METAMATERIALS

6th Annual CRI Summer Conference

The Center for Optoelectronics and Optical Communications
on the Campus of the Charlotte Research Institute
at the University of North Carolina at Charlotte

UNC CHARLOTTE

May 27th - 30th 2009
# Metamaterials Workshop Schedule

**Wednesday May 27th**

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<td>10.00</td>
<td>Materials and integration technologies for metamaterial structures</td>
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<td>Metamaterials for RF, Photonic and RF/Photonic Applications</td>
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<td>Low refractive index materials; a new class of optical thin film materials</td>
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<td>8.30</td>
<td>New horizons of nanoplasmonics</td>
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<td>The road to quantum level NIM metamaterials</td>
<td>Clifford Krowne, Naval Research Laboratory</td>
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<td>10.30</td>
<td>New propagation effects in semiconductors in the uv range</td>
<td>Michael Scalora, AMRDEC, US Army</td>
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<td>Natalia M. Litchinitser, SUNY at Buffalo</td>
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<td>Highly anisotropic form-birefringent structures and measurements.</td>
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<td>Total disorder as an alternative to perfect periodicity</td>
<td>Valentin Freilikher, Bar-Ilan U., Israel</td>
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<td>4.30</td>
<td>Asymptotic theory of wave process in networks of thin fibers</td>
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<td>Dinner in Witherspoon</td>
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<td>Optical Metamaterials</td>
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<td>9.30</td>
<td>Polarization properties of plasmonic/photonic hybrid crystals and applications</td>
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<td>Optical Mesomaterials: Coupled Microresonator Arrays</td>
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<td>2.00</td>
<td>Plasmon coupling in 2D arrays</td>
<td>John Heckel, Clemson University</td>
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<td>2.45</td>
<td>Propagation of waves in randomly perturbed periodic media</td>
<td>Yuri Godin, UNC Charlotte</td>
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<td>3.30</td>
<td>Two-dimensional acoustic metamaterials based on Mie resonances</td>
<td>Xianyu Ao, UNC Charlotte</td>
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<td>4.00</td>
<td>The III-Nitrides: Anything you can do I can do better...</td>
<td>Ian Ferguson, Georgia Tech / UNCC</td>
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<td>6.00</td>
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# Saturday May 30th

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<tr>
<td>9.00</td>
<td>Federal funding and industry collaboration session</td>
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SCIENCE TO SHAPE THE FUTURE OF THE ARMY
ARMY RESEARCH OFFICE 1951
The Charlotte Research Institute and the Center for Optoelectronics and Optical Communications at the University of North Carolina at Charlotte welcomes participants to its workshop on the applications of electromagnetic waves in complex media and metamaterials. This is the sixth summer workshop to be sponsored by the Charlotte Research Institute and we are very grateful to them for their support. We also thank Dr. Richard Hammond and the Army Research Office for their support, as well as Amber Bulkley and Taylor and Francis, the publishers of Waves in Random and Complex Media. For those who are interested in participating, there will be a special issue of WRCM devoted to this workshop, similar to that for our second workshop held in 2005 (WRCM Vol 16, (2006), issue 4).

The choice of the field of metamaterials for this year's workshop is an obvious one. The topic is growing rapidly and is starting to impact our thinking about the design of microwave, THz and optical components and devices. There are many opportunities for interdisciplinary collaboration and partnering with industry and we hope that this workshop will facilitate closer ties between those of us in this community. There remain many challenges and some skepticism about real world applications for metamaterials. Important amongst these are the need for tools to design artificial structures that exhibit desired material characteristics, as well as developing the means to fabricate them with sufficient precision and at low cost. The purpose of this CRI Workshop is to bring together a broad community of researchers and prospective users in the field to review the metamaterials R&D and to better understand the very interdisciplinary and fundamental aspects of what is feasible in the next few years. Presentations and discussions will include considerations of the basic theoretical and numerical models for describing propagation and scattering through linear and nonlinear periodic structures as well as investigating the extreme values and bandwidths for metamaterial permittivities and permeabilities one might be able to realize. Fabrication processes are advancing constantly but limitations to these processes and better ways to model the resulting materials' characteristics are needed.

Our goal is to provide a stimulating environment and ample opportunities for exchanging new ideas. Following the style of a Gordon Conference, we hope to provide sufficient time throughout each day and in the evenings for participants to interact with each other. A special thanks goes to those who have had to deal with all of the logistical and planning details that go into making a workshop such as this a success. This meeting would not have been possible without the hard work and dedication of Mark Clayton, Jerri Price, Margaret Williams and Scott Williams.

**Biography**

**Michael Fiddy** received his Ph.D in Physics from the University of London in 1977, and was a post-doc in the Department of Electronic and Electrical Engineering at University College London before becoming a tenured faculty member in 1979 at Queen Elizabeth College and then Kings College, London University. Between 1982 and 1987, he held visiting professor positions at the Institute of Optics Rochester and the Catholic University of America in Washington, DC. Dr. Fiddy moved to the University of Massachusetts Lowell in 1987 where he was Electrical and Computer Engineering Department Head from 1994 until 2001. In 2002 he moved to UNC Charlotte to become the founding director of the Center for Optoelectronics and Optical Communications. He was the topical editor for signal and image processing for the J.O.S.A. A from 1994 until 2001 and has been the Editor-in-Chief of the journal Waves in Random and Complex Media (Taylor and Francis) since 1996. He has chaired a number of conferences in his field, and is a fellow of the Optical Society of America, the Institute of Physics and the Society of Photo-Optical Engineers (SPIE). His research interests include inverse problems and optical information processing.
Metamaterials are expected to open a gateway to unprecedented electromagnetic properties and functionality unattainable from naturally occurring materials, thus enabling a family of new “meta-devices”. We review this new emerging field and significant progress in developing metamaterials for the optical part of the spectrum. Specifically, we describe recently demonstrated artificial magnetism across the whole visible, negative-index in the optical range, and promising approaches along with challenges in realizing optical cloaking. A new paradigm of engineering space for light with transformation optics will be also discussed.


Vladimir M. Shalaev, the Robert and Anne Burnett Professor of Electrical and Computer Engineering and Professor of Biomedical Engineering at Purdue University, specializes in nanophotonics, plasmonics, and optical metamaterials. Dr. Shalaev has several awards for his research in the field of nanophotonics and metamaterials. He is a Fellow of the American Physical Society, Fellow of The International Society for Optical Engineering (SPIE), a Fellow of the Optical Society of America. Dr. Shalaev is editor/co-editor for a number of journals and book series in the area of nanoscale optics. He has about 300 publications, in total, including 2 authored and 5 edited books, and 21 invited book chapters.
Title: *Materials and Integration Technologies For Metamaterial Structures*

10 A.M.

Metamaterial implementation relies on available materials and fabrication technologies. Often, materials that exhibit interesting metamaterial physical properties have significant disadvantages, as well. This is particularly true for active metamaterials, which offer switching and tuning capabilities, but these active materials can suffer from high loss. The integration of multiple materials can address these challenges. For example, a thin layer of an interesting metamaterial material can be deposited or bonded onto a substrate that is low loss, or a lossy substrate can be selectively removed from a metamaterial structure. In particular, we will examine heterogeneous integration, wafer bonding, and spin coating techniques for creating thin film of interest for integrated metamaterial structures.

