		Paper presentations
	11/18		
	11/20	12	
14	11/23		
	11/25	NO CLASSES - THANKSGIVING	

	11/27		
15	11/30		Paper presentations
	12/2		
	12/4	13	

OTHER COURSE POLICIES

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Syllabus
QISE 7112: Professional Seminar in Quantum Information Science and Engineering
Autumn 2026

FACULTY INSTRUCTOR:
TBD (email TBD)
Office: TBD
Office hours: TBD

COURSE DESCRIPTION: This seminar-style course will feature weekly instructor-facilitated discussion meetings about a selected reading, and/or aspects of professional development. Participating faculty in the quantum graduate program will present short talks to introduce students to different research in quantum information science and engineering. Other activities will include discussions on ethical questions posed by quantum computing and information, discussions of quantum startups and the rapidly developing quantum ecosystem, and general professional skills needed to compete for jobs in QISE.

Prerequisites: For graduate students admitted to the QISE program or any QISE related discipline (Chemistry, Mathematics, Physics, Computer Science Engineering, Electrical Engineering, or Materials Science Engineering), there are no prerequisites. All other graduate students must have prior approval of the instructor to enroll in this course.

COURSE LEARNING OBJECTIVES:

Students will learn general skills for navigating graduate school, including identifying a field of study, finding a research advisor, and developing a plan for funding their PhD. Students will be able to describe examples of interdisciplinary research presented in the course. Students will develop and explain an initial Individual Development Plan for their career goals, and describe examples of post-graduate career paths in academia, industry and government/non-profit sectors. Through participation in course discussions, students will be able to explain and describe potential impacts of quantum technologies on society (including ethical issues), national security and industry.

HOW THIS COURSE WORKS

FORMAT OF INSTRUCTION: Weekly presentations and discussions, including: faculty presentations on current research opportunities, ethics training (e.g., NSF RCR), professional networking (conferences, internships, profiles), landscape for quantum startup companies, explanation of progression through the program.

MODE OF DELIVERY: In person

NUMBER OF CONTACT HOURS PER WEEK: 1 x 55min class each week

CREDIT HOURS AND WORK EXPECTATIONS: This is a 1-credit-hour course. According to Ohio State policy (go.osu.edu/credithours), students should expect around 3 hours per week of time spent on course readings and activities.

COURSE TECHNOLOGY:

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- **Self-Service and Chat support:** go.osu.edu/IT
- **Phone:** 614-688-4357(HELP)
- **Email:** servicedesk@osu.edu

BASELINE TECHNICAL SKILLS FOR COURSES

- Basic computer and web browsing skills
- Navigating Carmen: for questions about specific functionality, see the Canvas Student Guide.

REQUIRED TEXTBOOK

- None

REQUIRED EQUIPMENT

- Personal computer (laptop): current Mac (OS X) or PC (Windows 7+) with high-speed internet connection recommended but not required.
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication should such a necessity arise

REQUIRED SOFTWARE

- None

CARMEN ACCESS

You will need to use BuckeyePass multi-factor authentication to access your courses in Carmen. To ensure that you are able to connect to Carmen at all times, it is recommended that you take the following steps:

- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass - Adding a Device help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Download the Duo Mobile application to all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service.

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

GRADING

The course will be graded on the ‘Satisfactory / Unsatisfactory’ basis. An Unsatisfactory grade will reflect a sustained lack of participation and/or missing 20% of the course meetings.

ASSIGNMENTS: Weekly readings

EXAMS. None

COURSE SCHEDULE

Week	Date	Class #	Topic
1	8/24		Introductions, models for funding support, finding a research advisor
	8/26		
	8/28	1	
2	8/31		Overview of research areas in QISE
	9/2		
	9/4	2	
3	9/7	NO CLASSES - LABOR DAY	
	9/9		Overview of post-graduate paths in QISE: academia, national lab, startups, large companies
	9/11	3	
4	9/14		Scientific ethics; research presentation
	9/16		
	9/18	4	
5	9/21		Overview of quantum technologies: quantum key distribution, quantum computer
	9/23		
	9/25	5	
6	9/28		Impacts of quantum technologies on society; research presentation
	9/30		
	10/2	6	
7	10/5		Impacts of quantum technologies on industry ; research presentation
	10/7		
	10/9	7	
8	10/12		
	10/14		
	10/16	NO CLASSES - AUTUMN BREAK	
9	10/19		Impacts of quantum technologies on national security ; research presentation
	10/21		
	10/23	8	
10	10/26		Research Presentations
	10/28		
	10/30	9	
11	11/2		Research Presentations
	11/4		
	11/6	10	
12	11/9		
	11/11	NO CLASSES - VETS DAY	
	11/13	11	Role of AI in research: literature searching, writing
13	11/16		OSU Alumni talks: pathways post-graduation

	11/18		
	11/20	12	
14	11/23		
	11/25	NO CLASSES - THANKSGIVING	
	11/27		
15	11/30		Individual Development Plans
	12/2		
	12/4	13	

OTHER COURSE POLICIES

ACADEMIC MISCONDUCT POLICY

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term “academic misconduct” includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-48.7 (B)). For additional information, see the Code of Student Conduct.

STATEMENT ABOUT DISABILITY SERVICES

The university strives to maintain a healthy and accessible environment to support student learning in and out of the classroom. If you anticipate or experience academic barriers based on your disability (including mental health, chronic, or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion.

If you are ill and need to miss class, including if you are staying home and away from others while experiencing symptoms of a viral infection or fever, please let me know immediately. In cases where illness interacts with an underlying medical condition, please consult with Student Life Disability Services to request reasonable accommodations. You can connect with them at slds@osu.edu; 614-292-3307; or slds.osu.edu.

STATEMENT ON RELIGIOUS ACCOMMODATIONS

Ohio State has had a longstanding practice of making reasonable academic accommodations for students' religious beliefs and practices in accordance with applicable law. In 2023, Ohio State updated its practice to align with new state legislation. Under this new provision, students must be in early communication with their instructors regarding any known accommodation requests for religious beliefs and practices, providing notice of specific dates for which they request alternative accommodations within 14 days after the first instructional day of the course. Instructors in turn shall not question the sincerity of a student's religious or spiritual belief system in reviewing such requests and shall keep requests for accommodations confidential.

With sufficient notice, instructors will provide students with reasonable alternative accommodations with regard to examinations and other academic requirements with respect to students' sincerely held religious beliefs and practices by allowing up to three absences each semester for the student to attend or participate in religious activities. Examples of religious accommodations can include, but are not limited to, rescheduling an exam, altering the time of a student's presentation, allowing make-up assignments to substitute for missed class work, or flexibility in due dates or research responsibilities. If concerns arise about a requested accommodation, instructors are to consult their tenure initiating unit head for assistance.

A student's request for time off shall be provided if the student's sincerely held religious belief or practice severely affects the student's ability to take an exam or meet an academic requirement and the student has notified their instructor, in writing during the first 14 days after the course begins, of the date of each absence. Although students are required to provide notice within the first 14 days after a course begins, instructors are strongly encouraged to work with the student to provide a reasonable accommodation if a request is made outside the notice period. A student may not be penalized for an absence approved under this policy.

If students have questions or disputes related to academic accommodations, they should contact their course instructor, and then their department or college office. For questions or to report discrimination or harassment based on religion, individuals should contact the Office of Institutional Equity. (Policy: Religious Holidays, Holy Days and Observances).

MENTAL HEALTH STATEMENT

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and Consultation Service (CCS) by visiting ccs.osu.edu or calling 614-292-5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on call counselor when CCS is closed at 614-292-5766 and 24 hour emergency help is also available 24/7 **by dialing 988 to reach the Suicide and Crisis Lifeline**.

STATEMENT ON TITLE IX

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu.

DIVERSITY STATEMENT

The Ohio State University affirms the importance and value of diversity of people and ideas. We believe in creating equitable research opportunities for all students and to providing programs and curricula that allow our students to understand critical societal challenges from diverse perspectives and aspire to use research to promote sustainable solutions for all. We are committed to maintaining an inclusive community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among all members; and encourages each individual to strive to reach their own potential. The Ohio State University does not discriminate on the basis of age, ancestry, color, disability, gender identity or expression, genetic information, HIV/AIDS status, military status, national origin, race, religion, sex, gender, sexual orientation, pregnancy, protected veteran status, or any other bases under the law, in its activities, academic programs, admission, and employment. (To learn more about diversity, equity, and inclusion and for opportunities to get involved, please visit: **https://odi.osu.edu/** or **https://cbsc.osu.edu**).

Syllabus
QISE 7113: 1st year Research Rotations in Quantum Information Science and Engineering
Autumn 2026

FACULTY INSTRUCTOR:
Research supervisor chosen by student (email TBD)
Office: TBD
Office hours: TBD

COURSE DESCRIPTION: This is an independent study style course where students learn research techniques through a 7 week experience with one of the faculty advisors in the new quantum interdisciplinary graduate program (QuGIP). Students may perform computational, theoretical or experimental work relevant to QISE depending on their choice of rotation supervisor.

Prerequisites: Permission of instructor.

COURSE LEARNING OBJECTIVES:

Students will be able to describe and apply research methods, including general tools (e.g. literature searching, scientific ethics, notebooks) and specific tools (e.g., code, characterization equipment, sample synthesis, relevant safety training) to a problem in one area of quantum information science and engineering. Students will be able to prepare and effectively present their research experience and results through an end-of-term oral presentation summarizing their experience and work done.

HOW THIS COURSE WORKS

FORMAT OF INSTRUCTION: variable depending on research supervisor, but may include laboratory work, theoretical calculations or computational work. An end of session presentation on the research experience is required.

MODE OF DELIVERY: In person

NUMBER OF CONTACT HOURS PER WEEK: n/a

CREDIT HOURS AND WORK EXPECTATIONS: 3x credits: This course is built from 1.5-credit hour increments for the 7 week term. According to Ohio State policy (go.osu.edu/credithours), students should expect around 6 hours per week of work per credit hour for a 7-week course. For research rotations, this translates to about 9 hours per week during the rotation. Activities will vary depending on the research supervisor, but will generally include time spent learning methods and attending group meetings.

COURSE TECHNOLOGY:

For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. In-person support information is available at https://it.osu.edu/help, and support via phone or email is available 24/7.

- **Self-Service and Chat support:** go.osu.edu/IT
- **Phone:** 614-688-4357(HELP)
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BASELINE TECHNICAL SKILLS FOR COURSES

- Basic computer and web browsing skills
- Navigating Carmen: for questions about specific functionality, see the Canvas Student Guide.

REQUIRED TEXTBOOK

- None

REQUIRED EQUIPMENT

- Personal computer (laptop): current Mac (OS X) or PC (Windows 7+) with high-speed internet connection recommended but not required.
- Other: a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication should such a necessity arise

REQUIRED SOFTWARE

- Software to be used will depend on the particular rotation research group. Examples include CrystalMaker, Origin, MATLAB, COMSOL, LABVIEW, and Mathematica.

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If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

GRADING

The course will be graded on the 'Satisfactory / Unsatisfactory' basis. A Satisfactory grade will reflect 1) consistent participation in research, including attendance at group and project meetings, completion of assigned tasks and required trainings and 2) a satisfactory end-of-term presentation, including appropriate introduction, methods and results sections. The research supervisor will be tasked with assessing both grade components. A satisfactory assessment is required in both components to pass the course.

EXAMS. None

COURSE SCHEDULE

Week	Date	Class #	Topic
1	8/24		**Begin Rotation - Session 1**
	8/26		
	8/28		
2	8/31		
	9/2		
	9/4		
3	9/7	NO CLASSES - LABOR DAY	
	9/9		
	9/11		
4	9/14		
	9/16		
	9/18		
5	9/21		
	9/23		
	9/25		
6	9/28		
	9/30		
	10/2		
7	10/5		
	10/7		
	10/9		
8	10/12		**Session 1 research presentations**
	10/14		
	10/16		
9	10/19		**Begin Rotation - Session 2**
	10/21		
	10/23		
10	10/26		
	10/28		
	10/30		
11	11/2		
	11/4		
	11/6		
12	11/9		
	11/11	NO CLASSES - VETS DAY	
	11/13		

13	11/16		
	11/18		
	11/20		
14	11/23		
	11/25	NO CLASSES - THANKSGIVING	
	11/27		
15	11/30		
	12/2		
	12/4		
16	12/7		
	12/9		
	12/11		**Session 2 research presentations**

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Student advising sheets

We include here advising sheets that we will use for students in the program. MS students will meet at the end of each semester with the QuGIP Graduate Studies Committee. Going forward, we will seek to adapt these forms to an ePortfolio platform, so that QuGIP students will have a record of their growth in the program that they can highlight to future employers.

Linked document here: Student advising sheets

QuGIP MS Graduate Student Advising Form

Student Name Last, First: **Specialization:**

MS option pursued (A = course focused, B= thesis focused)

course #	title	Required credits		Earned credits	Grade
		Opt A	Opt B		
QISE 7100	Foundations in QISE	3	3		
QISE 7101	Quantum Circuits and Algorithms	3	3		
QISE 7102	Grand Challenges in QISE	3	3		
Course taken:	Computational/Numerical Methods	1	1		
QISE 7111	Journal club	2	2		
QISE 7112	Professional Development Seminar	2	2		
QISE 7113 rotation 1 advisor:		3	3		
QISE 7113 rotation 2 advisor:		0	3		
GRADSCH 8000		0	1		
QISE-7999 thesis research		0	10		
Other course taken:		0	0		
Other course taken:		0	0		
Total			30		

Summer research project or internship (if applicable):

Project title:

Supervisor:

If you anticipate extending past the one year Fellowship period, please indicate your anticipated source of support (other Fellowship, GRA/GTA, grant # (if GRA), advisor):

Is there anything you'd like to discuss during your academic advising meeting?

To be completed by academic advisor:

Academic advising meeting date:

Academic advising meeting notes:

Assessment rubrics

Draft rubrics for MS Thesis and Defense (Summative)

Liked file: Rubrics

Example: Thesis rubric

MS thesis	Score	Outstanding = 3	Very Good = 2	Acceptable = 1	Significant work needed = 0
Organization		Uses organizational structures (introduction, headings, sequenced material, conclusions) within the paper to enhance and facilitate comprehension	Consistently uses organizational structures within the paper to facilitate comprehension	Some effort to use organizational structures within the paper, but doesn't impact comprehension	Lacking organizational structures. Difficult for reader to follow.
Mechanics		Demonstrates detailed attention to mechanics that enhances comprehension, including sentence structure, grammar, punctuation, and spelling	Few if any minor errors in sentence structure, grammar, punctuation, and/or spelling that do not impede understanding	Makes occasional errors in sentence structure, grammar, punctuation, and/or spelling that impede understanding	Makes frequent errors in sentence structure, grammar, punctuation and/or spelling that interferes with comprehension
Citations		Evidence that recent, high-impact and primary references cited throughout text	Appropriate references cited throughout, but maybe misssing a couple high-impact or primary references	References cited throughout, but little indication that primary, recent or high-impact papers were chosen	References not cited throughout text, ones chosen based on google search rather than impact or priority
Logical coherence		Discussion flows logically from one idea to the next, key questions anticipated and addressed at appropriate places	Strong attempt to maintain logical flow, some key questions anticipated, but only addressed later on	Logical flow, but fails to anticipate questions	Document missing key segues; argument not clear
Writing score					

MS thesis	Score	Outstanding = 3	Very Good = 2	Acceptable = 1	Significant work needed = 0
Organization		Uses organizational structures (introduction, headings, sequenced material, conclusions) within the paper to enhance and facilitate comprehension	Consistently uses organizational structures within the paper to facilitate comprehension	Some effort to use organizational structures within the paper, but doesn't impact comprehension	Lacking organizational structures. Difficult for reader to follow.
Mechanics		Demonstrates detailed attention to mechanics that enhances comprehension, including sentence structure, grammar, punctuation, and spelling	Few if any minor errors in sentence structure, grammar, punctuation, and/or spelling that do not impede understanding	Makes occasional errors in sentence structure, grammar, punctuation, and/or spelling that impede understanding	Makes frequent errors in sentence structure, grammar, punctuation and/or spelling that interferes with comprehension
Citations		Evidence that recent, high-impact and primary references cited throughout text	Appropriate references cited throughout, but maybe misssing a couple high-impact or primary references	References cited throughout, but little indication that primary, recent or high-impact papers were chosen	References not cited throughout text, ones chosen based on google search rather than impact or priority
Logical coherence		Discussion flows logically from one idea to the next, key questions anticipated and addressed at appropriate places	Strong attempt to maintain logical flow, some key questions anticipated, but only addressed later on	Logical flow, but fails to anticipate questions	Document missing key segues; argument not clear
Writing score					
Ch 1 Introduction					
Topic introduction		Topic is concisely introduced using fundamental principles	Topic is introduced, but lacks description of foundational principles	Topic is barely introduced or with flaws in foundational principles	Topic is ill-defined, or serious flaws in description of foundational principles
Problem rationale		Persuasive argument that an important problem has been identified	Problem has been identified with insufficient discussion	Problem has been identified, but not clear why important	Problem not clearly identified
Literature review		Current state of understanding of the problem summarized with appropriate references cited	State of the literature focusing on the problem is summarized, missing one or two key references	Similar studies (or lack thereof) summarized, but important references/milestones not cited	Missing substantial discussion of the field and important references
Broader impact		Discussion of potential impacts with at least one specific example	Discussion of potential impacts, but only in general terms	Vague discussion of impact	No effort to discuss impacts of the problem
Introduction score					
Ch 2: Research methods					

Rationale for proposed methods		Clear discussion for why proposed methods are suitable to solve the problem	Good discussion for proposed methods, but missing one or more key points	Some effort to relate proposed methods to problem, but connection unclear	No effort made to justify proposed methods
Methods summary		Discussion of proposed methods, supported with one or two examples of experimental, computational and theoretical data	Some discussion of proposed methods, supported by some examples	Focused discussion of proposed methods, but assertions are not supported	Methods only discussed in superfiicial terms, understandable only to experts in the techniques
Methods score					
Ch 3: Research results (typically 1-2 chapters expected)					
Specific objectives		Clear discussion of main reseach objectives or hypotheses	Discussion of main research objectives and/or hypotheses	Specific research objectives or hypotheses discussed, but are unclear	No discussion of objectives or hypotheses
Discussion of main results		Clear discussion of main results, with a logical progression of work supporting final conclusions. If there were roadblocks toward final objectives, clear discussion of challenge and next steps	Clear discussion of final work, but missing one example of foundational work or key challenges	Final work presented, but lacking discussion of key challenges or missing supporting elements	Missing discussion of key results, or discussion of challenges if work not completed.
Results score					
Ch 4: Conclusions					
Completed work and problem statement		Clear attempt to relate work completed to initial problem statement	Clear summary of completed work, but relation to problem statement missing important details	Detailed summary of completed work, but missing any discussion of relation to problem statement	Only sketch of completed work with no conclusions or connection to initial objectives
Key challenges and outlook		Clear discussion of key challenges and how overcome, or possible next steps if not overcome	Key challenges identified and discussion of how they impeded work	Key challenges identified	No discussion of challenges overcome or next steps
Conclusions score					
Overall assessment of MS thesis - (to be completed by each committee member <u>before</u> defense)		Several outstanding aspects clearly indicated, consistently above the 'acceptable bar' on all aspects	Outstanding in one aspect, but otherwise solid with no significant weaknesses	Consistently meets expectations	Several asepcts need substantial improvement. Revisions recommended.

