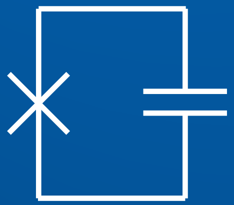
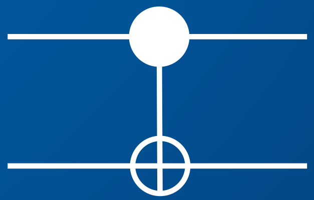
UR Quantum

Devices



Materials

Applications



Interconnects

Theory

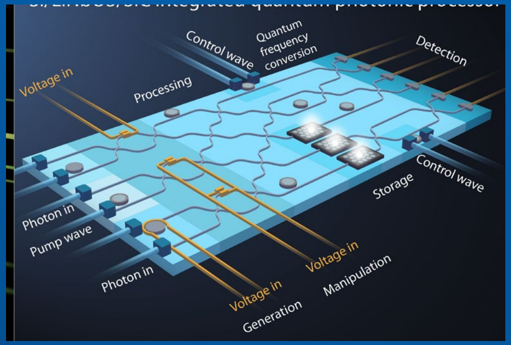
$|\psi\rangle$

UNIVERSITY of ROCHESTER

Quantum devices

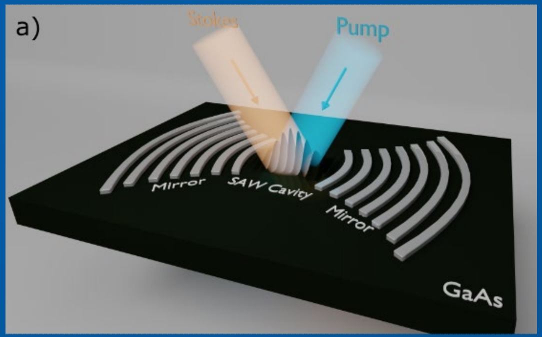
Faculty: Askari, Bigelow, Blok, Nichol, Renninger, Wu

Quantum photonics



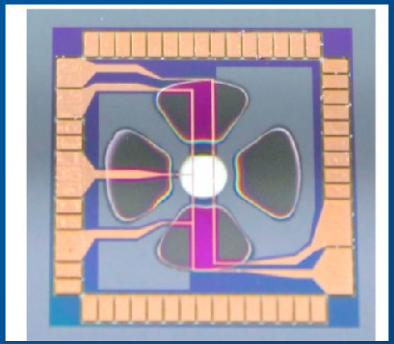
We create novel on-chip photonic devices and circuits to create, store, and transmit quantum states of light.

Quantum phononics



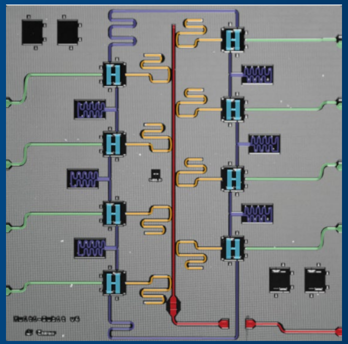
We are developing new platforms for quantum information processing, ultrasensitive metrology, and fundamental tests of quantum decoherence based on mechanical vibrations (phonons).

BEC on a chip



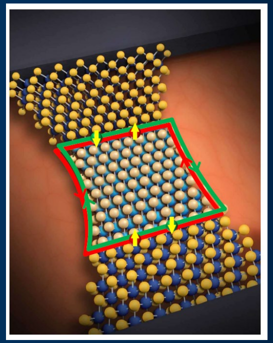
We study cold atoms on a chip for quantum simulation and atom interferometry in space

Qubits



We explore qubits made of superconductors, semiconductors, two-dimensional systems, and diamond

Topological systems

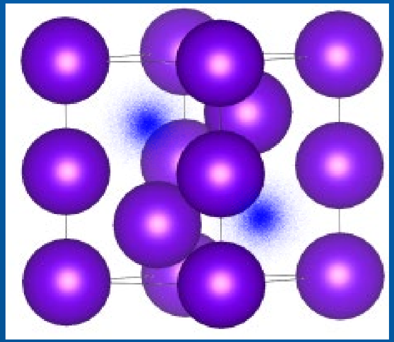


Topological qubits are predicted to be less susceptible to errors than conventional qubits. We study how to manipulate 2D materials, like graphene, with strain, to produce such qubits.