Practical concerns also impact metamaterial design and fabrication. Mechanical integrity, electrical parasitics, and yield are all design issues that can affect metamaterials. For example, active structures that switch with electrical inputs can be limited by parasitics such as capacitance. Appropriate use of dielectrics can minimize parasitic capacitance, creating higher speed metamaterial structures. Yield in metamaterials is also an interesting avenue of enquiry. What is the unit cell yield manufacturing tolerance in metamaterials? This is a key manufacturing question that may significantly impact the implementation and cost of metamaterials.

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**Biography**

*Nan Marie Jokerst* is the J. A. Jones Professor of Electrical and Computer Engineering at Duke University. She is also the Executive Director of the Shared Material Instrumentation Facility at Duke, which houses Duke’s cleanroom and materials/device characterization laboratories. Her MS and PhD degrees are in Electrical Engineering from the University of Southern California. She is a Fellow of the Institute of Electronics and Electrical Engineers (IEEE), and a Fellow of the Optical Society of America. Her awards include a NSF Presidential Young Investigator, a DuPont Young Faculty Award, a Newport Research Award, an IEEE Third Millennium Medal, and an IEEE Harriet B. Rigas Medal. Her photograph was on the cover of the 2005 “Women in Optics” SPIE calendar, and she was named the University of Southern California Viterbi School of Engineering “Alumni in Academia” in 2006. She has served the IEEE as the IEEE Photonics Society (formerly LEOS) Vice President for Conferences, Vice President for Technical Affairs, and as an elected member of the LEOS Board of Governors. She also Chaired the Engineering Council of the OSA. She has published over 250 journal and conference papers, and has 6 patents in integrated chip scale sensing, optoelectronics, and metamaterials/plasmonics.
Title: Metamaterials for RF, Photonic and RF-Photonic Applications
11.00 A.M.

Engineering the Electromagnetic Properties of Materials has enabled new classes of materials and devices with an atypical electromagnetic behavior. In this presentation will present our perspective on the broader class of “engineered-materials” consisting of material systems whose electromagnetic properties have been modified by either: altering the intrinsic properties of a bulk material through the introduction of either surface or volumetric subwavelength structures, i.e., structural modification, or hybrid materials that consist of a host material in association with subwavelength inclusions, such as conducting or dielectric objects. From this perspective, this allows for a unification of negative index materials (NIMs), left-handed materials (LHMs), photonic crystals (PhCs), photonic band gap materials (PBGMs), and even more conventional subwavelength structures, such as form birefringent and effective index materials into a collective framework wherein a common set of computation, experimentation, and fabrication tools can be developed. With this framework in mind, we developed and refined computational electromagnetic models (CEMs) suitable for designing and engineering EM-material systems that exhibit not only NIM but also more general dispersion properties, build and refined experimental setups to characterize and verify the dispersion properties associated with the materials designed. We also developed and refined the necessary growth and fabrication processes for realizing meta-material devices. In the course of this talk we will present a collective overview of the field in terms of design and analysis tools, fabrication, characterization, and, of course, application of these materials and their associated devices.

Dennis Prather began his professional career by joining the US Navy in 1982, where he still serves in the reserves as an Engineering Duty Officer. After active duty, he received the BSEE, MSEE, and PhD from the University of Maryland in 1989, 1993, and 1997, respectively. During this time he worked as a researcher for the Army Research Laboratory, where he performed research on both optical devices and architectures for information processing. His efforts included work on the modeling, design, and fabrication of meso-scale optical elements and their integration with active opto-electronic devices, such as infrared focal plane arrays and semiconductor lasers. During this work he developed computational electromagnetic models for the analysis of aperiodic-subwavelength and nano-scale photonic devices. In 1997 he joined the Department of Electrical and Computer Engineering at the University of Delaware. Here, his research focuses on both the theoretical and experimental aspects of active and passive nano-photonic elements and their integration into various subsystems. To achieve this, his lab develops and refines coupled computational electromagnetic and quantum mechanical models for the design of such devices. In addition, they also develop nano-fabrication and integration processes necessary for the integration of nano-photonic devices into subsystems. Specific devices and applications include: subwavelength structures, photonic crystal devices, high frequency optical modulators, meta-materials, and RF-Photonics.

Professor Prather is currently an Endowed Professor of Electrical Engineering, he is a Fellow of the Society of Photo-Instrumentation Engineers (SPIE) and the Optical Society of America (OSA), and a Senior Member of the Institute for Electrical and Electronics Engineers (IEEE). He received the Outstanding Junior Faculty in the College of Engineering in 2000, the William J. Kastner Award for Naval Engineering Excellence, in 2000, as well as the National Science Foundation CAREER Award, in 1999 and the Office of Naval Research Young Investigator Award, in 1999.
Low-Refractive-Index Materials – A New Class of Optical Thin-Film Materials

E. Fred Schubert* and Jong Kyu Kim (not pictured)

Future Chips Constellation; Rensselaer Polytechnic Institute, 110 Eighth Street Troy, NY 12180
Electrical, Computer, and Systems Engineering Department; Rensselaer Polytechnic Institute, 110 Eighth St. Troy, NY 12180; Department of Physics, Applied Physics, and Astronomy; Rensselaer Polytechnic Institute, 110 Eighth St. Troy, NY 12180
*Email < EFSchubert@rpi.edu >

Abstract

Title: Low-Refractive-Index Materials – A New Class of Optical Thin-Film Materials

2.00 P.M.

Among all the properties of optical materials, the refractive index is a most fundamental one. The refractive index determines many properties such as Fresnel reflection, Bragg reflection, Snell refraction, diffraction, the phase velocity, and the group velocity of light, to just name a few. The refractive index was first introduced centuries ago by Isaac Newton when determining the relative strength of refraction at the liquid-to-air interface. He realized that the degree of refraction is proportional to the mass density of the liquid, and therefore called the new optical quantity the “optical density”. Nowadays, this key quantity is known as the “refractive index”.

However, the availability of low-refractive-index materials would be very valuable. Consider a distributed Bragg reflector (DBR): Many properties of a DBR depend on the refractive index contrast between the two layers that constitute the DBR. The higher the index contrast, the higher the DBR reflectance, the broader the high-reflectivity band, the better the omni-directionality of the DBR. For this reason, it is desirable that the lower-index material of the DBR has a refractive index as low as possible, and, in addition, that the higher-index layer has an index that is as high as possible, thereby maximizing the index contrast. Consequently, low-index materials are a promising strategy for improving the properties of DBRs. This discussion shows how low-index materials can improve an optical component, such as a DBR. Furthermore, being able to “tune” the refractive index of a material, by precisely controlling its porosity, would open up tremendous possibilities in the design and control of optical materials.

Over the last few years, a new class of materials, low-refractive-index materials, has been developed [1-6]. Optical thin-film materials, with a refractive index as low as 1.05, have been demonstrated. The low-index materials are based on porous materials such as porous SiO2 [1-3], porous indium-tin oxide (ITO) [4-5], or porous TiO2. The porosity can be precisely controlled by using oblique-angle deposition, a technique in which the substrate is at non-normal angle with respect to the deposition source. Whereas dense films form for normal-incidence deposition, porous films with a self-organizing nano-structure form for oblique-angle deposition. The self-organizing nanostructure consists of a dense array of nano-rods.

More recently, a theoretical model describing the porosity of the films fabricated by oblique-angle deposition has been developed [6]. Inspection of the figure shows that refractive index values in the range between 1.05 ~ 1.4 and 1.17 ~ 2.1 for SiO2 and ITO, respectively, have been demonstrated. That is, no longer is the refractive index a fixed quantity that is associated with a certain material. Instead, the refractive index can be freely chosen and tuned to a broad range of desired values. We note that this is a fundamentally new paradigm in thin-film optics and photonics.