MS thesis defense						
Presentation slides			Well-matched to time allowed, clear formatting with good visibility of all content, clear prioritization	Well matched to allowed time, good visibility, but some superfluous content	Good visibility of content, more slides than time allows, little prioritization	Content hard to see, missing citations, missing prioritization
Presentation organization			Clear statement of the problem, motivation, methods and main results; blend of content depth for expert and non-expert audience	Clear organization, missing some supporting context or background info	Organization ok but not so clear, missing some key context or background; presentation too detailed for a broader audience	Lacking clear organization, too technically detailed and no effort made to include context or background information
Delivery of prepared content			Clearly spoken with emphasis on main points and not rushed	Clearly spoken with good timing, but emphasis not clearly defined	Some points rushed or unclear	Discussion is rambling and hard to follow
Completed work and problem statement			Clear attempt to relate work completed to initial problem	Clear summary of completed work, but relation to problem statement missing	Detailed summary of completed work, but missing any discussion of relation	Only sketch of completed work with no conclusions or connection to initial
Ability to answer questions: on content			Concisely answer questions with consistent emphasis on key point	able to fully answer questions	able to answer questions with some guidance	not able to answer straightforward questions on content presented
Key challenges and outlook			Clear discussion of key challenges and how overcome, or possible next steps if not overcome	Key challenges identified and discussion of how they impeded work	Key challenges identified	No discussion of challenges overcome or next steps
Defense score						
Overall assessment of defense (to reflect committee consensus during post-exam deliberations)			Several outstanding aspects clearly indicated, consistently above the 'acceptable bar' on all aspects	Outstanding in perhaps one aspect, but otherwise solid with no significant weaknesses	Consistently meets expectations	Several asepcts need substantial improvement. Revisions recommended.
TOTAL SCORE	0					
(out of 60 points)						

Fiscal Impact Statement

	Year 0 (< AY26-27)	Year 1 (AY26-27)	Year 2 (AY 27-28)	Year 3 (AY28-29)	Year 4 (AY29-30)
Projected Enrollment	**6**	6.0	6.0	7.0	20.0
Head-count full time	3	6.0	6.0	7.0	20.0
Head-count part time	0	0.0	0.0	0.0	0.0
Full Time Equivalent (FTE) enrollment	3.0	3.0	3.0	3.5	10.0
Projected Program Income					
Tuition (paid by student or sponsor)	$ 93,933.00	$ 98,629.65	$ 103,561.13	$ 126,862.39	$ 190,293.58
Externally funded stipends, as applicable (including benefits)	$ 233,653.44	$ 233,653.44	$ 240,663.04	$ 289,196.76	$ -
Expected state subsidy	$ -	$ -	$ -	$ -	TBD
Other income (if applicable, describe in narrative section below)	$ 387,659.49	$ 209,963.29	$ 338,195.27	$ 310,449.51	TBD
TOTAL PROJECTED PROGRAM INCOME:	**$ 715,245.93**	**$ 542,246.38**	**$ 682,419.45**	**$ 726,508.65**	**$ 190,293.58**
Program Expenses					
New Personnel Program Coordinator (50% FTE in AY24-25, AY25-26, 100% FTE in Y2,3); including benefits	$ 46,577.02	$46,577	$61,469	$98,827	$ 101,791.85
New facilities/building/space renovation (if applicable, describe in narrative section below)					
Tuition Scholarship Support (if applicable, describe in narrative section below)	$ 93,933.00	$ 98,629.65	$ 103,561.13	$ 126,862.39	$ 190,293.58
Stipend Support (if applicable, describe in narrative section below)	$ 233,653.44	$ 233,653.44	$ 240,663.04	$ 289,196.76	$ 382,673.00
Additional library resources (if applicable, describe in narrative section below)					
Additional technology or equipment needs (if applicable, describe in narrative section below)					
Other expenses (e.g., Waived Tuition and Fees, travel, office supplies, accreditation costs) (if applicable, describe in narrative section below)	$341,082	$163,386	$276,726	$211,622	$ -
TOTAL PROJECTED EXPENSE:	**$715,246**	$ 542,246.38	$ 682,419.45	$ 726,508.65	$ 674,758.43
NET	**$ -**	**$ -**	**$ -**	**$ -**	**$ (484,464.85)**

Budget Narrative:

The launch phase of the program (up through AY28-29) is fully funded by an NSF NRT award. The award budget includes stipends and tuition for 25 funded trainees (1 year each) ; 6 of these trainee-years of funding will be used for current OSU graduate students to pilot aspects of the program, while the remaining 19 trainee-years of support will be used to recruit new students. The NSF NRT award also includes funding for a program coordinator position, teaching buyout for faculty to support curriculum development of the new courses, and travel to annual NSF NRT meetings. In Y4 (AY29-30) and beyond, the program would have to be sustainable on its own. As outlined in the sustainable budget below, the principal expenses are program staffing (e.g.

program coordinator), and funds to cover instructional costs (teaching buyout or lecturer time). These costs will be offset by returned tuition from QuGIP MS students. Based on discussions with similar programs at the University of Wisconsin and UCLA, we estimate a sustainable cohort of 20 Masters students per year.

			FY29	FY30	FY31	FY32	FY33
STAFFING							
SALARIES AND WAGES							
Senior Personnel		Months					
Faculty director summer salary		1.00	$16,180.89	$16,666.32	$17,166.31	$17,681.29	$18,211.73
Faculty co-director summer salary		0.50	$8,090.44	$8,333.16	$8,583.15	$8,840.65	$9,105.87
Program Coordinator		1	$60,000.00	$61,800.00	$63,654.00	$65,563.62	$67,530.53
Program Assistant (could potentially be in-kind via CQISE)		0	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL SALARIES AND WAGES			$84,271.33	$86,799.47	$89,403.46	$92,085.56	$94,848.13
FRINGE BENEFITS (FY 2025 rates)							
Regular Appointment (staff):	30.00%		$18,000.00	$18,540.00	$19,096.20	$19,669.09	$20,259.16
Off-Quarter Faculty Appointmen	17.00%		$4,126.13	$4,249.91	$4,377.41	$4,508.73	$4,643.99
			$22,126.13	$22,789.91	$23,473.61	$24,177.82	$24,903.15
TOTAL STAFFING		TOTAL	$106,397.46	$109,589.38	$112,877.07	$116,263.38	$119,751.28
EDUCATIONAL EXPENSES							
Misc program expenses			$5,000.00	$5,150.00	$5,304.50	$5,463.64	$5,627.54
Materials and Supplies:	Symposium expenses: posters, promotional material		$1,000.00	$1,030.00	$1,060.90	$1,092.73	$1,125.51
Computer subscriptions (qBraid, QisKit, AWS)			$5,000.00	$5,150.00	$5,304.50	$5,463.64	$5,627.54
Instructor buyout	3 semesters / year		$96,666.67	$99,566.67	$102,553.67	$105,630.28	$108,799.18
		TOTAL	$107,666.67	$110,896.67	$114,223.57	$117,650.27	$121,179.78
TRAVEL							
Domestic							
QuGIP faculty travel to recruiting conference; CQE summit, SACNAS, NSBP,			$2,000.00	$2,060.00	$2,121.80	$2,185.45	$2,251.02
Student professional development travel grants			$4,000.00	$4,120.00	$4,243.60	$4,370.91	$4,502.04
		TOTAL	$6,000.00	$6,180.00	$6,365.40	$6,556.36	$6,753.05
TOTAL EXPENSES			**$220,064.13**	**$226,666.05**	**$233,466.03**	**$240,470.01**	**$247,684.11**
PROGRAM INCOME	**# MS students**		**20**	**20**	**20**	**20**	**20**
Industry sponsorship: QuGIP symposium			$10,000.00	$10,000.00	$10,000.00	$10,000.00	$10,000.00
Tuition income - MS	(assume 5% inflation)	**$ 24,169**	$483,378.00	$507,546.90	$532,924.25	$559,570.46	$587,548.98
			$493,378.00	$517,546.90	$542,924.25	$569,570.46	$597,548.98
NET INCOME			**$273,313.87**	**$290,880.85**	**$309,458.21**	**$329,100.44**	**$349,864.87**

Market Analysis / Needs Survey

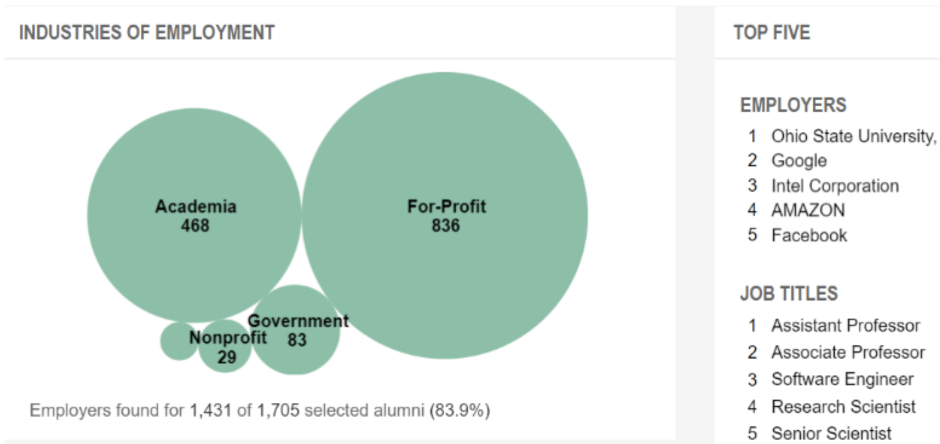
As discussed in the 2022 National Quantum Initiative Workforce report (https://www.quantum.gov/wp-content/uploads/2022/02/QIST-Natl-Workforce-Plan.pdf, c.f. below) a quantum-educated workforce will be needed to meet growing demand in this area. While quantum information science and engineering jobs are not yet called out as a separate category by the US Bureau of Labor Statistics, QISE-related jobs fall under several employment areas projected for high growth rates in the next decade, including Software Developers, Engineering instructors, Mathematical Science occupations and Materials engineers.

Occupation Title	Employment 2022 (thousands)	Employment 2032	% growth 2022-2032	Openings, 2022-2032 Annual	Median Annual Wage 2023
Software developers * Application Integration Engi	1,594.50	2,004.90	25.7	136.3	132,270
Software quality assurance analysts and testers * A	200.8	241.6	20.3	17.5	101,800
Industrial engineers * Efficiency Engineer* Manufa	327.3	365.7	11.7	22.8	99,380
Mechanical engineers * Auto Research Engineer* C	286.1	314.7	10	19.2	99,510
Engineering teachers, postsecondary * Aeronautica	45.5	49.7	9.3	4.1	106,910
Aerospace engineering and operations technologists	10.2	11	8.3	1	77,830
Chemical engineers * Absorption and Adsorption E	20.8	22.5	8.1	1.3	112,100
Electronics engineers, except computer * Antenna I	110.9	118.9	7.2	6.9	119,200
Technical writers * Assembly Instructions Writer* D	53.3	57	6.9	4.8	80,050
Agricultural engineers * Agricultural Engineer* Agri	1.6	1.7	6.3	0.1	88,750
Mathematical science occupations, all other * Harm	4.1	4.4	6.2	0.3	70,620
Aerospace engineers * Aerodynamics Engineer* Ae	63.8	67.7	6.1	3.8	130,720
Environmental engineers * Air Pollution Control En	47.3	50.2	6.1	3.4	100,090
Industrial-organizational psychologists * Engineerir	10.1	10.6	5.9	0.7	147,420
Bioengineers and biomedical engineers * Bio-Mech	19.7	20.7	5.1	1.2	100,730
Materials engineers * Automotive Sheet Metal Engi	22.3	23.5	5.1	1.5	104,100
Cartographers and photogrammetrists * Cadastral	14	14.7	5	1	76,210
Civil engineers * Architectural Engineer* Bridge Eng	326.3	342.5	5	21.2	95,890
Sales engineers * Aerospace Products Sales Enginee	60.9	63.8	4.7	5.9	116,950
Computer hardware engineers * Computer Hardwa	78.1	81.6	4.6	4.6	138,080
Electrical engineers * Electrical Design Engineer* El	188.8	196.6	4.2	11	106,950
Architectural and engineering managers * Electrical	201.5	209.7	4.1	13.6	165,370
Airline pilots, copilots, and flight engineers * Airline	91.7	95.2	3.9	10.8	219,140
Health and safety engineers, except mining safety en	22	22.8	3.7	1.3	103,690

In regards to academic degree attainment, on an anecdotal note we've had discussions with leadership in the quantum MS degree programs at UCLA and Univ. Wisconsin. Both have experienced high growth rates during their first three years, and quickly reached a sustainable cohort size of ~ 20 self-funded MS students / yr, with ~ 100 applications / yr. It is important to note that these programs are housed in Physics departments; our interdisciplinary program will thus draw on a larger base of students. The closest comparable PhD program in QISE is at the Univ. of Chicago. The program started has grown by over 50% in its first three years, with 57 QISE PhD students reported in 2022-23 (https://pme.uchicago.edu/sites/default/files/2023-10/PME_Annual_Report_2022-2023.pdf).

We similarly note an absence of program classification (CIP) codes (https://nces.ed.gov/ipeds/cipcode/browse.aspx?y=55) specifically in the interdisciplinary field of QISE. In the attached comparison analysis by Lightcast, we selected a subset of codes adjacent to QISE that include optics science, and chemical, mathematical and atomic physics. The report indicates a national growth in degree attainment of ~ 10% in these areas, with a projected growth of 8.3% in related employment over the next decade.

Consistent with this table, we also include here three snapshots of the current employment market in quantum, evidenced by a job posting mailer collated by the Chicago Quantum Exchange, and quantum job postings on Indeed.com and LinkedIn. These examples illustrate the variety of employers looking to establish a footprint in QISE, such as Intel, Google, Amazon, and JP Morgan Chase. These are also companies which are top employers of OSU graduates in the participating departments as shown here:



Locally at Ohio State, student demand for this program is evidenced through quantum pilot courses taught by participating faculty, including PHY 6820 – Quantum Information (taught in Sp18,19 by *Gauthier*, Sp21 by *Trivedi*), MATH 8800 – Topological Phases of Matter (*Penneys*-Sp21), MATH 8000 – Quantum Information and Computation, *Bu*-SP25), PHY 8800 – Architectures for Quantum Information Processing (*Singh* – SP25) at the graduate level, as well as MATH 2194 – Mathematical Methods of Quantum Information Science (*Penneys*), and CSE 5889 - Classical and Quantum Logic (*Atiq*, Au22) at the advanced undergraduate level. These courses are in high demand by students from a variety of backgrounds; for example, *Trivedi's* graduate course had a registration of 21 students (6 Phys Grad, 8 Phys UG, 4 Eng UG, 2 Math G) including undergraduates with second majors in unexpected fields such as psychology and history, and approximately 20 more auditing the course. Similarly, *Bu's* pilot course in SP25 reached its maximum enrollment of 20 students, with graduate students from math, physics and other departments taking the course.

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New York, NY
Machine Learning · Python +2
2 connections work here
Viewed · Promoted · 23 applicants

Quantum Computing Research - Lead Software Engineer
JPMorganChase
New York, NY
Machine Learning · Python +2
621 company alumni work here
Viewed · Promoted

Research Scientist, Mixed-Signal Designer - AWS Center for Quantum Computing
Amazon Web Services (AWS)
Pasadena, CA
$136K/yr - $212.8K/yr
130 company alumni work here
Viewed · Promoted · 12 applicants

Applied Research Scientist – Quantum-inspired and Randomized Algorithms - Vice President
JPMorganChase
New York, NY
153 school alumni work here
Promoted

Quantum Device Characterization Scientist
HRL Laboratories, LLC
Malibu, CA (On-site)
$132.8K/yr - $166K/yr · 401(k) benefit
6 company alumni work here
Promoted

Quantum Error Correction Research Scientist

Amazon Web Services (AWS)

Research Scientist, Mixed-Signal Designer - AWS Center for Quantum Computing

Pasadena, CA · Reposted 2 weeks ago · 12 applicants

$136K/yr - $212.8K/yr · Full-time

10,001+ employees · IT Services and IT Consulting

1 connection works here · 130 company alumni work here · 232 school alumni work here

Skills: Material Characterization, Product Service, +8 more

See how you compare to 12 applicants. Try Premium for $0

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Apply | Save

Meet the hiring team

Damon Russell · 2nd
Principal Research Scientist
1 mutual connection

Message

About the job

Description

The AWS Center for Quantum Computing in Pasadena, CA, is looking to hire a Research Scientist specializing in Mixed-Signal Design. Working alongside other scientists and engineers, you will design and validate hardware performing the control and readout functions for AWS quantum processors. Candidates must have a strong background in high-speed, mixed-signal design at the printed circuit board (PCB) level. Working ef within a cross-functional team environment is critical. The ideal candidate will have

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227 results
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Postdoc of Spin-photon interfaces in silicon photonics
NNF Quantum Computing Programme (NQCP)
Berkeley, CA (On-site)
Viewed · Promoted

System Integration Engineer, Quantum
HRL Laboratories, LLC
Malibu, CA (On-site)
$132.8K/yr - $166K/yr · 401(k) benefit
6 company alumni work here
Viewed · Promoted

Quantum Test Engineer, Senior
HRL Laboratories, LLC
Malibu, CA (On-site)
$132.8K/yr - $166K/yr · 401(k) benefit
6 company alumni work here
Viewed · Promoted

Applied Research Lead - Quantum Network Services, Vice President
JPMorganChase
New York, NY
621 company alumni work here
Viewed · Promoted · 10 applicants

Advanced Quantum Testbed Project Scientist
Berkeley Lab
Berkeley, CA (On-site)
$119.1K/yr - $166.8K/yr
59 school alumni work here
Viewed · Promoted · 9 applicants

Quantum Computing Research - Principal Software

HRL Laboratories, LLC

System Integration Engineer, Quantum

Malibu, CA · Reposted 2 weeks ago · 40 applicants

$132.8K/yr - $166K/yr · On-site · Full-time · Mid-Senior level

1,001-5,000 employees · Research Services

6 company alumni work here · 52 school alumni work here

Skills: Export Control Compliance, Export Controls, +8 more

See how you compare to 40 applicants. Try Premium for $0

Am I a good fit for this job? | How can I best position myself for

Apply | Save

About the job

Based in Southern California with locations in Malibu, Calabasas, Westlake Village and Camarillo; HRL has been on the leading edge of technology, conducting pioneering research and advancing the state of the art.