Quantum materials

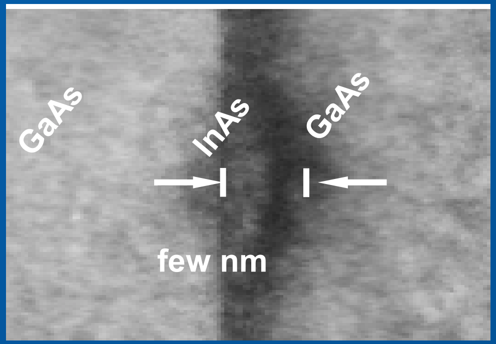
Faculty: Boyd, Collins, Dias, Lin, Krauss, Vamivakas, Wicks

Extreme matter



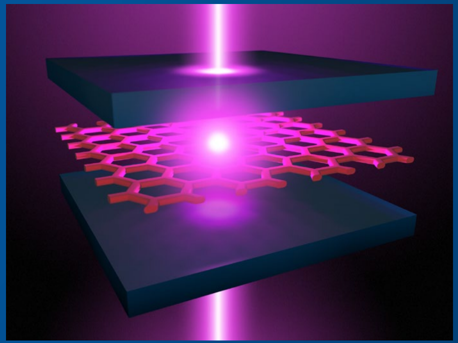
Using the facilities at the Laboratory for Laser Energetics, we subject materials to conditions of extreme pressure and temperature to explore new quantum effects.

Quantum confined materials



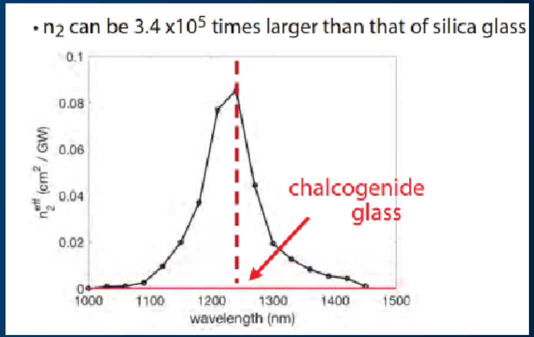
We explore how tailor-made semiconductors, like quantum dots, can create new functionality by confining electrons to enhance their quantum-mechanical behavior.

2D materials



Two-dimensional materials, like graphene, have superlative electrical, mechanical, and optical properties. We study how to use these systems to generate quantum states of light.

Nonlinear quantum photonics

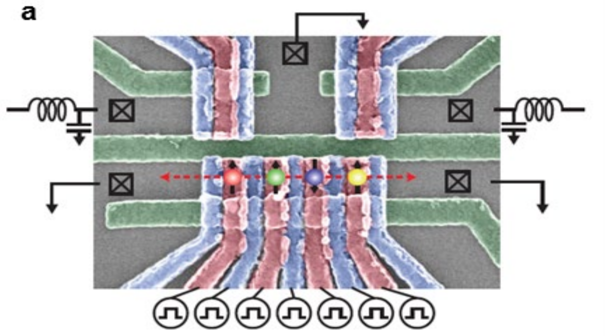


Materials whose index of refraction (related to the speed of light) decreases to zero can exhibit large non-linear effects, which are critical for technological applications.

