Areas of particular interest:

Molecular Spectroscopy Using Ring-Down Cavities and its Application to Semiconductor Crystal Growth
KA Bertness 50.81.52.B5883
Gases such as phosphine, ammonia, arsine, nitrogen, silane, and germane are widely used in semiconductor synthesis and processing. Most of these processes are highly sensitive to contamination, although the precise incorporation mechanisms and concentrations of concern are poorly known. We have developed cavity ring-down spectroscopy as a tool for high sensitivity measurements of impurities in gases along with the capability of using many of these gases in gas-source molecular beam epitaxy growth. The system has a sensitivity for measuring water as an impurity down to approximately 30 ppb in phosphine and 10 ppb in nitrogen using laser light near 935 nm. We anticipate the availability of new laser sources in the next few years that will significantly enhance the flexibility and sensitivity of the instrument. Because of its fast time response, cavity ring-down spectroscopy is also useful for measuring time-dependent effects and confirming the efficacy of purifiers. We invite proposals extending the capability of the instrument to new impurities or host gases (e.g, novel studies of correlations of gas properties with semiconductor crystal properties and fundamental studies of the impurity incorporation process).

Photonic Crystals
R Mirin 50.81.52.B3901
Photonic crystals are meta-materials whose optical properties are determined by the photonic band structure that arises from resonant photon scattering off the nanometer-scale physical structure, in direct analogy with well-established concepts of electronic bands in semiconductors. Photonic crystals offer the new possibility of creating materials with custom-tailored bandgaps and dispersion curves, liberating light-emitting devices from the constraints caused by the underlying material dispersion. We are pursuing an active program of photonic crystal dispersion engineering with the aim of vastly enhancing the performance of semiconductor light emitters. Specifically, we are designing, fabricating, and measuring photonic crystal nanocavities for Purcell-enhanced single-photon sources, circular Bragg gratings for enhanced light extraction in LEDs, chirped waveguide gratings for dispersion control in semiconductor mode-locked lasers, and waveguide arrays for nonlinear soliton formation. Our capabilities include electromagnetic modeling, nanofabrication, quantum-optical measurements, and ultrafast measurements.

Semiconductor Quantum Optics
R Mirin 50.81.52.B4380
We are developing a regulated source of single photons by fabricating a single photon turnstile with a single quantum dot. Our goals include spontaneous emission control and delivery of the individual photons to any other on-chip location through photonic crystal waveguides. Important technologies for this project include microcavities, microdisks, photonic crystals, and nonlinear optics. We invite experimental and/or theoretical proposals that can complement and expand on this ongoing effort. Available resources include epitaxial semiconductor growth, e-beam lithography, fabrication facilities, and finite difference time domain software for electromagnetic modeling.

Optical Spectroscopy of Quantum Dots
R Mirin 50.81.52.B5884
Self-assembled semiconductor quantum dots have been demonstrated for many optoelectronic devices (lasers, optical amplifiers, and photodetectors) and proposed for novel applications such as quantum computing. However, there is still a lack of fundamental knowledge about the optical and electronic properties of these quantum dots, such as homogeneous linewidth, oscillator strength, coupling, and carrier escape mechanisms, especially at the single quantum dot level. We invite proposals that will investigate these or other fundamental characteristics of self-assembled quantum dots.

Coherent Spectroscopy of Quantum Dots
R Mirin 50.81.52.B6459
We are currently performing high-resolution optical spectroscopy on self-assembled semiconductor quantum dots. Our technique employs narrow linewidth tunable lasers and heterodyne detection. Recent results from our group have shown that these structures are almost purely radiatively broadened at 9 K. We are soliciting proposals to extend this experimental method to investigate multi-exciton and charged exciton complexes. We are interested in the fundamental properties of these transitions as well as the coherence in these coupled-state systems. Optical phenomena such as electromagnetic-induced transparency should be observable.

MBE Growth of Quantum Dots
R Mirin 50.81.52.B5885
We are developing single photon sources based on epitaxially grown single quantum dots. Many quantum dots are deposited during growth and individual dots are isolated by masking and etching. The goal of this project is to use novel methods of controlling the exact placement and size of the quantum dots. This will enable schemes of coupling two or more quantum dots for applications in quantum information and quantum optics.

