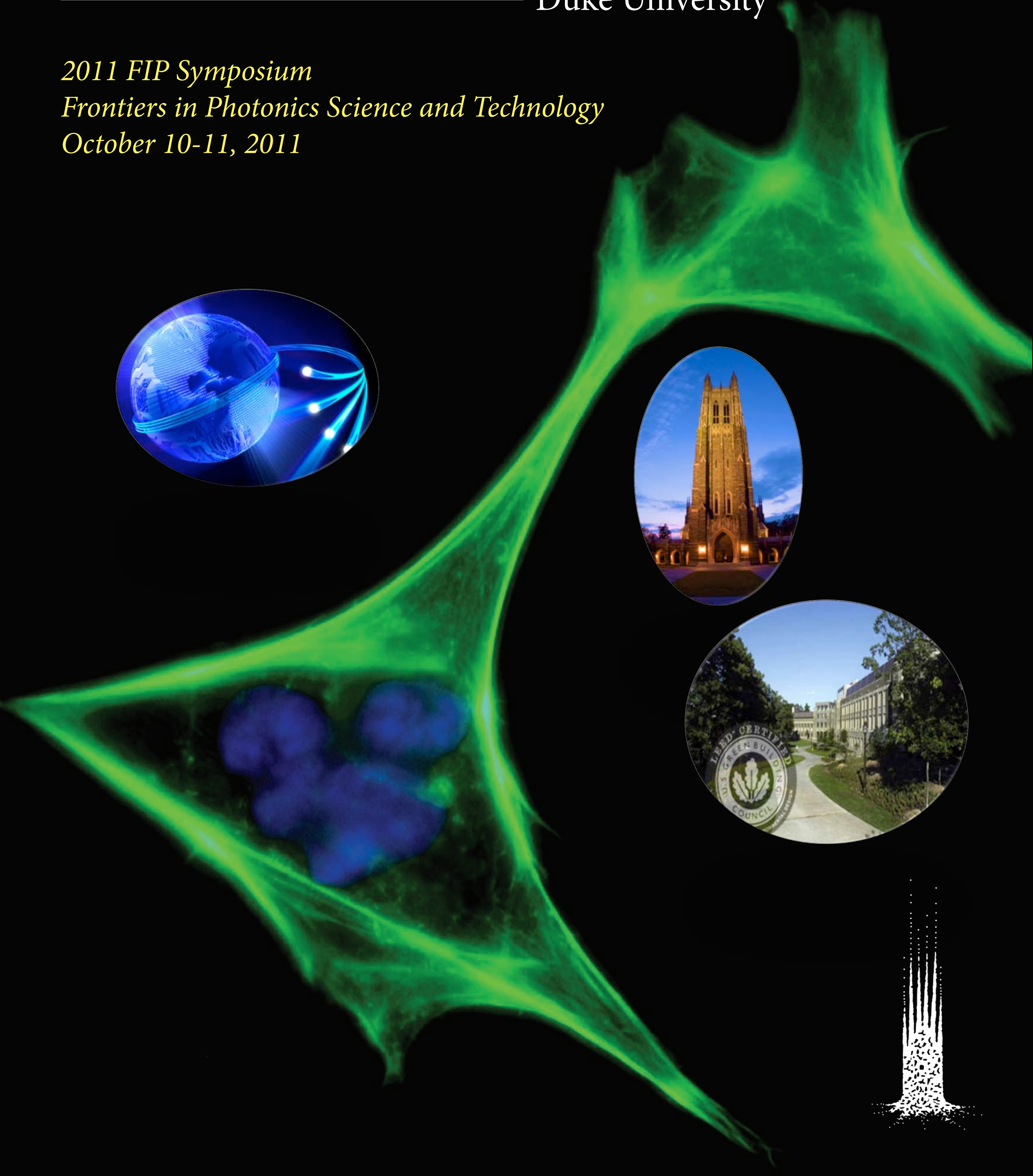
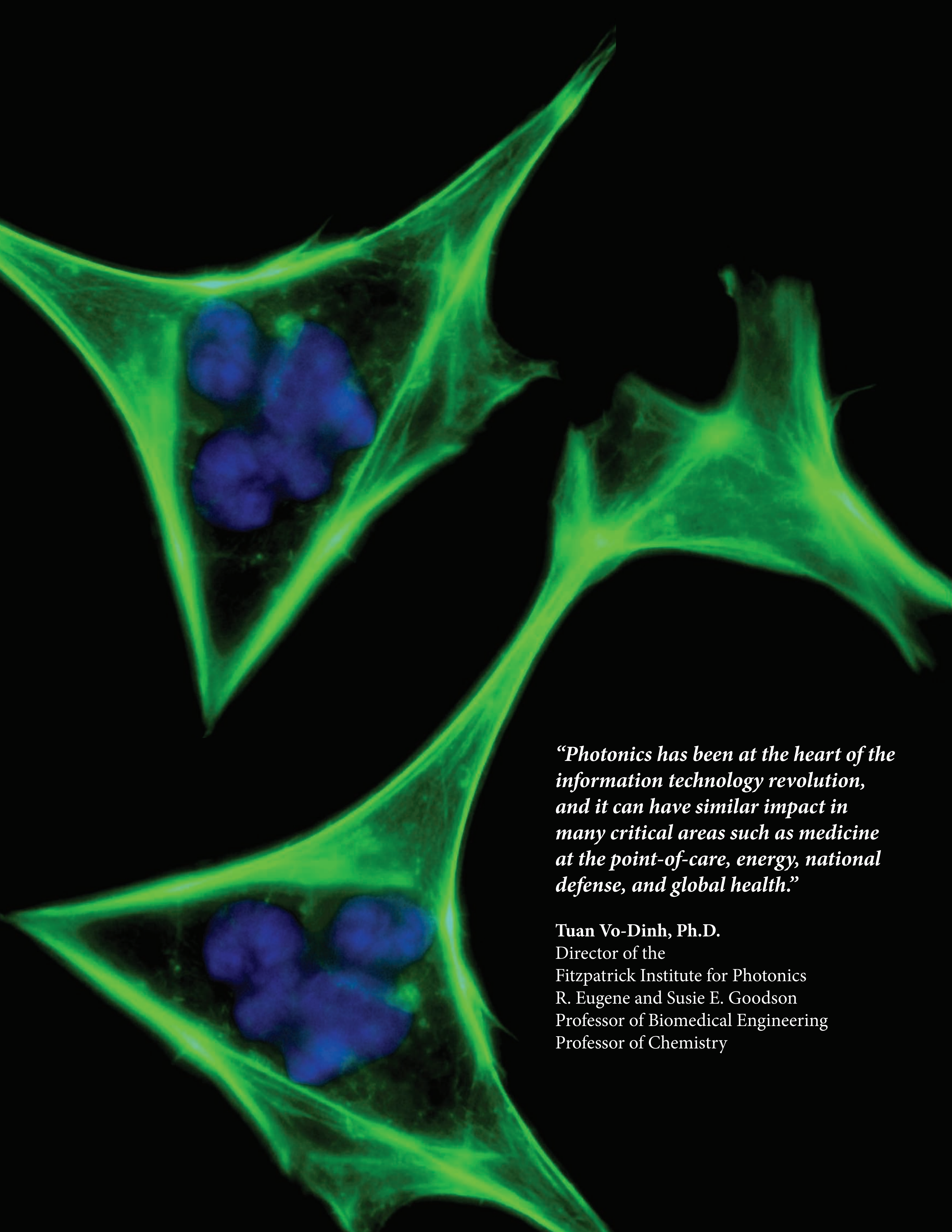
Fitzpatrick Institute for Photonics

Duke University

2011 FIP Symposium
Frontiers in Photonics Science and Technology
October 10-11, 2011





"Photonics has been at the heart of the information technology revolution, and it can have similar impact in many critical areas such as medicine at the point-of-care, energy, national defense, and global health."