Quantum Applications

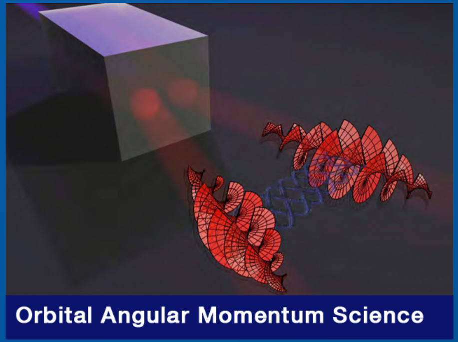
Faculty: Blok, Boyd, Cardenas, Nichol, Vamivakas

Computing



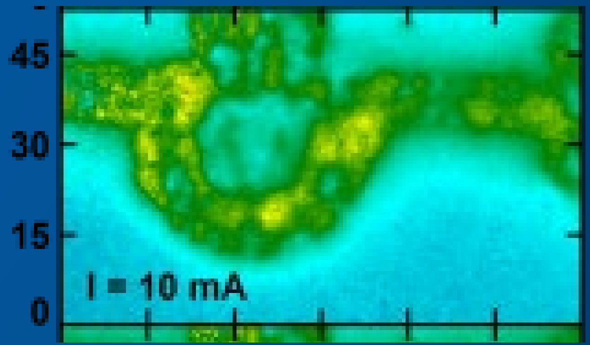
Using a variety of qubits, including those based on superconductors, semiconductors, two-dimensional materials, and diamond, we study how to implement quantum computing algorithms.

Communication



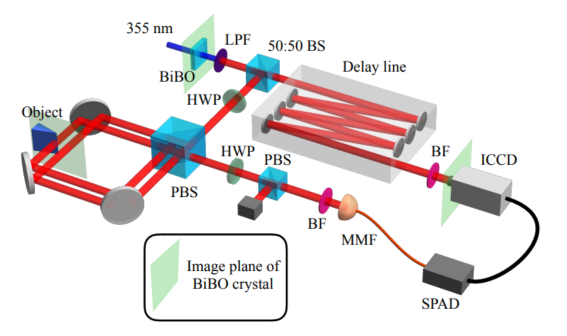
We study how to harness the quantum properties of light to achieve robust quantum teleportation with free-space optics.

Sensing



We use qubits based on diamond to form the some of the most sensitive detectors of electromagnetic fields.

Imaging

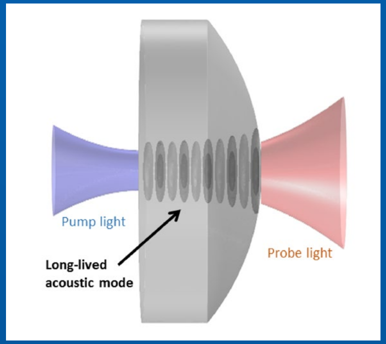


We exploit the quantum properties of superposition and entanglement to enhance optical imaging capabilities

Quantum interconnects

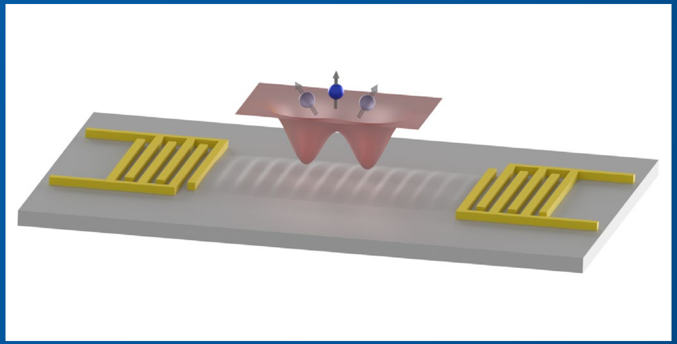
Faculty: Blok, Boyd, Cardenas, Nichol, Vamivakas

Phonon-photon



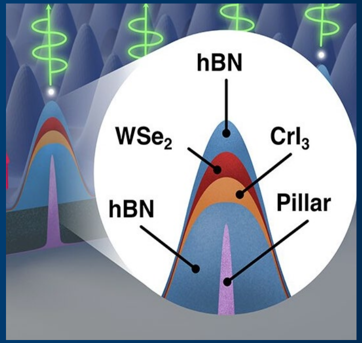
Mechanical vibrations (phonons) interact with nearly all quantum systems. We are exploring how phonons can enable optical interconnects for quantum systems.