Engineered Quantum States of Light
R Mirin, TS Clement, SD Dyer 50.81.52.B6460
We are investigating methods of creating new quantum states of light such as Schrodinger cat states, NOON states, and Fock states. These new states have a variety of applications, including linear optical quantum computing, quantum metrology (e.g., Heisenberg limited interferometry), and fundamental physics (loop-hole free Bell measurements). We are particularly interested in utilizing our high quantum efficiency photon number resolving detectors to enable creation of these states. Our group includes both experimentalists and theorists. We invite proposals to further develop and utilize quantum states of light.

Spectroscopy of Wide-Bandgap Mesoscopic Materials Characterization by CW and Ultrafast Nonlinear Optics
NA Sanford, JB Schlager 50.81.52.B4766
Scanning near-field and confocal microscopies provide unique methods of characterizing a wide variety of semiconductor, dielectric, and hybrid optoelectronic materials and interfaces. We are developing methods of nanoscopic multiphoton spectroscopy and nonlinear optics for examining local structural and electronic properties of the wide-bandgap III-nitride alloy semiconductors with particular emphasis on quantum-confined heterostructures formed in compound III-nitride nanowires. The techniques include ultraviolet (UV) second-harmonic generation in addition to cw and time-resolved, multiphoton UV spectroscopy that employ NSOM and confocal techniques. We are particularly interested in the study of local defects, polytyping, inversion domains, and alloy segregation. We are also interested in studies of nanoscale strain and piezoelectricity, and the impact of such phenomena on the spectroscopy of quantum confined wires and discs. Our efforts are generally collaborative with other NIST staff that specialize in high-resolution cathodoluminescence, TEM, EBSD, and CBED.

Nanowire Resonators, Oscillators, Mechanical Properties, and Applications
NA Sanford, KA Bertness 50.81.52.B6728
Nanowires fabricated in GaN and related III-nitride compound semiconductors offer compelling functionality for nanomechanical, NEMS, sensors, oscillators, resonators, and clocks. This work is a natural extension of our related efforts in the growth and characterization of wide-bandgap nanowire structures. We invite proposals that seek to explore studies of fundamental

coupled piezoelectric and nanomechanical phenomena in III-nitride nanowires, as well as proposals that address application areas for these structures such as nanowire surface functionalization leading to advanced sensor development.

Metrology and Prototyping of Wide-Bandgap Semiconductor Quantum Nanowire Structures and Devices

NA Sanford, KA Bertness, A.Roshko 50.81.52.B5887

Semiconductor quantum nanowires offer new applications in areas such as chemical sensors, NEMs, nanolasers, and nanoscale thermoelectric devices. A key aspect of these structures that makes the research challenging and enables the utility of various nanowire devices is that many physical phenomena do not scale from the macro to nano regimes. Our research primarily focuses on nanowires grown from wide-bandgap semiconductors including the group III-nitride (GaN, AlN, InN) and ZnO material systems. We are interested in nanowire growth techniques that include MBE, vapor transport, and catalyst methods. We are interested in a range of research topics, from the applied to the fundamental, covering such areas as understanding the evolution of the microstructure of nitride semiconductors; development of nanotemplates for patterned growth of nanowires; optimization of p-type doping in nanostructures; developing methods of making electrical contact to single nanowires or arrays of nanowires; and development of new measurement methods for quantifying nanoscale piezoelectric, transport, and optoelectronic phenomena. Current device interests include nanowire lasers, LEDs, photodetectors (primarily in the UV), UV and visible light emitters (i.e., for solid state lighting and water purification), and field emitting ion sources for mass spectrometry. We are also working on the design and fabrication of prototype nanowire electronic devices such as FETs. We welcome proposals aimed at new technological aspects of semiconductor quantum nanowire research and application. Our characterization resources include triple-axis x-ray diffraction, atomic force microscopy, scanning electron microscopy, ultrafast nonlinear optical characterization, near-field scanning optical microscopy, cw and time-resolved photoluminescence, device processing, and electrical measurements. Opportunities exist for collaborative work within NIST for more specialized characterization such as TEM, field-emission SEM, STM, cathodoluminescence, nanoscale electrical and thermal measurements.