Tuan Vo-Dinh, Ph.D.
Director of the
Fitzpatrick Institute for Photonics
R. Eugene and Susie E. Goodson
Professor of Biomedical Engineering
Professor of Chemistry

Welcome to the Fitzpatrick Institute for Photonics

Symposium on Photonics Science and Technology
2011 FIP Annual Meeting
October 10-11, 2011, Duke University

Symposium Chair – Tuan Vo-Dinh, Director, Fitzpatrick Institute for Photonics

Scientific Program Committee – Jungsang Kim, Daniel Gauthier, David Beratan, Joseph Izatt, Nan Jokerst, Kam Leong, Barry Myers, William Reichert, David Smith, Warren Warren, Adam Wax, Weitao Yang

Symposium Administrative Manager – August Burns, Business Manager, Fitzpatrick Institute for Photonics

Assistant Coordinator – Yan Zhang, Lab Manager, Fitzpatrick Institute for Photonics

Monday, October 10, 2011

Fitzpatrick Building

8:00 am - 9:00 am Registration

9:00 am - 5:00 pm Meeting

5:00 pm Poster Session-Reception

Tuesday, October 11, 2011

Fitzpatrick Building

8:30 am - 9:00 am Registration

9:00 am - 12:00 pm Meeting

Symposium on Photonics Science and Technology

2011 Fitzpatrick Institute for Photonics (FIP) Annual Meeting
October 10-11, 2011, Duke University

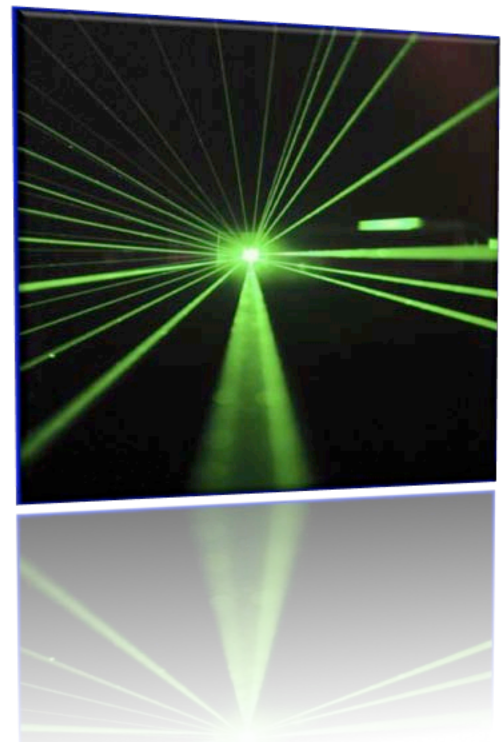
The Fitzpatrick Institute for Photonics is an extensively interdisciplinary Duke effort to advance photonics and optical sciences. The institute leverages Duke's faculty from the Pratt School of Engineering, Trinity Arts and Sciences, and the Duke Medical School to explore problems at the boundary nexus of nano-bio-info-opto convergence.

The Fitzpatrick Institute for Photonics (FIP) has 82 Faculty Members from 27 Participating Departments, Centers & Institutions at Duke University

Departments –

- Anesthesiology
- Biology
- Biomedical Engineering (BME)
- Chemical Biology
- Chemistry
- Civil & Environmental Engineering (CEE)
- Computer Science
- Electrical and Computer Engineering (ECE)
- Gastroenterology
- Mathematics
- Mechanical Engineering and Materials Science (MEMS)
- Neurosurgery
- Oncology
- Ophthalmology
- Orthopaedic Engineering
- Pathology
- Pediatrics
- Physics
- Radiation Oncology
- Radiology
- Surgery

Center for Metamaterials & Integrated Plasmonics
Division of Infectious Diseases & International Health
Duke Comprehensive Cancer Center
Duke Human Vaccine Institute
Institute for Genome Science and Policy
Nicholas School of the Environment



FIP Research Programs and Program Directors

Biophotonics – Joseph Izatt
Nano/Micro Systems – Nan Jokerst
Quantum Optics and Information Photonics – Daniel Gauthier
Photonic Materials – David Smith
Advanced Photonic Systems – William "Monty" Reichert
Nanophotonics – Kam Leong
Systems Modeling, Theory & Data Treatment – Weitao Yang
Novel Spectroscopies – Warren Warren

Symposium on Photonics Science and Technology

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ADVANCE PROGRAM

Provost
Peter Lange

Monday, October 10 (Fitzpatrick Center) – Morning Session

8:00-9:00 am Registration

9:00-9:10 Welcome Address
Peter Lange, Provost, Duke University

9:10-9:25 Opening Remarks
Tom Katsouleas, Professor and Dean, Pratt School of Engineering, Duke University

Tuan Vo-Dinh, FIP Director, R. Eugene and Susie E. Goodson Professor of Biomedical Engineering and Professor of Chemistry, Duke University

9:25-10:15 Symposium Keynote: "GFP: Lighting Up Life" – Martin Chalfie, Nobel Laureate in Chemistry (2008), William R. Kenan Jr. Professor of Biological Sciences, Columbia University

10:15-10:30 FIP Award Presentation – 2011 Pioneer in Photonics Award

10:30-10:45 Coffee Break

10:45-11:55 Session 1: Duke Distinguished Lectures

- **10:45-11:20** "Surfing on a Laser Wave: The Grand Challenge of Extending the High Energy Frontier" – Tom Katsouleas, Professor and Dean, Pratt School of Engineering, Duke University
- **11:20-11:55** "Managing Interference" – Robert Calderbank, Professor and Dean of Natural Sciences, Duke University

12:00-1:20 pm Lunch Break
(Lunch Boxes Provided)

We invite you to attend the Poster Session Exhibit throughout the Symposium. Posters are exhibited in the Atrium area of the Fitzpatrick Center

Symposium on Photonics Science and Technology

2011 Fitzpatrick Institute for Photonics (FIP) Annual Meeting
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Monday, October 10 (Fitzpatrick Center) – Afternoon Session

1:20-2:00 pm Plenary Lecture: "Quantum Computers and Raising Schrödinger's Cat" – David J. Wineland, NIST Fellow, National Institute of Standard and Technology

2:00-3:00 Session 2: Quantum Architectures
Chair: Jungsang Kim, Associate Professor, Department of Electrical and Computer Engineering, Physics and Computer Science, Duke University

