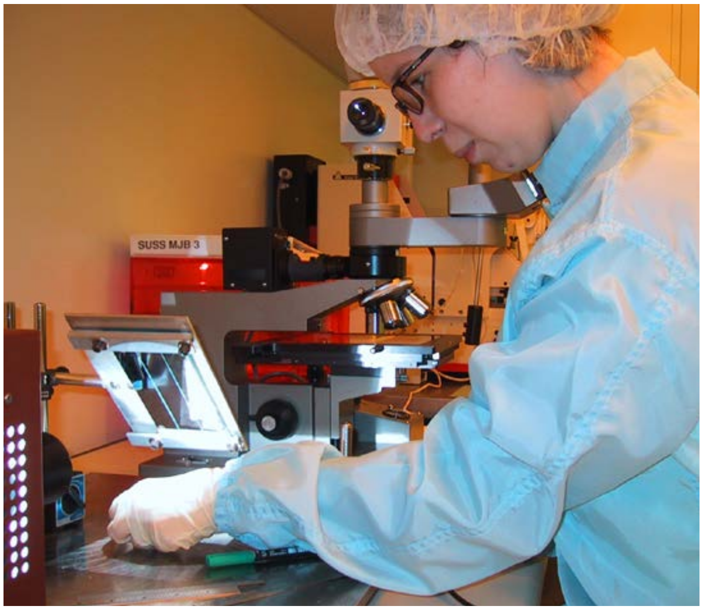


When a large number of atoms condense into a fluid or solid, behaviors emerge that are only indirectly related to the physics of the individual atoms. Superconductivity is one such emergent behavior, which could not be anticipated from even a detailed study of an isolated atom. The goal of condensed matter physics is not only to measure and explain such emergent phenomena but also to manipulate these properties to produce the novel effects we desire. This allows us to both investigate fundamental physics and to develop commercially important applications.

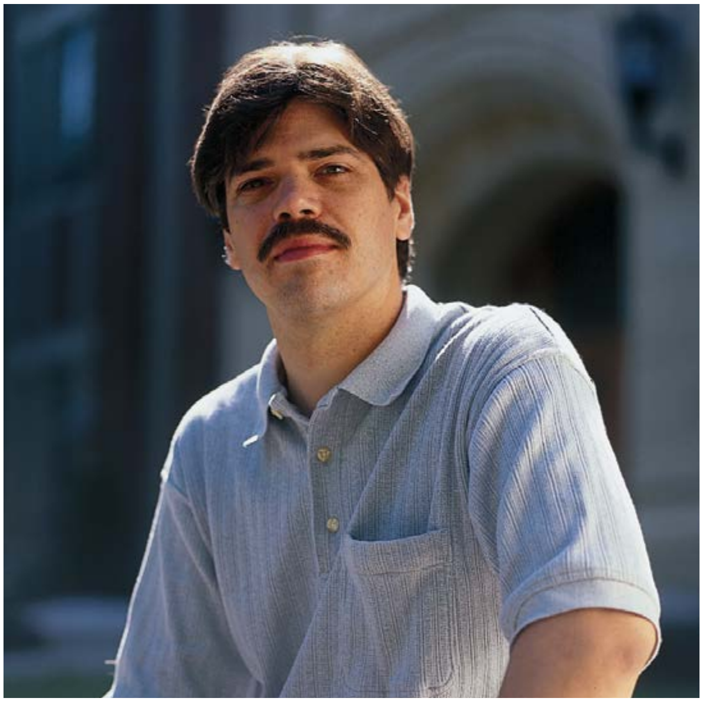
A student in condensed matter physics must have a thorough understanding of both the microscopic quantum mechanics that underlies the system and the classical macroscopic theories of mechanics, electromagnetism, and statistical mechanics that describe its large scale behavior. This broad background enables students to go on to careers in academia, government labs, and industry.

The condensed matter group encompasses semiconductor physics, soft-matter physics, and nanophysics. A major focus of our group is the experimental and theoretical study of highly confined electron systems in artificially structured semiconductors and other low dimensional materials. We cover all aspects of these systems from fundamental theory to device fabrication. This group operates as part of the Center for Semiconductor Physics in Nanostructures (C-SPIN) one of the National Science Foundation's few Materials Research, Science and Engineering Centers. C-SPIN is a multi-million dollar, interdisciplinary research collaboration between scientists at the University of Oklahoma and the University of Arkansas. We have theoretical and experimental efforts in nano-scale semiconductor devices, spin transport in semiconductors and high-speed transistors. In addition to semiconductor studies, the group also has research efforts in high-efficiency photovoltaics, graphene, self-assembled monolayers, molecular plasmonics, nanoparticles, and lithium ion conducting polymers. Some of this work is performed in conjunction with researchers in the Departments of Chemistry and Biochemistry, Electrical & Computer Engineering, and Chemical, Biological, & Materials Engineering.

The majority of our experimental research takes place in the department's state-of-the-art laboratories. Our well equipped facilities include: a dual-chamber molecular beam epitaxy (MBE) system for the growth of III-V and IV-VI semiconductors; several scanning tunneling and atomic force microscopes for high resolution imaging and patterning of atomic surfaces; a cleanroom for optical lithography and semiconductor processing; a thin-film laboratory for routine vapor deposition; low temperature (<20 mK) and high magnetic field (15 T) facilities for optical and electrical studies; optical microscopes for single nanoparticle spectroscopy; a grazing angle infrared spectrometer for molecular spectroscopy of monolayers; full characterization techniques for solar cells analysis including a class-A solar simulator, an external quantum efficiency system with capacitance-voltage analysis equipment; and picosecond pulsed laser systems for our polymer studies. Scanning electron and transmission electron microscopes are available in the Samuel Roberts Noble Electron Microscopy Laboratory and are routinely used by our students for their research.