Essential Duties

Create and perform advanced measurements that utilize spin qubits to fully validate control systems.

Develop, implement, and document measurement techniques and use them to characterize control system performance, including signal generation and transmission.

Design and test of analog/mixed-signal integrated circuits including data converters, signal generation and signal processing circuits, and RF/ microwave electronics.

Contribute to specification and design of custom electronic equipment.

Perform on a highly collaborative technical teams that tackle high-risk, high-impact

Messaging

Program Overview

Health/Medical Physics

Lightcast Q1 2025 Data Set

April 2025

The Ohio State University | Ohio State Online

Ohio

Parameters

Completions Year: 2023

Jobs Timeframe: 2024 - 2034

Job Postings Timeframe: Jan 2024 - Jan 2025

Programs:

Code	Description
51.2205	Health/Medical Physics

Regions:

Code	Description
0	United States

Education Level:

Description	Description
Master's degree	Ph.D. or professional degree

Tuition Type: Tuition & Fees

Graduate Status: Undergraduate

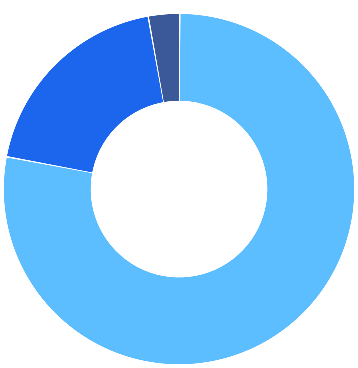
Residency: In-State

27	208	Completions Distribution
Institutions	**Completions**	
13% Growth (2019-2023)	25% Growth (2019-2023)	

Program Overview

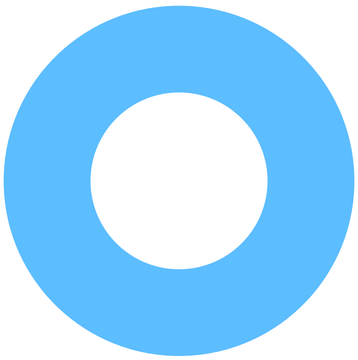
	Completions (2023)	% Completions	Institutions (2023)	% Institutions
All Programs	208	100%	27	100%
Distance Offered Programs	42	20%	2	7%
Non-Distance Offered Programs	166	80%	26	96%

Market Share by Institution Type



Institution Type	Completions (2023)	Market Share
Public, 4-year or above	162	77.9%
Private not-for-profit, 4-year or above	40	19.2%
Private for-profit, 4-year or above	6	2.9%

Market Share by Program

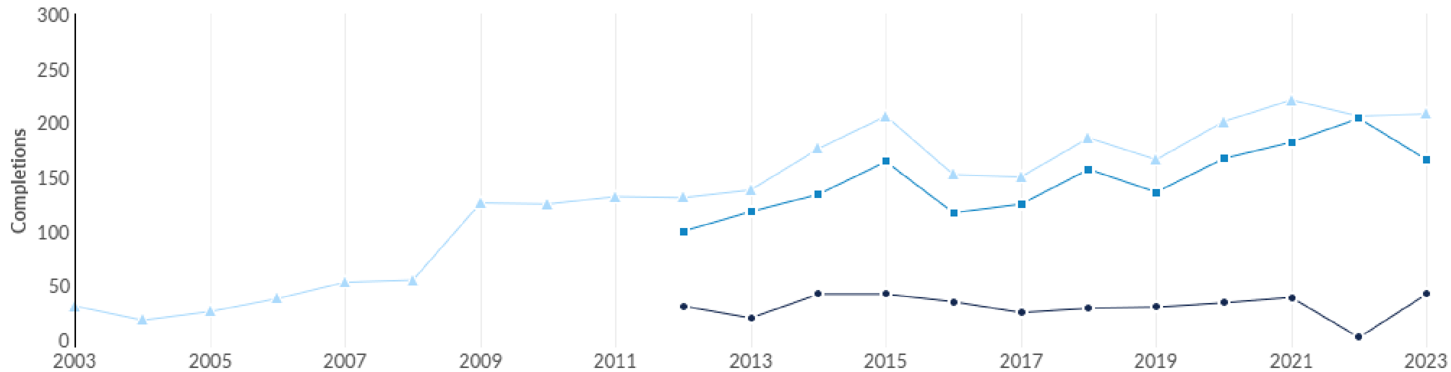


	Program	Completions (2023)	Market Share
	Health/Medical Physics (51.2205)	208	100.0%

Completions by Institution

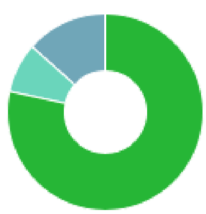
Institution	Completions (2023)	Growth % YOY (2023)	Market Share (2023)	IPEDS Tuition & Fees (2023)	Completions Trend (2019-2023)
Oregon State University	29	31.8%	13.9%	$13,494	
University of Wisconsin-Madison	29	16.0%	13.9%	$11,205	
Illinois Institute of Technology	16	128.6%	7.7%	$50,917	
Georgia Institute of Technology-Main Campus	15	25.0%	7.2%	$11,764	
Rutgers University-New Brunswick	12	71.4%	5.8%	$17,239	
San Diego State University	10	25.0%	4.8%	$8,290	
Hofstra University	9	12.5%	4.3%	$55,450	
The University of Tennessee-Knoxville	9	50.0%	4.3%	$13,484	
University of California-San Francisco	8	-42.9%	3.8%	N/A	
University of Kentucky	7	0.0%	3.4%	$13,212	
University of New Mexico-Main Campus	7	-65.0%	3.4%	$8,115	
Vanderbilt University	6	0.0%	2.9%	$63,946	
John Patrick University of Health and Applied Sciences	6	200.0%	2.9%	$19,520	
Louisiana State University and Agricultural & Mechanical College	5	25.0%	2.4%	$11,954	
University of Alabama at Birmingham	4	0.0%	1.9%	$8,832	
Florida Atlantic University	4	33.3%	1.9%	$4,879	
Wayne State University	4	-66.7%	1.9%	$15,464	
University of Minnesota-Twin Cities	4	-20.0%	1.9%	$16,488	
University of Nevada-Las Vegas	4	100.0%	1.9%	$9,142	
University at Buffalo	4	0.0%	1.9%	$10,782	

Regional Trends



		2012 Completions	2023 Completions	% Change
●	Distance Offered Programs	31	42	+35.5%
■	Non-Distance Offered Programs	100	166	+66.0%
▲	All Programs	131	208	+58.8%

Regional Completions by Award Level



	Award Level	Completions (2023)	Percent
●	Master's Degree	163	78.4%
●	Post-masters certificate	17	8.2%
●	Doctor's Degree	28	13.5%

Similar Programs

14	4,986
Programs (2023)	Completions (2023)

CIP Code	Program	Completions (2023)
40.0801	Physics, General	3,669
40.0201	Astronomy	307
14.1201	Engineering Physics/Applied Physics	266
40.0899	Physics, Other	229
40.0807	Optics/Optical Sciences	208
40.0202	Astrophysics	112
40.0809	Acoustics	98
40.0101	Physical Sciences, General	61
40.1101	Physics and Astronomy	21
40.0802	Atomic/Molecular Physics	8

Target Occupations

**Filtered by the proportion of the national workforce in these occupations with a Master's degree or Doctoral or professional degree*

16,578	*+8.3%*	$74.94/hr $155.9K/yr	*1,181*
*Jobs (2024)**	*% Change (2024-2034)**	Median Earnings	*Annual Openings**

Occupation	*2024 Jobs**	*Annual Openings**	Median Earnings	*Growth (2024 - 2034)**
Physicists	*16,578*	*1,181*	$74.94/hr	*+8.26%*

Job Postings Summary

4,209	3 : 1	852	27 days
Unique Postings	**Posting Intensity**	**Employers Competing**	**Median Posting Duration**
11,513 Total Postings	Regional Average: 3 : 1	1.00M Total Employers	Regional Average: 27 days

There were **11,513** total job postings for your selection from January 2024 to January 2025, of which **4,209** were unique. These numbers give us a Posting Intensity of **3-to-1**, meaning that for every 3 postings there is 1 unique job posting.

This is close to the Posting Intensity for all other occupations and companies in the region (3-to-1), indicating that they are putting average effort toward hiring for this position.

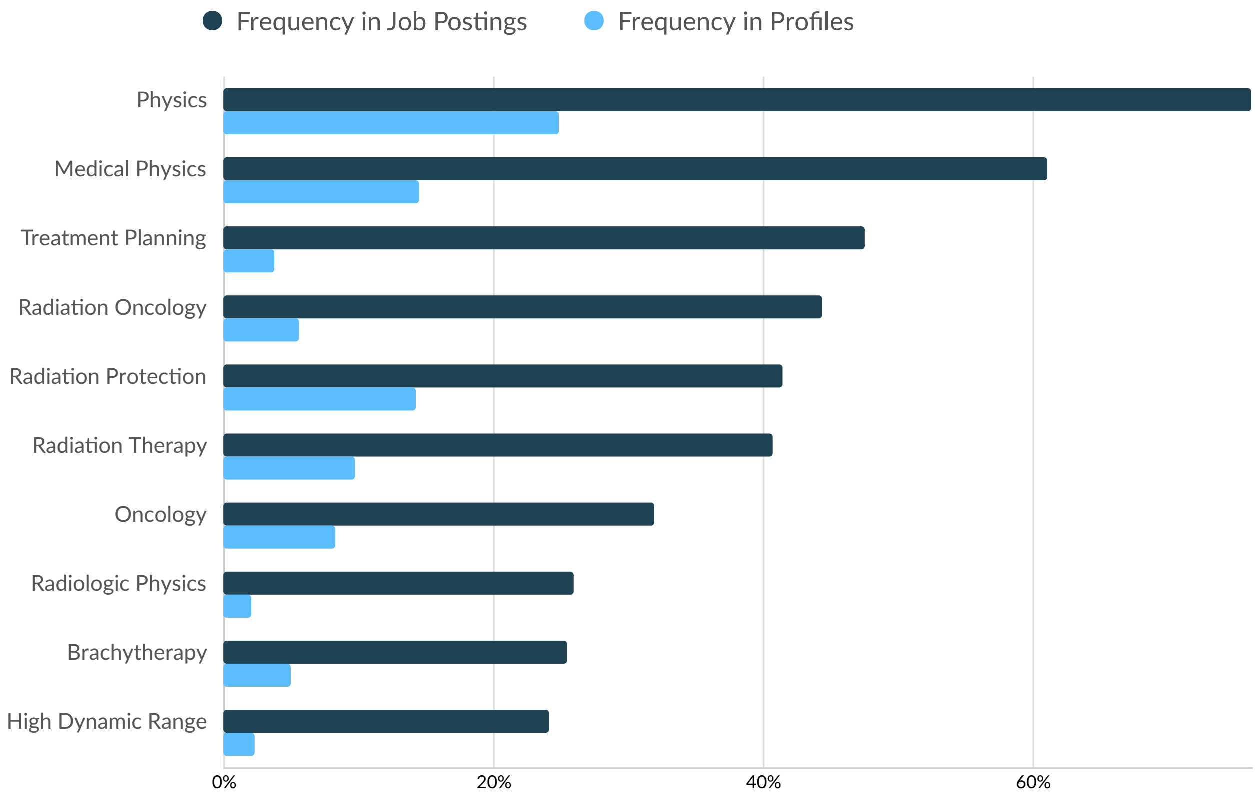
Top Companies Posting

Company	Total/Unique (Jan 2024 - Jan 2025)	Posting Intensity	Median Posting Duration
Varian Medical Systems	346 / 166	2 : 1	28 days
Lawrence Livermore National Laboratory	290 / 64	5 : 1	52 days
Epic Travel Staffing	88 / 58	2 : 1	30 days
US Oncology Network	96 / 53	2 : 1	31 days
Lawrence Berkeley National Laboratory	102 / 41	2 : 1	40 days
Bayer	101 / 39	3 : 1	32 days
Argonne National Laboratory	138 / 38	4 : 1	30 days
Pacific Northwest National Laboratory	47 / 38	1 : 1	18 days
Akumin	59 / 37	2 : 1	16 days
MLee Healthcare Staffing and Recruiting	108 / 37	3 : 1	21 days

Top Posted Job Titles

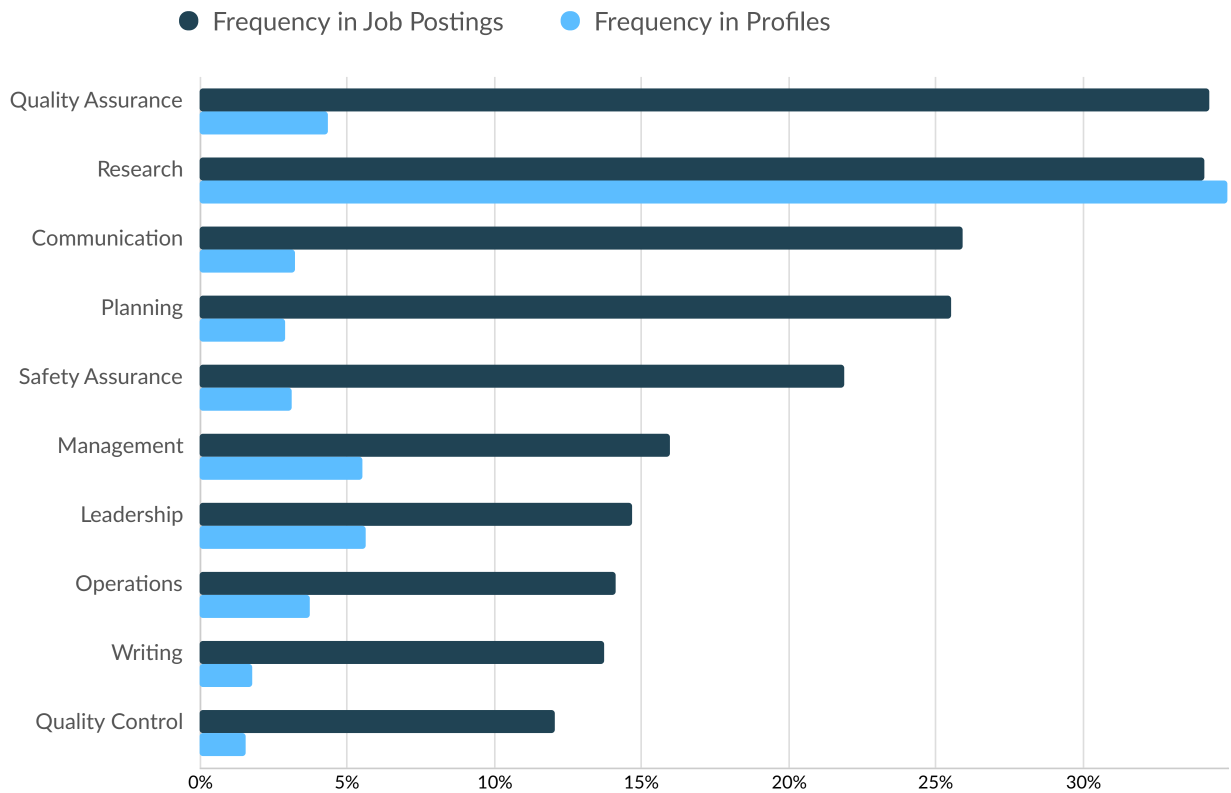
Job Title	Total/Unique (Jan 2024 - Jan 2025)	Posting Intensity	Median Posting Duration
Medical Physicists	3,257 / 1,378	2 : 1	25 days
Physicists	1,253 / 490	3 : 1	20 days
Radiation Oncology Physicians	1,149 / 329	3 : 1	30 days
Health Physicists	594 / 206	3 : 1	29 days
Radiation Physicists	516 / 192	3 : 1	21 days
Chief Medical Physicists	162 / 78	2 : 1	32 days
Radiation Oncologists	176 / 64	3 : 1	33 days
Research Physicists	182 / 63	3 : 1	25 days
Oncology Physicians	129 / 62	2 : 1	30 days
Diagnostic Medical Physicists	155 / 58	3 : 1	28 days