Our existing programs use gas-source molecular beam epitaxy growth of nitrides, phosphides, and arsenides with a focus on nanostructures. Other in-house collaboration includes vapor phase and catalyst growth methods for nanowire growth. Also, a wide range of clean room processing equipment is available in order to carry out prototyping of specialized nanostructures.

Quantum Structures within Semiconductor Nanowires

KA Bertness, NA Sanford, JB Schlager 50.81.52.B6960

Semiconductor nanowires offer a unique template for arrays of quantum dots with a degree of spatial control not presently possible with planar growth methods. GaN nanowires allow unique coupling of mechanical, electrical and optical properties which can be exploited to vary transport and optical transition efficiency between quantized nanostructures. For example, variations in nanowire alloy composition can be used to create tunnel junctions for single electron transistors which are grown in series with quantum dots. Quantum dots can be coupled with surface plasmons to create new probes with spatial resolution below 10 nm. The nanowires can also serve as a quasi-one-dimensional growth substrate with nonpolar surfaces onto which strings or shells of quantum dots can be grown. Our existing programs have extensive capability for group III nitride nanowire growth and characterization (see opportunity 50.81.52.B5887). Proposals that involve simple extensions to other materials systems are also welcome.

Templates for Nanostructure Positioning

A Roshko, KA Bertness 50.81.52.B6961

Nanostructures are of significant interest due to their unique physical properties and potential for electronic, electromechanical and optoelectronic devices. However, current growth methods lead to random spatial distributions and, therefore, relatively large size distributions. Lack of homogeneity reduces the potential of nanostructures for many applications. We are interested in developing substrates with templates based on surface morphology, strain, or other means for controlled positioning of nanostructures including semiconductor quantum dots and/or wide bandgap nanowires. We have extensive facilities for nanostructure growth and characterization (see opportunity 50.81.52.B5887.)

Superconducting and Nanometer-Scale Devices for Infrared to Millimeter-Wave Applications

E Grossman 50.81.52.B1533

Our goal is to explore the physical mechanisms and limitations of devices operating in the frequency range from 0.1 to 100 THz, and to develop novel devices and measurement techniques. For the short wavelength end, we use electron-beam lithography to fabricate the submicron structures required to minimize parasitic impedances. One specific research area includes mixers and harmonic mixers for frequency synthesis and high-resolution spectroscopy; another research area involves IR to millimeter-wave imaging radiometry. Our main focus is on high-sensitivity bolometers and superconducting multiplexers based on SQUIDS. Other devices of interest include high-Tc superconducting bolometers; room-temperature, thin-film bolometers; lithographic and/or micromachined coupling structures, particularly antennas and integrating cavities; superconducting mixers/rectifiers; and room-temperature mixers/rectifiers (e.g., lithographic metal-insulator-metal diodes).

Flat Panel Display Metrology

EF Kelley (Boulder) 50.81.52.B4369
PA Boynton (Gaithersburg) 50.81.51.B4369

NIST's flat panel display laboratory serves the display industry by developing and quantifying good electronic display metrology for industrial use. With the explosion of the information age, the Internet, and e-commerce, the use of flat panel displays has become a growing need for US industries. Good display measurement methods are needed for several reasons: (1) specification language needs to rest solidly upon good metrology, (2) fierce competition between technologies requires good metrology to distinguish features, and (3) users and implementers of displays need accurate characterizations of displays for selection purposes. NIST is doing research in (1) equipment on improving measurements made on displays; (2) development of display metrology with various standards organizations; (3) development of display metrology assessment methods and equipment to provide guidance for the implementation of good measurement methods in the display industry; and (4) display reflectance characterization, measurements, and modeling using the bi-directional reflectance distribution function. Opportunities are available at both Boulder and Gaithersburg campuses.

High Speed Optoelectronics Measurements

PD Hale, DF Williams 50.81.52.B4008

Increasing data rates and bandwidths of optical telecommunications, cable television systems, remote microwave antenna links, and computer data interconnections all require advanced techniques for accurately determining optical transmitter and receiver frequency response in both magnitude and phase. Methods being investigated at NIST include heterodyne and ultrashort pulse technologies. Current research focuses on fully calibratable measurement of frequency response with low uncertainty to 110 GHz and extension to 400 GHz in the near future. We are especially interested in the measurement of response phase with low uncertainty using high-speed sampling techniques and in methods for verifying these measurements in a coaxial or on-wafer environment. Future calibration artifacts will require fabrication of ultrafast photodetectors. We are also interested in theoretical studies of the modulation characteristics, frequency response, spectral response, saturation, and electrical characteristics of optical receivers that would further enhance our metrology effort.