Biographical Sketch

E. Fred Schubert received his Ph.D. in Electrical Engineering from the University of Stuttgart (Germany) in 1986. From 1981 to 1985 he worked on compound semiconductor crystal growth at the Max Planck Institute for Solid State Research, Stuttgart, as a Member of Scientific Staff. During 1985 to 1995, he was a Post-doctoral Fellow, Member of Technical Staff, and Principal Investigator at AT&T Bell Laboratories in Holmdel and Murray Hill, New Jersey. In 1995, he entered academia at Boston University as a Professor of Electrical Engineering. He joined Rensselaer Polytechnic Institute in 2002 where he is the Wallstreet Senior Constellation Professor of the Future Chips Constellation with appointments in the Electrical Engineering Department and Physics Department. He is the founding director of the Smart Lighting Engineering Research Center awarded to Rensselaer Polytechnic Institute in 2008.

Dr. Schubert has made pioneering contributions to the field of compound semiconductor materials and devices in particular to the fields of alloy broadening, delta-doping, resonant-cavity light-emitting diodes, enhanced spontaneous emission in Er-doped Si/SiO2 microcavities, elimination of unipolar heterojunction band discontinuities, p-type superlattice doping in AlGaN, photonic-crystal light-emitting diodes, polarization-enhanced ohmic contacts, omni-directional reflectors, light-emitting diodes with remote phosphors, low-refractive index materials, and solid-state lighting. Dr. Schubert is inventor or co-inventor of 30 US patents and has authored or co-authored more than 250 publications. He authored the books Doping in III–V Semiconductors (1993), Delta Doping in Semiconductors (1996), and the first and second edition of Light-Emitting Diodes (2003 and 2006); the latter book was translated into Russian and Japanese. Awards include Senior Member IEEE (1993); Literature Prize of Verein Deutscher Elektrotechniker for book “Doping in III–V semiconductors” (1994); Fellow SPIE (1999); Alexander von Humboldt Senior Research Award (1999); Fellow IEEE (1999); Fellow OSA (2000); Boston University Provost Innovation Award (2000); Discover Magazine Award for Technological Innovation (2000); R&D 100 Award for RCLLED (2001); Fellow APS (2001); RPI Trustees Award for Faculty Achievement (2002 and 2008); Honorary membership inEta Kappa Nu (2004); 25 Most Innovative Micro- and Nano-Products of the Year Award of R&D Magazine (2007); and the SCIENTIFIC AMERICAN 50 Award (2007).
Title: Fabrication of nanostructures using the Imprio100 step&repeat nanoimprint system
3.00 P.M.

Nanoimprint lithography is a high-resolution, high-fidelity, high-throughput replication process for the fabrication of nanostructures. Applications can be found in various fields such as photonic crystals, metamaterials, diffractive/subwavelength optics, micro-lens arrays, data storage, and LED’s. The Imprio100, from Molecular Imprints Inc (MII), uses the Step and Flash Imprint Lithography (SFIL) process and consists of patterning nano-scale features in UV-cured resist and the subsequent pattern transfer into the desired film or substrate material. In this talk, we describe our SFIL process development effort and present patterning/etch results on various film and substrate materials (ex. Silicon, fused silica, GaAs, silicon nitride, aluminum) performed on our Imprio100 and our STS plasma etch tools. Additional data from MII is also included.

Lou Deguzman received the B.A. and M.S. degrees in Physics from the University of California, Berkeley (1991) and San Jose State University (1995), respectively, and a Ph.D. in Optical Science and Engineering from the University of Alabama in Huntsville (2000). He joined Digital Optics Corporation (Charlotte, NC) from 2000 until 2003 as a Sr. Process Development Engineer. He is currently a research staff member in the Center for Optoelectronics and Optical Communications at the University of North Carolina at Charlotte since 2003. His research interests include diffractive/polarization optics, nanoimprint lithography, slowlight and laser diodes/LED’s.

Alec Martin received a B.S. in Engineering degree from the University of South Carolina – Columbia (1986) and an MS in Electrical Engineering from the University of North Carolina at Charlotte (2005). He joined Intel Corporation (Chandler, AZ) from 2005 until 2006 as a Sustaining Engineer in the Thin Films Group. He is currently a research staff member in the Center for Optoelectronics and Optical Communications at the University of North Carolina at Charlotte since 2006. His research interests include compound semiconductors, in particular III/V materials, and X-Ray diffractometry.
Frozen mode regime in bounded photonic crystals

Dr. Alexander Figotin
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Phone: 949-824-5506
E-mail: afigotin@uci.edu

Abstract

Title: Frozen mode regime in bounded photonic crystals
4.00 P.M.

In photonic crystals the effects of spatial dispersion culminate at frequencies where the light group velocity vanishes. Vanishing group velocity always implies a dramatic increase in density of states, which is extremely attractive for a variety of practical applications including emission and amplification of light, lasing, enhancement of various light-matter interactions such as nonlinear and nonreciprocal effects, etc. In addition, vanishing group velocity implies certain qualitative changes in eigenmode structure. These changes can be accompanied by some spectacular effects in light propagation and scattering, such as the frozen mode regime (FMR). FMR is accompanied by a dramatic enhancement of light intensity. FMR is a fundamentally new wave phenomenon – it does not reduce to any known optical resonance. Formally, FMR is not a resonance, in a sense that it is not particularly sensitive to the size and shape of the photonic crystal. FMR is much more robust and powerful, compared to any known slow-wave resonance. It has much higher tolerance to absorption and structural imperfections than common Fabry-Perot resonance, where the entire photonic crystal works as a resonator. On the other hand, it is possible to combine FMR and a common optical resonance, in which case we have the phenomenon of giant slow wave resonance. The Q-factor associated with such a resonance can be by two orders of magnitude higher, compared to that of the regular Fabry-Perot resonance in the same or similar periodic structure. More importantly, FMR provides the possibility of a dramatic reduction in size – up to an order of magnitude – of some basic optical devices without compromising their performance.

Bio

Alexander Figotin graduated from Kharkov State University, Former Soviet Union, in 1976 and was awarded MS with High Honors in Mathematics. He got his Ph.D. in Mathematical Physics from Tashkent State University, Former Soviet Union, 1980.

Since that time A. Figotin worked in many areas of modern mathematical physics and applied mathematics. The areas related to the proposal includes: propagation of electromagnetic waves in periodic and nonlinear media known as photonic crystals.

He started to work on photonic crystals in 1994 in the University of North Carolina at Charlotte. In 1998 A. Figotin and his group moved to the Department of Mathematics in University of California at Irvine. When in Irvine, 1998-2005, A. Figotin and his group were studying important magnetic and nonlinear phenomena in photonic crystals as well fundamental properties of dispersive and dissipative media. A. Figotin is an author of more than 60 papers and one monograph. The group created and headed by A. Figotin has an expertise in all essential aspects of the theory and computation of photonic crystals including: periodic media, defects (cavities), nonlinear and nonreciprocal phenomena in periodic media. This rather unique combination of all essential components in one group gives an excellent opportunity to develop novel approaches in design of photonic crystals as novel electronic materials.
Title: Absorption suppression in periodic composite structures

4.45 P.M.

We study electromagnetic properties of composite materials, such as photonic crystals, involving lossy components. We show that composite structure can dramatically suppress the losses associated with the absorptive component, while preserving or even enhancing its useful functionality. As an example, we consider a magnetic photonic crystal, in which the lossy magnetic component provides nonreciprocal Faraday rotation. We show that electromagnetic losses in the magnetic photonic crystal with proper configuration can be reduced by up to two orders of magnitude, compared to those of the uniform magnetic sample made of the same lossy magnetic material. The dramatic absorption reduction is not a resonance effect and can occur over a broad frequency range covering a significant portion of the respective photonic frequency band. Alternatively, we can suppress the losses and, in addition, to make the size of the composite structure much smaller than that of the uniform sample. Such a combination can be achieved at the expense of the bandwidth and can be subject to additional physical limitations (see the details in A. Figotin and I. Vitebskiy, Phys. Rev. B77, 104421 (2008)).