The condensed matter theory group is interested in many areas of research including new quantum phases in strongly correlated systems, quantum criticality and transport in semiconductor and carbon nanoscale systems. New quantum phases include such diverse examples as chiral edge states in topological insulators, novel superconducting condensates in carbon-based systems, and polarized arrays of quantum rings. Quantum criticality refers to phase transitions driven by quantum fluctuations rather than temperature, such as those in Dirac materials like graphene, high temperature superconductors and possibly transition metal dichalcogenides. The group's transport studies involve currents in heat, charge, energy, spin and pseudo-spin in mesoscopic systems in general. In addition theory is an important partner to the above experimental efforts.

The faculty in condensed matter physics share appointments in the engineering physics program. The engineering physicist provides the link between the pure scientist and the engineer by applying fundamental scientific theories to the solution of technological problems. As the miniaturization of transistors, lasers, and memory elements continues, an understanding of their operation increasingly requires knowledge of the underlying physics.



[Lloyd A. Bumm]

associate professor

B.S. 1982 Clarkson University

Ph.D. 1991 Northwestern University

I am interested in surface physics at the nanometer-scale in condensed systems. In practical terms, can I build an electronic device out of a single molecule? Insight into critical technological problems, such as molecular-scale electronics, molecular light-emitting diodes, and light harvesting systems, relies on understanding fundamental physical processes at the nanometer scale. When a single molecule is placed between two electrodes, what is its electrical conductivity? How does light modify the molecule's electrical properties?

My focus is to understand the electronic and the optoelectronic characteristics of individual molecules and functional nanometer-scale assemblies. The experimental approach is to combine the molecular-scale resolution of scanning probe techniques, such as scanning tunneling microscopy (STM) and atomic force microscopy (AFM), with optical spectroscopy.

We use self-assembled monolayers (SAMs) as a matrix platform in which other molecules can be tethered. SAMs have the advantage that they can be easily prepared under bench-top conditions and their molecular components can be readily imaged by STM. Our recent work has concentrated on developing methods for natural patterning of SAMs on the nanometer scale, including surface-structure directed chemistry. We have a strong collaboration with Ron Halterman's synthetic organic group in chemistry to make the unique molecules used for our work. We have also developed flat gold nanoparticles (FGNPs) as plasmonic substrates for our STM studies. In addition to STM, my group also has developed capability in single nanoparticle spectroscopy for molecular plasmonics and in grazing angle-infrared spectroscopy for SAM characterization. Our group is also interested in developing novel scanning probe techniques.

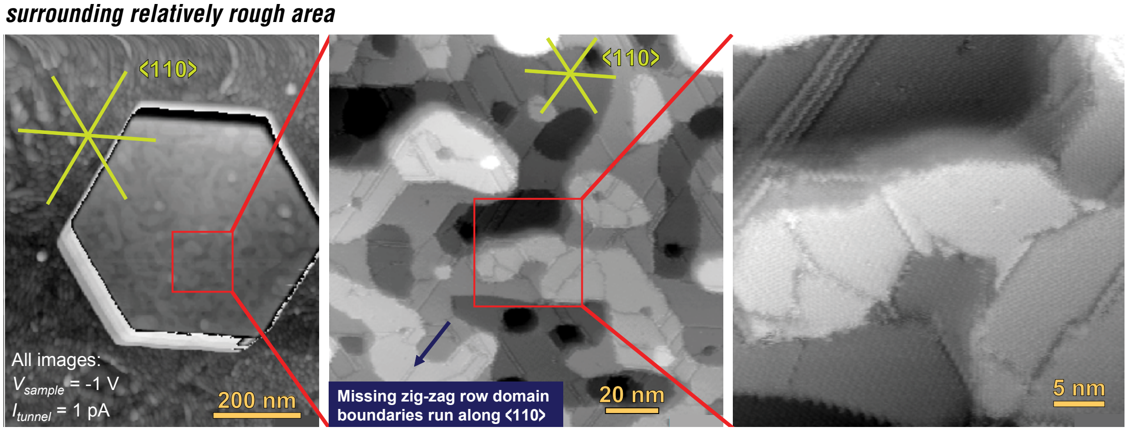
A. Singh, D.H. Dahanayaka, A. Biswas, L.A. Bumm, R.L. Halterman, "Molecularly-Ordered Decanethiol Self-Assembled Monolayers on Au(111) from in-situ-Cleaved Decanethioacetate: An NMR and STM study of the efficacy of reagents for thioacetate cleavage," *Langmuir,* 26(16), 13221-13226 (17 Aug 2010).

L.A. Bumm, "Measuring Molecular Junctions: What is the standard?" *ACS Nano*, **2**(3), 403-407 (2008).

M. Achermann, K.L. Shuford, G.C. Schatz, D.H. Dahanayaka, L.A. Bumm, V.I. Klimov, "Near-field spectroscopy of surface plasmons in flat gold nanoparticles," *Optics Letters,* **32**(15), 2254-2256 (01 Aug 2007).

D.H. Dahanayaka, J.X. Wang, S. Hossain, and L.A. Bumm, "Optically Transparent Au{111} Substrates: Flat Gold Nanoparticle Platforms for High-Resolution Scanning Tunneling Microscopy," *J. Am. Chem. Soc.* **128**(18), 6052–6053 (10 May 2006).

An STM image sequence of progressively smaller areas of a flat gold nanoparticle (FGNP) with a decanethiol self-assembled monolayer (SAM) supported on indium-tin oxide (ITO) coated glass. The left image shows the hexagonal FGNP with its gold (111) terraces. Note the edges of the hexagon are aligned with the Au<110> crystallographic directions. The surrounding relatively rough area is the ITO coating on the substrate. The center image shows the Au(111) terraces and the SAM structural domain boundaries, which are also aligned along Au<110> directions. The right image resolves the individual molecules of decanethiol in the SAM.