Spin-phonon/microwave photon



Qubits based on electron spins have very long coherence times, much longer than other solid-state systems. We study how to interface spins in semiconductor quantum dots with mechanical vibrations (phonons) and microwave photons

Spin-optical photon

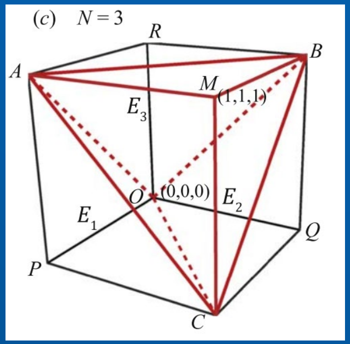


We also study how to couple spins to optical photons through direct optical coupling in 2D materials.

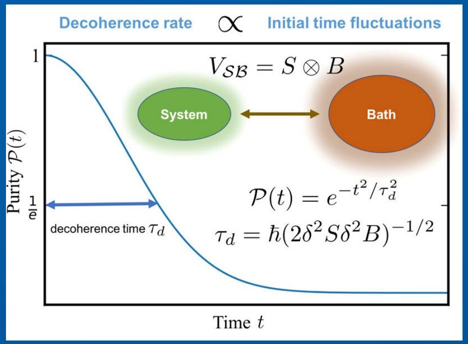
$|\psi\rangle$ Quantum theory

Faculty: Eberly, Franco, Jordan, Huo

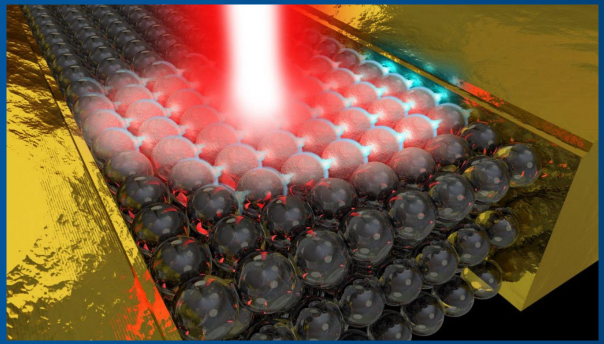
Entanglement



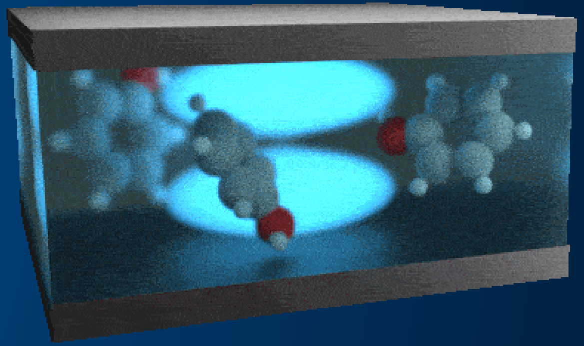
Coherence



Quantum control



Electromagnetic environments



Entanglement and coherence are the two of most essential resources that quantum information processors use to achieve an advantage over classical information processing devices. We study how to understand and quantify these key quantities.

We study how to use light, electricity, and magnetism to manipulate quantum systems in new ways for improved information processing capabilities.

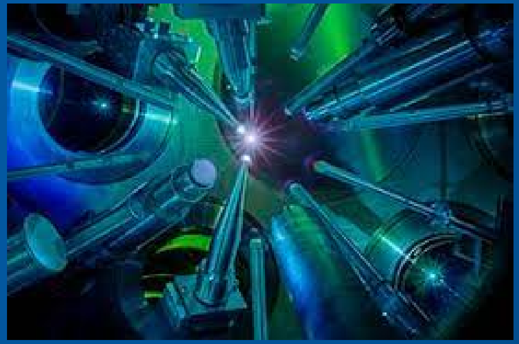
Molecules in chemical reactions can be placed in electromagnetic cavities to modify their reaction dynamics and potentially produce new molecules.

UR Quantum facilities

URnano

The University of Rochester Integrated Nanosystems Center (URnano) offers a unique set of nanofabrication tools for lithography, deposition, etch, and characterization of quantum devices.

Laboratory for Laser Energetics



The Laboratory for Laser Energetics is a research facility at UR primarily funded by DOE. Using the facilities at LLE, researchers explore quantum effects in matter under conditions of extreme pressure or temperature.