Ilya Vitebskiy got his Ph.D. in Theoretical Physics in 1979 in former USSR. In 1985 he was awarded the degree of Doctor of Physical and Mathematical Sciences. For six years, until 1995, he headed the Department of Theoretical Physics in the Institute for Single Crystals in Kharkov, former USSR. He also worked as a professor of theoretical physics at Kharkov State University. During that time he graduated six doctoral students, all in the area of solid state physics. In year 2000 he joined the research group of Alex Figotin, where he has been involved in a number of projects related to the electrodynamics of photonic crystals. Dr. Vitebskiy is an author and coauthor of nearly 100 scientific papers in peer-reviewed journals. Nearly half of his publications were prepared in close cooperation with experimental research laboratories in Grenoble, Moscow, and Kharkov. He is also a co-inventor in four US patents. The most recent scientific results are related to electrodynamics of composite media. Area of expertise includes:

- Condensed matter physics
- Theory of electric, magnetic, and acoustic properties of crystalline materials.
- Electronic and nuclear magnetic resonance. Spin waves.
- Phase transitions and critical phenomena.
- Electrodynamics and acoustics of composite structures
Dr. Robert Wilhelm
Executive Director
Charlotte Research Institute
University of North Carolina at Charlotte

An experienced educator, researcher, engineer, and businessman, Dr. Robert G. Wilhelm provides executive and administrative leadership for the Charlotte Research Institute (CRI), UNC Charlotte’s portal for business-university science and technology partnerships. With its research centers housed in three new custom-designed buildings on the Charlotte Research Institute Campus, CRI helps companies initiate new partnerships at UNC Charlotte and offers a variety of opportunities to engage talented faculty and make use of specialized facilities that are available only at UNC Charlotte.

Wilhelm is a Professor of Mechanical Engineering and Engineering Science in the William States Lee College of Engineering. Dr. Wilhelm has wide experience in both academic and business circles. At UNC Charlotte since 1993, Wilhelm was a founding faculty member for PhD programs in Mechanical Engineering, Biotechnology, Information Technology, and Nanoscience. He served on the committees to form the School of Computing and Informatics and the PhD program in Optical Sciences and Engineering. Most recently he served as the associate director of the Center for Precision Metrology, an Industry/University Cooperative Research Center funded by the National Science Foundation. Before coming to Charlotte, Wilhelm worked at the Palo Alto Laboratory of Rockwell Science Center and at Cincinnati Milacron. He co-founded a high-technology manufacturing company, OpSource, Inc., in 2001.

Wilhelm holds a bachelor’s degree in industrial engineering from Wichita State University, a master’s degree in industrial engineering from Purdue University, and a doctorate in mechanical engineering from the University of Illinois at Urbana-Champaign. Wilhelm also pursued postgraduate studies in Great Britain as a Rotary Foundation Fellow. His research and teaching have been recognized with the National Science Foundation Young Investigator Award. Dr. Wilhelm serves on a number of regional, national, and international advisory boards for scientific research, engineering, community and economic development, and philanthropy.
Abstract

Title: New Horizons of Nanoplasmonics
8.30 A.M.

Nanoplasmonics deals with collective electron dynamics on the surface of metal nanostructures, which arises as a result of excitations called surface plasmons. The surface plasmons localize and concentrate optical energy in nanoscopic regions creating highly enhanced local optical fields. They undergo ultrafast dynamics with timescales as short as a few hundred attoseconds. There are numerous existing applications of nanoplasmonics: nanoantennas and waveguides for efficient coupling of light with semiconductor devices including photovoltaic cells and light-emitting diodes, labels for biomedical research, ultrasensitive detectors and sensors of molecules and biological objects for biomedicine and defense, etc. We will focus on the latest developments in nanoplasmonics. Among them is SPASER as a quantum nanoscale generator of optical fields, generation of high harmonics in the EUV range, ultrafast optical modulator with THz bandwidth, generators and modulators of THz radiation, coherent control of ultrafast processes on the nanoscale, attosecond nanoplasmonic field microscope, etc.

Biography

Mark I. Stockman, Ph. D., D. Sc., is a Professor of Physics and Astronomy at Georgia State University in Atlanta, GA. Born in Kharkov (Ukraine), US citizen. MS (Honors) in Theoretical Physics from Novosibirsk State University (Russia), 1970. Ph. D. in Theoretical Physics from Institute of Nuclear Physics (Novosibirsk), Russian Academy of Sciences, 1975. D.Sc. in Theoretical and Optical Physics from Institute of Automation and Electrometry (Novosibirsk), Russian Academy of Sciences, 1989. Recent research focuses on electronic and optical properties of metal and metal-semiconductor nanostructures. Published 150 major research papers.

Presented numerous tutorial, keynote, and invited talks and lectures at major Conferences in the field of optics and nanoplasmonics. Chairman of Metal Nanoplasmonics Conference at 2005-2009 SPIE Meetings at San Diego, co-Chair of Nanoplasmonics and Metamaterials Conference at OSA 2008 Frontiers in Optics Meeting. Courses Nanoplasmonics at SPIE Photonics West and 2005-2008 SPIE Optics and Photonics Meetings (USA), ETOPIM ‘Conference at Sidney (Australia); Ecole Normale Supérieure de Cachan (France) (2006); Erasmus Mundus School at Porguerolles Island, France (July, 2008); University of Stuttgart (September, 2008), max Plank Institute for Quantum Optics (Munich, May 2009).

Distinguished Visiting Professor at Ecole Normale Supérieure de Cachan (France) (March, 2006 and July, 2008); Invited Professor at Ecole Supérieur de Physique et de Chimie Industrielle, Paris, France, May-June, 2008; Guest Professor at the University of Stuttgart (September-November, 2008) and Ludwig Maximilian University at Munich, Germany and Max Plank Institute for Quantum Optics (Garching at Munich, Germany) (December 2008 – August 2009).

Theoretical condensed matter and optical physics, nanoplasmonics; theory of ultrafast, coherent, and nonlinear photoprocesses in nanosystems, and strong field nanoplasmonics.
Title: The Road to Quantum Level NIM Metamaterials
9.30 A.M.

It is well known now that small scale microscopic and even nanoscopic NIM metamaterials can be fabricated as well as modelled sufficiently well to potentially present real world applications. These seem to be developing in the realm of materials science and engineering for lens for antennas, novel antennas, and electronic devices [1]. The question now is can materials be developed, based upon quantum mechanics and quantum optics and cavity-QED [2], which provide an alternate route for NIM which can offer different opportunities for exploitation. Recent research shows that searching for new uses for NIM and other metamaterials can lead to other potential applications, such as for angstrom level spin detection via optical interrogation [3].