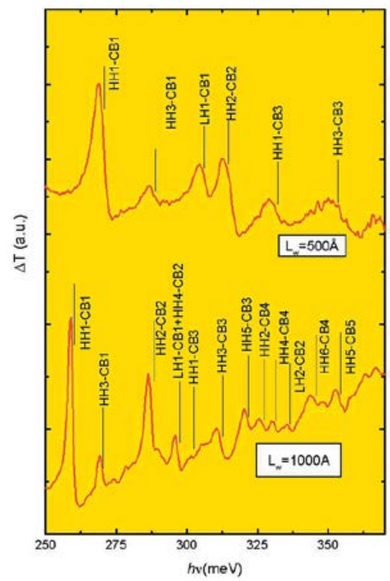
[Ryan E. Doezema]

emeritus professor

Regents' Professor

B.A. 1964 Calvin College

Ph.D. 1971 University of Maryland



A plot of the spectra for excitons (electron-hole pairs) in parabolic InSb quantum wells with different widths. The samples were grown at OU. The figure is labeled by the transition type, between heavy hole (HH) or light hole (LH) states to conduction band (CB) electron states.

My research interests center on the magneto-electronic properties of semiconductors. The work is focused on the lower-dimensional electron systems formed in synthetically created quantum wells and superlattices. Photonic transitions between quantum levels in the wells, and between magnetic levels induced by strong external magnetic fields, are studied using both a far-infrared, optically-pumped laser system as well as a Fourier transform infrared spectrometer. Our group's goals include the determination of electron dispersion as well as relaxation processes.

We are especially interested in novel properties of quantum-well systems caused by band structure effects such as extreme non-parabolicity. Our work is made possible by the flexibility for designing quantum-well systems with the MBE system as part of the Center for Semiconductor Physics in Nanostructures (C-SPIN). Our experiments concentrate on the narrow-gap system InSb which, as a quantum-well material, shows much promise for infrared and laser devices. We have been able to determine the defining characteristics of the binding potentials for these quantum wells (gap mismatch and band offset). We have observed spin resonance in this system and, in asymmetric wells, evidence of spin splitting in zero magnetic field because of strong spin-orbit coupling. Spin-orbit effects are also responsible for spin-dependent anticrossing behavior which we recently observed in this system.

A recent study of the exciton spectrum in high magnetic fields has led to first results in understanding the holes in InSb quantum wells that subsequemt cyclotron resonance experiments have confirmed.

C.K. Gaspe, M. Edirisooriya, T.D. Mishima, P.A.R. Dilhani Jayathilaka, R.E. Doezema, S.Q. Murphy, M.B. Santos, L.C. Tung and Y-J. Wang, "Effect of Strain and Confinement on the Effective Mass of Holes in InSb Quantum Wells," *J. Vac. Sci.Tech.B* **29**, 03C110 (2011).

M.B. Santos, M. Edirisooriya, T.D. Mishima, C.K. Gaspe, J. Coker, R.E. Doezema, X. Pan, G.D. Sanders, C.J. Stanton, L.C. Tung, and Y-J. Wang, "Cyclotron resonance in p-doped InSb quantum wells," *Physics Procedia* **3**, 1201 (2010).

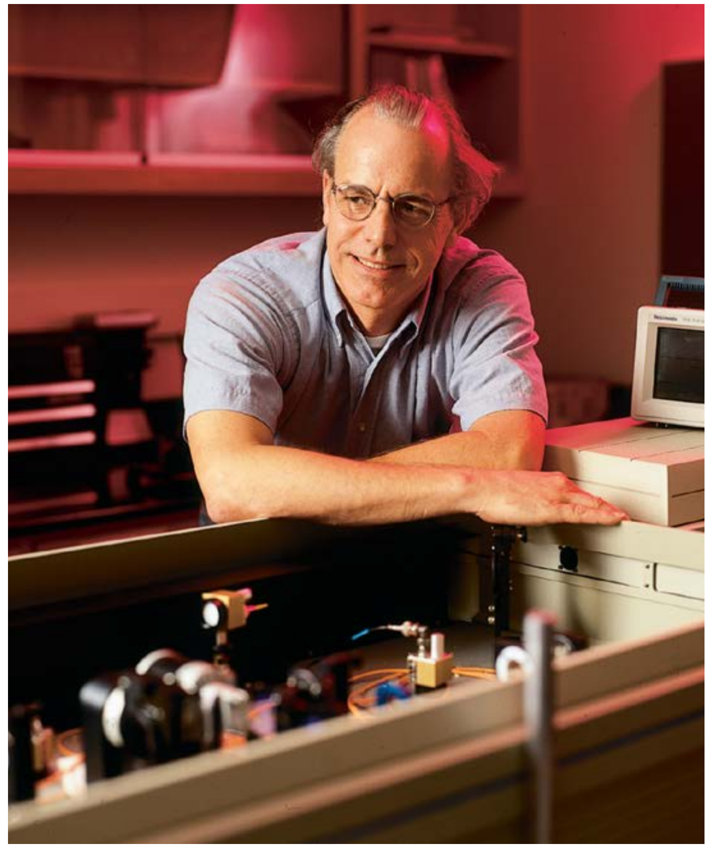
W. Gempel, X. Pan, T. Kasturiarachchi, G.D. Sanders, M. Edirisooriya, T.D. Mishima, R.E. Doezema. C.J. Stanton, and M.B. Santos, "Magnetoexcitons in Strained InSb Quantum Wells," *Springer Proceedings in Physics*, **119**, 213 (2008).