- **2:00-2:30** Invited Lecture: "Quantum Networks of Trapped Ions" – Christopher Monroe, Bice Zorn Professor of Physics, Joint Quantum Institute, University of Maryland
- **2:30-3:00** Invited Lecture: "Challenges in Quantum Computer Architecture" – Kenneth Brown, Blanchard Assistant Professor, School of Chemistry and Biochemistry, School of Computational Science and Engineering, and School of Physics, Georgia Institute of Technology

3:00-3:20 Coffee Break and Poster Session

3:20-5:00 Session 3: Scalable Systems and Technologies
Chair: Daniel Gauthier, Robert C. Richardson Professor of Physics, Duke University

- **3:20-3:50** Invited Lecture: "Quantum information processing with Rydberg atoms" – Mark Saffman, Professor of Physics, University of Wisconsin-Madison
- **3:50-4:20** Invited Lecture: "Robust microfabricated surface ion traps with arbitrary lateral geometries" – David Moehring, Senior Research Staff, Sandia National Laboratories
- **4:20-4:40** "Integration Technologies for Scalable Quantum Information Processing with Trapped Ions" – Jungsang Kim, Associate Professor of Electrical and Computer Engineering, Physics and Computer Science, Duke University

4:40-5:00 "Colloidal Quantum Dot-Conducting Polymer Nanocomposites for Multi-spectral Photodetection" – Adrienne Stiff-Roberts, Assistant Professor of Electrical and Computer Engineering, Duke University

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5:00-6:30 Poster Session
Judge: Bernard Fischer, Associate Professor of Pediatrics, Duke University
Judge: Jie Liu, Professor of Chemistry, Duke University
Judge: Fan Yuan, Professor of Biomedical Engineering, Duke University

We invite you to attend the Poster Session Exhibit throughout the Symposium.
Posters are exhibited in the Atrium area of the Fitzpatrick Center

Theme Lab Visits (see Registration Desk for participation)

5:30-6:30 Cocktail Reception
(Heavy hors d'oeuvres will be served)

Tuesday, October 11, (Fitzpatrick Center)

SPECIAL EDUCATION PROGRAM FOR HIGH-SCHOOL STUDENTS

Introduction of high school students to science and engineering

Breakfast with a NOBEL LAUREATE

featuring Dr. Martin Chalfie, who received the 2008 Nobel Prize
for his discovery and development of the green fluorescent protein (GFP)

Symposium on Photonics Science and Technology

2011 Fitzpatrick Institute for Photonics (FIP) Annual Meeting
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Tuesday, October 11 (Fitzpatrick Center) Morning Session

8:30-9:00 am Registration

9:00-10:20 Session 4: Quantum Communications
Chair: Harold Baranger, Professor of Physics, Duke University

- **9:00-9:30** Invited Lecture: "Hyperentanglement: More IS better" – Paul Kwiat, John Bardeen Professor of Physics and of Electrical and Computer Engineering, University of Illinois
- **9:30-10:00** Invited Lecture: "Light in a Twist: optical orbital angular momentum" – Miles Padgett, Professor of Optics and Astronomy, University of Glasgow, United Kingdom
- **10:00-10:20** "Information Capacity of a Single Photon" – Daniel Gauthier, Robert C. Richardson Professor of Physics, Duke University

10:20-10:40 Coffee Break

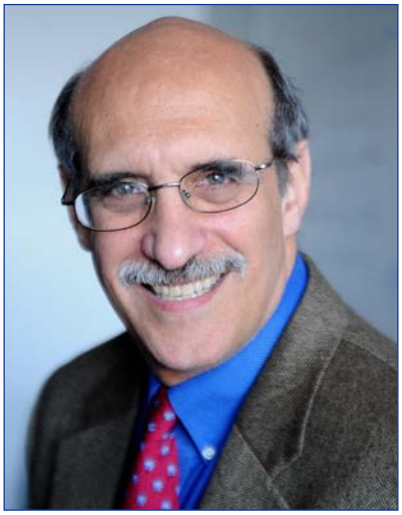
10:40-12:00 Session 5: Quantum Optics
Chair: Adrienne Stiff-Roberts, Assistant Professor in Electrical and Computer Engineering, Duke University

- **10:40-11:10** Invited Lecture: "Parallel generation of 15 quadripartite entangled states in the optical frequency comb" – Olivier Pfister, Professor of Physics at University of Virginia
- **11:10-11:40** Invited Lecture: "Auxiliary Entanglement in Spontaneous Parametric Down-Conversion" – Warren Grice, Senior Research Scientist at Oak Ridge National Laboratory
- **11:40-12:00** "Flying Qubits for Quantum Networks: Photon Blockade Without a Cavity" – Harold Baranger, Professor of Physics, Duke University

12:00-12:10 pm Poster Awards

12:10 pm Symposium Adjourns

Keynote Speaker



Martin Chalfie, Ph.D.
Nobel Laureate in Chemistry (2008)
William R. Kenan, Jr. Professor of Biological Sciences
Columbia University

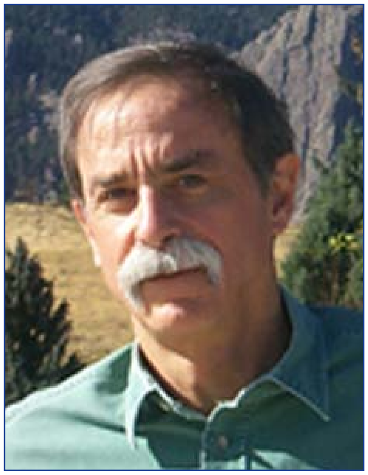
"GFP: Lighting Up Life"

Yogi Berra once said, "You can observe a lot by watching." Unfortunately, before the early 1990s observations in the biological sciences were usually done on dead specimens that were specially prepared and permeabilized to allow entry of reagents to stain cell components. These methods allowed a glimpse of what cells were doing, but they gave a necessarily static view of life, just a snapshot in time. GFP and other fluorescent proteins revolutionized the biological sciences because these proteins allowed scientists to look at the inner workings of living cells. GFP can be used to tell where genes are turned on, where proteins are located within tissues, and how cell activities change over time. Once a cell can be seen, it can be studied and manipulated. I will provide some examples of how having a dynamic view of life opens up new and exciting avenues of research. The discovery and development of GFP also provide a very nice example of how scientific progress is often made: through accidental discoveries, the willingness to ignore previous assumptions and take chances, and the combined efforts of many people. The story of GFP also shows the importance of basic research on non-traditional organisms.
Martin Chalfie is the William R. Kenan, Jr. Professor of Biological Sciences and former chair of the Department of Biological Sciences at Columbia University. In 2008 he shared the Nobel Prize in Chemistry with Osamu Shimomura and Roger Y. Tsien for his introduction of Green Fluorescent Protein (GFP) as a biological marker.

Dr. Chalfie was born in Chicago, Illinois. He obtained both his A.B. and Ph.D. from Harvard University and then did postdoctoral research with Sydney Brenner at the MRC Laboratory of Molecular Biology, Cambridge, England. He joined the faculty of Columbia University as an Assistant Professor in 1982 and has been there ever since.