TAP:Test and Packaging Rochester NY

The American Institute for Manufacturing Integrated Photonics TAP facility is the world's first open access 300 mm state-of-the-art facility for integrated silicon photonics test, assembly, and packaging

Govind P. Agrawal

James Wyant Professor at The Institute of Optics
Appointments in Physics and Laser Energetics Lab

Research areas (experiment):

- Silicon photonics, nonlinear fiber optics, quantum states of light, coherence and polarization, optical communication

Major accomplishments:

- Entangled photons through four-wave mixing, dynamic photonic resonators, temporal reflection and waveguides, graded-index solitons, lens-induced coherence

Interests in collaboration:

- Quantum-state propagation in optical waveguides
- Quantum communication through classical channels
- Website: http://www2.optics.rochester.edu/workgroups/agrawal/grouphomepage.php

Nicholas Bigelow

Lee A. DuBridge Professor of Physics
Appointments in The Institute of Optics and Material Science

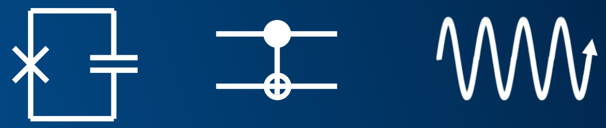
Research areas:

- Quantum fluids, Bose-Einstein Condensates, Atom Optics, Ultracold Molecules, Atom Chips
- Space based quantum physics: fundamental and applied quantum sensing technologies

Major accomplishments:

- Experimental and theoretical spinor BEC physics, spin squeezing, ground state ultracold polar molecules, quantum thermodynamics, topological states of spinor BEC such as Skyrmions, on-orbit (ISS) BEC and atom interferometry gradiometer and gyroscopy pathfinder
- **Interests in collaboration:**
- Interfacing quantum systems
- Topological defects and excitations, quantum simulation and emulation
- Quantum sensing, Quantum thermodynamics
- https://sites.google.com/site/bigelowcatgroup/

Machiel Blok



Assistant Professor of Physics

<u>Research areas (experiment)</u>:

- Superconducting circuits, quantum information and simulation.

<u>Major accomplishments</u>:

- Demonstration of a multi-level (ternary) quantum processor, development of new high-impedance spiral resonators.

<u>Interests in collaboration:</u>

- Quantum transduction, quantum internet and hybrid quantum systems
- Theory groups working on bosonic quantum error correction and/or qudit quantum computing
- https://labsites.rochester.edu/bloklab/

Robert W. Boyd

M. Parker Givens Professor of Optics and Physics

Research areas (experiment):

- Quantum optics, quantum communication, nonlinear optics, nonlinear optical imaging

Major accomplishments:

- Author of *Nonlinear Optics,* demonstration of slow and fast light in solids, quantum imaging, and development of composite nonlinear materials.

Interests in collaboration:

- Nonlinear optics
- Quantum communication
- Website: https://www.hajim.rochester.edu/optics/sites/boyd/index.html

Jaime Cardenas

Assistant Professor in The Institute of Optics

Research areas (experiment):

- Nanophotonics, 2D material lasers, photonic packaging, on-chip weak value amplification, nonlinear photonics

Major accomplishments:

- Novel photonic packaging technology, on-chip 2D material enhanced photoluminescence on-chip, demonstrated chipscale weak value amplification interferometer

Interests in collaboration:

- Integrating quantum systems on a photonic chip
- Bio-sensing
- Quantum state generation and manipulation
- https://www.hajim.rochester.edu/optics/cardenas/

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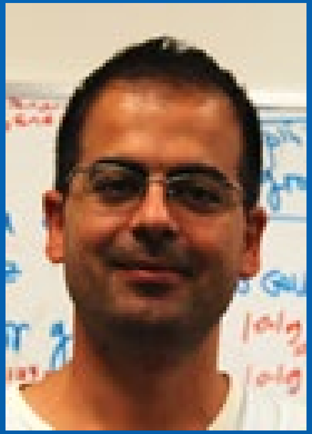
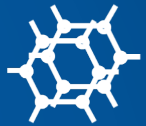


Hanan Dery  $|\psi\rangle$

Associate Professor of electrical and computer engineering.
Appointments in Physics and Materials Science

<u>Research areas (theory)</u>:

- Two-dimensional crystals, spintronics, many-body physics.