[John E. Furneaux]

professor

B.S. 1969 U.S. Military Academy

Ph.D. 1979 University of California, Berkeley



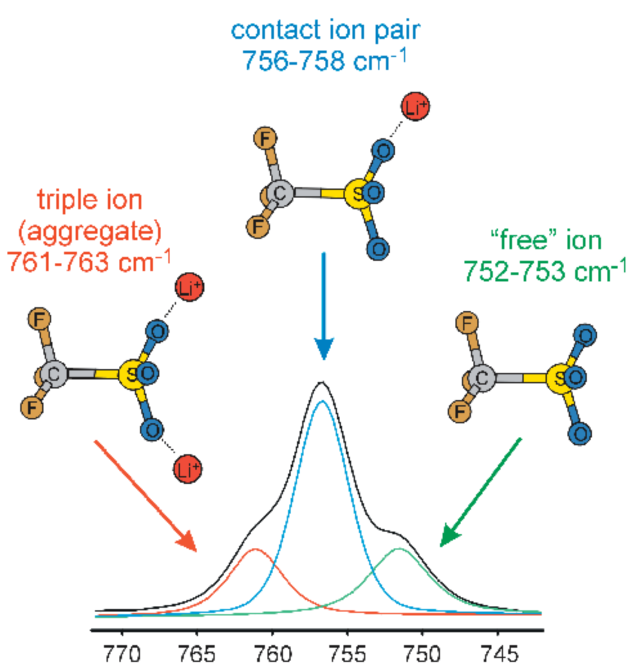
My main research effort is in lithium ion conducting polymers in collaboration with Professor Frech in Chemistry. We are particularly interested in the interactions between the polymer and the ion conducting salt that can provide insight as to the mechanisms of Li ion diffusion. We are studying these properties by combining two newly available technologies, a state-of-the-art tunable pulsed laser system including an optical parametric oscillator (OPO), and a step-scan FTIR.

We are also studying ionic association and polymer configurations and coordinations as a function of salt concentration and temperature in order to understand the basic interactions in these systems. We have ongoing collaborations for novel polymer preparations with Dan Glatzhoffer in chemistry, for modeling with Ralph Wheeler in chemistry, and with researchers at the University of St. Andrews, Scotland, and Uppsala University, Sweden, where I was on sabbatical in 1997-1998.

Sabina Abbrent, Jan Lindgren, J. E. Furneaux, Jorgen Tegenfeld, and C. Wendsj, "A Comparative Study of Gel Electrolytes Containing Polar of Non-Polar Polymer Chains," Solid State Ionics, in preparation.

J. E. Furneaux, S. V. Kravchenko, Whitney Mason, V. M. Pudalov and, M. D'Iorio, "Scaling of a Metal/Insulator Transition in a 2D System at B=0," *Surface Science* **949,** 361/362, (1996).

Whitney Mason, S. V. Kravchenko, and J. E. Furneaux, "Experimental Evidence of the Coulomb Gap in High-Mobility 2D Electron System in Silicon," *Surface Science* **953,** 361/362, (1996).



A plot of the IR spectrum of a lithium-ion conducting polymer sample. The ionic association of the trifolate anion affects peak position and intensity.

[Matthew B. Johnson]

professor

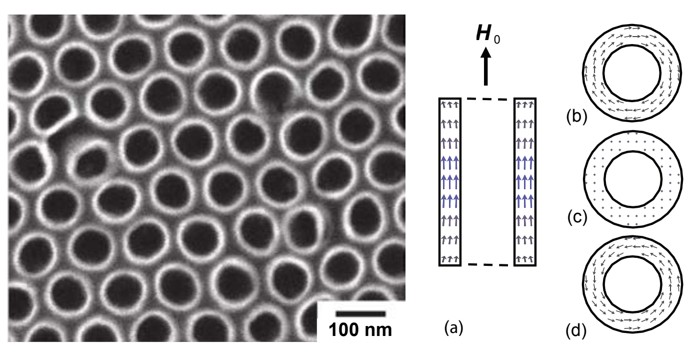
B.S. 1979 University of Waterloo

Ph.D. 1989 Caltech

Nanotechnology, the fabrication and manipulation of structures on the nanometer scale, has lead to the observation of new physical behavior and the development of new technologies. My research involves the fabrication, characterization, and study of a wide variety of individual nanostructures and their arrays.

Materials of interest include: semiconductors, ferro-electrics and ferro-magnets, superconductors and polymers through nanotubes. In particular, I am interested in well-ordered arrays of nanostructures because such arrays will show new collective properties in much the same way that crystals show new properties compared with the properties of the individual constituent atoms or molecules from which they are made.

Fabrication techniques used in my lab include: lithography involving electron and ion-beams as well as scanning probe microscopy, and deposition from thermal and electron-beam evaporation and sputtering through molecular beam epitaxy. Characterization involves various types of scanning probe microscopies, x-ray diffraction, optical techniques including, UV-Vis, photoluminescence, various infrared techniques; scanning electron microscopy (SEM) and conventional and high-resolution transmission electron microscopy (TEM). Collective behavior etc. are studied using low-temperature magneto-transport available at OU and magnetometry, terahertz spectroscopy, Brillouin scattering, low-temperature magnetic force microscopy, and other more exotic techniques available through National Labs and various collaborations.



Left: Scanning electron microscope micrograph of an hexagonal array of the high-aspect-ratio nickel nanorings.
Right: Simulated magnetization distributions (H_0 = 5 mT) for a nickel nanoring in the twisted bamboo phase. (a) A cross section containing the ring axis, and (b) top, (c) middle, and (d) bottom cross sections normal to the ring axis (viewed along the H_0 direction).

J.C. Keay, P.R. Larson, K.L. Hobbs, M.B. Johnson, J.R. Kirtley, O.M. Auslaender, and K.A. Moler, "Sequential vortex hopping in an array of artificial pinning centers," *Phys. Rev. B* **80,** 165421 (2009).

Z. Tian, R.Q. Yang, T.D. Mishima, M.B. Santos, R.T. Hinkey, M.E. Curtis, and M.B. Johnson, "InAs-based interband cascade lasers near 6 mm," *Electron. Lett.* **45**, 48 (2009).

H. Wang, R.P. Nair, M. Zou, P.R. Larson, A.L. Pollack, K.L. Hobbs, M.B. Johnson, and O. K. Awitor, "Friction Study of a Ni Nanodot-patterned Surface," *Tribology Lett.* **28**, 183 (2007).

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Z.K. Wang, H.S. Lim, H.Y. Liu, S.C. Ng, M.H. Kuok, L.L. Tay, D.J. Lockwood, M.G. Cottam, K.L. Hobbs, P.R. Larson, J.C. Keay, G.D. Lian, and M.B. Johnson, "Spin Waves in High-aspect-ratio Nickel Nanorings," *Phys. Rev Lett.* **94**, 137208 (2005).