C. M. Krowne has authored or co-authored about two hundred or more conference and journal papers in solid state electronics, microwave circuits, electromagnetics, and physics and has several patents. He has also written major portions of four books for Academic Press in the Advances in Imaging and Electron Physics series on propagation in anisotropic media and circulation behavior in nonreciprocating media (vol. 92, 1995; vol. 98, 1996; vol. 103, 1998; vol. 106, 1999), plus contributions on numerical modeling of microstrip circulators in the ferrite devices area and left-handed materials for microwave devices and circuits for the 1999 and 2004 Wiley Electrical and Electronics Engineering Encyclopedias. Recently he co-edited with Prof. Y. Zhang a book for Springer on negative refractive materials in Oct. 2007. Recently, also he was recognized for being one of the most downloaded authors for an article in the MTT transactions in the year 2004 (two hundred or more).
Title: New Propagation Effects in Semiconductors in the UV Range:

10.30 A.M.

Harmonic generation and Inhibition of Absorption, Negative Refraction and Sub-Wavelength Imaging, Anomalous Momentum States, and Non-Plamonic Nanometer-size waveguides.

I will discuss novel propagation effects in semiconductors at frequencies above the absorption edge, including inhibition of linear absorption using phase-locked harmonic pulses, negative refraction, anomalous momentum states, sub-wavelength imaging and ultrathin, nanometer-size guiding channels.

Biography: Michael Scalora is a scientist at Charles M. Bowden Research Facility with the US Army, at Redstone Arsenal, Alabama USA. He obtained the Master of Science and the PhD degrees in Physics from Rensselaer Polytechnic Institute, Troy NY, in 1988 and 1990, respectively. His research activities include the study of light propagation phenomena in photonic band gap structures and metamaterials.
Title: Fundamentals of Superlattices and Photonic Crystals: Technical Issues in Implementation

11.30 A.M.

Both superlattices and photonic crystals incorporate structural periodicity to mimic solids having translational symmetry. In fact, the only solution involving a medium other than free space or with uniform filling is a periodic structure. Superlattices were introduced nearly 40 years ago using periodic potential energy barriers, basically in 1D, one dimensional-modulation. Photonic crystals were actually introduced many years ago in 1D, extended to 3D almost 60 years ago as artificial dielectrics for microwaves. The structural modulation involves materials with different dielectric constants, however, basically is entirely similar to changes in potential energy because without the presence of charges, there is no screening therefore the refractive index is unity. More than 20 years ago, photonic crystals came as something evolved from electronic superlattices to photons. But in fact, the reverse is true, electronic superlattices evolved from photonic to electronic systems. Technologically, the single most difference between the two lies in size. To preserve coherence, the periodicity, \( d \), must be less than the coherence length, \( \Lambda \), whether it is the scattering length for electrons known as the mean free path, or the coherence length of photons. At room temperatures, \( d < 1-5 \text{nm} \) for superlattices, while for photons, \( d < 0.1-1 \text{\mu m} \), depending on the wavelengths involved. For this reason, it is far simpler to fabricate 3D photonic crystals than even 1D superlattice. The single most physical manifestation for superlattice is the Bloch oscillation when electrons are driven to the Brillouin zone boundary forming the basis of THz oscillators and as amplifiers due to the negative differential conductance. The most intriguing counterpart for photonic crystals at the Brillouin zone boundary is the zero group velocity allowing confinement of photons. We should not forget that x-ray mirrors are structured with modulation using high- and low-Z materials. From basic physics, the most important difference between SL and PC is the Coulomb interaction for electrons allowing coupling in SL. However, since refractive index comes from electrons, PC can also be affected by occupation under high excitation. My personal view is that photonic crystals are taking off in some unimaginable ways and directions, while, superlattices are basically confined to 1D modulation using high-tech epitaxial growth. Obviously I do not take these self-assembly techniques serious enough, because with all the expectations, none has emerged as anything useful. In the final analysis, what works drives mankind forward.

Raphael Tsu, known as Ray Tsu started his career at Bell Labs. He co-developed superlattices with Esaki at IBM Research Center in 1970. Before he joined UNC-Charlotte, he served several countries and laboratories, in time-order, Max Planck Institute, Stuttgart, Institute of Physics in Brazil, Energy Conversion Devices in MI, and Solar Energy Research Institute of DOE in CO.
Title: Waves in Graded Index and Nonlinear Metamaterials

1.30 P.M.

Photonic metamaterials emerge as a source of nearly unlimited opportunities for the realization of refractive indices that were not previously accessible, including positive, negative, and even zero values, and for gaining unprecedented control over the spatial refractive index distribution. In this talk, we discuss our recent results on linear and nonlinear phenomena taking place in negative-index and graded-index photonic metamaterials structures with refractive index changing between positive and negative values, and their potential applications.

Natalia M. Litchinitser, an Assistant Professor in the Department of Electrical Engineering at the State University of New York at Buffalo. Her research interests include linear and nonlinear optics in metamaterials, photonic devices, and optical communications. Dr. Litchinitser earned a Ph.D. degree in electrical engineering in 1997 from the Illinois Institute of Technology and a master's degree in physics in 1993 from the Moscow State University in Russia. Natalia Litchinitser previously held a position of a Member of Technical Staff at Bell Laboratories, Lucent Technologies and later at Optical Fiber Solutions Laboratories where she received the R&D 100 Award (team award) for development of Tunable Dispersion Compensator. She was also awarded Aileen S. Andrew Postdoctoral Fellowship to conduct a postdoctoral research at the Institute of Optics at the University of Rochester. Dr. Litchinitser authored 5 invited book chapters, and over 70 journal and conference research papers.
Title: Highly anisotropic form-birefringent structures and measurements

2.30 P.M.

We report measurement results of highly form-birefringent structures including anomalous spectral phase from Mandatori structure [1] and internal field distribution of Figotin structure [2]. With rapid prototyping of low cost ABS plastics, highly anisotropic form-birefringent layers can be fabricated for microwave operation frequencies in good precision and large volume. Our X-band measurements confirmed negative effective index of refraction and tunable negative group index of Mandatori structure. We also report internal field distribution measurements of a 100-period Figotin structure and compare the result with simulations.

Title: Total disorder as an alternative to perfect periodicity

3.30 P.M.

Creation of new optical and microwave tunable elements is now an important area of research and technology. Photonic crystals are promising candidates for this purpose. However, even small random deviations from the periodicity of a dielectric structure could affect significantly its optical characteristics. Considerable effort and creativity have therefore been invested to develop highly periodic dielectric systems. Alternatively, for many applications it may be possible to utilize disordered samples as tunable narrow-line resonant elements. In this talk, I will present the results of the recent theoretical and experimental studies of the localized states (resonances) in dissipative one-dimensional disordered structures. I will show how the unique spectral properties of these structures could be harnessed to create and couple resonant micro-cavities, control light transport and spontaneous emission, etc.