<u>Major accomplishments</u>:

- Designing of a spin-based computer architecture (2007), identifying the dominant spin relaxation mechanisms in Si and Ge (2010-2014), unraveling the coupling of excitons to coherent short-wave charge excitations in monolayer transition-metal dichalcogenides and the role of phonon-assisted recombination next to localization centers (2015-2019).

<u>Interests in collaboration:</u>

- Experimentalists who characterize optical devices made of 2D crystals
- Material scientists, condensed matter physicists
- http://www.hajim.rochester.edu/ece/people/faculty/dery_hanan/index.html

Joseph Eberly $|\psi\rangle$

Andrew Carnegie Professor of Physics

Research areas (theory):

- Dynamical modeling of quantum systems, including photons and decoherent entanglement.

Major accomplishments:

- Discovery of periodic quantum collapse and revival, first demonstration of diffraction-free Bessel beams, defining and demonstrating ESD and ESF (entanglement sudden death and sudden freezing), virtual detector theory with path summation to analyze multi-electron ionization, proof of the Polarization Coherence Theorem, connection between entanglement and de Broglie's duality, large quantum X-matrices and their use, concurrence triangle inequalities, first genuine measure of entanglement for three-qubit quantum states.

Interests in collaboration:

- Studies that challenge interpretations (e.g., of measurement or quantum theory itself)
- Electron entanglement during atomic and molecular photo-excitation

Ignacio Franco $|\psi\rangle$

Assistant Professor in Chemistry
Appointments in Physics and Materials Science

Research areas (theory):

- Theoretical chemistry, quantum dynamics, molecular simulations. Quantum control, strong laser-matter interactions, theory of open quantum systems, molecular electronics, single-molecule spectroscopies.

Major accomplishments:

- Introduced a general strategy for the quantum control of electrons that is now used for laser-driven ultrafast electronics and optical actuators. Developed theories of decoherence in matter that have opened new ways to preserve quantum coherence. Developed the theory and simulation of molecular junctions as a platform to investigate Chemistry and Physics at the nanoscale.

Interests in collaboration:

- People using light for the quantum control of matter.
- People developing schemes to preserve and measure quantum coherence in matter.
- People interested in using light for ultrafast electronics and electronic communication.
- http://www.chem.rochester.edu/groups/franco/

Andrew N. Jordan $|\psi\rangle$

Professor of Physics

Research areas (theory):

- Quantum physics: Measurement, Metrology, Thermodynamics, Information, Foundations
- Condensed matter physics: Transport, Superconductivity, Fluctuations and Sensing
- Optics: Precision measurements, entanglement based Sensing, Interferometry

Major accomplishments:

- Stochastic path integral approach to continuous quantum measurement; design of quantum heat engines and refrigerators; theory of weak measurement; optical precision measurement development; theory of time-dependent quantum metrology.

Interests in collaboration:

- Understanding general quantum effects.
- Quantum sensing in various platforms.
- Photonic integrated circuits.
- https://sites.google.com/view/andrewnjordan/

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Gabriel T. Landi $|\psi\rangle$

Associate Professor of Physics

<u>Research areas (theory)</u>:

- Open quantum dynamics.
- Thermodynamics in the quantum regime.
- Quantum transport.

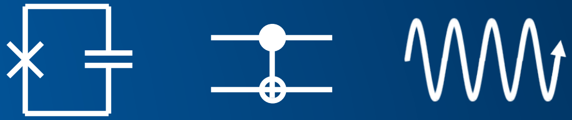
<u>Major accomplishments</u>:

- Formulation of the 2nd law of thermodynamics to include information as a resource, and in quantum optical systems using quantum phase space. Thermodynamic uncertainty relations in nanoscale processes.