D.G. Cooke, F.A. Hegmann, Y.I. Mazur, W.Q. Ma, X. Wang, Z.M. Wang, G.J. Salamo, M. Xiao, T.D. Mishima. M.B. Johnson, "Anisotropic photoconductivity of InGaAs quantum dot chains measured by terahertz pulse spectroscopy," *Appl. Phys. Lett.* **85**, 3839, (2004).

[Bruce A. Mason]

associate professor

American Physical Society Fellow

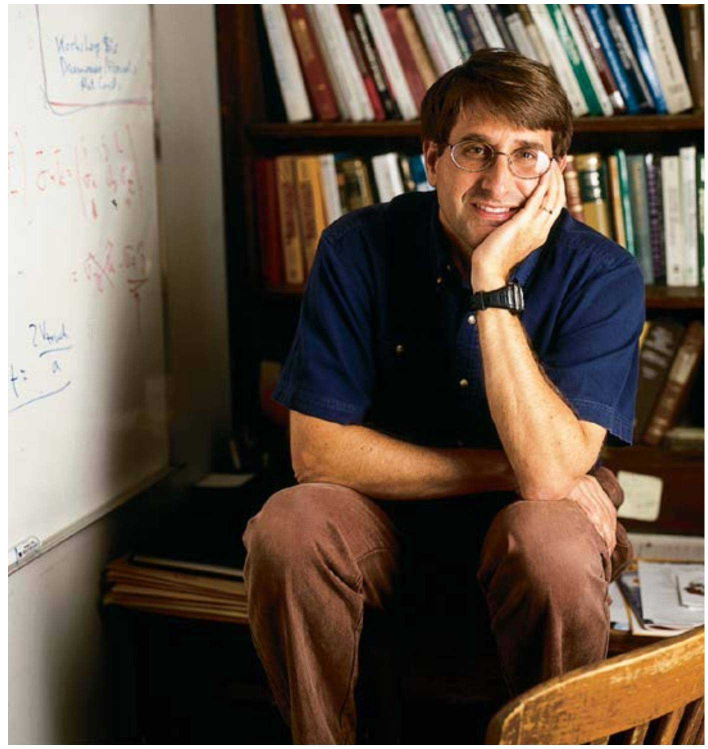
Longmire Prize for Scholarship of Teaching

B.A. 1980 Oberlin College

Ph.D. 1985 University of Maryland

Trained as a solid state theorist, in the mid-1990's I started to explore ways in which the computational tools used in research could expand and enliven courses for both graduate and undergraduate students. This led to the study of new technologies for supporting learning and ways to help other faculty take advantage of these tools.

My work now focuses on efforts to enhance physics and astronomy education through web-based resources. I am director of the ComPADRE network of educational resource collections (http://www.compadre.org), a collaboration of the American Association of Physics Teachers, the American Physical Society, and the Society of Physics Students and part of the National Science Digital Library (http://nsdl.org). I am also the editor of the physics collection on MERLOT (http://www.merlot.org), a multi-discipline and multi-institutional organization promoting the scholarly use of multimedia educational resources.



Mario Belloni, Wolfgang Christian, Bruce Mason, Open Source and Open Access Resources for Quantum Physics Education. *J. Chem. Ed.* **86**, 125 (2009).

Bruce Mason, Digital Libraries in Support of Science Education: A Case for Computational Physics, *Comp. in Sci. & Eng.* **8**, 62 (2006).

M.F. Khodr, P.J. McCann, and B.A. Mason, Optimizing and Engineering EuSe-PbSe$_{0.78}$Te$_{0.22}$-EuSe Multiple-Quantum-Well Laser Structures, *IEEE J. Quantum Electron.* **34,** 1604 (1998).

C.E. Hembree, B.A. Mason, J. T. Kwiatkowski, J. Furneaux, and J.A. Slinkman, Calculations of the spin dependence of transport and optical properties in wide parabolic quantum wells, *Phys Rev B* **50**, 15197 (1994).

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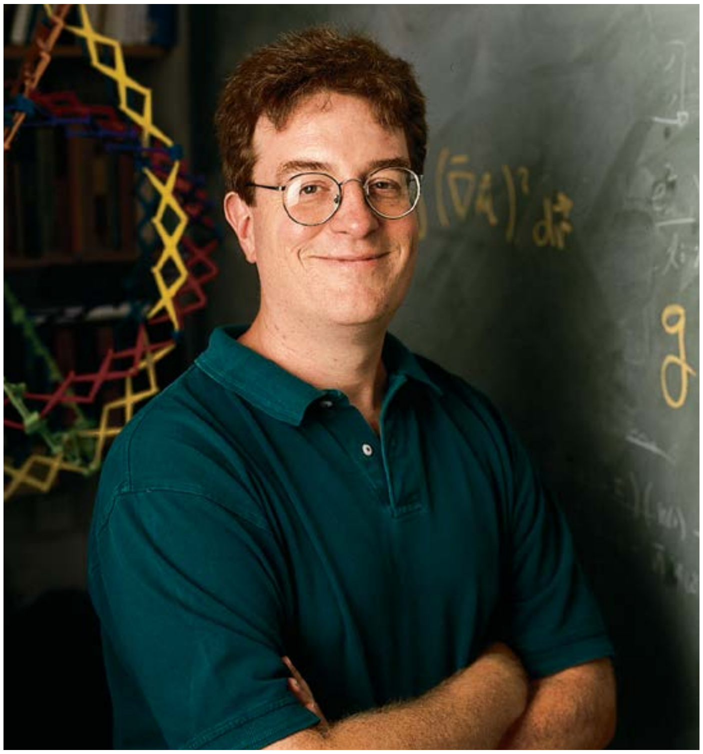


[Kieran Mullen]

professor

Presidential Professor

B.S. 1982 Georgetown

Ph.D. 1989 University of Michigan

I am interested in the physics of novel effects in mesoscopic systems. My recent work falls in three broad categories: submicron electronic devices, heat transport in carbon nanotubes and graphene nano-sheets, and two dimensional electron gasses.