Top Specialized Skills



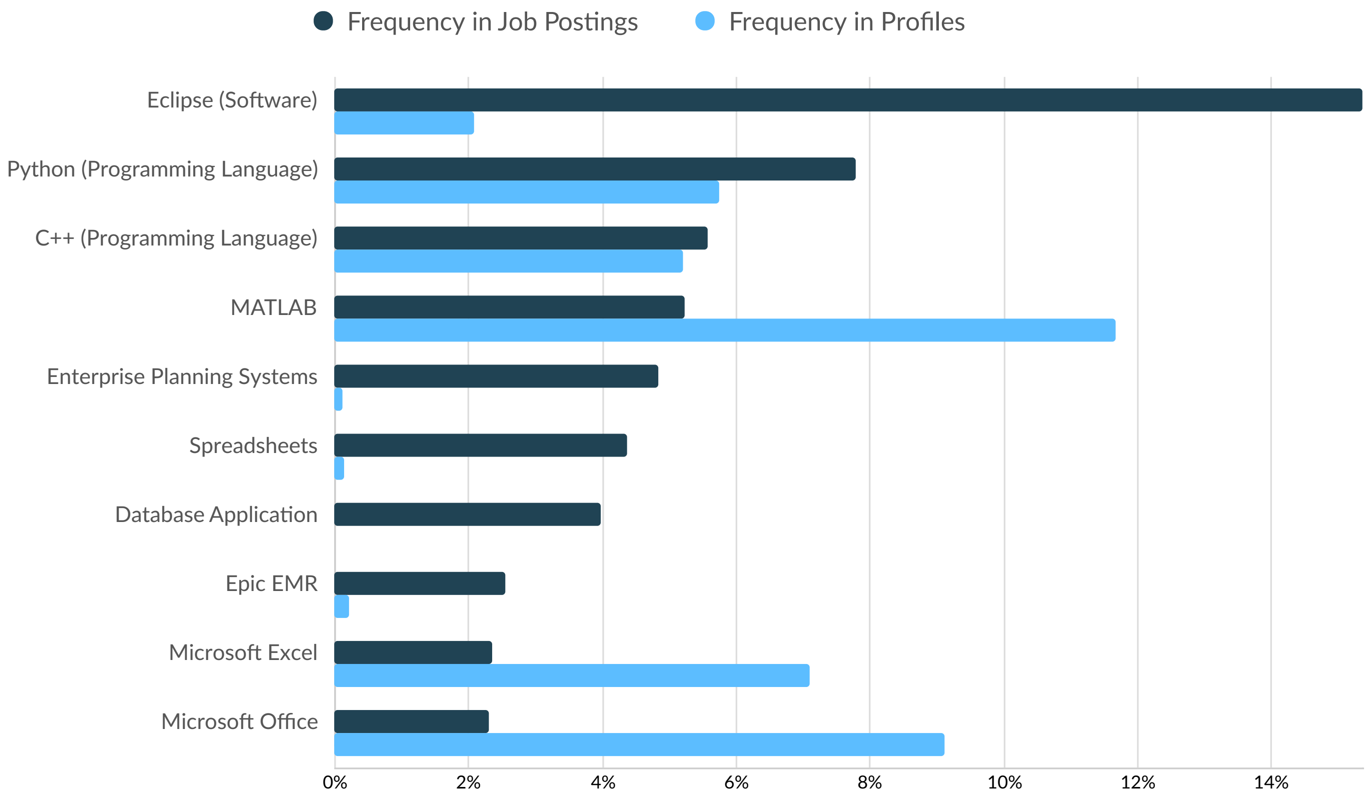
Skills	Postings	% of Total Postings	Profiles	% of Total Profiles	Projected Skill Growth	Skill Growth Relative to Market
Physics	3,206	76%	3,285	25%	+12.5%	Growing
Medical Physics	2,568	61%	1,912	14%	+8.0%	Stable
Treatment Planning	2,002	48%	499	4%	+6.7%	Stable
Radiation Oncology	1,866	44%	737	6%	+14.0%	Growing
Radiation Protection	1,742	41%	1,892	14%	+4.1%	Lagging
Radiation Therapy	1,715	41%	1,286	10%	+2.2%	Lagging
Oncology	1,345	32%	1,093	8%	+2.4%	Lagging
Radiologic Physics	1,095	26%	279	2%	+3.1%	Lagging
Brachytherapy	1,073	25%	657	5%	+2.7%	Lagging
High Dynamic Range	1,015	24%	308	2%	+11.5%	Growing

Top Common Skills



Skills	Postings	% of Total Postings	Profiles	% of Total Profiles	Projected Skill Growth	Skill Growth Relative to Market
Quality Assurance	1,446	34%	574	4%	+15.4%	Growing
Research	1,437	34%	4,618	35%	+17.2%	Growing
Communication	1,092	26%	425	3%	+3.6%	Lagging
Planning	1,075	26%	383	3%	+10.9%	Growing
Safety Assurance	922	22%	413	3%	+9.7%	Growing
Management	672	16%	735	6%	+5.3%	Stable
Leadership	620	15%	748	6%	+8.5%	Stable
Operations	595	14%	492	4%	+8.1%	Stable
Writing	580	14%	237	2%	+11.8%	Growing
Quality Control	508	12%	204	2%	+11.9%	Growing

Top Software Skills



Skills	Postings	% of Total Postings	Profiles	% of Total Profiles	Projected Skill Growth	Skill Growth Relative to Market
Eclipse (Software)	647	15%	276	2%	+10.2%	Growing
Python (Programming Language)	328	8%	761	6%	+24.5%	Rapidly Growing
C++ (Programming Language)	235	6%	690	5%	+10.0%	Growing
MATLAB	220	5%	1,543	12%	+16.0%	Growing
Enterprise Planning Systems	204	5%	17	0%	+5.7%	Stable
Spreadsheets	184	4%	19	0%	+22.2%	Rapidly Growing
Database Application	168	4%	0	0%	+15.0%	Growing
Epic EMR	108	3%	29	0%	+16.4%	Growing
Microsoft Excel	99	2%	939	7%	+17.7%	Growing
Microsoft Office	97	2%	1,205	9%	+18.5%	Growing

Top Qualifications

Qualification	Postings with Qualification
Board Certified In Radiology	1,474
Board Certified/Board Eligible	1,207
Security Clearance	288
Basic Life Support (BLS) Certification	186
Valid Driver's License	132
Secret Clearance	81
Cardiopulmonary Resuscitation (CPR) Certification	79
Top Secret-Sensitive Compartmented Information (TS/SCI Clearance)	70
Certified Health Physicist	63
Medical License	37

Appendix A

Program Selection Details

CIP Code	Program Name
51.2205	Health/Medical Physics

Appendix B - Data Sources and Calculations

Institution Data

The institution data in this report is taken directly from the national IPEDS database published by the U.S. Department of Education's National Center for Education Statistics.

Occupation Data

Emsi occupation employment data are based on final Emsi industry data and final Emsi staffing patterns. Wage estimates are based on Occupational Employment Statistics (QCEW and Non-QCEW Employees classes of worker) and the American Community Survey (Self-Employed and Extended Proprietors). Occupational wage estimates are also affected by county-level Emsi earnings by industry.

Lightcast Job Postings

Job postings are collected from various sources and processed/enriched to provide information such as standardized company name, occupation, skills, and geography.

State Data Sources

This report uses state data from the following agencies: Alabama Department of Labor; Alaska Department of Labor and Workforce Development; Arizona Commerce Authority; Arkansas Division of Workforce Services; California Employment Development Department; Colorado Department of Labor and Employment; Connecticut Department of Labor; Delaware Office of Occupational and Labor Market Information; District of Columbia Department of Employment Services; Florida Department of Economic Opportunity; Georgia Labor Market Explorer; Hawaii Workforce Infonet; Idaho Department of Labor; Illinois Department of Employment Security; Indiana Department of Workforce Development; Iowa Workforce Development; Kansas Department of Labor; Kentucky Center for Statistics; Louisiana Workforce Commission; Maine Department of Labor; Maryland Department of Labor; Commonwealth of Massachusetts, Mass.gov; Michigan Department of Technology, Management and Budget; Minnesota Department of Employment and Economic Development; Mississippi Department of Employment Security; Missouri Economic Research and Information Center; Montana Department of Labor and Industry; Nebraska Department of Labor, NEworks; Nevada Department of Employment, Training and Rehabilitation; New Hampshire Employment Security; New Jersey Department of Labor and Workforce Development; New Mexico Department of Workforce Solutions; New York Department of Labor; North Carolina Department of Commerce; North Dakota Job Service; Ohio Department of Job and Family Services; Oklahoma Employment Security Commission; Oregon Employment Department; Pennsylvania Department of Labor and Industry, Center for Workforce Information and Analysis; Rhode Island Department of Labor and Training; South Carolina Department of Employment and Workforce; South Dakota Department of Labor and Regulation; Tennessee Department of Labor & Workforce Development; Texas Workforce Commission; Utah Department of Workforce Services; Vermont Department of Labor; Virginia Employment Commission; Washington State Employment Security Department; West Virginia Department of Commerce; Wisconsin Department of Workforce Development; Wyoming Department of Workforce Services

QUANTUM INFORMATION SCIENCE AND TECHNOLOGY WORKFORCE DEVELOPMENT NATIONAL STRATEGIC PLAN

A Report by the

SUBCOMMITTEE ON QUANTUM INFORMATION SCIENCE

COMMITTEE ON SCIENCE

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

February 2022

About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development (R&D) enterprise. A primary objective of the NSTC is to ensure science and technology policy decisions and programs are consistent with the President's stated goals. The NSTC prepares R&D strategies that are coordinated across Federal agencies aimed at accomplishing multiple national goals. The work of the NSTC is organized under committees that oversee subcommittees and working groups focused on different aspects of science and technology. More information is available at http://www.whitehouse.gov/ostp/nstc.

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About the NSTC Subcommittee on Quantum Information Science

The National Science and Technology Council (NSTC) Subcommittee on Quantum Information Science (SCQIS) was legislated by the National Quantum Initiative Act and coordinates Federal R&D in quantum information science and related technologies under the auspices of the NSTC Committee on Science. The aim of this R&D coordination is to maintain and expand U.S. leadership in quantum information science and its applications over the next decade.

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Abbreviations and Acronyms

AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
ARL	Army Research Laboratory
ARO	Army Research Office
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
ESIX	Subcommittee on Economic and Security Implications of Quantum Science
IARPA	Intelligence Advanced Research Projects Activity
IWG	Interagency Working Group
LPS	National Security Agency Laboratory for Physical Sciences
NASA	National Aeronautics and Space Administration
NDAA	National Defense Authorization Act
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NQCO	National Quantum Coordination Office
NQI	National Quantum Initiative
NSA	National Security Agency
NSF	National Science Foundation
NSTC	National Science and Technology Council
ODNI	Office of the Director of National Intelligence
OMB	Office of Management and Budget
ONR	Office of Naval Research
OSTP	Office of Science and Technology Policy
OUSD(R&E)	Office of the Undersecretary of Defense for Research and Engineering
QIST	Quantum Information Science and Technology
QED-C	Quantum Economic Development Consortium
QLCI	Quantum Leap Challenge Institutes
R&D	Research and Development
SCQIS	Subcommittee on Quantum Information Science
STEM	Science Technology Engineering and Mathematics.
USPTO	United States Patent and Trade Office

Executive Summary

Workforce development in Quantum Information Science and Technology (QIST) is a priority for the United States as part of the National Quantum Initiative.[1] To ensure economic and national security, several actions are recommended here to evaluate the QIST workforce landscape, prepare more people for jobs with quantum technology, enhance STEM education at all levels, accelerate exploration of quantum frontiers,[2] and expand the talent pool for industries of the future.

Beyond the significant technical challenges facing QIST research and development (R&D), the shortage of talent constrains progress. The field is currently creating more job openings than can be filled, with the variety of jobs related to QIST expanding in academia, industry, national labs, and government. New and sustained workforce training efforts are critical for maintaining American leadership in QIST. Fortunately, the requisite skills are widely applicable and in high demand. Therefore, investments that grow the professional expertise needed for QIST R&D will pay dividends in many sectors of the economy.

Building the Nation's QIST workforce will require coordination among U.S. Government agencies, academic institutions, professional societies, non-profit organizations, industry, and international partners. There are also important roles for STEM educators and institutional experts on diversity, equity and inclusion, to ensure that training in QIST will position more individuals for rewarding careers, and expand America's capacity for high-tech innovation.

Presidential Science Advisor Dr. Eric Lander spoke about the importance of growing the American high-tech workforce by, "not just cloning the people who are in it but expanding to include everybody in this country who wants to be part of it."[3] He said, "Focusing on the hardest, most important problems; making and investing in the right technical bets; and building and growing the scientists, engineers, and entrepreneurs of tomorrow – all in our unique American model of fair and free-market competition and cooperation is how we will continue to lead."

To ensure the United States creates a diverse, inclusive, and sustainable workforce that possesses the broad range of skills needed by industry, academia, national laboratories, and the U.S. Government, this document expands upon the workforce policies outlined in the *National Strategic Overview of Quantum Information Science*. It provides updates on current activities, additional recommendations, and criteria for success. Four critical actions are identified:

1. **Develop and maintain an understanding of the workforce needs in the QIST ecosystem, with both short-term and long-term perspectives;**
2. **Introduce broader audiences to QIST through public outreach and educational materials;**
3. **Address QIST-specific gaps in professional education and training opportunities; and**
4. **Make careers in QIST and related fields more accessible and equitable.**

[1] https://www.quantum.gov/wp-content/uploads/2020/10/2018_NSTC_National_Strategic_Overview_QIS.pdf
[2] https://www.quantum.gov/wp-content/uploads/2020/10/QuantumFrontiers.pdf
[3] https://www.whitehouse.gov/ostp/news-updates/2021/10/07/readout-of-white-house-summit-on-quantum-industry-and-society/

Introduction

Quantum Information Science and Technology (QIST)[4] is a research and development (R&D) priority for the United States because it pushes the frontiers of science and engineering.[5] It lays a foundation for industries of the future, and can impact national security. To accelerate QIST R&D and grow the Nation's capacity to develop quantum technologies, the United States needs a talented, diverse, and adaptable workforce. However, the supply of such talent currently does not meet demand from the rapidly expanding industrial, national laboratory, government, and academic efforts. This is evident both in the United States and internationally.[6,7] Therefore, enhanced pathways are needed for near-term career pivots into the field, and also for longer-term approaches that develop talent through education, training, and outreach. To address these needs, a national strategy for QIST workforce development is presented here.

Historically, talent and creative ideas in QIST have come from experts in quantum physics and information theory. These fields have already produced transformative technologies for society. Quantum physics led to transistors, lasers, magnetic resonance imaging (MRI) scanners, and atomic clocks (e.g., for GPS navigation). Information theory catalyzed the development of computers, digital communication, and the internet. Collectively these fields – quantum physics and information theory – ushered in the modern digital age. Their confluence in the late 20th century, manifested as QIST, is now yielding more discoveries and new technologies based on new ways to acquire, encode, manipulate, process, and distribute information.

QIST now involves practitioners trained in a wide variety of disciplines such as computer science, engineering, chemistry, and materials science, who are working together often in multidisciplinary teams to pioneer revolutionary approaches to computing, simulation, sensing, timing, and networking. Furthermore, QIST advances are providing foundational knowledge and leading to applications in a growing number of fields. Quantum computing algorithms and hardware may facilitate developments in medicine, energy science, and agriculture, for example, with simulations of molecules involved in pharmaceutical compounds, artificial photosynthesis, or fertilizer technology.[8,9] Quantum sensing offers new modalities and enhanced measurement sensitivity relevant for domains as diverse as ocean navigation and neuroscience. Quantum networks can support disruptive applications in sensing, computing, and communication. But the pace of these developments ultimately depends on the people – the workforce – in QIST.

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4 As described in the National Quantum Initiative Act, the term ''quantum information science'' means the use of the laws of quantum physics for the storage, transmission, manipulation, computing, or measurement of information.

5 https://www.quantum.gov/wp-content/uploads/2020/10/QuantumFrontiers.pdf

6 https://www.zdnet.com/article/quantum-computings-next-challenge-finding-quantum-developers-and-fast/

7 https://www.nytimes.com/2018/10/21/technology/quantum-computing-jobs-immigration-visas.html

8 Commercial applications of quantum computing, doi:10.1140/epjqt/s40507-021-00091-1

9 Quantum computing: progress and prospects, doi:10.17226/25196

Given the potential impacts of QIST,[10,11] the United States – along with many other nations – has embarked on a journey to further understand and harness the capabilities inherent in QIST. Building on decades of sustained Federal investments, the Unites States launched its National Quantum Initiative to accelerate the pace of QIST R&D.[12,13] Concurrently, there has been a global increase in investment by academia, industry, and national-level programs.[14]

The National Quantum Initiative Act (NQI Act) and the FY 2019-2022 National Defense Authorization Acts (NDAA) highlight the need for a QIST workforce.[15,16] Indeed, the development of a QIST-ready workforce with a broad range of skills is vital to ensure that the United States can contribute to and benefit from the quantum technology innovations of the 21st century. For it is the workforce that will accomplish the basic and applied R&D in a broad range of technologies, supply chains, and applications that are crucial for a healthy QIST portfolio across sensing, communication, and computation.

Challenges: Investments in QIST by new and existing companies have accelerated over the last decade, and the supply of talent is not keeping up with demand. Furthermore, while government funding for new quantum research centers established pursuant to the NQI Act and NDAAs (see Figure 4) will train more researchers, these new centers are creating even more staffing demands for QIST experts in the near term. The resulting growth in QIST-related careers now necessitates a commensurate increase in the number of scientists and engineers who are appropriately trained or positioned to easily transition into work on QIST-oriented technologies.[17] Workforce development has been a leading topic at numerous quantum-related workshops and conferences,[18– 23] and several new academic programs in QIST have been launched. To comprehensively understand the long-term and short-term scope of the QIST workforce shortage, there remains a need for additional information, including but not limited to data on the technical demands, training, awareness, retention, etc. Several challenges are listed here, and addressed in the following Sections.