High-Speed Optical Receivers and Optoelectronic Integrated Circuits

PD Hale, R Mirin, DF Williams 50.81.52.B4767

The need for ever smaller size and increased bandwidth of optoelectronic devices is requiring these devices to be packaged in hybrid modules and optoelectronic integrated circuits. Characterization of the frequency response and electrical properties of these devices requires a change in measurement strategy away from coaxially connected modular devices to on wafer measurements. We are developing a new fully calibratable on-wafer measurement paradigm for calibrating optoelectronic and electronic devices to bandwidths exceeding 110 GHz. We are interested in fabricating new high-speed receivers that will be used as calibration artifacts in this new measurement strategy. Possible designs might include metal-semiconductor-metal photoconductive switches or p-i-n photodiodes grown in low-temperature GaAs or InGaAs. The work will result in artifacts that will be used to calibrate high-speed measurement equipment.

Optical Pulse Characterization and System Monitoring

PD Hale, KB Rochford, CM Wang, KA Remley, DF Williams 50.81.52.B6436

Optical component measurements alone will not be adequate to design and operate the next generation of optical communications, which will include dynamic channel add/drop switching, routing, gain control, equalization, and dispersion compensation. Accurate methods to dynamically characterize system impairment by thorough measurements of optical signal amplitude, phase, jitter, and noise are needed. Research opportunities are available to develop methods that will assess system impairment, particularly methods that will discriminate between failure modes and offer insight into the strengths and weaknesses of various modulation, error correction, and dispersion compensation schemes.

Characterization of Dispersion Compensation and Equalization Schemes

PD Hale, KB Rochford, CM Wang, KA Remley, DF Williams 50.81.52.B6461

Various optical and electrical methods of dispersion compensation and gain equalization are now being employed to extend the length of short and long reach optical communications systems. Electrical impairments known as frequency dependent loss and multipath interference also appear in board level electrical interconnects, wireless communications, and data storage. Although the impairments appear in systems that differ greatly and can affect vastly different time scales, they can be addressed through similar techniques of equalization and filtering. We are soliciting methods for characterizing equalization and dispersion compensation methods, and particularly their efficacy for correcting low probability impairments.

Waveform Metrology

PD Hale 50.81.52.B5521

Current techniques used by industry for characterizing digital waveforms, both electrical and optical, are qualitative at best. As a result, the specifications for test equipment and communication systems are conservative and are not well understood. For example, the computer and communications industries both need measurements of different types of jitter and inter-symbol interference because these effects could cause erroneous bit transmission. We have developed a world-class capability for characterizing and calibrating equipment used in the acquisition of high-speed waveforms. We are looking for proposals that will investigate calibrated waveform measurement and the quantitative study of waveform metrics that characterize parameters such as random jitter, inter-symbol interference, and eye margin.

Tunable Laser Ensemble Development for Laser Radiometry

JH Lehman 50.81.52.B5888

The calibration of laser power and energy, and optical fiber meters over wavelengths ranging from 0.2 μm to 10 μm requires laser sources that are stable, broadly tunable, and having well defined optical properties (e.g., polarization, beam quality). Our goal is to go beyond merely demonstrating what wavelengths may be produced by novel methods. This will enable cost-efficient, routine, calibration services having low uncertainties. We may employ new methods and equipment or optimize existing methods and equipment to ensure that NIST can provide laser power measurement comparisons with standards laboratories around the world as well as manufacturers of laser and optical fiber power measurement equipment. Several new projects are under consideration to provide novel, robust methods for the generation and transportation of tunable laser light.