<u>Interests in collaboration:</u>

- Experimentalists interested in open quantum processes.
- Quantum fluctuations in nanoscale transport.
- Thermodynamic processes in the quantum regime.
- http://www.fmt.if.usp.br/~gtlandi/

Qiang Lin



Professor of Electrical and Computer Engineering

Research areas (experiment):

- Integrated quantum photonics, quantum simulation, quantum computing. Nonlinear integrated photonics.

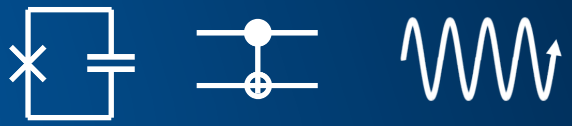
Major accomplishments:

- Demonstration of ultrabroadband quantum frequency combs on chip. Demonstration of cyclic entanglement and non-reciprocity on quantum correlation.

Interests in collaboration:

- Quantum theory on high-dimensional entanglement and large-scale quantum photonic integrated circuits.
- Quantum measurement, state tomography, and quantum algorithms.
- Quantum optics on integrated photonic platforms
- https://photonlab.hajim.rochester.edu/

John Nichol



Associate Professor of Physics

Research areas (experiment):

- Quantum dots, semiconductor spin qubits, quantum computing, quantum simulation, quantum sensing.

Major accomplishments:

- Demonstration of new methods for quantum state transfer, high-resolution noise spectroscopy, and exploration of coherent spin-valley oscillations in semiconductor quantum-dot spin qubits

Interests in collaboration:

- Interfacing solid-state quantum systems with other quantum systems including microwave resonators and mechanical systems
- Theory of noise and optimal quantum gates in spin qubits
- http://www.labsites.rochester.edu/nicholgroup

Pablo A. Postigo

Professor of Optics

Research areas (experiment):

- Deterministic, highly indistinguishable single-photon sources at room temperature
- Quantum optical sensing of temperature

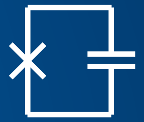
Major accomplishments:

- Demonstration of distant single-photon coupling to photonic crystal microcavities
- Development of new platforms for deterministic single-photon sources at room temperature
- Investigation of single-photon indistinguishability

Interests in collaboration:

- Applications of optical quantum systems
- https://csic.nanopod.es

Will Renninger



Assistant Professor in The Institute of Optics

Research areas (experiment):

- Photon-phonon transduction, novel photon and phonon states, fiber sensing, nonlinear frequency conversion, ultrafast nonlinear optics, solitons, ultrashort pulse sources

Major accomplishments:

- Optically generating and controlling GHz phonons with intrinsically limited dissipation at low temperatures, manipulating second sound with light, new optomechanical interactions, observations of new states of light, advanced ultrashort optical source development

Interests in collaboration:

- Solid-state quantum system researchers, especially systems that may couple with phonons
- Material scientists interested in coherent phonons
- Photon-phonon, photon-photon, photon-rf, or rf-phonon transduction
- https://labsites.rochester.edu/renninger/

Stephen M. Wu

Assistant Professor, Department of Electrical and Computer Engineering
Appointments in Physics and Materials Science

Research areas (experiment):

- Quantum materials growth and synthesis, nanoelectronics engineering, quantum electronic devices, spintronics

Major accomplishments:

- Strain-engineered phase changes in quantum materials, gate-controllable magnetic devices, gate-controllable phase change devices.

Interests in collaboration:

- Theory collaborators for quantum materials exploration
- Materials/surface characterization collaborators for quantum phase identification
- Interfacing solid-state quantum systems with other quantum systems
- http://labsites.rochester.edu/swulab/

Nick Vamivakas

Professor in The Institute of Optics
Appointments in Physics and Materials Science

Research areas (experiment):

- solid-state quantum optics, quantum sensing, quantum states of light, nanophotonics, optical trapping, advanced imaging

Major accomplishments:

- Generating quantum states of light from solid-state materials, new approaches to sensing based on levitated particles, advanced scene characterization, active metasurface optics

Interests in collaboration:

- People that design and fabricate photonic integrated circuits
- Interfacing solid-state quantum systems with other quantum systems
- Material scientists
- http://labsites.rochester.edu/vamivakaslab/