A primary challenge for growing the QIST workforce is understanding the technical needs of the ecosystem. This is compounded by issues such as: the breadth of technologies involved (e.g., software and hardware that span sensing, computing, and networking and communication); the need for subject matter experts (at both the basic research, systems development, and engineering levels); and the wide

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[10] https://www.ida.org/research-and-publications/publications/all/a/as/assessment-of-the-future-economic-impact-of-quantum-information-science
[11] https://crsreports.congress.gov/product/details?prodcode=R45409
[12] https://science.osti.gov/-/media/nqiac/pdf/NQI_Program-coordination_NQIAC_20201027.pdf
[13] https://www.congress.gov/bill/115th-congress/house-bill/6227/
[14] https://cifar.ca/wp-content/uploads/2021/05/QuantumReport-EN-May2021.pdf
[15] https://www.congress.gov/115/plaws/publ232/PLAW-115publ232.pdf (Sec. 234)
[16] https://www.congress.gov/116/plaws/publ92/PLAW-116publ92.pdf (Sec. 220
[17] https://www.aps.org/publications/apsnews/202106/qis.cfm
[18] https://www.afrl.af.mil/News/Article/2426785/afrl-set-to-co-host-two-day-virtual-quantum-collider-20/
[19] https://quantum-workforce.kavlimeetings.org/
[20] QED-C | TAC - QED-C (quantumconsortium.org)
[21] Preparing for the quantum revolution: What is the role of higher education, doi:10.1103/PhysRevPhysEducRes.16.020131
[22] https://quantum.mines.edu/nsf-qe-ed/;
[23] https://www.bnl.gov/c2qaquantumcareerevent

variety of required skills that comprise and support QIST. More data on all of these issues would better inform and track workforce development efforts.

A second challenge is that exposure to QIST at the high school or undergraduate level in the United States is limited, and rarely available prior to advanced coursework or research.[24] The ensuing lack of awareness can leave talented high school and undergraduate students to pursue other directions. A hypothesis is that more students might stay in STEM fields if they get excited about quantum and other cutting-edge technologies earlier in their education.[25,26] Moreover, because many QIST- and STEM-related jobs require some familiarity with quantum mechanics, the nation's capacity for several high-tech industries will be enhanced if sound approaches are implemented to further raise awareness of QIST.[22]

A third challenge is attracting and retaining professional talent as QIST becomes more of a global enterprise, requiring both domestic training and international cooperation. The United States has benefited tremendously from experts coming from all around the world to participate in R&D efforts in academia, national laboratories, and industry to advance their careers. As opportunities in QIST grow outside the United States, efforts to provide a welcoming cooperative environment should be sustained and adapted to create, attract, and retain talent by leveraging the strengths of institutions spanning all Carnegie Classification levels including 2-year-, minority-serving-, high research activity (R2), and Predominantly Undergraduate institutions (PUI).[27] Furthermore, recruitment and retention of expert talent into jobs that support federal needs often comes with additional challenges including requirements of citizenship, that are exacerbated by a tight and competitive labor market. This recruitment is critical as QIST activities undertaken by Federal Departments and Agencies (hereafter referred to as 'Agencies'), federal laboratories, Federally-Funded R&D Centers (FFRDC's), University-Affiliated Research Center Laboratories (UARCs), and the defense industrial base support basic research, infrastructure, and standards development, and provide hands-on training for junior scientists and technologists in QIST.

A fourth and overarching challenge is to develop a more diverse QIST workforce that is inclusive of all Americans who wish to participate in this area. This requires a systemic culture shift to create inclusive, supportive, and equitable work and learning environments, policies, and structures for people from every race, ethnicity, and gender.[26,28] Factors ranging from negative individual interactions to broad institutional practices result in a loss of diverse talent in many of the STEM fields that feed QIST (e.g., computer information science engineering, electrical engineering, materials science and engineering,

[24] Building a Quantum Engineering Undergraduate Program, arXiv:2108.01311
[25] https://www.aip.org/sites/default/files/aipcorp/files/teamup-full-report.pdf
[26] Women are underrepresented in fields where success is believed to require brilliance, doi:10.3389/fpsyg.2015.00235
[27] https://carnegieclassifications.iu.edu/classification_descriptions/basic.php
[28] https://www.aip.org/sites/default/files/aipcorp/files/teamup-full-report.pdf

and physics).[29,30,31,32,33,34] Integrating problem solvers from different backgrounds into a team enhances the likelihood of scientific success and promotes continuous innovation and economic growth,[35] and it is the right thing to do based on principles of equity and inclusion. Expanding the workforce in this way will take intentional actions, examples of which are discussed this document. The resulting benefits should enhance the impact of QIST research, stimulate innovation, and foster the development of technologies that benefit all of America, as new approaches and points of view are represented from the lab to the boardroom.

Approach: Given the varying lead times for outreach, education, and professional training to realize substantial impacts, it is necessary to have a strategy that helps address both the short- and long-term challenges outlined above. Furthermore, recognizing the critical nature of this need for several Agencies, coordination of federal efforts in workforce development should be done in such a way that enables more rapid progress in QIST R&D for all involved entities.

This Plan builds on lessons learned since the release of the *National Strategic Overview for Quantum Information Science (NSO)*[36] in 2018, and reflects the evolving QIST landscape. The next Sections update and expand upon policies and recommendations highlighted in the NSO, and support the following vision:

Vision

The United States should develop a diverse, inclusive, and sustainable workforce that possesses the broad range of skills needed by industry, academia, and the U.S. Government, while being able to scale and adapt as the QIST landscape evolves.

The strategic approach to realizing this vision is organized around four broad actions that are collectively, and individually, designed to confront the challenges outlined above:

- **Action 1:** Develop and maintain an understanding of the workforce needs in the QIST ecosystem, with both short-term and long-term perspectives;
- **Action 2:** Introduce broader audiences to QIST through public outreach and education materials;
- **Action 3:** Address QIST-specific gaps in professional education and training opportunities; and
- **Action 4:** Make careers in QIST and related fields more accessible and equitable.

The remainder of this report is organized as follows: each section focuses on an action, discusses the current landscape, provides specific recommendations for continued or expanded federal activities,

[29] https://www.quantum.gov/wp-content/uploads/2021/10/2021_NSTC_ESIX_INTL_TALENT_QIS.pdf
[30] Preparing for the quantum revolution: What is the role of higher education, doi:10.1103/PhysRevPhysEducRes.16.020131
[31] https://ira.asee.org/wp-content/uploads/2019/07/2018-Engineering-by-Numbers-Engineering-Statistics-UPDATED-15-July-2019.pdf
[32] https://www.aps.org/programs/women/resources/statistics.cfm
[33] https://www.aps.org/programs/minorities/resources/statistics.cfm
[34] Systemic inequalities for LGBTQ professionals in STEM, https://doi.org/10.1126/sciadv.abe0933
[35] Groups of diverse problem solvers can outperform groups of high-ability problem solvers, doi:10.1073/pnas.0403723101
[36] https://www.quantum.gov/wp-content/uploads/2020/10/2018_NSTC_National_Strategic_Overview_QIS.pdf

and suggests opportunities for industry academia, and other members of the community. Attention is given to growing diversity, fostering inclusion, and ensuring equity with regard to educational, research, and work opportunities. Each action will require partnerships with STEM education and institutional diversity and equity experts to inform and guide QIST R&D entities to effect genuine and long-lasting change. Finally, the Appendix outlines many of the ongoing federal activities that support QIST workforce generation. As shown in Figure 1, progress and long-term success will be measured in careers. Progress can be monitored by assessing how well programs inspire individuals, educate learners, and provide experiences to train the future workforce.

Inspire	Educate	Experiences	Careers
Motivate students and broaden public understanding via foundational education and outreach. Examples include: • **Q-12 Partnership** • **World Quantum Day**	**Develop and deploy formal and informal approaches. Examples include:** • **Quantum 101** • **QIST Minors** • **QIST Masters**	**Grow confidence through unique opportunities. Examples include:** • **Internships** • **Externships** • **Hands-On Research** • **After School Programs**	**Make people aware of the impactful and diverse options in QIST and encourage them to pursue careers in:** • **Industry** • **Academia** • **Government**

Figure 1: The success of this report will largely be measured by the QIST community's ability to inspire people to engage in QIST. This engagement will be met via accessible education of people at various education and career levels, the development of training experiences at various education and career levels, and pathways that efficiently connect workers to jobs and career opportunities.

Action 1. Develop and Maintain an Understanding 0f Workforce Needs in the QIST Ecosystem, with both Short-Term and Long-Term Perspectives

Goal: Understand the supply of and demand for QIST workers; assess the state of educational and training opportunities; and track the overall demographic make-up of the field.

To ensure that the United States remains a global leader in the rapidly evolving and competitive field of QIST, a more complete understanding of the workforce, education, and training landscape is required. The focus and size of education and outreach programs should be tuned to meet the workforce needs of industry, academia, and Agencies. Unfortunately, the QIST workforce landscape is difficult to assess due to the complex and interdisciplinary nature of the work, the globally interconnected circulation of talent and ideas, the sometimes-rapid evolution from basic research to industry developments, and the fact that tracking of workforce data specifically for QIST is just beginning. Furthermore, at the same time as new fundamental science sub-areas are still emerging, other areas of QIST are shifting from fundamental scientific research towards engineering and technology development, and from prototypes to product.

The breadth of this change is reflected in the range of core fields (e.g., computer science, electrical engineering, materials science, mathematics, chemistry, and physics), as well as in emerging and supporting fields (e.g., marketing and sales, manufacturing, systems engineering, and product development and design). Though there is breadth in the core and emerging fields, there is an understanding that technical skills including analytical problem solving and data analysis, along with organizational skills such as being able to work in teams, are important for QIST professionals to acquire. Current data suggests that deep, focused *QIST expertise* is still in demand, often at the PhD level or higher. However, there is growing demand for individuals who are *QIST-proficient* (having an undergraduate QIST-related major, minor, or track), *QIST-aware* (e.g., having just a single undergraduate course connecting with QIST), or *STEM professionals* (individuals who possess complementary skillsets needed by QIST industry) (see Figure 2).[37,38] As a result, companies, educators, and researchers are still grappling to understand exactly what skills are needed for both today's and tomorrow's workforce.

1.1 Current Landscape

At this time, there is no singular, comprehensive source of data that provides definitive, quantitative information regarding the QIST workforce landscape. Based on the information that is available, there appears to be a talent shortage at all levels. This assessment is based on:

- information from the Quantum Economic Development Consortium (QED-C), which administers a periodic survey to its members, as well as separate data collected and analyzed by researchers;[39]

[37] Building a Quantum Engineering Undergraduate Program, arXiv:2108.01311

[38] The exact definition of quantum-aware can vary. Here it is used to imply familiarity with the common language and general specifications associated with certain quantum technologies.

[39] Preparing for the quantum revolution: What is the role of higher education, doi:10.1103/PhysRevPhysEducRes.16.020131

- anecdotal input from a series of conferences, meetings and conversations with representatives from industry, academia, national labs, and the Federal government; and
- data available through online job boards.[40]

The QED-C surveys and job boards provide a useful, if incomplete, picture of the skillsets and educational training levels that the QIST ecosystem currently needs. Workers who possess skills in QIST software and hardware development, along with some business acumen are in particularly high demand.[41] Beyond jobs specifically requiring deep QIST expertise, there is a broad range of positions drawing on various science and engineering fields with needed skills including coding, data analysis, and digital and radio-frequency circuit design, as well as laboratory experience and knowledge of optical, materials, and mechanical engineering.[42]

Only about half of the roles sought by industry require QIST proficiency. The remainder rely on workers with, at most, a basic awareness of QIST. The desired education levels span bachelor's, master's, and doctoral degree recipients. Because this snapshot captures a field that largely exists in the R&D stage, continued monitoring of the needed skills and educational depths will be required as QIST matures and evolves.

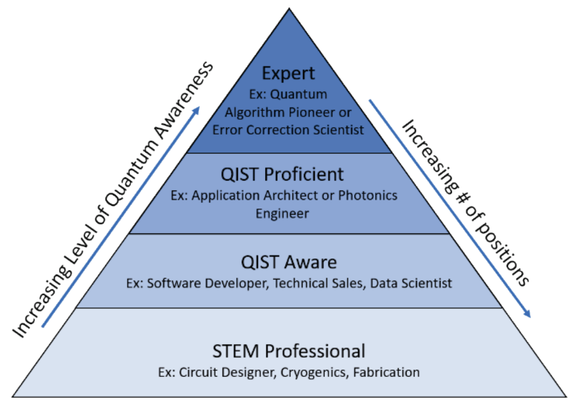

Figure 2: Borrowing from the quantum engineer pyramid,[47] the figure highlights the different levels of awareness that are referenced throughout this report. The levels do not indicate overall education, as a STEM professional could have an advanced degree in their area, with no quantum background. Likewise, a quantum-expert need not obtain a PhD in the field. Additional examples of job types and degree levels are available.[41]

The Federal government and many external professional societies track relevant metrics around STEM degree production.[43,44] Several Agencies and universities also support workshops that discuss academic STEM and QIST-specific programs. As a result, a more complete picture of the number of students graduating with the required skills is beginning to develop.

Programs to develop QIST-specific and related talent are being implemented at several levels, ranging from short courses to undergraduate minors to master's degree programs, and more are in development.[45,46,47,48] Yet, there is still a significant challenge because in many, if not most, U.S. academic institutions, traditional undergraduate quantum physics education focuses on treatments of quantum mechanics with very little content addressing quantum information science, or QIST per se.

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40 https://quantuqumconsortium.org/quantum-jobs/
41 Assessing the needs of the quantum industry, arXiv:2109.03601
42 Preparing for the quantum revolution: What is the role of higher education, doi:10.1103/PhysRevPhysEducRes.16.020131
43 https://www.nsf.gov/statistics/
44 https://www.aps.org/programs/education/statistics/index.cfm
45 https://www.per-central.org/items/detail.cfm?ID=15731
46 Achieving a quantum smart workforce, doi:10.1088/2058-9565/abfa64
47 Building a Quantum Engineering Undergraduate Program, arXiv:2108.01311
48 https://www.csusm.edu/quest/index.html

One possible metric of success in building the workforce is the growth of these programs nationwide, in terms of development and student participation.[49] A second metric is in building a diverse quantum workforce, in terms of the diversity of students who are identified as QIST-aware, -proficient, and -experts. Whether these newly developed programs will meet workforce needs is still an open question, which is partially complicated by continued uncertainty as to what constitutes a QIST qualified worker. For example, while an analysis of PhD dissertation titles provides some insight,[50] discerning between QIST-related and more general quantum physics and materials research is subjective. This poses an ongoing challenge for program development and data collection alike.

Finally, broadening participation in QIST is critical and will require a better understanding of current demographics within the QIST ecosystem. Currently, the best available demographics data are drawn from QIST-relevant fields, such as computer science, electrical engineering, and physics.[51,52] Unfortunately, these fields have among the lowest participation rates for people from backgrounds historically underrepresented in STEM, including Hispanics or Latinos, Blacks or African Americans, American Indians or Alaska Natives, persons with disabilities, and women from all backgrounds. In absolute numbers, women make up the largest of the underrepresented groups.[53,54,55] While low participation from these underrepresented backgrounds in QIST can be inferred from this data, limited demographic data on QIST-specific degree production means that the full extent of participation is difficult to ascertain. Instead, it must be drawn from the larger, coarser data previously mentioned. While demographic data from relevant fields provides a starting point, better tracking of QIST-specific progress towards creating opportunities, and attracting and retaining a diverse cadre of talent is needed.

Summary: Ensuring that a diverse, properly sized, and skilled workforce is developed to meet the evolving needs of the QIST ecosystem will require more training opportunities and more data. A full picture of the workforce landscape should be informed by metrics that elucidate the size and makeup of the growing QIST R&D community and assesses trends, forecasts and contingencies for both the supply (of) and demand for talent. While new programs to educate and train workers are being developed, the impact of these programs on workforce and skills-adoption should be assessed in the broader context of STEM education and high-tech employment. Based on the limited available data, the QIST R&D community must work deliberately to increase participation of people from underrepresented backgrounds in STEM, and to gain a deeper understanding of the QIST workforce landscape. Roles and responsibilities for these efforts are described next, in Sections 1.2 and 1.3.

[49] https://www.per-central.org/items/detail.cfm?ID=15731

[50] https://www.quantum.gov/wp-content/uploads/2021/10/2021_NSTC_ESIX_INTL_TALENT_QIS.pdf

[51] Women, Minorities, and Persons with Disabilities in Science and Engineering

[52] Preparing for the quantum revolution: What is the role of higher education, doi:10.1103/PhysRevPhysEducRes.16.020131

[53] https://ira.asee.org/wp-content/uploads/2019/07/2018-Engineering-by-Numbers-Engineering-Statistics-UPDATED-15-July-2019.pdf

[54] https://www.aps.org/programs/women/resources/statistics.cfm

[55] https://www.aps.org/programs/minorities/resources/statistics.cfm

1.2 Recommendations for U.S. Government

- The National Science and Technology Council (NSTC) Subcommittee on QIS (SCQIS), through its Interagency Working Group on QIST Workforce, should coordinate with the NSTC Committee on STEM Education (CO-STEM) to align data collection efforts and on-going STEM activities across the Federal government, including implementation of the STEM Education Strategic Plan.
- Agencies should support studies of U.S. and international QIST workforce supply and demand, and gather data on the demographics of populations in the QIST workforce and educational pipelines. For example, the NSF National Center for Science and Engineering Statistics survey of graduates could add specific tags for QIST in its data collection process.[56]
- The National Quantum Coordination Office (NQCO), SCQIS, and the Subcommittee on the Economic and Security Implications of Quantum Science (ESIX) should encourage the National Quantum Initiative Advisory Committee to develop and implement protocols to assess industry workforce needs and projections, with instruments that respect proprietary information.
- The SCQIS and ESIX should continue engaging with industry through consortia and other venues to better understand future workforce needs and supply.
- Surveys and workshops sponsored by Agencies should be designed to better understand what motivates workers to pursue careers in QIST and related STEM fields, as well as what factors draw talent into Federal government jobs.
- The SCQIS and ESIX should carry out biennial assessments of QIST workforce needs in the Federal government, including the civilian, intelligence, and defense sectors.

1.3 Opportunities for Academia, Industry and the Broader QIST Ecosystem

- Researchers can contribute by working with consortia such as the QED-C, professional societies, and other multi-institutional bodies to help assess the overall market for QIST talent, and understand what skills are most in demand. Quantitative results forecasting the demand for various skill sets in the QIST workforce can help to guide the development of appropriate training opportunities and programs.
- Consortia and professional societies can improve data collection by including questions about QIST jobs in their surveys. When carefully done, this can include studies of job roles that are adjacent to, but critical for, QIST, studies of end users and early adopters of QIST, and analyses of key positions in facilities and supply chain industries that enable QIST R&D.
- Thoughtfully collecting and using demographics data, including information needed to track the inclusion, participation, retention, and career outcomes of people from historically underrepresented backgrounds in STEM fields can help ensure that programs are structured to achieve a diverse QIST talent pool.
- Employers can engage with educators to provide guidance that may be used to align curricula and training experiences with the current and anticipated needs of the QIST economy.