He uses the nematode Caenorhabditis elegans to investigate nerve cell development and function, concentrating primarily on genes used in mechanosensory neurons. His research has been directed toward answering two quite different biological questions: How do different types of nerve cells acquire and maintain their unique characteristics? and How do sensory cells respond to mechanical signals? In the course of his studies, he has introduced several novel biological methods in addition to his work with GFP.

Dr. Chalfie is a member of the National Academy of Sciences and the Institute of Medicine and a fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, the Institute of Medicine, and the Royal Society of Chemistry (Hon.). He shared the 2006 Lewis S. Rosenstiel Award for Distinguished Work in Basic Medical Science from Brandeis University and the 2008 E. B. Wilson Medal from the American Society for Cell Biology with Roger Tsien.



PLENARY SPEAKER

Dave J. Wineland, Ph.D.

2007 National Medal of Science Awardee
Physicist, National Institute of Standards and Technology

"Quantum Computers and Raising Schrödinger's Cat"

Quantum systems such as atoms can be used to store information. For example, we can store binary information in two energy levels of an atom by labeling the state with lower energy a "0" and the state with higher energy a "1." However, quantum systems can also exist in superposition states, thereby storing both states of the bit simultaneously - a situation that makes no sense in our ordinary-day experience. This property can lead to an increase in memory and processing capacity that scales exponentially with the number of bits. It would enable a quantum computer to efficiently solve certain problems such as factorizing large numbers, which may be intractable on a classical computer. Actually building a useful quantum computer is an extremely daunting task due to the necessity of overcoming decoherence, which includes all processes that destroy superposition states. Nevertheless, in the near term, the principles of quantum information processing are finding applications in metrology such as for atomic clocks. A small quantum processor would also realize a mesoscopic version of "Schrödinger's Cat," a bizarre situation conceived by Erwin Schrödinger in 1935 where a cat could be simultaneously dead and alive. A number of physical systems are currently considered for building a quantum computer; this talk will focus on the use of trapped atomic ions.

David Wineland received a bachelor's degree from Berkeley in 1965 and his Ph.D. from Harvard in 1970, under Norman Ramsey. After a postdoctoral appointment at the University of Washington, under Hans Dehmelt, he joined NBS (now NIST), where he is the leader of the Ion-Storage Group in the Time and Frequency Division at Boulder. The group's research has focused on laser cooling and spectroscopy of trapped atomic ions with applications to atomic clocks, quantum-limited metrology, and quantum state control. Dr. Wineland was awarded the 2007 National Medal of Science from President George W. Bush for his "outstanding leadership in developing the science of laser cooling and manipulation of ions, with applications in extremely precise measurements and standards, quantum computing, and fundamental tests of quantum mechanics, and for his major impact on the international scientific community through training scientists and outstanding publications."*

*http://www.nist.gov/public_affairs/releases/wineland082508.cfm

Duke Distinguished Speakers

Robert Calderbank, Ph.D.

Dean of the Natural Sciences
Professor of Computer Science, Mathematics,
Electrical and Computer Engineering
Duke University

"Managing Interference"

We consider a new framework for full-duplex communication in ad-hoc wireless networks. An individual node in the wireless network either transmits or it listens to transmissions from other nodes but it cannot to both at the same time. There might be as many nodes as there are 48 bit MAC addresses but we assume that only a small subset of nodes contribute to the superposition received at any given node in the network.

We use ideas from compressed sensing to show that simultaneous communication is possible across the entire network. Our approach is to manage interference through configuration and it makes use of quantum error correcting codes.

Robert Calderbank is Dean of Natural Sciences and Professor of Electrical Engineering at Duke University where he directs a research program at the interface of signal processing and wireless communication. Prior to joining Duke in 2010, he was Director of the Program in Applied and Computational Mathematics at Princeton University, and before joining Princeton in 2004 he was Vice President for Research at AT&T. At the start of his career at Bell Labs Professor Calderbank developed technology that was incorporated in a progression of voiceband modem standards that moved communications practice close to the Shannon limit. Together colleagues at AT&T Labs he showed that good quantum error correcting codes exist and developed the group theoretic framework for quantum error correction. He is a co- inventor of space-time codes for wireless communication, where correlation of signals across different transmit antennas is the key to reliable transmission. Professor Calderbank was elected to the US National Academy of Engineering in 2005.

Tom Katsouleas, Ph.D.

Dean, Pratt School of Engineering
Professor of Electrical and Computer Engineering
Duke University

"Surfing on a Laser Wave: The Grand Challenge of Extending the High Energy Frontier"

Particle accelerators are among the largest and most successful machines ever built by humans. They have been responsible for more discoveries about the fundamental nature of matter and energy than any other tool. However, they have clearly hit limits of size and cost, and the continued exploration of the high energy physics frontier as well as the realization of promising applications in medicine and industry require a new technology. Plasma-based accelerators have emerged as the leading candidate. Acceleration of particles in plasma waves driven by lasers and particle beams have made remarkable advances in the past five years, including the doubling of the energy of the 3km long Stanford Linear Accelerator in a one-meter long plasma and the generation of GeV monoenergetic beams in a centimeter long gas/plasma. This talk reviews the recent history and basic principles of plasma-based acceleration and highlights simulation advances and upcoming experiments that will take the field the next step toward the energy frontier. The talk will examine the role of accelerators and plasmas in addressing the NAEs Grand Challenges for the 21st Century.

Thomas C. Katsouleas became dean of Duke University's Pratt School of Engineering, in July 2008, where he is also a Professor of Electrical and Computing Engineering. He earned a Ph.D. in physics and B.S. in physics, from UCLA in 1979 and 1984, respectively. He continued at UCLA where he served for seven years on the faculty. He joined the University of Southern California faculty as an associate professor of electrical engineering in 1991, becoming full professor in 1997. There he also served as an Associate Dean of Engineering and Vice Provost of Information Technology Services. He currently serves as associate editor of the IEEE Transactions on Plasma Science, co-chair of the ASEE Global Symposium on Engineering Education (Shanghai, 2011) and chair of the National Academy of Engineering Advisory Committee on Grand Challenges. Katsouleas' primary research interest is in the use of plasmas as novel particle accelerators and light sources. His talk today reprises his award address for the 2011 Plasma Science Achievement Award from the IEEE.

Invited Speakers

Kenneth Brown, Ph.D.
Blanchard Assistant Professor
Schools of Chemistry and Biochemistry; Computational Science and Engineering; and Physics
Georgia Institute of Technology

"Challenges in Quantum Computer Architecture"

The development of a large-scale quantum computer faces two challenges: faulty hardware components and the inability to copy quantum information. Despite the no-cloning theorem, it is possible to use fault-tolerant quantum error correction techniques to generate arbitrarily reliable logical components. In the context of an algorithm, the inability to copy quantum information requires that a block of data that needs to interact with two other data blocks must be transported first from one block and then to the other. Although it is widely appreciated that the bulk of resources in a scalable quantum computers will be devoted to error correction, the significant cost of communication in the computer is only now being understood [1]. I will discuss methods for estimating the communication cost on two distinct hardware layouts for ion trap quantum computation in the context of concatenated error correcting codes. In the first hardware layout, the ions are held in multiple zones and communications is performed by physically shuttling ions between zones [2]. The second hardware layout uses photons to create entangled ions in distant traps by the process of heralded entanglement [3]. These entangled ions are then used as teleportation channels to transfer information. I will compare possible architectures for arranging these systems on the logical level. Finally, I will briefly describe how these same architectural ideas can be applied in the setting of topological error correction.