"Mesoscopic" systems are those in between the regimes of classical and quantum physics, typically less than a micron across. Experimentalists can routinely fashion devices so small that the electrostatic energy of a single electron can control the flow of current, or in which electrons can travel coherently from one side of the device to the other. The theoretical challenges are to understand how the quantum mechanical effects in the microscopic device couple to macroscopic world of voltmeters and ammeters, and how to take advantage of the novel dynamics for new applications.

Heat transport in small devices and nano-composites is also often not diffusive. In order to understand how energy flows through such systems we have to go beyond a Boltzmann equation approach and look at the dynamics of the electron and phonon modes. Careful control of material properties on the nanometer scale can enable us to design devices and materials with novel thermal and electrical properties.

My third area of interest the dynamics on electrons when they are confined to a two dimensional plane. This leads to a host of interesting topics including localization, unusual behavior in a strong magnetic field, and the existence of electron "bubbles" called skyrmions.

"Using normal modes to calculate and optimize thermal conductivity in functionalized macromolecules," Abdellah Ait Moussa and Kieran Mullen, *Phys. Rev. E* **83**, 056708 (2011).

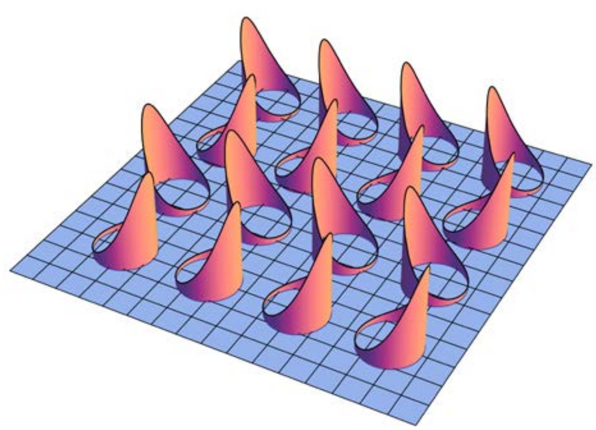
"R-Matrix Theory for Nanoscale Phonon Thermal Transport across Devices and Interfaces," K.G.S.H. Gunawardana, K. Mullen, *Numerical Heat Transfer, Part B: Fundamentals* **60**(4), 2011.

"Optimal Matching of Thermal Vibrations into Carbon Nanotubes," K.G.S.H. Gunawardana and K. Mullen, *Proceedings of 41st ISTC* -Witchita, KA, Oct 19-22, 2009, *SAMPE Journal*.

"Theory of Activated Transport in Bilayer Quantum Hall Systems," B. Roostaei, K.J. Mullen, H.A. Fertig, and S.H. Simon, *Phys. Rev. Lett.* **101**, 046804 (2008).

"Polarization transitions in interacting ring 1D arrays," Bahman Roostaei and Kieran J. Mullen, *Phys. Rev. B* **78**, 075411 (2008).

"Calculated Thermal Properties of Single-Walled Carbon Nanotube Suspensions," Hai M. Duong, Dimitrios V. Papavassiliou, Kieran J. Mullen, Brian L. Wardle, Shigeo Maruyama, *J. Phys. Chem. C*, **50**, 112 (2008).



A plot showing the charge density of a 2D array of singly charged nano-rings in the anti-ferroelectric state. Increasing the distance between the rings produces a quantum phase transition to a uniform, unpolarized state.

[Sheena Murphy]

associate professor

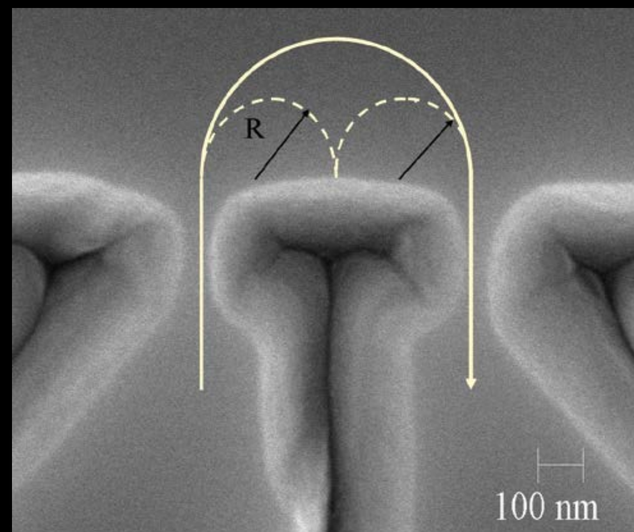
B.S. 1984 MIT

Ph.D. 1991 Cornell

Over the last few years, my group has focused on the study of electronic systems in confined geometries. Two-dimensional confinement is achieved when the electrons reside in a thin low bandgap semiconductor sandwiched between layers of a higher bandgap material. Further confinement results from processing the semiconductor sample into wires or dots using optical and electron-beam lithography techniques. As of late, it is in these reduced dimensional systems that some of the more significant developments in condensed matter physics have been found such as the integer and fractional quantum Hall effect, and quantized conductance in point contacts, to name a few.

At the University of Oklahoma, we have access to a particularly interesting semiconductor system, InSb. This material has an extremely low electron effective mass resulting in high mobility and a very large Lande g factor resulting in large spin effects. My group has been engaged in the study spin-orbit and spin transport in this system.

We perform our experiments at low temperatures (from 10K to 0.01K) and in high magnetic fields (up to 15 Tesla). In addition to our low temperature/high field facilities, we also use the optical lithography and electron-beam lithography facilities of the Solid State group. In this facility we can fabricate devices with tens of nanometer-sized features, package them for our experiments and perform room temperature inspection and characterization. In addition our affiliation with the OU/Arkansas Materials Center gives us access to a number of other magnetic, optical and electronic probes.