Valentin Freilikher, whose birthplace was the USSR, received his M. Sc. in physics from Kharkov State University in 1965. He received his Ph.D. in physics from the USSR Academy of Science in 1970, as well as a Senior Research Scientist Degree from the USSR Academy of Science. His first faculty position was with the Institute of Radiophysics and Electronics Academy of Science, Kharkov USSR, and lasted from 1965 to 1991. In 1988 he headed the Microwave Group in a Round-the-World expedition on the Scientific Research Vessel "Academik Vinogradov." In 1994 he joined Bar-Ilan University in Israel as Head of the Bar-Ilan Microwave Remote Sensing Center, and in 1991 became a professor with the department of physics, a position which he still holds. His areas of research are the physics of disordered systems; microwave remote sensing.
Title: Asymptotic theory of wave process in networks of thin fibers

4.30 P.M.

We will discuss a one-dimensional approximation for the problem of wave propagation in networks of thin fibers. The main objective here is the form of the boundary (gluing) conditions at branching points of the limiting one-dimensional graph. The results will be applied to Mach-Zehnder interferometers on chips and to periodic chains of the interferometers. The latter allows us to find parameters which guarantee the transparency and slowing down of wave packets.
The emerging field of Metamaterials utilizes nano-scale dielectric or metal-dielectric composites at dimensions that can be much smaller than the wavelength of light to obtain extraordinary electromagnetic properties, not existing in naturally occurring materials. In particular, metamaterials can alter the propagation of electromagnetic waves, resulting in negative refraction, negative refractive index or even cloaking. That is, a proper structure made of metamaterials can completely hide a macroscopic object, eliminating all scattering and back-reflections of EM waves. Facilitating unique properties, these structures can have a profound impact on wide range of applications such as sub-wavelength focusing and imaging, transmission of sub-wavelength information, enhancement of nonlinear effects and integrated nano-photonics.

In this workshop, I will show our latest experimental results in the field of optical metamaterials. These include low-loss and broad-band negative-refraction of visible light, the first 3D “fishnet” negative-index metamaterials and the first cloak operating at optical frequencies; an all-dielectric “carpet cloak” with broad-band and low-loss performance.
Title: **Polarization Properties of Plasmonic/Photonic Hybrid Crystals and Applications**

9.30 A.M.

The polarization characteristics of complex aperture arrays, compound grating structures and other periodically patterned structures are discussed. The polarization and wavelength dependence of optical phenomena in these structures are discussed, including anomalous transmission, light channeling, focusing, circulation and weaving. It is shown that all of these anomalous optical properties occur for all polarizations of incident light, but with important differences. Applications of these phenomena to polarimetric sensing, focal plane arrays, imaging and other applications are discussed.

**Bio sketch**

**David Crouse** received a BS in Physics from Purdue University in 1997 and a Ph.D. in Electrical Engineering at Cornell University in 2002. He is currently an associate professor in the Department of Electrical Engineering at The City College of New York and performs research on plasmonics crystals, metamaterials and nanotechnology. Dr. Crouse is also Director of the Center for Advanced Technology in Photonics Applications at the City University of New York.
Coupled microresonator arrays can be considered as “optical mesomaterials” due to the mesoscale size of constituting cavities in the order of several wavelengths. In such structures the light can be trapped in cavities at the resonant frequencies, and it can tunnel from cavity to cavity under resonant conditions. Some insight into the optical transport properties of such systems can be obtained due to a tight binding approximation for photonic atoms. However the behavior of real physical coupled cavity systems is complicated by the disorder-induced light localization and scattering effects. The focus of this presentation is on developing new concepts related to light transport in mesoscale structures formed by microspheres including percolation of whispering gallery modes, photonic nanojet-induced modes, and the role of structural disorder and dimensionality. Such structures allow the control of tight binding photonic dispersions in slow light devices, filters, and array-resonator LEDs. They also stimulate developing novel micro-probes with subwavelength resolution for biomedical applications.
Title: **Demonstrating Cloaking at Optical Frequencies**

**11.30 A.M.**

The ability of rendering objects invisible using a cloak for concealing objects has been a tantalizing goal. We present the demonstration of a cloak operating in the optical regime. The cloak can operate at a wide bandwidth and conceals a deformation on a flat reflecting surface, under which an object can be hidden. The device is composed of nanometer size silicon structures with spatially varying densities across the cloak. The density variation is defined using transformation optics to define the effective index distribution of the cloak.

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**Bioorabhu**

**Jaime Cardenas** earned his Ph.D. from the University of Alabama in Huntsville in Optical Science and Engineering. His research was in single air interface bends and waveguide microcantilevers. After two years as a process engineer, Jaime is now postdoctoral associate in the Cornell Nanophotonics Group investigating low loss Silicon waveguides.
Title: 

Plasmon coupling in 2-D arrays of Ag Nanoparticles

2.00 P.M.

The relevance of Ag nanoparticles (NPs) to metamaterials stems from the inherent negative permittivity of the metal in the visible spectral range. Optical properties of Ag NPs are determined by the excitation of plasmon resonances that are the collective oscillations of the conduction electrons. The excitation of plasmon resonances represents the most efficient mechanism by which light interacts with matter. High efficiency, tunability, and photochemical robustness make the NPs ideal building blocks for optical and photonic devices. Especially interesting are assemblies of closely spaced Ag NPs undergoing plasmon coupling. The focus of this presentation is on plasmon coupling in 2D arrays of Ag NPs. Single crystal, monodispersed NPs in the size range from 10 to 200 nm synthesized using a chemical method were self-assembled into 2D arrays. A sharp resonance was observed and assigned to a delocalized plasmon mode involving coherent electron oscillations in several NPs. The effect of the particle size, interparticle distance, dielectric medium, incident angle, and polarization of light on the coupling was studied. In addition, a new class of plasmonic NPs is presented. They are anisotropic metal organic hybrids with potentially new optical properties, as is exemplified by asymmetric surface-enhanced Raman and Rayleigh scattering.

Biography

John C. Heckel received his B.S. in Chemistry from Philadelphia University, Philadelphia, PA in 2005. He is currently working towards a Ph.D. in Analytical Chemistry at Clemson University, Clemson, SC, in the group of Dr. George Chumanov. The majority of Heckel’s work involves the synthesis, characterization, and application of noble plasmonic materials. He has published in the Journal of American Chemical Society, Journal of Colloid and Polymer Science, and Langmuir (submitted) in addition to presenting at three national conferences. This year, Heckel was selected to attend the 2009 Lindau Meeting of Nobel Laureates in Lindau, Germany.
We study the variance of the transfer matrix of a periodic 1D Schrödinger operator perturbed by the white noise. It is shown that if the frequency of propagation lies inside the band, then the total variance is proportional to \( N\sigma^2 \), where \( \sigma \) is the intensity of the white noise and \( N \) is the number of periods. However, if the wave frequency is close to the band edge, the resulting variance is proportional to \( N\sigma^{2/3} \). Thus, propagation becomes highly sensitive to random perturbations.

Numerical simulations reveal that even small noise in periodic potential can suppress transmission near the band edges and make it strongly irregular inside the band. Further increase of the noise amplitude leads to intermittent behavior of the transmission coefficient, and makes transmission possible only for few random frequencies in the band.
Title: Two-dimensional acoustic metamaterials based on Mie resonances

3.30 P.M.

The concept of negative refraction and metamaterials can be extended to acoustic and elastic waves. Natural material has neither a negative mass density nor a negative bulk modulus. Acoustic metamaterials with negative bulk modulus and/or negative mass density may have unique applications as their electromagnetic counterparts.

We show that the effective bulk modulus and mass density of phononic crystals are related to monopolar and dipolar Mie resonances, respectively. Further, these two kinds of resonances can be combined to generate pass bands with negative refractive index. The resonant units in metamaterials need not to be distributed periodically. Magnifying lenses for acoustic waves, analogous to electromagnetic hyperlenses, can be realized based on an acoustic metamaterial with strong anisotropy.

Bioabakhu

Xianyu Ao was born in China, in 1980. He received the Ph.D. degree in optical engineering from Zhejiang University, China, in 2006. From 2006 to 2008, he was a visiting scholar with Department of Physics, The Hong Kong University of Science and Technology, Hong Kong. He is currently a postdoctoral researcher with Department of Physics and Optical Science, UNC Charlotte, USA.