[56] https://www.nsf.gov/statistics/srvygrads/

Action 2. Introduce Broader Audiences to QIST Through Public Outreach and Educational Materials

Goal: Increase awareness and knowledge of the implications and opportunities of QIST within the public and with students of all backgrounds.

Early and continued engagement in STEM fields is a key factor in retaining and mitigating attrition among people from backgrounds historically underrepresented in STEM fields.[57,58] Furthermore, parental and mentor knowledge of opportunities plays an important role in career choices.[59] While QIST falls within the general realm of STEM,[60] it has its own challenges and opportunities regarding outreach, education, and workforce development. For instance, QIST is still largely unknown and thus its benefits are likely not yet clear to most students, teachers, parents, or the general public.

To encourage growth in this base of domestic talent, it is aspirational that all learners should be empowered to see a place for themselves in the quantum-related careers roster.[61] This requires that learners are provided exposure to QIST via accessible outreach and educational opportunities. These can be during regular school and business activities, and also in informal learning venues such as museums, movies, games, and other media. The goal is that they understand what QIST careers exist and what skills are needed to contribute. In this way, K-12 education and outreach can play a pivotal role in building a diverse future QIST workforce.

2.1 Current Landscape

There is much work to be done to link students and teachers with resources at the right levels to nurture their excitement about QIST, while avoiding unrealistic hype. While global availability of open cloud-connected quantum computing prototypes offers profound outreach possibilities, continued effort around creating educational opportunities that connect to QIST concepts is needed. Mass media, pop culture, or press releases from Agencies, universities, and industry are common ways that students and families first hear about the field.[62] Adding "hooks" to QIST in such public venues can be powerful, but care must be taken to ensure that messaging is realistic, accurate, and points towards opportunities for further learning. The science education and communication communities have experience to draw from, so the quantum community should work with other science outreach experts, and experts in diversity, equity, and inclusion to project a message that encourages a broad range of participants in a wide range of venues to support access by a broader audience. Finally, while there have been some QIST-focused science exhibitions at museums,[63] there is a clear opportunity to expand offerings to increase in-person and virtual informal exposure to QIST.

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[57] https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf
[58] https://www.usnews.com/news/articles/2011/08/29/stem-education--its-elementary
[59] Utility-value intervention with parents increases students' STEM preparation and career pursuit, doi:10.1073/pnas.1607386114
[60] Developing a National STEM Workforce Strategy, doi:10.17226/21900
[61] Influencing participation of underrepresented students in STEM fields: matched mentors and mindsets, doi:10.1186/s40594-020-00219-2
[62] What the public thinks it knows about science, doi:10.1038/sj.embor.7400040
[63] https://www.mos.org/press/press-releases/QMC2019Winner

Box 1: Key Concepts for QIS Learners
An NSF sponsored workshop identified several Key Concepts for QIS Learners,[64] and produced a list with supporting fundamentals that can be curated, expanded, and adapted for students across computer science, mathematics, physics, and chemistry, as well as broader public audiences. Community input is welcomed, and related curricula are sought.[65] Key Concepts for QIS Learners include: ● Mathematics of probability, vectors, algebra, trigonometry, complex numbers, and linear transformations to describe the physical world via quantum mechanics ● The description of a quantum state ● Quantum measurement outcomes and applications ● The quantum bit, or qubit ● Entanglement and superposition ● Coherence and decoherence ● Quantum computers that solve certain complex computational problems more efficiently than classical computers ● Quantum communication using entanglement or a transmission channel, such as optical fiber, to transfer quantum information between different locations ● Quantum sensing using quantum states to detect and measure physical properties with the highest precision allowed by quantum mechanics To read more about Key Concepts for QIS Learners see https://qis-learners.research.illinois.edu/

At the American high school level, some schools still do not offer physics courses, and a majority of students will not have taken a physics course during their K-12 education;[66] even fewer students have the option to take computer science courses.[67] Based on available data, it appears that only a small minority of these available classes include quantum physics or QIST concepts.[68] Furthermore, those schools that do offer these opportunities tend to have lower enrollment of people from backgrounds historically underrepresented in STEM fields.[69] Another major challenge is that only about 1/3 of high school physics teachers majored in physics.[70] Efforts, partially supported by NSF, are underway to provide critically needed teacher development opportunities, but they are still small and will need to grow.[71,72]

To start addressing teacher preparation, student access, and community awareness, NSF, in coordination with the NQCO, facilitated a workshop where a group of various stakeholders outlined nine key QIST concepts across computer science, mathematics, physics, and chemistry that could be further expanded and adapted for students as well as broader public audiences.[73] These Key Concepts

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64 https://qis-learners.research.illinois.edu/
65 https://q12education.org/learning-materials
66 High School Physics Overview | American Institute of Physics (aip.org); hs-courses-enroll-13.pdf (aip.org)
67 A Minuscule Percentage of Students Take High School Computer Science in the United States: Access Isn't Enough
68 Based on discussions with the American Association of Physics Teachers
69 https://www.future-ed.org/work/closing-the-excellence-gap/
70 A Review of High School Physics Education in the United States of America
71 https://quantumforall.org/
72 NSF Award # 2015205 - Cross-Discipline Approach to Quantum Computing in High Schools: Building towards a Quantum Computing Workforce
73 https://qis-learners.research.illinois.edu/

for QIS Learners are highlighted in Box 1. Expansion of these concepts and related teaching tools, with engagement of high school teachers, is underway as part of a project with an NSF grant.[74] Connecting these efforts with a broader audience requires the efforts of the larger QIST community.

To this end, OSTP and NSF spearheaded the National Q-12 Education Partnership (Q-12 Partnership) to begin fostering and grow such a community. This partnership, between the Federal government, industry, professional societies, and the educational community, is working to expand access to K-12 quantum learning tools, and inspire the next generation of quantum leaders (See Figure 3).[75] The Q-12 Partnership is growing a curated list of resources for QIST education, with materials contributed from a growing variety of teachers, professors, and R&D leaders.

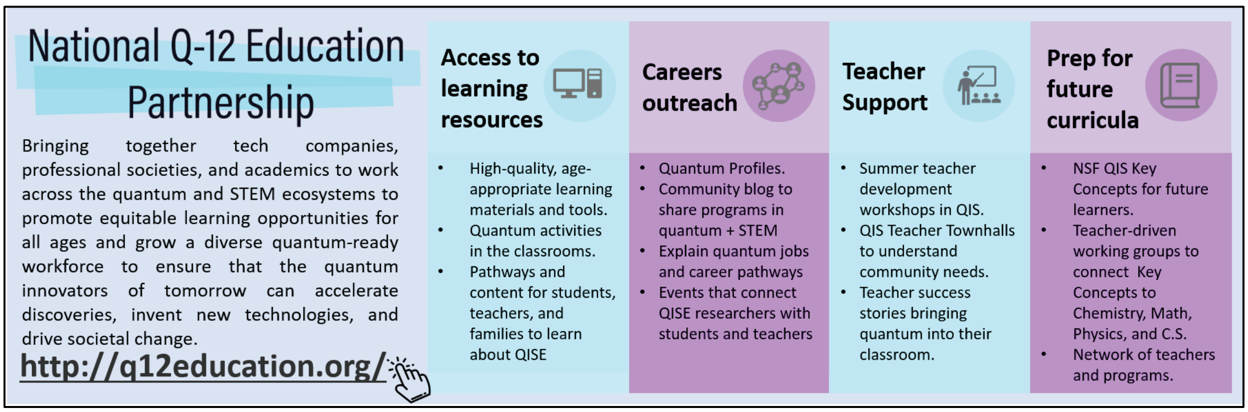

Figure 3: The National Q-12 Education Partnership is a collective effort to connect young students to QIST.

At the postsecondary level, a few colleges and universities have begun to offer introductory quantum courses that target non-STEM students.[76] These Quantum 101, or 'quantum for all,' courses provide a great opportunity to raise awareness and potentially draw students into the field. They can also be useful for adults or professionals in adjacent fields who want more background. Such courses can be offered in community colleges, military schools, as well as at a four-year college or university, including widely accessible teaching-focused state universities found throughout the nation. The latter have a higher proportion of first-generation college students as well as students from backgrounds historically underrepresented in STEM fields, providing a path for creating a diverse and inclusive QIST workforce. Some populations that take short courses or standalone classes for continuing professional education may also have opportunities to engage in QIST-related work in the near-term.

In conjunction with the above activities, building a bridge from educational pathways to training and work opportunities is an important step. Agencies, through existing and targeted programs, have begun to tackle this challenge. In 2020, the NSF issued two Dear Colleague Letters encouraging the submission of proposals for quantum-related activities at the K-12 level.[77,78] NSF's Education and Human Resources

[74] NSF Award # 2039745 - Q2Work: Supporting learners and educators to develop a competitive workforce in quantum information science and technology
[75] https://www.quantum.gov/wp-content/uploads/2020/12/SummaryQ12KickOffEvent.pdf
[76] https://www.edx.org/course/quantum-mechanics-for-everyone
[77] NSF Dear Colleague Letter: Advancing Quantum Education and Workforce Development (NSF 21-033)
[78] NSF Dear Colleague Letter: Advancing Educational Innovations that Motivate and Prepare PreK-12 Learners for Computationally-Intensive Industries of the Future (NSF 20-101)

(EHR) directorate has also been funding teacher development opportunities,[79,80] and convergence activities for early quantum education.[81] NIST, for its part, leverages its Student High School Internship Program (SHIP) and Pathways program to give students hands-on opportunities to work in a lab, as the Army Research Office, Office of Naval Research, and Air Force Research Lab have done with intern and co-op programs. NASA's internship program includes a broad array of hands-on opportunities with NASA mentors, including in the areas of quantum computing and communication. See the Appendix for more examples of engagements by Agencies.

Summary: To develop the QIST workforce over the long term, more broadly available outreach, engagement, and early educational opportunities should be created and sustained. These opportunities should be designed to illustrate core principles, demystify QIST, highlight positive impacts on society, and explain QIST career options, while minimizing hype. Such activities should benefit the public, including educators, mentors, students, and families from all backgrounds. While QIST-based teacher development opportunities exist, they are still small in scale and too few students have the opportunity to engage with QIST core concepts. Enhanced education and outreach should be widely accessible and leverage promising practices in matters of diversity, equity, and inclusion.[82]

2.2 Recommendations for U.S. Government

- The NQCO should work with Agencies and the broader QIST ecosystem to amplify public outreach activities and incorporate clear and realistic descriptions of QIST advances, challenges, and opportunities.
- Government sponsored efforts that include workforce development activities, such as DOE's National Quantum Information Science Research Centers and NSF's Quantum Leap Challenge Institutes, should strive to create a positive and accurate branding of QIST. They should focus attention on realistic possibilities, and highlight ongoing efforts to create an environment that encourages, welcomes, and inspires involvement by everyone who might wish to participate.
- Agencies such as NSF and NASA should support efforts that promote the development of QIST awareness, starting with K-12 age groups. Such activities can add QIST concepts to existing education and outreach programs, invoke cultural and media institutions, leverage games, people profiles, experiences, and curricula to highlight QIST ideas, and build upon public-private partnerships such as the National Q-12 Education Partnership for QIS Education.
- Funding Agencies are encouraged to solicit and prioritize proposals for activities that widely disseminate key QIST concepts. Additional opportunities should be made available for grants and funding for QIST outreach and early education efforts. Opportunities to connect QIST-related activities with other K-12 initiatives should also be considered.
- Agencies should coordinate with each other and with professional societies and educational institutions to assess the level of engagement of various demographic groups in STEM, and QIST

[79] NSF Award # 2048691 - Preparing Secondary Teachers and Students for Quantum Information Science
[80] NSF Award # 2015205 - Cross-Discipline Approach to Quantum Computing in High Schools: Building towards a Quantum Computing Workforce
[81] NSF Award # 2040614 - Convergence Accelerator: National Quantum Literacy Workforce Curriculum and Training Network
[82] https://www.whitehouse.gov/wp-content/uploads/2021/09/091621-Best-Practices-for-Diversity-Inclusion-in-STEM.pdf

in particular, by tracking participation rates and studying potential barriers faced by individual groups, to determine how to improve, scale, and sustain participation in STEM fields.

- Stronger partnerships between museums/science centers and Agencies are recommended, to expand the intellectual breadth, geographic distribution, and accessibility of QIST exhibits, for example, by developing more digital exhibits and leveraging innovative approaches for hands-on, interactive engagement with broader audiences.

2.3 Opportunities for Academia, Industry and the Broader QIST Ecosystem

- QIST education research is needed. In addition to curriculum development, research on QIST education can inform workforce development approaches and programs. Assessing modules and lesson plans for K-12 courses and college-level Quantum 101 courses, and studying the educational impacts of such courses for both non-STEM and STEM majors can improve the way these concepts are taught, and broaden awareness of QIST concepts and career opportunities.
- To provide awareness of QIST concepts and career options, community colleges and other institutions that might not have formal QIST programs or courses can connect with local industries and universities to hold seminars, host speakers, and host outreach activities to highlight the need for vocational skills related to QIST, and showcase opportunities to pursue further studies through bridge programs, transfers, and higher education.
- To ensure broad access, the QIST community is encouraged to develop vetted and open-access repositories of learning resources that help students and educators find QIST lessons, games, simulations, laboratory demonstrations, or other media relevant for their knowledge, interest, and needs. Because the quality of a student's first contact with a subject is often a critical factor for their continued engagement, the formal assessment of early educational materials is paramount.
- Educators should stress the importance of mathematics and digital literacy, which are core competencies and indicators for future STEM engagement. Unfortunately, these are areas where U.S. students on the whole have room for improvement.[83,84] The overall benefits of STEM training should be emphasized, along with connections to other fields such as electrical and optical engineering, data science, computing and computer science, cyber-security, and artificial intelligence.
- The QIST education community is encouraged to continue working with secondary education teachers on the key concepts for QIST learners, so that the curated list and associated curricula connect to current science standards and learning objectives.[85] Materials and hands-on opportunities should be framed and written to promote both formal and informal engagement to target different audiences (e.g., math, computer science, or physics learners), while highlighting the field's transdisciplinary nature.

[83] A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students, doi:10.1186/s40594-018-0118-3
[84] https://nces.ed.gov/timss/results19/index.asp#/math/intlcompare
[85] For example: https://q12education.org/learning-materials/framework

Action 3. Address QIST-Specific Gaps in Professional Education and Training Opportunities

Goal: Optimize graduate education and training opportunities for jobs in QIST.

Post-secondary education (post-high school education including professional certification, associate's, bachelor's, master's and doctoral degrees, and professional retraining programs) serves a crucial role in providing the education, training, and skills needed to enter the QIST workforce. As mentioned previously, industry, government, and academia are seeking a workforce which possesses varied depths of QIST knowledge and skills, with a critical need for non-QIST-specific skills.[86,87,88]

Short-term workforce needs will likely be filled by a combination of recent graduates and mid-career workers that transition into QIST employment. The role of engineers cannot be overemphasized. Much of the workforce moving into QIST employment is likely to come from computer science and engineering, electrical engineering, materials engineering, and other closely related fields. The overlap of engineering skills required for the development of a host of quantum technologies has led to the catch all term of 'quantum engineering'.[86] These new roles offer a strong contrast to previous QIST educational strategies which focused mainly on physics departments. Support for the development of a range of part-time or evening professional certificate and degree programs with an engineering focus is important. Given the prevalence of master's degree programs in many QIST-relevant fields (engineering, computer science, etc.) the opportunity to retool for QIST via a QIST-focused master's degree will be important, and such curricula should be assessed with respect to the impact on workforce development and broadening participation. Also important is support for students who are fully employed or non-traditional workers looking to make a career shift or change. Finally, steps must be taken to ensure that prospective entrants to the QIST workforce are connected with the employers who need their skills.

Looking toward a future in which mature QIST technologies are available, opportunities for training end users to leverage QIST cannot be overlooked. The end-user group is currently undefined but expected to be broad and cross multiple domains. For example, doctors may be able to obtain improved brain images from QIST-enhanced MRI, and military commanders may use QIST systems to optimize problems that tackle complicated logistics challenges. Training of QIST end users is a longer-term objective that will most likely be modeled after other training approaches; however, they will be distinctly different due to the expectation that these professionals will stay in their traditional career role, utilizing the advantages of QIST with the addition of QIST expertise. Inspiration for curricula can be gleaned from computer science (CS), and CS+X education programs to train and develop workforces for the industry.[89] Here, the X stands in for other fields that would leverage CS. Similarly, Quantum+X education could catalyze interdisciplinary training for the emerging quantum industry.

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[86] Building a Quantum Engineering Undergraduate Program, arXiv:2108.01311
[87] Achieving a quantum smart workforce, doi:10.1088/2058-9565/abfa64
[88] Preparing for the quantum revolution: What is the role of higher education, doi:10.1103/PhysRevPhysEducRes.16.020131
[89] https://cs.illinois.edu/about/history-timeline

Figure 4: The NQI and the FY20 NDAA authorized the creation of quantum institutes and centers to accelerate R&D in the United States. These networks of universities, companies, national laboratories, and Federal facilities play an outsized role in training the workforce, developing education materials and pathways, and performing public awareness campaigns at all levels.[90-100] *Examples of some of the ongoing efforts include: (1) job fairs that highlight different career pathways and opportunities for professional networking, (2) science outreach talks aimed at introducing a diverse group of students to QIST, (3) short schools and workshops focusing on both fundamental and applied QIST, (4) postdoctoral fellowships, (5) a portfolio of internships and apprenticeships for both undergraduate and graduate students, and (6) quantum education research. Learn more at* www.quantum.gov.