[1] M.G. Whitney, N. Isailovic, Y. Patel and J. Kubiatowicz, A Fault Tolerant, Area Efficient Architecture for Shor's Factoring Algorithm, Proc. of the 39th Annual Intl. Symp. on Computer Architecture (ISCA), 383 (2009).
[2] D. Kielpinski, C. Monroe & D. J. Wineland, Architecture for a large-scale ion-trap quantum computer, Nature 417, 709 (2002).
[3] L.-M. Duan and C. Monroe, Quantum Networks with Trapped Ions, Rev. Mod. Phys. 82, 1209 (2010).

Kenneth Brown received his B.S. in Chemistry from the University of Puget Sound in 1998. For his PhD, he studied theoretical quantum information science as a Hertz Fellow at UC Berkeley. Following his PhD, he held a postdoctoral position at MIT where he performed quantum information experiments using NMR and ion traps. Since 2007, he has been an assistant professor at Georgia Tech where he leads a research group studying quantum information and cold molecular ions.

Warren Grice, Ph.D.

Senior Research Scientist
Center for Quantum Information Science
Oak Ridge National Laboratory

"Auxiliary Entanglement in Spontaneous Parametric Down-Conversion"

In most photonic quantum information applications, information is encoded into the photons' polarization degrees of freedom. This is a natural choice, given that polarization can be completely described by a linear combination of only two basis states. It has experimental appeal, as well, since it is relatively easy to manipulate polarization using simple optical elements. However, a more complete description of the photon also includes its energy and its spatial mode. And while it might seem that these have little to do with polarization, it turns out that spatial and spectral entanglement can have adverse effects in polarization entanglement experiments. I will discuss the source of these auxiliary entanglements and will present a series of theoretical and experimental results illustrating the subtle relationships between various types of entanglement. Strategies for managing these auxiliary entanglements will also be discussed.

Dr. Warren Grice is a senior research scientist at Oak Ridge National Laboratory and serves as the director of its Center for Quantum Information Science. He conducts research primarily in the field of quantum optics, particularly in the design and fabrication of novel sources of entangled photons. Recent projects include entangled photon sources for Quantum Key Distribution and Quantum Computing. Dr. Grice holds a B.S. in Physics from Western Kentucky University and a Ph.D. in Optics from the University of Rochester (1997), where his thesis work on ultrafast quantum optics was completed under the direction of Ian Walmsley. Before coming to ORNL, Dr. Grice was a member of the faculty of the Department of Physics at Southern Illinois University Edwardsville.

Paul G. Kwiat, Ph.D.

John Bardeen Professor of Physics
Professor of Electrical and Computer Engineering
University of Illinois

"Hyperentanglement: More IS better"

Entanglement is now seen as one of the critical resources in the new field of quantum information processing. For example, it enables ultra-secure quantum cryptography and teleportation. However, only recently have researchers begun to explore the fact that two parties, e.g., photons, can in fact be simultaneously entangled in multiple degrees of freedom. Here we discuss the benefits of such "hyperentanglement", focusing on its use for high-capacity quantum communication and high-speed quantum cryptography.

Paul G. Kwiat is the Bardeen Chair in Physics, at the University of Illinois, in Urbana-Champaign. A Fellow of the American Physical Society and the Optical Society of America, and recipient of the OSA 2009 R. W. Wood Prize, he has given invited talks at numerous national and international conferences, and has authored over 130 articles on various topics in quantum optics and quantum information, including several review articles. His research includes the phenomena of quantum interrogation, quantum erasure, and optical implementations of quantum information protocols, particularly using entangled—and hyperentangled—photons from parametric down-conversion.

David Moehring, Ph.D.

Senior Research Staff
Sandia National Laboratories

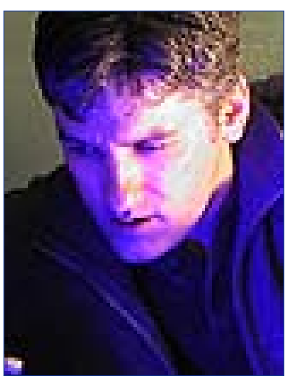
"Robust microfabricated surface ion traps with arbitrary lateral geometries"

We will present the status of Sandia's efforts to engineer surface ion traps, specifically detailing our ability to reliably fabricate arbitrary surface geometries. These achievements include the precision placement of backside holes for loading from a neutral atom source, multi-level metalization which supports vertical interconnects and low electrical power loss in the substrate, and low profile wirebonds for surface laser access [1, 2]. We have combined these capabilities to produce a successful and robust Y-junction trap which takes advantage of numerical simulations to tailor the RF pseudopotential field in the junction with precisely shaped electrodes [3]. We will also present ongoing collaborative work at fabricating structures for quantum simulations. In addition we will describe traps with an integrated high finesse optical cavity, junction traps capable of reordering strings of ions with multiple species, and ring shaped traps.

[1] D. Stick, et al., arXiv:1008.0990v2 [physics.ins-det] (2010).
[2] D. T. C. Allcock, et al., arXiv:1105.4864v1 [quant-ph], accepted for publication (2011).
[3] D. L. Moehring, et al., New J. Phys. 13, 075018 (2011).

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

David Moehring has spent the last 10 years in quantum information processing specializing in the entanglement between single atoms and single photons. His Ph.D. in the group of Chris Monroe presented a theoretical and experimental realization for the entanglement of two trapped atomic ions, including the first explicit demonstration of quantum entanglement between a single trapped ion and its single emitted photon, as well as the entanglement between two macroscopically separated trapped ions. From 2007-2009, he was an Alexander von Humboldt Research Fellow in the group of Gerhard Rempe at the Max Planck Institute for Quantum Optics where his research focused on the entanglement between a single photon and a single atom strongly coupled to a high-finesse optical cavity. Since 2009, David is been a Senior Member of Technical Staff at Sandia National Laboratories where he has led an effort developing microfabricated ion traps.



Christopher Monroe, Ph.D.