His research interests include waves in periodic media, optical waveguides, and numerical and analytical techniques in modeling.
**Title:** The III-Nitrides: Anything you can do I can do better...

4.00 P.M.

This presentation will review the utility of the III-Nitrides in a number of different material and device applications.

**Ian T. Ferguson** will join UNC Charlotte in August as Chair of the ECE Department. He is currently a Professor in the School of Electrical and Computer Engineering and School of Materials Science and Engineering at Georgia Institute of Technology (Georgia Tech) and Director for the Focused Research Program on Next Generation Lighting at Georgia Tech. He joined Georgia Tech from EMCORE Corporation where he was the Director of Research Development, and where he held other positions including Director of Intellectual Property and General Manager for In-Situ Products. His research focuses on the area of wide band-gap materials and devices (emitters, detectors and electronics) using GaN and ZnO and developing these materials for illumination, spintronic and nuclear detection applications. He has over 250 refereed publications, six book chapters, edited ten conference proceedings, one book and multiple patents. He has given over 300 invited, contributed talks and seminars throughout the US, Europe and Asia. He founded the International Conference on Solid State Lighting which is now in its ninth year. He has been actively involved in the entrepreneurial process of establishing new companies, receiving a National Small Business Association Tibbets Award at the White House (Washington, DC) for contributions to the SBIR program.
Participant Biographies

**S. V. Babu** received his B.Tech (Chem. Eng.) from Andhra University, INDIA, in 1962. He received his M.Tech (Chem. Eng.) from the Indian Inst. of Tech., Kharagpur, INDIA, in 1963, and did his graduate study in chemical engineering at Johns Hopkins Univ., Baltimore, USA, from 1963 to 1966, and received his Ph.D. (Physics) from SUNY at Stony Brook, USA, in 1971. Dr Babu is the Distinguished University Professor and Director, CAMP (Center for Advanced Materials Processing), at Clarkson University.

**Kushal Bhattacharjee** is a Principal Engineer in RF Micro Devices, Greensboro, North Carolina. He received his M.S. degree (1978) in Physics from Indian Institute of Technology, New Delhi, India, M.S.E.E (1984) from Rensselaer Polytechnic Institute, Troy, NY, and PhD (1991) from University of Connecticut, Storrs, CT.

His research interest includes SAW, BAW, Acousto-optic and electro-optic devices, and Micro-Electro Mechanical (MEMS) devices with particular applications in signal processing technology.

He has worked as Research and Development engineer in several companies, such as, Andersen Laboratories, TRW Space & Defense, and Motorola. He also led several research projects involving multinational teams and universities. He is a member of the Technical Program Committee of IEEE Ultrasonics, Ferroelectric, and Frequency Control Society.

**Lee W. Casperson** received his B.S. degree in Physics from M.I.T. and his M.S. and Ph.D. degrees in Electrical Engineering and Physics from Caltech. He has been a professor at UCLA, Portland State University, and UNC Charlotte, where he was recently chairman of the Department of Electrical and Computer Engineering. He was elected Fellow of the American Physical Society (APS), the Optical Society of America (OSA), and the Institute of Electrical and Electronics Engineers (IEEE). He was awarded the IEEE Centennial Medal and served as Distinguished Traveling Lecturer of the American Physical Society Division of Laser Science.

Dr. Casperson's principal research interests concern lasers and optical systems, and he has over 200 research publications with emphasis on laser-related devices, techniques, and phenomena. Long-term interests include high gain media, propagation, waveguides, and resonators.

Metamaterials and their Applications
**Shahab Chitchian** is a Ph.D. candidate in Optical Science and Engineering at UNC Charlotte. He works as research assistant in Biomedical Optics Lab under Dr. Nathaniel Fried supervision. He got both his B.Sc. and M.Sc. in Electrical Engineering on 2004 and 2007, respectively.

**Yi-Chen Chuang** is currently a PhD student in the Optical Science and Engineering Program at University of North Carolina at Charlotte (UNC-Charlotte). Her research focuses on the dispersion properties of the periodic structures based on the fractional Talbot effect. Miss Chuang served as the vice president and secretary of the UNC-Charlotte SPIE student chapter in the year of 2007 and 2006, respectively. She also enjoys outreach activities and other volunteer works related to optics.

**Tom DuBois** (Charles H Stone Professor of Chemistry) received his B.A. degree from McMurry College in Abilene, Texas and his MS and PhD degrees from The Ohio State University, Columbus, Ohio. He has nearly 100 research presentations and publications and has served as the PI or Co-PI on numerous grants and contracts. His research successes are represented by notable publications in the area of inorganic chemistry, microcomputer interfacing, lithography and microelectronics, and computational chemistry. More recently Professor DuBois has focused on chemical bonding, catalysis, nanomaterials, and photochromic/thermochromic materials through computational chemistry. As a mentor, he has directed the research projects of over 50 undergraduate chemistry majors, directed or co-directed the research projects of over 35 graduate MS and Ph.D. students in chemistry, electrical engineering and in the Interdisciplinary PhD Program in Biology.

**Richard A. Dudley** is a junior at the University of North Carolina at Charlotte, pursuing a bachelors of science in Physics and Mathematics with a concentration in Astrophysics and a minor in Philosophy. Currently working under M.A. Fiddy developing highly anisotropic metamaterials for microwave applications. Presented “Artificial Materials for Microwave Applications” at UNCC’s 2009 Undergraduate Research Conference and received Honorable Mention. Is actively involved in the UNCC chapter of the Society of Physics Students and is the current President. Projects include restoring the UNCC campus Observatory as well as plans for hosting an annual star party in association with the Charlotte Amateur Astronomers.
Richard Hammond has published numerous scientific articles in a wide range of fields, from general relativity to quantum mechanics, and has pioneered a new theory of gravitation that has won international acclaim. He has won awards from NASA for his research and teaching, international awards for research on gravity, and was invited to Cal Tech’s Jet Propulsion Lab to study solar system tests of Einstein’s theory. Hammond is an adjunct professor at the University of North Carolina at Chapel Hill and works for the Army Research Office as a theoretical physicist.

At ARO, Dr. Hammond has responsibility for optical physics, imaging science and unconventional optics that address the needs of the Army which rely on sensing, imaging processing, and autonomous target tracking and recognition. The Physics Division emphasizes fundamental science that uses photons and their properties (e.g., coherence, wavelength, polarization) in ways that will significantly improve information processing capabilities for the Army in the coming decades.

Robert Hudgins received a BS in physics from Purdue University in 1993, a MS in physics and a PhD in EE from the University of Cincinnati in 1997 and 2003 respectively. He worked as a Post Doc for the Optics Center at UNC Charlotte in 2004, then for the Physics department as a lab manager and physics instructor in 2006. After that, he accepted a position with A-Metrics LLC, a start up company, as Chief Science Officer in 2007. The next year he returned to the Optics Center as the Clean Room Manager, his current position. His interests include sol gel processing for optical devices, slow light structures and devices, laser diodes/LEDs, and facilitating research with university and industrial personnel.