Finally, improving participation will require removing barriers and improving the culture, at both the individual level and at institutions. For students, training for a QIST career can be demanding, with time and financial costs being contributing factors in the decision to start or continue training and education programs.[101] Similarly, some institutions[102] also face challenges entering the QIST community because providing cutting-edge learning experiences to students often requires capital intensive infrastructure and a stable base of in-house QIST talent.[103,104,105] To meet the demand of training a diverse QIST

[90] https://www.quantum.gov/wp-content/uploads/2021/12/NQI-Annual-Report-FY2022.pdf
[91] https://quantumsystemsaccelerator.org/our-ecosystem/
[92] https://sqms.fnal.gov/workforce-development-opportunities/
[93] https://www.bnl.gov/quantumcenter/student-opportunities.php
[94] https://www.q-next.org/opportunities/
[95] https://qscience.org/opportunities/
[96] https://rqs.umd.edu/education/
[97] https://qubbe.uchicago.edu/research/workforce.html
[98] https://ciqc.berkeley.edu/educ-overview
[99] https://hqan.illinois.edu/education-and-workforce
[100] https://www.colorado.edu/research/qsense/workforce
[101] Source: uncertainties in the job market, loss of employment benefits, caregiver responsibilities
[102] Institutions may include, but are not limited to, 2- and 4-years colleges, non-R-1 institutions, MSIs, and HBCUs.
[103] Minority serving institutions, doi:10.17226/25257
[104] Community colleges in the evolving STEM education landscape doi:10.17226/13399
[105] http://www.tandfonline.com/doi/abs/10.1111/ecge.12016

workforce, there should be sustained investments to build education infrastructure and capacity at R2 and Minority Serving Institutions (MSIs), Historical Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs), and Hispanics-Serving Institutions (HSIs), in order to enable their students to become QIST-aware, QIST-proficient, and QIST-experts. Efforts at each level must be undertaken to create an environment that not only welcomes participants of all backgrounds, but also removes barriers of entry into the QIST ecosystem, and strives to lower attrition of those who are engaged in the QIST workforce.

3.1 Current Landscape

The core concepts underpinning QIST are often taught in specialized, advanced undergraduate physics, chemistry, engineering, or computer science courses. However, much of the material in these courses still focuses on breakthroughs prior to the current era of QIST prototypes. This is also true of graduate coursework at most U.S. institutions, where the majority of educational engagement with QIST concepts and hands-on training has been available. Even at institutions with strong QIST programs, there are only a few examples where QIST concepts are deliberately included in the core curricula of fields such as engineering or computer science. However, curricula are beginning to change as schools start to offer thematic minor programs and introductory QIST courses.[106] QIST-focused certificate programs are also starting to be deployed.[107,108] In contrast, many international allies and competitors are already integrating QIST concepts at a much earlier stage, whether in physics departments or related areas.[109] The establishment of the U.S. NQI Centers and Institutes, Figure 4, is helping to provide additional training and educational opportunities.

Industry currently provides teaching materials, online access to quantum hardware, and certificate programs that are available to the public and educators. However, these efforts are mostly company-specific and do not focus on developing core concepts. As a result, these opportunities are most helpful to users who are already familiar with QIST concepts and want to build proficiency in the available tools.

Summary: Post-secondary education and training programs may have the greatest impact on the quality and adaptability of the U.S. QIST workforce. From undergraduate courses and internships to graduate research positions and cross-training opportunities, programs in higher education should include several on-ramps to facilitate pathways for students at all levels. A broad spectrum of training opportunities can meet the varied depth and disciplinary needs of QIST careers. Opportunities to up-skill or retrain researchers and professionals at various career stages are needed. Furthermore, recognizing that investments in education, training, and retraining can foster multiple points of entry and exit to/from QIST careers, it is valuable to develop programs that enable more workers to acquire skills that complement and support QIST R&D, even if they do not become subject matter experts. Industry has a crucial role, and is making important contributions to the QIST education landscape. There is, however, a need for broad engagement with professional educators to ensure that QIST

[106] https://www.compadre.org/per/items/5465.pdf
[107] https://professional.uchicago.edu/find-your-fit/professional-education/certificate-programs-quantum-engineering-and-technology
[108] https://learn-xpro.mit.edu/quantum-computing
[109] Analysis of secondary school quantum physics curricula of 15 different countries: Different perspectives on a challenging topic, doi:10.1103/PhysRevPhysEducRes.15.010130

training opportunities create lasting, platform agnostic, value in the form of a broadly-skilled, agile, talent pool.

3.2 Recommendations for U.S. Government

- Agencies should look for ways to leverage graduate fellowships and undergraduate stipends to incentivize students to include QIST-related courses and research experiences in their educational pathway. For example, one could create a QuantumCorps scholarship program patterned after the successful NSF CyberCorps Scholarships for Service program.
- Agencies should support the creation of QIST career pivot programs that can retrain or up-skill professionals in adjacent fields. These programs can directly address QIST workforce needs by augmenting targeted skill sets for professionals in related specialties, or complementing partially-relevant skill sets with key additional knowledge, possibly through short courses, practice with new instrumentation, or certification with specific facilities, tools, or software. Such programs can also train QIST end users in various disciplines.
- Agencies should take advantage of existing programs, and develop new ones as need, that expand the range of institutions that can offer on-ramps to QIST jobs. Options include (but are not limited to) adding QIST to existing undergraduate and graduate curricula, giving students greater access to research infrastructure, and supporting faculty at a broader range of institutions to expand their own QIST knowledge and research programs.
- Agencies should encourage QIST curriculum development and curriculum research at several levels, including introductory courses, thematic minors, and master's programs. Assessment of these curricula should study how they support transitions among STEM fields and prepare participants for careers in QIST, and STEM more generally.
- Agencies should leverage public-private partnerships to support development of platform-independent resources for interested parties to engage with quantum computing hardware and software.
- Agencies should consider devoting additional resources for the development of QIST training courses that have significant hardware components, recognizing the pedagogical value of hands-on laboratory activities.

3.3 Opportunities for Academia, Industry and the Broader QIST Ecosystem

- Institutions of higher education can expand QIST courses and programs to increase opportunities for future workers and to build proficiencies that connect various specializations with QIST expertise. Opportunities include:
    - Formal (concentrations, minors, majors, and master's degrees) and informal (internships and externships) QIST programs that highlight QIST-specific challenges and techniques, with pathways to employment upon graduation.
    - QIST specific courses, which focus on the underlying science and theory, in addition to technologies and engineering aspects of QIST, with hands-on learning opportunities in software and hardware development and uses.
    - Short-term workforce needs can be addressed by QIST career pivot programs, including the development of relevant professional certificates, developed in conjunction with industry and non-profit associations, that target workers in QIS-adjacent/relevant fields.

- Institutions are recommended to develop and deploy a wide variety of resources for educators such as lesson plans, modules, courses, specializations, minors, and other potential courses of study at all education levels, and to encourage assessment and dissemination of such materials.
- Institutions are recommended to increase the adoption of skills training that crosses multiple technology areas in support of QIST. These include, but are not limited to, circuit testing and design, cryogenic engineering, microelectronics programming, nanofabrication techniques, and significant exposure to modern photonics and laser science.
- Employers from all sectors should continue to engage with educators and academic programs to provide guidance on how to align curricula and other educational experiences with changes occurring in the QIST economy.

Action 4. Make Careers in QIST and Related Fields More Accessible and Equitable

Goal: Reduce barriers to participation in QIST-related careers for everyone who may wish to work in this field. Increase the pool of talent available for QIST-related jobs throughout the Nation and in Federal Government, by strengthening and diversifying programs that have shaped and developed the QIST ecosystem thus far. Grow the QIST ecosystem further by including entities, institutions, and organizations that have not yet been engaged in QIST activities.

As the need for QIST expertise grows, we must ensure that considerations of diversity, equity, and inclusion play a key role in all developments. We must continue – and augment – the approaches that have led to U.S. leadership in QIST by developing multiple on-ramps for individuals from all areas of science and all backgrounds to ensure that the United States remains a world-leader. We also must maintain a welcoming environment for talent entering from outside the United States. Finally, we must ensure that the specific needs of the Federal government are addressed. Here, "we" refers to the entire QIST R&D and education community, including Agencies, industry, academic institutions at all levels, non-profits, and professional societies.

Maintaining and growing a robust pool of experts begins by supplementing and expanding the approaches that have made QIST a success in the United States over the past 25 years. To this end, the NSO highlighted the ongoing role and need for continued support and expansion of fundamental research, and encouraged the creation of more interdisciplinary and cross-disciplinary opportunities. The former can be met through continued support and appropriate strengthening of existing research training programs offered by Agencies. The latter can be accomplished with special programs that bring together subject matter experts from different disciplines in a coherent fashion, for example, to work on aspects of a project or a grand challenge through joint efforts, or with supplemental funding of graduate students advised by QIST faculty from multiple university departments. The National QIS Centers and Institutes highlighted in Figure 4 serve as good examples, but more efforts and additional on-ramps into the field are required.

Programs should be developed that increase the research capacity of institutions not yet deeply involved in QIST and provide new opportunities for students to participate in QIST research at a greater number of institutions. A prime example of such a program is the recent NSF solicitation "Expanding Capacity in Quantum Information Science and Engineering (ExpandQISE)." The ExpandQISE program is designed to engage the full spectrum of research talent by helping build and maintain a close connection between new efforts and the existing impactful work done at the QISE Centers (shown in Fig. 4) and other leading QISE research Institutions, while creating and nurturing the necessary critical mass at institutions not yet fully involved in QISE.[110]

As in the ExpandQISE program, considerations of diversity, equity, and inclusion must lie at the core of how the community moves forward. A diverse, equitable, and inclusive workforce leads to a more innovative environment, helping ensure that the technologies developed and the problems to which they are applied benefit the most people. As previously mentioned, QIST is currently composed of

[110] https://www.nsf.gov/pubs/2022/nsf22561/nsf22561.htm

several fields that have traditionally struggled to achieve diverse and equitable environments. This must be changed. Much work has been done over the last decade with varying degrees of success, and many lessons can be learned from current efforts in these and other fields.[111–115] However, taking these lessons, applying them, and generating change in QIST and beyond must be the focus of deliberate actions that begin immediately. For example, the TEAM-UP report recommends efforts be undertaken to create an inclusive environment, where all participants see a positive role for themselves in the community. Showcasing a diverse set of individuals through QIST profiles is a pillar of the Q-12 Partnership, and provides an opportunity for further engagement in this effort across the QIST community. Another example of such a deliberate action is requiring that the makeup of QIST panels and workshop attendees reflect the broad community of participants, ensuring that all gatherings encourage participation by people from backgrounds historically underrepresented in STEM.[116]

The QIST community needs to undertake a careful analysis of its efforts and ensure policies are being translated into practices and action, with their effectiveness monitored.[117] This report recognizes the outstanding challenges that still remain to be addressed, and recommends a focused effort over the next year to develop a QIST-specific understanding of these challenges at all levels and on-ramps, along specific actions beyond those noted in this report. This effort should start with listening sessions on how diversity, equity, and inclusion impact each level of QIST education and training, and their respective on-ramps to the field.

As we work to grow the QIST talent pool, it is also important to recognize the vital role that international participants have in the U.S. QIST ecosystem.[118] They participate in and contribute to almost all facets of the ecosystem. They study and carry out research as undergraduate and graduate students, perform independent research as post-docs, and lead research programs in industry and academia. Many immigrate to the United States, where they continue to contribute in a variety of ways, including in federal service. Others move back to their home countries or establish programs in new locations, which strengthens the global network of collaborators. The success of the U.S. enterprise has relied, and will continue to rely upon, this integral component of the QIST workforce.

The Federal government requires QIST subject matter experts to conduct cutting-edge research, inform policy decisions made by senior leaders, and oversee the strategic portfolio of government investments in QIST. The careful and dedicated work of civil servants over the last three decades has contributed significantly to shepherding the field to its current state, and will continue to play a vital role in future. The field's continued maturation will benefit from a steady stream of talented individuals working in government, who can develop and manage the next generation of programs that advance the science and develop QIST-related technologies. In contrast to jobs in academia and industry, most Federal government jobs have additional requirements, such as U.S. citizenship. The fact that more than half of

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[111] https://www.aip.org/sites/default/files/aipcorp/files/teamup-full-report.pdf
[112] https://www.whitehouse.gov/wp-content/uploads/2021/09/091621-Best-Practices-for-Diversity-Inclusion-in-STEM.pdf
[113] Engineering societies' activities in promoting diversity and inclusion, doi:10.17226/25323
[114] Promising practices for addressing the underrepresentation of women in science, engineering, and medicine, doi:10.17226/25585
[115] Transforming trajectories for women of color in tech, doi:10.17226/26345
[116] https://www.nih.gov/about-nih/who-we-are/nih-director/statements/time-end-manel-tradition
[117] https://chicagoquantum.org/events/open-quantum-initiative-workshop-building-a-diverse-quantum-ecosystem

the conferred QIST-related graduate degrees are awarded to foreign national students emphasizes the need for promotion of available pathways to U.S. citizenship for those STEM-educated foreign nationals who are interested, as part of a balanced workforce development strategy. This strategy should incorporate the requirements specific to the Federal government by investing in the development of a domestic workforce across the QIST-aware, -proficient, and -expert levels.[118] Reaching out to the vast pool of domestic talent currently not part of the STEM workforce and ensuring that these individuals can identify a role to play has tremendous potential to addressing this need.

Finally, in planning the development of talent, one must heed the necessary timelines for education and training. For example, prioritizing increases for basic research staffing in QIST can increase the expert workforce within two years (by funding postdocs and engaging MS students) or over five to ten years (by engaging PhD, or undergraduates who may continue in the field). To fill immediate needs (6 months – 1 year), the existing talent pool of professional academic, industrial, national lab, and government science and technology experts are well-positioned to make lateral moves into QIST. This transition can be facilitated if assistance and incentives are provided, either through government- or privately-sponsored programs. For example, sabbaticals, fellowships, and professional exchange programs offer avenues for experts to stay at the forefront of the field, while also providing opportunities for attaining skills in QIST.

4.1 Current Landscape

QIST workforce development is often achieved through hands-on training opportunities supported by Agencies that conduct and fund basic research in QIST and adjacent fields. Funding helps to support research assistantships, internships, fellowships, and summer programs for students and postdocs. In some cases, this can serve as a bridge to federal employment. For example, the NIST-NRC Postdoctoral Research Associateship program brings in researchers as temporary federal employees, making the transition to a federal career easier.[119] While support for basic research in QIST has mostly increased across the QIST-relevant S&T Agencies over the past five years, Agencies are still struggling to hire and retain QIST experts. Hiring challenges are largely fueled by pay disparity between competing industry and government offers, lengthy on-boarding times, and requirements for extensive background checks that can prolong the hiring process.[120] Additionally, better public information campaigns are needed to highlight federal employment opportunities in QIST, for instance in the DOD labs and the Laboratory for Physical Science (LPS). Finally, working within the existing hiring framework is compressing pay scales, which carries the threat of motivating existing government experts to consider looking for more lucrative employment outside the government.

With respect to adapting talent, development programs and fellowships, such as the NSF Quantum Computing & Information Science (QCIS) Faculty Fellows program, the DOD Vannevar Bush Faculty Fellowship (VBFF) Program, the DoD Multidisciplinary University Research Initiative (MURI), the DoD Laboratory University Collaboration Initiative (LUCI) Fellowship, as well as the visiting scholar programs and senior technical leadership development programs are important in facilitating exchanges

[118] https://www.quantum.gov/wp-content/uploads/2021/10/2021_NSTC_ESIX_INTL_TALENT_QIS.pdf
[119] https://www.nist.gov/iaao/academic-affairs-office/nist-nrc-postdoctoral-research-associateships-program
[120] https://www.quantum.gov/wp-content/uploads/2022/01/Summary-QIS-Fed-Workforce-JAN2022.pdf

between industry, academia, and the government. Finally, all Agencies recognize that QIST has become an activity involving a cross section of disciplines, and have started to look at ways to assemble much-needed multi-disciplinary teams to address major challenges.[121]

Summary: As the field of QIST advances, we must ensure all available sources of talent can participate. The United States will need a strong domestic workforce, including a growing number of people with QIST expertise who can be cleared to work in Government jobs. Taking deliberative steps to address inequities and grow a diverse workforce is required to meet the coming challenges. While continued support and expansion of core QIST-related research programs and training opportunities is one crucial avenue for the development of such talent, additional opportunities for training through internships and fellowships at Federal facilities can expand the pipeline, offering an important pathway for attracting talent to the Federal government. Finally, while domestic talent is deeply needed, the U.S. must also continue to support and recognize the importance of international talent in the QIST ecosystem.

4.2 Recommendations for U.S. Government

- The SCQIS and its workforce IWG should undertake a series of listening sessions and community engagements to develop an increased understanding of diversity, equity, and inclusion in QIST. A key focus should be understanding how the different on-ramps to the QIST workforce can be made more equitable. Such efforts will require community engagement, and this report should serve as a starting point for expanding this conversation.
- The SCQIS and its workforce IWG should coordinate with the NSTC Committee on STEM Education (Co-STEM) as they implement the STEM Education Strategic Plan. Coordination should help identify best practices and lessons learned across STEM to support actions and activities that can be tailored to QIST, which will increase diversity and enable an equitable and inclusive environment.
- Agencies should continue to support and invest in core R&D programs that train experts in disciplines related to QIST. This includes research experiences and mentoring at a wide variety of colleges and universities, including investments in MSI, R2, and community colleges.
- Agencies represented on the SCQIS and ESIX should collaborate to create QIST learning and training opportunities for Federal government staff.
- Agencies should review and maximize hiring authorities that enable them to be competitive in attracting and retaining talent to work on QIST topics. Such reviews should look at policies that provide professional support and educational opportunities to retain and advance entry of mid-career employees.
- Internships and externships can assist prospective individuals in exploring job options in the QIST workforce by creating opportunities for people at various career stages, or at various stages of education, to spend time in industry, government facilities, and national laboratories. Agencies should encourage institutes, centers, and other large efforts to foster internships and externships, as well as interdisciplinary collaborations and hiring practices, and support research programs that expand QIST training opportunities such as sabbaticals, fellowships, and visiting scholar programs.