Bice Zorn Professor of Physics
Joint Quantum Institute
University of Maryland

"Quantum Networks of Trapped Ions"

Trapped atomic ions are among the most promising candidates for quantum information processing, with each atom typically storing a single quantum bit (qubit) of information in appropriate internal electronic levels. All of the fundamental quantum operations have been demonstrated between small numbers of atoms [1], and the central challenge now is how to scale the system to larger numbers of interacting qubits. The Coulomb interaction between trapped ions allows entangling operations through the collective motion of the ion crystal, which is excited through the state-dependent optical dipole forces. Such a quantum network may be limited in size by the stability and coherence of the motion of larger ion crystals, and current efforts are devoted to the physical movement of individual atomic ions through complex ion trap structures [2] or alternatively by mapping qubits onto photons that can allow the probabilistic entanglement between remotely-located atomic crystals [3]. On the other hand, when such a laser force is applied globally, an effective spin-spin interaction emerges whose sign and range can be precisely controlled with the laser [4], and any possible spin correlation function can be measured with standard state-dependent fluorescence techniques. This allows the quantum simulation of interesting spin models that possess nontrivial ground states for the investigation of quantum phase transitions, quantum frustration, and the emergence of spin liquid behavior. Work on all of these fronts will be reported, including quantum simulations of magnetism with N = 16 atomic qubits as well as progress on operating deterministic gates between atoms separated by macroscopic distances.

[1] R. Blatt and D. J. Wineland, Nature 453, 1008 (2008).
[2] D. Kielpinski et al., Nature 417, 709 (2002).
[3] L.-M. Duan and C. Monroe, Rev. Mod. Phys. 82, 1209 (2010).
[4] R. Islam et al., Nature Comm. 2, 377 (2011).

Christopher Monroe is an experimental physicist, in the realm of atomic, molecular and optical physics. After getting his undergraduate degree from MIT in 1987, Monroe obtained his PhD with Carl Wieman at the University of Colorado in 1992. From 1992-2000, Monroe joined the Ion Storage Group of David Wineland at the National Institute of Standards and Technology in Boulder, CO, as a National Research Council postdoctoral fellowship from 1992-1994, and a staff physicist in the same group from 1994-2000. With Wineland, Monroe led the research team that demonstrated the first quantum logic gate in 1995, and exploited the use of trapped atomic ions for applications in quantum control and the new field of quantum information science. Monroe was awarded the 1997 Presidential Early Career Award for Scientists and Engineers and with Wineland shared the 2000 International Award for Quantum Communications. In 2000, Monroe moved to the University of Michigan, where he developed the use of single photons to couple quantum information between atomic ions, also demonstrating monolithic ion traps integrated on a semiconductor chip. He was awarded the I. I. Rabi Prize of the American Physics Society in 2001 for his work with trapped ions. In 2006, Monroe became Director of the FOCUS Center at the University of Michigan, a NSF Physics Frontier Center in the area of ultrafast optical science. In 2007, Monroe became the Bice Zorn Professor of Physics at the University of Maryland and a Fellow of the Joint Quantum Institute between Maryland and NIST. Here, his group exploits photonic links between separated atomic qubits for teleportation and other applications, uses crystals of trapped ions for quantum simulations of magnetism, and also investigates the use of ultrafast pulses for quantum manipulation of atomic qubits. Monroe's general scientific interests include quantum optics, cold atomic physics, quantum information science, the interface between atomic and solid state physics, and fundamental issues in quantum physics.

Miles Padgett, Ph.D.

Professor of Optics and Astronomy
University of Glasgow, United Kingdom

"Light in a Twist: optical orbital angular momentum"

A feature of wave superposition is that one plus one does not necessarily equal two. The interference of two equivalent waves can result in a zero intensity – e.g. Young's double slits. However, the waves fill 3D space not just a 2D screen and Young's dark fringes map out planes. But two waves are a special case. In general, when three or more waves interfere, complete destructive interference forms dark lines (phase singularities) around which the phase advances or retards by 2π. This azimuthal phase gradient means that the Poynting vector, and associated energy flow, circulates too – hence the dark lines are also called "optical vortices". Despite their appearance in all natural light fields, it was not until the early 1990's that it was recognized by Allen et al that light beams containing a single line phase singularity carried an angular momentum, completely independent of the photon spin. This orbital angular momentum can be created using simple lens systems, or holograms - made from 35mm film or encoded onto liquid crystal displays. Both whole beams, and single photons can carry this information, or transfer it to particles to create an optical spanner.

In this talk I hope to introduce the underlying physical properties and discuss a number of manifestations of orbital angular momentum, which highlight how optics still contains surprises and opportunities for both the classical and quantum worlds.

Miles Padgett holds the Kelvin Chair of Natural Philosophy in the School of Physics and Astronomy at the University of Glasgow. He heads a 15-person team covering a wide spectrum from blue-sky research to applied instrument development. In 2001 he was elected to Fellowship of the Royal Society of Edinburgh. In 2007/8 he was a Leverhulme Trust Royal Society Senior Research Fellow. In 2008 Padgett was awarded the Institute of Physics Optics and Photonics Division Prize and in 2009 the Young Medal and Prize for "pioneering work on optical angular momentum". Since 2009, he is supported by a Royal Society–Wolfson Merit Award. The group's work has led to the fundamental understanding of light's momentum, including conversion of optical tweezers to optical spanners, observing the topology of vortex lines in optical speckle, and demonstrating an angular form of the EPR paradox.

Olivier Pfister, Ph.D.

Professor of Physics
University of Virginia

“Parallel generation of 15 quadripartite entangled states in the optical frequency comb”

“The physical implementation of nontrivial quantum computing is a daunting experimental challenge due to decoherence and the need for scalability. Recently, Nick Menicucci, Steve Flammia, and I discovered a novel theoretical scheme [1] for realizing a scalable quantum register of very large size, entangled in a cluster state, in the optical frequency comb (OFC) defined by the eigenmodes of a single optical parametric oscillator (OPO). The classical OFC is well known as implemented by the femtosecond, carrier-envelope-phase- and mode-locked lasers which have redefined frequency metrology in recent years. The quantum OFC is a set of harmonic oscillators, or Qmodes, whose amplitude and phase quadratures are continuous variables. Continuous-variable manipulation is a mature field for one or two Qmodes. In this talk I will present an experimental breakthrough [2]: the entanglement of 60 Qmodes of the OFC of a single OPO into 15 “square” cluster entangled states of 4 Qmodes each. I will also detail why we believe we actually had ten times as many Qmodes as we could measure.

[1] N.C. Menicucci, S.T. Flammia, and O. Pfister, Phys. Rev. Lett. 101, 130501 (2008).
[2] M. Pysher, Y. Miwa, R. Shahrokhshahi, R. Bloomer, and O. Pfister, Phys. Rev. Lett. 107, 030505 (2011). “

Olivier Pfister received a B.S. (1987) in Physics from Université de Nice, France, and an M.S. (1989) and a Ph.D. (1993) in Physics from Université Paris-Nord, France. He was a Research Associate with John L. Hall at JILA, University of Colorado (1994-7) and with Daniel J. Gauthier at Duke University (1997-9). He then joined the faculty of the University of Virginia, where he is now a Professor of Physics. Olivier Pfister is a member of the American Physical Society and of the Optical Society of America. His current research interests include experimental quantum computing with light and quantum optical measurements at the ultimate precision.

Mark Saffman, Ph.D.

Professor of Physics
University of Wisconsin-Madison

“Quantum information processing with Rydberg atoms”

Neutral atoms are attractive candidates for quantum information processing due to their stability and weak interaction with the environment. The challenge of implementing a strong and controllable two-atom interaction was met recently with the demonstration of Rydberg blockade, and its use for a two-qubit entangling quantum logic gate. I will review the physics of the Rydberg blockade effect, present experimental results showing deterministic entanglement of a pair of neutral atoms, and outline the prospects for using Rydberg atoms for scalable quantum computing and simulation.