Robert Ingel has a B.A. in Physics, an M.S. in Materials Engineering and a Ph.D. in Engineering in Design of Materials from Catholic University of America in Washington D.C. Dr. Ingel worked at the U.S. Naval Research Laboratory in Washington D.C. for twenty with time off to complete his graduate work and as a visiting scientist at the Max Plank Institut Für Metallforschung. Dr. Ingel worked for the South Carolina Research Authority’s Advanced Research & Development Institute and taught materials courses at Clemson University. On relocation to Charlotte, NC, Dr. Ingel continues consulting, has taught at UNC-Charlotte and is currently a research professor in the Center for Optoelectronics and Optical Communication. Dr. Ingel has over 45 technical and scientific publications and numerous presentations on topics such as ceramic composite fabrication, processing and characterization, graphical representation of technical data and computational modeling techniques including finite element methods and model reduction/homogenization techniques. His current research is on numerical modeling methods for photonic and metamaterials and the fabrication and characterization of materials for electromagnetic applications.

Roger H Lang received his Ph.D. in Electrophysics from the Polytechnic Institute of Brooklyn. Before receiving his Ph.D., he worked at Bell Telephone Laboratories on satellite antennas for two years. He did Post-Doctoral work on wave propagation in random media at the Courant Institute of Mathematical Sciences at New York University. He joined The George Washington University in 1970 as an Assistant Professor in the Department of Electrical Engineering and Computer Science. He has been Chair of the Electrical Engineering and Computer Science Department from 1984-88 and Chair of the Department of Electrical and Computer Engineering from 1999-2000. He now holds the position of Professor in the Department of Electrical and Computer Engineering. In 2005 he was appointed L. Stanley Crane Professor of Engineering and Applied Science.

Metamaterials and their Applications
Serguei Maximenko received the M.S. degree in electrical engineering from Taganrog State University of Radio Engineering, Russia (1998) and PhD from University of South Carolina, Columbia, SC (2005). He is currently pursuing postdoctoral training at the Naval Research Laboratory, Washington, DC. in Electronics Science & Technology Division. His main research interests lie in Structural/Electronic/Optical characterization and growth of wide bandgap (SiC, GaN, Ga$_2$O$_3$) and photovoltaic bulk/film/nanostructured materials, where he has published over 20 high-impact research papers over the last years [1-12].

Mona Mayeh is a PHD candidate in physics and optical science. Her research is focused on design and fabrication of optical sensors and all-fiber laser beam shaping devices. She has received her master’s and bachelor’s degrees in optical science and engineering and electrical engineering respectively.

Iftekhar Mirza graduated with a Bachelor in Electrical Engineering with distinction and with a Minor in Mathematical Sciences from the University of Delaware in 2003. He is currently pursuing a Ph.D degree in Electrical and Computer Engineering at the University of Delaware with expected graduation in 2009. Iftekhar is the recipient of the Nanoelectronics, Electromagnetics and Photonics Graduate Faculty award for the years 2008 and 2009 and also co-chaired the Metamaterial Antenna technical session at the IEEE Antenna Propagation Society Conference, San Diego, in 2008. Iftekhar’s research interests are in Metamaterials and its applications in microwave and optics. He is a student member of the OSA.

Shane Ritter, PE, is currently a PhD student in electrical engineering at the University of North Carolina at Charlotte. Shane is a Mississippi native having completed his BS in electrical engineering from Mississippi State University in 1990 and his MS in electrical engineering from Mississippi State University in 1997. Shane is currently working as a graduate assistant with the optics department at UNCC working on several related project dealing with meta-materials and their abilities to produce negative indices of refraction. Shane’s concentration has been in using numerical methods and programs such as COMSOL to model potential meta-materials and structures and their effects on light and refraction.

Metamaterials and their Applications
John O. Schenk joined the Navy after High School Graduation, later on became a Professional Airline Pilot and Flight Instructor. In parallel with Aviation studied Electrical Engineering earning a B.S. And M.S. in Electrical Engineering with honors from University of Massachusetts, Lowell. His Master’s Thesis was Interferometric Bio-Medical Imaging. Following the Master’s Graduation, he continued on with Harvard Medical School as a Research Scientist in Optical Coherence Tomography, during which he designed and developed a complete Optical Coherence Tomography Imaging System that resulted in a prestigious publication in the National Academy of Science. Industrial Experience was obtained as an Electrical Engineer and Consultant in Computer Science for various Microwave Semiconductor Companies. Currently working on Microwave Meta Materials Imaging Research under Dr. Michael Fiddy as a Ph.D student in Optical Science and Engineering.

OLEG SMOLSKI is an Associate Research Professor of Physics at the University of North Carolina at Charlotte. Prior to this, he was a Research Scientist with the College of Optics and Photonics at University of Central Florida for over four years and has been involved in execution of DARPA/DSO programs focused on developing high peak power diode laser systems. Major expertise of Dr Smolski is laser diode technology including surface-emitting devices, gain- and Q-switching lasers, emitters with an in-plane integrated DOE etc. Oleg Smolski received the Ph.D. degree in Physics in 1986 from the Ioffe Physico-Technical Institute in St Petersburg, Russia, where he worked as Researcher for next twelve years in the laboratory headed by Prof. Zh. Alferov, 2000 Nobel Prize Winner in Physics. His knowledge and experience in the field of semiconductor lasers was extended performing research in University of Connecticut, and then serving as a manager of Packaging, Test and Reliability Group at Infinite Photonics, Inc. Dr Smolski is co-author of 30 scientific papers.

Viktor O. Smolski is pursuing his PhD degree in Electrical Engineering in University of North Carolina at Charlotte. He received BS degree in Electrical Engineering from University of Central Florida in 2006. His current research interests are high power semiconductor lasers with monolithically integrated diffractive optics elements as well as the design and fabrication of micro optics components.

Phil Williams is an innovative and highly energized leader and team builder with over 36 years of cross industry experience and a global track record of success including founding, growing, and follow on sale of successful technology companies, one of which included the turnaround and spin out of a Communications Test/Measurement Systems division of a publicly traded global German-American Company with operations in Research Triangle Park, NC focused in DC to Light Test & Measurement instruments and systems. Mr. Williams ultimately purchased the systems division and later sold it in 2001 and exited in January 2008 and has continued his work as an independent industry consultant serving Military/Aerospace and industry. Other experience includes P&L, M&A, global sales and marketing in over 30 countries, new product development, embedded systems, sensors/detectors, sensor fusion, RF, digital/analog, optical, nano-machine automation, burn-in life test of VCSELs, pump lasers, laser Bars.

Metamaterials and their Applications
Haitao Zhang received his Ph. D. in Materials Science and Engineering from Northwestern University in 2005, his M. S. in Materials Science from Fudan University in 2000, and his B. S. in Materials Science from Fudan University in 1997. Dr. Zhang’s research interests include synthesis and characterization of thin films and nanostructures of functional materials, measurement of material properties, and fabrication of devices for electronic and photonic applications. Chemical vapor deposition (CVD) and physical vapor deposition (PVD) are main techniques employed to develop these functional thin films and nanostructures. Currently, his research work is focused on metal and metal oxide based materials in two major applications: (1) energy harvesting devices like solar cells and photo-electrochemical cells, and (2) energy-efficient devices such as chemical sensors and light-emitting devices.
**Emergency Contact Information**

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Emergency dial 911
Non-emergency 7-2200
From off campus dial 704-687-2200

Carolinas Medical Center (University Hospital) 704-568-6000

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Witherspoon Residence Hall Front Desk 7-4980
From off campus dial 704-687-4980

Optoelectronics Center 7-8117
From off campus dial 704-687-8117

Scott Williams Cell Phone 704- 315-9519

**Off Campus Transportation**

Crown Cab 704-334-6666

Yellow Cab 704-332-6161