Carbon Nanotube Coatings for Laser Power and Energy Measurements

JH Lehman 50.81.52.B5889

Several areas of research are currently being pursued: improved coatings for thermal detectors, ultraviolet detectors resistant to damage and aging, and improved transfer standards for pulsed-laser radiation measurements. In each case, our goal is to develop and maintain optical detectors that are traceable to electrical standards for the purpose of maintaining calibration services in the area of laser power and energy measurements. Nearly all of the primary standards for laser power and energy measurements at NIST are based on thermal detectors. Our goal is to establish carbon nanotube coatings as a practical choice for the next generation of standards. We also employ a variety of photodiode-based detectors as transfer standards for routine laser power calibrations for our customers. In each of these areas, the practical matters of providing cost-efficient, routine calibrations having low uncertainties must be considered. Topics of interest also include new technologies and/or methods for developing and transferring detector-calibration information from one area to another.

Optical Properties of Carbon Nanotube Coatings

JH Lehman 50.81.52.B6729

Several areas of research are currently being pursued based on determination and modification of optical properties of bulk carbon nanotubes (CNTs) on a pyroelectric detector platform. Using this unique measurement platform, we seek to demonstrate improved coatings for thermal detectors, purification, separation, modeling, and quantitative metrology for bulk carbon nanotubes. We emphasize using laser sources and detector responsivity over wet chemistry and conventional spectroscopy. The dielectric function and topology of bulk single wall nanotubes is of interest and is relevant to modeling in addition to the experimental work. Raman spectroscopy measurements that are compatible with CNTs on the pyroelectric detector platform must be optimized to corroborate our detector measurement results and modeling.

Ultraviolet Laser Metrology

JH Lehman, ML Dowell 50.81.52.B1563

In recent years, ultraviolet (UV) laser—specifically diode lasers—have found increased use in a variety of industrial, commercial, homeland security, and medical applications. For example applications range from high definition digital video to detection of chemical and biological aerosols. Currently there is no primary standard for calibration of high-power continuous laser power meters. Aging and hardening of materials exposed to UV laser radiation is among the challenges to developing new measurement tools. Currently we are pursuing carbon nanotube based coatings for thermal detectors as well as optoelectronic means of creating artificial spectra for calibration of chemical, biological, and explosive sensors. Our work includes the development of high-accuracy UV primary and transfer standard detectors, beam profile characterization, laser power, energy, and dose measurement services.

Infrared Frequency Comb Development and Application

NR Newbury 50.81.52.B5523

A supercontinuum of light that spans over an octave in frequency can be generated by launching pulses from femtosecond fiber lasers into highly nonlinear optical fiber. Through recently developed techniques, this supercontinuum can be phase-locked to a reference and thereby provide a stable frequency comb with a spacing equal to that of the laser repetition rate. These frequency combs revolutionized optical frequency metrology since optical frequencies can now easily be measured relative to the time standard. We invite proposals that explore the generation, properties, and applications of infrared frequency combs. We are particularly interested in the generation of stable frequency combs in the telecommunications band at high repetition frequencies, with very robust configurations, and with very low excess noise. We are also very interested in expanding the applications of these sources outside of frequency metrology into the areas of remote sensing, frequency transport over fiber networks, coherent optical communication, and optical spectroscopy.

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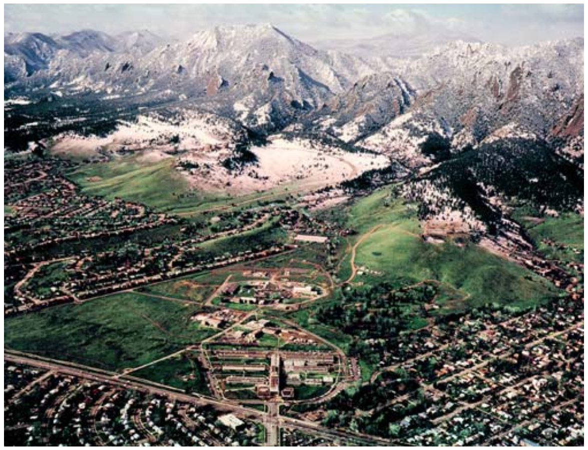

NRC/NIST Postdoctoral Research Associateships

The **Optoelectronics Division** of the National Institute of Standards and Technology invites applications for postdoctoral research awards in optoelectronics

Eligibility: Must be a U.S. citizen and within five years of doctorate
Duration: Two years, maximum
Location: Boulder, Colorado
Stipend: $63,400
Benefits: Relocation expenses, health and life insurance, retirement plan
Deadline: The first deadline for applications is February 1, 2009; the second competition's deadline will be August 1, 2009