Mark Saffman was educated at Caltech and the University of Colorado at Boulder. He has 30 years of experience in industrial and academic research and development working in the areas of optical diagnostics for fluids and plasmas, experimental atomic physics, quantum and nonlinear optics, and quantum information processing. He has made notable contributions to light scattering instrumentation, optical solitons and pattern formation, sources of entangled light, and quantum computing.

His current research effort is devoted to the development of neutral atom based quantum computing devices. His research team was the first to demonstrate a quantum CNOT gate between two trapped neutral atoms, and the deterministic entanglement of a pair of neutral atoms. This was done using dipole mediated interactions between highly excited Rydberg atoms. He is currently developing scalable neutral atom processors using arrays of trapped alkali atoms.

Duke Speakers

Harold Baranger, Ph.D.
Professor of Physics
Duke University

"Flying Qubits for Quantum Networks: Photon Blockade Without a Cavity"

The manipulation of individual, mobile quanta is a key goal of quantum information processing and communication; to achieve this, nonlinear phenomena in open systems can play a critical role. We show theoretically that a variety of strong quantum nonlinear phenomena occur in a completely open one-dimensional waveguide coupled to a two-, three-, or four- level system. These include the phenomena of photon blockade, electromagnetically induced transparency, creation of single photon states, and strong bunching and anti-bunching, all in the absence of a cavity. Many-body bound states appear due to the strong photon-photon correlation mediated by the local system. These bound states cause photon blockade which regulates the flow of photons and can generate a sub-Poissonian single photon source on demand. This theoretically demonstrated control over light quanta at the single-photon level helps pave the way for realizing fully open quantum networks. (Work done in collaboration with Huaixiu Zheng and D. J. Gauthier, and funded by the Office of Naval Research.)

Harold Baranger's research has focused on electrical conduction through nanostructures throughout his career, particularly on the role of quantum interference and electron-electron interactions. He has paid close attention to analogies between electronic and photonic systems, such as those that arise, for instance, in propagation through random media or decoherence caused by a dissipative environment. Baranger got his Ph.D. degree in 1986 from Cornell, did a post-doc at Université Paris Sud (Orsay), and then spent 13 years at Bell Labs as a member of the research staff before coming to Duke 12 years ago. Currently, Baranger's group is pursuing three directions: (1) the development and control of electron-electron correlations in quantum wires and dots, (2) waveguide QED-- nonlinear quantum optics in open systems, and (3) non-equilibrium electron transport in nanosystems.

Daniel Gauthier, Ph.D.
Robert C. Richardson Professor of Physics
Duke University

"Information Capacity of a Single Photon"

A photon is an indivisible quantum of light so one might think that it is only possible to encode at most one bit of information on a photon that is used in a communication system. On the other hand, a photon is described by many degrees of freedom (e.g., polarization, frequency, time of arrival, etc.), which opens up the possibility of encoding many bits on a single photon. I will describe our recent experiments where we are attempting to encode approximately 10 bits per photon, close to the limits imposed by the quantum mechanical version of Shannon's limits for the capacity of a communication channel.

Daniel J. Gauthier is the Robert C. Richardson Professor of Physics at Duke University. He received the Ph.D. degree from the Institute of Optics at the University of Rochester in 1989 under the mentorship of Prof. Robert W. Boyd and was a post-doctoral Research Associate at the University of Oregon from 1989-1991 under the mentorship of Prof. Thomas W. Mossberg. He moved to Duke University in 1991 as an Assistant Professor of Physics. His research interests include nonlinear and quantum optics, slow and fast light, metamaterials and plasmonics, and nonlinear dynamics of electronic and optical systems. He is currently leading a effort to achieve high-bit-rate quantum key distribution in which many bits are encoded per photon, funded through the DARPA DSO InPho program. He is a Fellow of the American Physical Society and the Optical Society of America.

Jungsang Kim, Ph.D.

Associate Professor
Electrical and Computer Engineering
Duke University

"Integration Technologies for Scalable Quantum Information Processing with Trapped Ions"

Trapped ions are one of the leading candidates to realize scalable quantum information processing, where high quality qubits and many of the basic qubit manipulation have been demonstrated. Construction of large-scale quantum computer based on trapped ions faces challenges similar to those faced in the 1940's and 1950's for digital computers: lack of technology platform that will enable large-scale integration of basic logic elements. We will describe a modular and scalable architecture for constructing ion-trap based quantum computer using qubit manipulation techniques that have been demonstrated to date. New integration technologies that will enable higher levels of scalability at all scales of physical hardware implementation will be described, including microfabricated ion traps, MEMS micromirrors for rapid beam steering that enables individual addressing of atomic qubits, and optical components integrated with the microfabricated traps for efficient interaction between ions and photons.

Jungsang Kim received his B.S. degree in Physics in 1992 from Seoul National University (SNU) in Seoul, Korea, and his Ph.D. in Physics from Stanford University in 1999, working on the topic of quantum optics in semiconductor devices. He joined Bell Laboratories in Murray Hill, New Jersey where he served as a Member of Technical Staff and a Technical Manager, developing large-scale MEMS-based optical switches and advanced wireless communication systems. He joined the Department of Electrical and Computer Engineering at Duke University in 2004. His research interest lies in construction of high-performance complex systems, including ion-trap quantum computers, quantum communication networks, and high-performance imaging systems.

Adrienne Stiff-Roberts, Ph.D.

Assistant Professor
Electrical and Computer Engineering
Duke University

"Colloidal Quantum Dot-Conducting Polymer Nanocomposites for Multi-spectral Photodetection"

Multi-spectral photodetection can increase the spectral resolution of IR imaging focal plane arrays and improve the power conversion efficiency of solar cells. Colloidal quantum dots (CQDs) could provide an important advantage as the active region material in such devices because multi-spectral photon detection across a wide spectral range can be integrated at the device level by changing the nanoparticle material, size, and/or shape. In addition, there are no inherent restrictions, such as strain or contamination, to limit the different types of nanoparticle materials that can be combined in a single heterostructure. However, two long-standing, fundamental challenges to the use of CQD-conducting polymer nanocomposites for photodetection are controlling the nanoscale morphology and achieving efficient charge transfer through insulating ligand layers surrounding the quantum dots. Therefore, in this talk, I will review progress in addressing these fundamental challenges.