The figure shows a scanning electron microscope image of an InSb magnetic focusing device. In such a device an electron injected from the left entrance slit will be focused into the right hand slit under the influence of an appropriately tuned perpendicular magnetic field. Two focusing trajectories are shown: the solid trace for a low magnetic field; and the dotted trace corresponding to a higher magnetic field. Large spin-orbit effects in InSb based devices suggest that electrons with different spins may travel along different paths allowing for the intriguing possibility of spin-polarized currents.

"Comprehensive doping and temperature studies of spin relaxation in InSb," D. Guzun, E.A. DeCuir, Jr., Vas. P. Kunets, Yu I. Mazur, G. Salamo, S.Q. Murphy, P.A.R. Dilhani Jayathilaka, T.D. Mishima, M.B. Santos, *Appl. Phys. Lett.* **95**, 241903 (2009).

"Measurement of the Dresselhaus and Rashba Spin-orbit coupling via weak anti-localization in InSb quantum wells," A. R. Dedigama, S. H. Gunawardana, S. Q. Murphy, M. Edirisooriya, N. Goel, T. D. Mishima and M. B. Santos, in *Narrow Gap Semiconductors 2007,* Proceedings of the 13th International Conference, U. K. Book Series, Springer Proceedings in Physics, v.119, (2008).

"Current focusing in InSb heterostructures," A. R. Dedigama, D. Deen, S. Q. Murphy, N. Goel, J. Keay, M. B. Santos, K. Suzuki, S. Miyashita, and Y. Hirayama, *Physica* E34 647 (2006).

[Michael B. Santos]

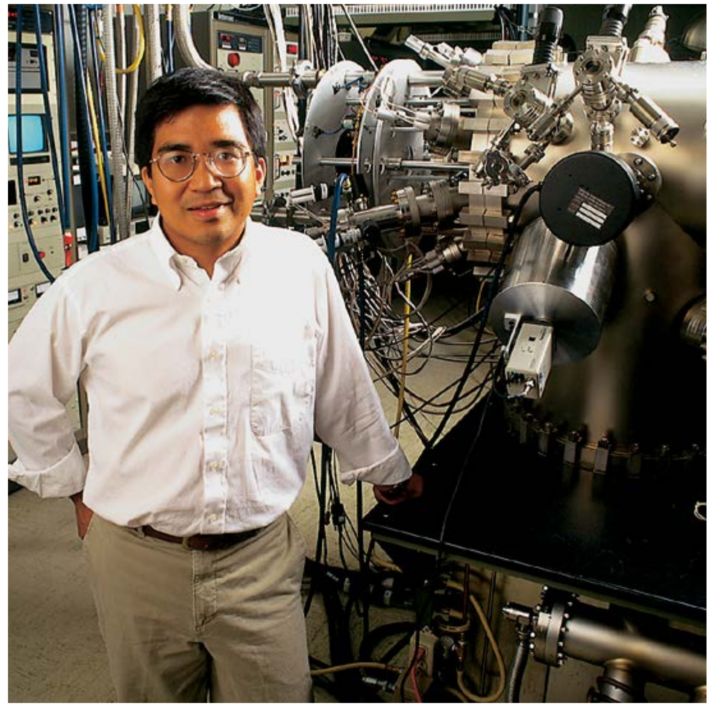
professor

B.S. 1986 Cornell

Ph.D. 1992 Princeton

The interests of my research group focus on the growth of narrow-gap semiconductors and device applications for these materials. We use molecular beam epitaxy to grow heterostructures for three research efforts: high-mobility and spin-dependent electron transport experiments, mid-infrared interband-cascade devices, and nanostructures for photovoltaic applications. Because the bandgap of InSb is the smallest of all binary III-V compounds, two-dimensional electron systems in InSb quantum wells have a small effective mass, a large g-factor, and strong spin-orbit effects. The room-temperature mobility in these structures is higher than in quantum wells made of any other semiconductor. We are exploring ways to exploit this and other features in devices based on ballistic transport and electron spin. Magneto-transport studies on these materials are being pursued with Sheena Murphy's group and external collaborators. In addition, we are working with Sheena Murphy's group on the search for new materials that exhibit topological-insulator behavior.

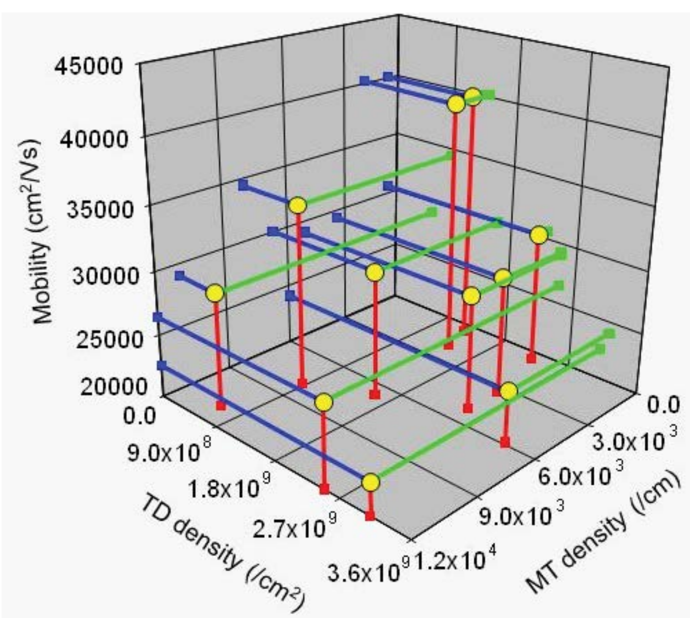
Our group also grows InAs/GaSb/AlSb structures for research on mid-infrared devices, including lasers and photodetectors, based on the interband-cascade architecture. This effort is led by Rui Yang in the electrical engineering department and also involves Matthew Johnson's group. Our group's newest effort is a collaboration with Ian Sellers' group and industrial collaborators on superlattice and quantum-dot structures for studying mechanisms that would enable third-generation photovoltaic devices.



"InAs-based mid-infrared interband cascade lasers near 5.3 µm," Z. Tian, Y. Jiang, L. Li, R.T. Hinkey, Z. Yin, R.Q. Yang, T.D. Mishima, M.B. Santos, and M.B. Johnson, *IEEE J. Quantum Electron.* **48**, 915 (2012).