[121] Details of these programs can be found on individual agency websites and at quantum.gov

- The Government should strive to increase access to hands-on learning opportunities – especially for students and faculty at institutions that do not have extensive research infrastructure – by leveraging Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) activities at NSF–funded university sites, NSF Quantum Leap Challenge Institutes, NIST, and the DOE-supported National QIS Research Centers, and also in research facilities operated by DOD, including its designated DOD QIST Centers.
- Agencies should expand support for efforts that build communities such as the QED-C, NSF-industry partnerships, TRIPLETS, INTERN, Convergence Accelerator, DOD MURI programs, and other approaches. Such programs may be tailored to connect potential students to industry and other job opportunities. These activities should include outreach efforts to ensure that students are aware of, and have access to, opportunities in industry that have similar objectives and complement government-sponsored programs.
- Agencies should strive to expand opportunities for post-graduate QIST work within Federal laboratories through programs like the NIST-NRC Postdoctoral Research Associateship that provide a bridge to Federal government employment.
- Agencies should also contribute to, and support contributions to, the *quantum profiles* (see Figure 2 and Sec. 4.3) to illustrate impactful career paths.
- Agencies should work to ensure that QIST education and workforce activities connect with and leverage the larger list of STEM activities supported across the Federal government.
- Agencies should cooperate with international partners to enable circulation and growth of talent through exchange programs and other mechanisms.

4.3 Opportunities for Academia, Industry and the Broader QIST Ecosystem

- The QIST community is encouraged to develop a campaign that promotes careers in QIST through *QIST profiles*.[122] This effort should work to spotlight the breadth of roles, skills, and levels of knowledge needed throughout the QIST ecosystem. Marketing should highlight a broad range of participants and opportunities from diverse racial, ethnic, and gender backgrounds, as well as educational diversity (e.g., R2, community colleges, and MSI educational paths), serving as a means to connect with underrepresented groups. Resources should be Section 508 compliant to ensure universal accessibility.
    - Industry is encouraged to play a role in this effort, highlighting careers and continuing to contribute to the development of accessible QIST platforms and learning tools.
    - The QIST community should develop studies that seek to understand how language, images, and media inspire different target populations (students, general public, educators, etc.) to develop positive branding that resonates with, and is accessible to, a diverse audience.
- To recruit students and professionals with diverse backgrounds, the QIS R&D community can create unique experiences that give learners a chance to see QIST "in action" and demonstrate how individuals with widely different talents can make a meaningful contribution to the field.
- The academic community can encourage long-term mentorship of QIST students, alumni, and workers to guide these individuals throughout their educational and career paths, improving

[122] https://q12education.org/about/careers

retention of talent, especially of people from backgrounds that are historically underrepresented in STEM.
- Institutes, centers, and other large group efforts can nurture interdisciplinary collaborations and hiring practices, to expand QIST training opportunities and grow the impact of QIST R&D.
- The industrial and academic communities can work to strengthen recruitment and retention of domestic and international QIST talent into U.S. companies and universities.
- The industrial and academic communities can work with quantum consortia and professional societies to identify mechanisms (internships, externships, extended visits, training programs, and partnerships) to increase the quality, diversity, and flow of QIST workers across sectors, connecting them to employment opportunities, and identify levers to encourage more interaction across disciplines and recruit more talent into QIST.

Conclusion

The United States has invested in QIST through focused research programs, technology transfer, and national and global infrastructure for over 25 years. The establishment of the National Quantum Initiative is a bold acknowledgement that QIST R&D is important and that a substantial workforce in this area is needed. An appropriately educated and trained workforce is vital to ensure the United States and international allies reap the benefits that QIST can bring to national and economic security. Healthy development of QIST manufacturing and supply chains, infrastructure, discoveries, and innovations all depend upon a robust, talented, and agile workforce. Furthermore, advances in technologies often come from the confluence of outstanding talent and the emergence of unforeseen applications that naturally arise from foundational research. Due to the massive increase in investments that are helping spur technological development in QIST, workforce adaptability is crucial in hedging against the near-term hurdles that must be overcome to remain competitive in this global enterprise.

As QIST evolves, education and training at all levels, from K-12 to graduate education and beyond, will need to keep pace to fill the workforce gaps. To aptly inform QIST curriculum development, outreach, and education programs will require coordination and feedback mechanisms between industry, academia, national labs, and government to assess the evolving, highly varied, and interdisciplinary QIST workforce needs and skills. Developing the national workforce will require drawing on all available talent by broadening outreach, and by increasing learning and professional opportunities for people from all backgrounds and from a larger range of institutions. To improve engagement, special care must be taken with regards to the branding of QIST, to increase awareness of breakthroughs, and to improve public engagement. Additionally, policy actions relevant to QIST in the area of workforce, education, and broadening participation should be continuously assessed at all levels.

The health of the QIST ecosystem depends on the combined and highly interdependent work and workforce produced by academia, government, national labs, and industry. Sustained investment in this growing ecosystem will support continued discoveries and breakthroughs in QIST, the inception of future technologies, and the development of top talent.

Appendix: QIST Opportunities Supported by Federal Agencies

Below is a sample of the education and training opportunities offered by several of the Agencies engaged in QIST. The majority of the mentioned programs here have explicit connections to QIST. Learn more about QIST opportunities by going to www.quantum.gov and exploring individuals agencies websites.

DOD: The DOD's basic research agencies in the individual services – the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Office of Naval Research (ONR) – as well as the Office of the Secretary of Defense (OSD) and the three service labs, support QIST workforce development through existing programs such as the Vannevar Bush Faculty Fellowship Program (VBFF), the Multidisciplinary University Research Initiative (MURI), the Laboratory University Collaboration Initiative (LUCI), Single Investigator grants, the Science Math and Research for Transformation (SMART) program, and the National Defense Science and Engineering Graduate (NDSEG) Fellowship program. These offer opportunities connecting extramural researchers to the service labs, through internships for students and educators, fellowships for students and postdocs, summer programs for students and faculty, and outreach activities for students and teachers ranging from K-12 through post-secondary education. Notably, many of these activities involve the international research community through grants and open-campus initiatives. Organizations within DOD have also sponsored a variety of QIST-specific summer schools, and the Quantum Computing Graduate Research (QuaCGR) Fellowship Program. QuaCGR is sponsored jointly by the ARO and the Laboratory for Physical Sciences (LPS) to stimulate U.S. graduate student participation in research related to quantum computing, and to assist in the training of graduate students to prepare them for careers in quantum information science.

Individual government organizations stood up a number of internal quantum-focused courses for their existing workforce, while also leveraging those provided by industry. Opportunities to aid the workforce in attaining QIST laboratory skills were set up with various government laboratories by offering off-site tours at their facilities. Engagement with the U.S. Naval War College (USNWC) brought insight into potential technologies for future operational vignettes. Summer internships of SMART, NREIP, Pathways Students, and NDSEG interns were specifically crafted to provide exposure to and experience with QIST.

DOE: The DOE's mission includes workforce development activities that either produce a workforce in areas of DOE need or make use of the unique resources at DOE's 17 National Laboratories. In addition to programs that provide visiting faculty, undergraduate, graduate, and community college students with opportunities to do research at DOE's labs, the five NQIA-authorized National QIS Research Centers will sponsor QIST-specific workforce development activities.

IARPA: IARPA's mandate is to conduct cross-community research, target new opportunities and innovations, and generate revolutionary capabilities. Workforce development is accomplished through numerous research programs, some of which are tailored towards QIST. IARPA also participates in the ODNI Intelligence Community postdoctoral program.

NASA: Through its internship and Pathways programs, NASA engages directly with STEM students to develop their understanding and build connections with NASA's subject matter experts. Within NASA's Space Communications and Navigation (SCaN) Program, NASA focuses on quantum communication in its SCaN Internship Project (SIP) at the high school junior through PhD candidate levels, as well as outreach with the general public and in K-12 schools. Through the Quantum Artificial Intelligence Lab (QuAIL) group, NASA mentors' students at all levels in quantum computing, quantum sensing, and quantum-enhanced machine learning, that includes seeking physics insights in order to co-design robust quantum hardware, developing high performance quantum circuit simulators, designing quantum software tools and algorithms, and implementing end-user applications on emerging quantum hardware.

NIST: The primary means by which NIST supports the QIST workforce development is via technical and scientific training of university graduate students, postdoctoral researchers and guest researchers who participate in the NIST mission and programs, its joint institutes (JILA, JQI, and QuICS), its Summer Undergraduate Research Fellowship (SURF) program, and its Summer High School Intern Program (SHIP).

NSA: NSA takes a holistic approach to workforce development and actively invests in national and local activities to broaden STEM participation. In addition to participating in most of DOD's workforce programs, NSA offers a range of STEM-focused opportunities that are regularly used for QIST workforce development. These include internships, scholarships, a co-op program, and more for students starting in high school and continuing beyond advanced degrees. LPS has also initiated both national and targeted quantum computing fellowships for graduate students, and participates in the ODNI IC Postdoctoral Research Fellowship Program. In addition, LPS has also created a national-level quantum information science research center supporting fundamental research, workshops, and QIST co-curricular activities for post-secondary education students.

NSF: At the NSF, all aspects of education, from K-12, undergraduate, and graduate levels are addressed together with teacher training and development, informal education, broadening participation and inclusion, diversity, and partnership. This is achieved by a suite of programs that are also open to QIST-specific needs.[123] NSF also has QIST-specific programs, such as the "TRIPLETS" program that funds a university PI, industrial partner, and graduate student to work together over a period of three years; the Quantum Computing and Information Science Faculty Fellows (QCIS-FF) program; and the Quantum Leap Challenge Institutes (QLCI) program that funds multidisciplinary teams. NSF is continuously assessing the effectiveness of their programs in addressing dynamically changing challenges, such as making sure the opportunities for growth in competitiveness are made available to all institutions.

[123] NSF Dear Colleague Letter: Advancing Quantum Education and Workforce Development (NSF 21-033)

[partners_cqe] Open Jobs in the CQE Community

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1. Applied Physicist (Experienced or Senior) Research & Technology (BR&T)/Advanced Computing Technology, Boeing
Description: Boeing's global research and development team creating and implementing innovative technologies that make the impossible possible and enabling the future of aerospace. Candidates will apply their knowledge of quantum physics to build a comprehensive suite of capabilities in experimental quantum sensing or quantum networking. Successful candidates will have a deep understanding of both theory and laboratory practices in at least one of the following areas: optical clocks; optical time transfer; optical frequency comb-based metrology; quantum network-based entanglement of quantum systems (e.g., atomic, ionic, or quantum dot systems)
How to apply: Learn more
Location: Huntington Beach, CA
Contact: Questions can be directed to Makan Mohageg at makan.mohageg@boeing.com or Bogdan Neculaes Bogdan.Neculaes@boeing.com.

2. Applied Physicist (Associate or Mid-Level), Research & Technology (BR&T), Boeing
Description: The selected candidate will apply their knowledge of quantum physics to build a comprehensive suite of capabilities in experimental quantum sensing or quantum networking. Successful candidates will have a foundational understanding of both theory and laboratory practices in at least one of the following areas: Optical clocks; Optical time transfer; Optical frequency comb-based metrology. Experience in experimental and/or theoretical aspects of one or more of the following fields is desired: Quantum network-based entanglement of quantum systems (e.g., atomic, ionic, or quantum dot systems); Quantum sensors; Quantum communication; Atomic physics; Nonlinear optics; Experiments in cryogenics conditions
How to apply: Learn more
Location: Huntington Beach, CA
Contact: Questions can be directed to Makan Mohageg at makan.mohageg@boeing.com or Bogdan Neculaes Bogdan.Neculaes@boeing.com.

3. Quantum Error Correction Research Software Developer (Hybrid), Xanadu
Description: In this role you will be focusing on writing maintainable and efficient code to simulate cutting edge research in fault tolerant quantum computing. You will help develop and maintain the tools necessary for simulating error corrected quantum computation, especially based on bosonic, measurement-based, photonic architectures. To this end you will use, design, develop, and optimize parallelization techniques as well as simulation algorithms. Strong software development skills and technical communication skills are essential for this role.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

4. Technical Engagement Manager (Hybrid), Xanadu
Description: We are seeking a Technical Engagement Manager to join our team. The ideal candidate will be responsible for managing and driving technical engagements with our clients and partners. This role requires a combination of technical expertise, project management skills, and excellent communication abilities. You will work closely with the Head of Product, as well as the research and hardware teams to position and evangelize the products for customers and partners and provide guidance on the value proposition and benefit those customers and partners can achieve with our services and platforms. The Technical Engagement Manager will act as a bridge between our engineering teams and external stakeholders, ensuring successful project delivery and fostering strong relationships.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

5. Microelectronics Packaging Engineer (On-site), Xanadu
Description: As part of the Hardware Team in Toronto, you will take your hands-on experience in delivering high-performance electronic chip packaging solutions and apply it to Xanadu's cryogenic photon number resolving detector development. In the role of microelectronics packaging technician, you will be responsible for mounting and integrating the electronic components of our superconducting detectors and their readout systems. This will include a mix of electronic, mechanical, and optical component assembly with diagnostics and metrology on the assembled components. You will be involved in developing cutting-edge packaging techniques in the context of large-scale arrays cryogenic superconducting photon detectors.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

6. Optoelectronic Packaging Engineer (Hybrid), Xanadu
Description: As a key member of the Hardware Team in Toronto, your role as a packaging engineer is crucial. You will bring your experience in delivering ultra-low-loss chip packaging solutions to Xanadu's rack-scale quantum computer development. Your work will be instrumental in designing and testing the elements that make up our complex photonic full-build assemblies and producing robust optomechanical and packaging solutions.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

7. Senior Photonics Design Engineer (Hybrid), Xanadu
Description: The successful candidate will work within the photonic integration team to develop cutting-edge passive and active components used throughout Xanadu's fault tolerant architecture. The candidate will take advantage of internally developed cloud simulation pipelines to effectively determine novel design strategies. Particular emphasis will be based on the execution of design of experiments (DOEs), while applying design for manufacturing (DFMs) concepts, exploring performance tradeoffs with Xanadu's 200mm and 300mm fabrication partners. They will gain experience with state-of-the-art foundry processes, while utilizing scalable analysis pipelines to make decisions and close the design loop. The candidate will need to use their deep understanding of analysis and simulation techniques to create sub milli dB loss components.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

8. Quantum Algorithms Researcher (Hybrid), Xanadu
Description: As a quantum algorithms researcher, you will be a part of Xanadu's software and algorithms group, working with our team of scientists and software developers. Your role will include developing new quantum algorithms, identifying applications, inventing key intellectual property, and publishing scientific papers. You will also work on problems of real-world impact with our industry partners and customers. Your main focus will be to develop optimized quantum algorithms for challenging computational problems in quantum chemistry and materials science. The goal is to

determine in great detail how quantum computing can have the largest technological impact, and to use these insights to guide Xanadu's strategic roadmaps, customer relationships, and partnerships.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

9. Quantum Computing Educator (Hybrid), Xanadu
Description: As a Quantum Computing Educator at Xanadu, you will be helping to bring quantum computing—a cutting-edge society-transforming technology—to the world. Focusing on our open-source quantum computing software PennyLane, you will develop exciting high-impact content read by thousands of scientists, developers, educators, students, and enthusiasts each month.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

10. Quantum Computing Scientist - Product (Hybrid), Xanadu
Description: In this role, you will be a Quantum Computing Scientist working within our product management team contributing to our flagship Python-based quantum software library PennyLane. Drawing on your technical background, you will be responsible for building and maintaining the product vision for a specific focus area within PennyLane (quantum chemistry, quantum machine learning, high-performance computing, compilation).
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

11. Quantum Machine Learning Researcher (Hybrid), Xanadu
Description: As a Quantum Machine Learning Researcher at Xanadu, you will be part of Xanadu's Software and Algorithms group, working in collaboration with our team of scientists and software developers. Your goals are to contribute core ideas that push the boundaries of quantum machine learning research, and to support the team in making Xanadu's software ready for future developments in the field. You produce high-quality papers on relevant topics and keep closely involved with the scientific community to identify new developments.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

12. Quantum Software Developer - Compilation (Hybrid), Xanadu
Description: As part of the PennyLane Compilation team, you will be responsible for developing and maintaining JIT and AOT hybrid compilation pipelines for PennyLane, an open-source software framework for quantum machine learning, quantum computing, and quantum chemistry.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

13. Senior/Intermediate Quantum Software Developer (Hybrid), Xanadu
Description: As part of the Xanadu Software Team, you will be responsible for developing and maintaining PennyLane, an open-source framework for quantum machine learning, quantum computing, and quantum chemistry. Further duties include contributing to the development of a quantum cloud platform, and building and designing software and services with PennyLane. The selected candidate must possess the ability to learn advanced scientific and technical concepts quickly and with minimal direction. Strong technical skills and a demonstrated ability to learn new concepts is important for this position.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

14. Machine Learning Developer– Design Platform (Hybrid), Xanadu

Description: As a ML Developer at Xanadu, you will contribute to our internal ML tool stacks to support Hardware R&D which aims to build the first commercially viable quantum computer. The ML team's focus is to build and improve the modeling, optimization, simulation, data processing, and design methodology for our internal research. Situated at the intersection of multiple technical disciplines, you will have the unique opportunity to work with world leading researchers, scientists, engineers, and software developers. By infusing cutting-edge ML into the software tools, you have the chance to super-charge their research progress and even reshape how they work.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

15. Microelectronics Packaging Engineer (On-site), Xanadu
Description: As part of the Hardware Team in Toronto, you will take your hands-on experience in delivering high-performance electronic chip packaging solutions, and apply it to Xanadu's cryogenic photon number resolving detector development. In the role of microelectronics packaging technician, you will be responsible for mounting and integrating the electronic components of our superconducting detectors and their readout systems. This will include a mix of electronic, mechanical, and optical component assembly with diagnostics and metrology on the assembled components. You will be involved in developing cutting-edge packaging techniques in the context of large-scale arrays cryogenic superconducting photon detectors.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

16. Grant Manager (Hybrid), Xanadu
Description: As part of the Xanadu Software Team, you will be responsible for developing and maintaining PennyLane, an open-source framework for quantum machine learning, quantum computing, and quantum chemistry. Further duties include contributing to the development of a quantum cloud platform, and building and designing software and services with PennyLane. The selected candidate must possess the ability to learn advanced scientific and technical concepts quickly and with minimal direction. Strong technical skills and a demonstrated ability to learn new concepts is important for this position.
Location: Toronto, ON, Canada
How to apply: Learn more
Contact: Questions can be directed to Aaron Walker at aaron@xanadu.ai.

Please find additional jobs on the CQE website.

To request an event or job be added to the CQE mailing list and/or website, please contact quantum@uchicago.edu.