"Nonlinear Magnetic Field Dependence of Spin Polarization in Two-Dimensional Electron Systems," K.F. Yang, H.W. Liu, T.D. Mishima, M.B. Santos, K. Nagase, Y. Hirayama, *New Journal of Physics* **13**, 083010 (2011).

"Effect of Strain and Confinement on the Effective Mass of Holes in InSb Quantum Wells," C.K. Gaspe, M. Edirisooriya, T.D. Mishima, P.A.R. Dilhani Jayathilaka, R.E. Doezema, S.Q. Murphy, M.B. Santos, L.C. Tung and Y-J. Wang, *Journal of Vacuum Science and Technology B* **29**, 03C110 (2011).



A plot of the electron mobility in an InSb quantum well at 300K, as a function of the densities of threading dislocations (TD) and microtwins (MT). One goal of modern semiconductor research is to grow perfect layered structures with no defects, in order to achieve high mobility for electrons travelling through the structure.

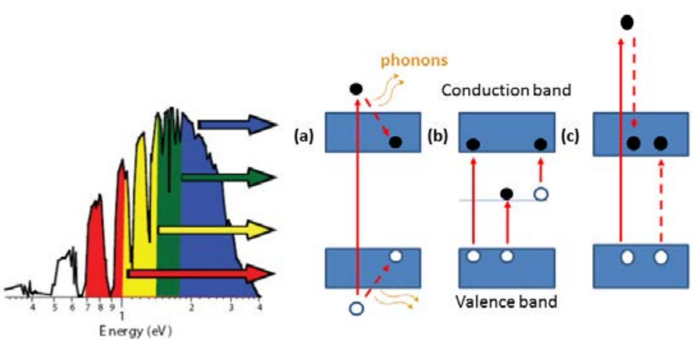
[Ian R. Sellers]
assistant professor

B.Eng. 1999 University of Liverpool
M.Sc. 2000 Imperial College London
Ph.D. 2004 University of Sheffield

The development of epitaxial growth of semiconductors has enabled the control and manipulation of structures on an atomic scale. As such, it is now possible to investigate experimentally the fundamental properties of semiconductor nanostructures while creating interesting opportunities for next generation semiconductor devices. My research at OU focuses on the magneto-optical and optoelectronic properties of semiconductor quantum dots.

The primary focus of this research is in utilizing experimental techniques such as magneto-photoluminescence, electroluminescence, and impedance spectroscopy, amongst others, to investigate the physical properties of semiconductor quantum dots and nano-rings. My interest in these areas is driven primarily by possible applications in both magnetic memory elements and next generation photovoltaics. Specifically, we have been investigating magneto-optical effects such as the optical Aharonov-Bohm effect and magnetic polarons in semiconductor nano-rings, and the feasibility of utilizing quantum dot structures in 3rd generation photovoltaics. In addition, I have also been working with industrial collaborators at the Sharp R&D facility in Oxford (UK) to investigate the physical properties of dilute nitride semiconductors for applications in multi-junction solar cells for concentrator photovoltaics.

As well as working closely with the groups of Santos and Mullen here at OU, I have ongoing collaborations with the University of Oxford and University College London in the UK, CRHEA-CNRS in France, as well as SUNY Buffalo, Ohio University and Queens College CUNY, here in the United States.



Since solar radiation consists of broad band emission the single energy gap of semiconductor solar cells cannot harness the full energy generated by the sun. Photons emitted with an energy less than the band gap are not absorbed, while higher energy photons relax rapidly to the band edge via the generation of heat as illustrated in (a). Third generation photovoltaics aims to improve sub-band absorption of photons through the creation of an intermediate band (b) or by generating additional carriers via multi-exciton generation (c). QDs are strong candidates for both processes.

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My primary research interests are low dimensional quantum critical systems. This is the case of superconductors with nodal gaps, such as cuprates, and also of a broad class of materials with Dirac-like electronic excitations, known as Dirac materials.

The most popular examples of Dirac systems in Condensed Matter today are graphene and topological insulators and superconductors. Graphene, one of my current topics of research, is a new allotropic form of carbon formed by a single atomic layer of graphite. As a Dirac material, its elementary excitations behave as massless Dirac fermions and mimic properties known in quantum electrodynamics. The quantum numbers which appear from its electronic structure offer a rich playground for the emergence of new quantum phenomena at room temperature.

My current interests range from strongly correlated phases in low dimensional systems, such as superconductivity and quantum magnetism, to problems involving disorder, localization, strain fields, phonons and electron-electron interactions in perturbative and non-perturbative regimes. I am also interested in mesoscopic systems in general, which offer an interesting window for the observation of new quantum phenomena.

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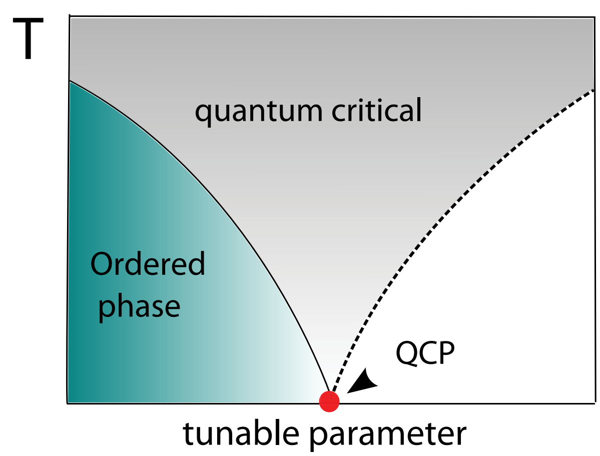

Generic phase diagram temperature vs a tunable parameter near a quantum critical point (QCP). Examples of quantum critical phases theoretically predicted to emerge in Dirac materials include superconductivity and the Kondo effect, among other possible states. In those systems, the quantum criticality emerges from the suppression of the electronic density of states at the Dirac point.