Adrienne D. Stiff-Roberts is an Assistant Professor in the Department of Electrical and Computer Engineering at Duke University. Dr. Stiff-Roberts received both the B.S. degree in physics from Spelman College and the B.E.E. degree in electrical engineering from the Georgia Institute of Technology in 1999. She received an M.S.E. in electrical engineering and a Ph.D. in applied physics in 2001 and 2004, respectively, from the University of Michigan, Ann Arbor. Her current research interests include materials growth of polymer, nanoparticle, and organic/inorganic hybrid nanocomposite thin films by matrix-assisted pulsed laser evaporation (MAPLE); epitaxial materials growth of thin-films and nanostructures; structural, optical, and electrical materials characterization of organic and inorganic materials; and the design, fabrication, and characterization of organic and inorganic optoelectronic devices, especially multi-spectral photodetectors. Dr. Stiff-Roberts is a recipient of the National Science Foundation CAREER Award (2006), the Office of Naval Research Young Investigator Award (2007), the IEEE Early Career Award in Nanotechnology of the Nanotechnology Council (2009), and the Presidential Early Career Award in Science and Engineering (2009).

Symposium on Photonics Science and Technology

2011 Fitzpatrick Institute for Photonics (FIP) Annual Meeting
October 10-11, 2011, Duke University

Poster Session Exhibit

Poster # 1 **Multimodal in situ imaging of human vaginal surfaces and their coating by microbicide gels**
Tyler K. Drake1, Michael G. DeSoto1, Jennifer J. Peters1, Marcus H. Henderson1, Amy P. Murtha2, David F. Katz1,2, and Adam Wax1
1Department of Biomedical Engineering, Duke University, Durham, North Carolina 27708, USA
2Department of Obstetrics and Gynecology, Duke University, Durham, North Carolina 27710, USA

Poster # 2 **The Synthesis and Coating of Long, Thin Copper Nanowires to make Flexible, Transparent Conducting Films on Plastic Substrates**
Aaron R. Rathmell and Benjamin J. Wiley, Chemistry Department, Duke University*

Poster # 3 **Silica-Coated Gold Nanostars for Combined Surface-Enhanced Raman Scattering (SERS) Detection and Singlet-Oxygen Generation: A Potential Nanoplatform for Theranostics**
Andrew M. Fales, Hsiangkuo Yuan, Tuan Vo-Dinh
Fitzpatrick Institute for Photonics, Biomedical Engineering Department, Duke University

Poster # 4 **Microfluidics-Assisted Synthesis of Gene-Loaded Nanocomplexes**
Yi-Ping Ho, Christopher L. Grigsby, Kam W. Leong
Department of Biomedical Engineering, Duke University, Durham, NC

Poster # 5 **Wireless Metamaterials for Time Reversal Imaging Applications**
Alexander R. Katko, Allen M. Hawkes, Steven A. Cummer
Department of Electrical and Computer Engineering and Center for Metamaterials and Integrated Plasmonics, Duke University

Poster # 6 **Toward single-photon nonlinear optics via atomic crystallization**
Joel A. Greenberg and Daniel J. Gauthier
Duke Physics Department and Fitzpatrick Institute for Photonics, Duke University

Poster # 7 **Precise control of protein expression using a high-throughput screening strategy and integrated high quality on-chip gene synthesis**
Jiayuan Quan1,2, Ishtiaq Saaem1,2, Nicholas Tang1, Siying Ma1,2, & Jingdong Tian1,2,†
1 Department of Biomedical Engineering,
2 Institute for Genome Sciences and Policy, Duke University, 136 Hudson Hall, Box 90281, Durham, NC 27708, USA.
†Correspondence should be addressed to J.T. (jtian@duke.edu).

Poster # 8 **Flying Qubits for Quantum Networks: Photon Blockade Without a Cavity**
Huaixiu Zheng, Daniel J. Gauthier, and Harold U. Baranger
Department of Physics, Duke University, Durham, North Carolina 27708, USA

Poster # 9 **Imaging the Distributions of Eumelanin and Pheomelanin in Human Tissue**
Mary Jane Simpson1, Jesse W. Wilson1, Thomas Matthews1, Simone Degan1, Tanya Mitropoulos1, Maria A. Selim2, Warren S. Warren1
1. Chemistry, Duke University, Durham, NC, United States. 2. Pathology, Duke University Hospital, Durham, NC, United States.

Poster # 10 **A Custom, Wide-field Imaging Array for Breast Cancer Margin Assessment Using Diffuse Reflectance Spectroscopy**
Sulochana Dhar1, Justin Y. Lo2, Bing Yu2, Martin A. Brooke1, Nimmi Ramanujam2, Nan M. Jokerst1
1Department of Electrical and Computer Engineering, Duke University, Durham, NC
2Department of Biomedical Engineering, Duke University, Durham, NC

Poster # 11 **Plasmonic Gold Nanostars: A Potential Agent for Molecular Imaging and Cancer Therapy**
*Hsiang-Kuo Yuan 1, Christopher G. Khoury 1, Andrew Fales 1, Christy M. Wilson 2, Gerald A. Grant 2, Tuan Vo-Dinh 1,3,4**
1 Department of Biomedical Engineering, Duke University, Durham, NC 27708, USA
2 Department of Surgery, Division of Neurosurgery, Duke University Medical Center, Durham, NC 27708, USA
3 Department of Chemistry, Duke University, Durham, NC 27708, USA
4 Fitzpatrick Institute for Photonics, Duke University, Durham, NC 27708, USA

Poster # 12 **Overcoming High Flow Rate Imaging Limitations in Doppler Optical Coherence Tomography**
Hansford C. Hendargo 1, Ryan P. McNabb 1, Al-Hafeez Dhalla 1, Neal Shepherd 2, and Joseph A. Izatt 1
1. Department of Biomedical Engineering Duke University 2. Department of Pediatrics, Duke University Medical Center

Poster # 13 **Multiply Scattered Low Coherence Interferometry (MS/LCI) for Extended Depth Imaging in Scattering Media**
Michael Giacomelli, Adam Wax
Fitzpatrick Institute for Photonics, Biomedical Engineering, Duke University

Poster # 14 **Utilizing 2-NBDG Fluorescence to Study Hypoxia-Induced Changes in Breast Cancer Glycolysis**
Amy Frees1, Narasimhan Rajaram1, Tony Jiang1, Stacy Millon1, Mark Dewhirst2, Nirmala Ramanujam1
1. Department of Biomedical Engineering, 136 Hudson Hall, Campus Box 90281, Durham, NC 27708-0281, USA
2. Duke University Medical Center, Durham, NC, USA

Poster # 15 **Nucleic Acid Detection using Plasmonic Coupling Interference (PCI) Nanoprobes:**
A Novel Approach for Medical Diagnostics and Biosensing Applications
*Hsin-Neng Wang, and Tuan Vo-Dinh**
Fitzpatrick Institute for Photonics
Departments of Biomedical Engineering and Chemistry
Duke University
Durham, NC 27708, USA
** Correspondence: E-mail: tuan.vodinh@duke.edu*

Poster # 16 **Light scattering and absorption spectroscopy in three dimensions using quantitative low coherence interferometry for biomedical applications**
Francisco E. Robles and Adam Wax.
Department of BME and Medical Physics program, Duke University.

Poster # 17 **Detection of dysplasia in Barrett's esophagus and colon with angle-resolved low coherence interferometry (a/LCI)**
Neil G. Terry1, Yizheng Zhu1, Matthew T. Rinehart1, William J. Brown1,6, Steven C. Gebhart1,6, Stephanie Bright2, Elizabeth Carretta2, Courtney G. Ziefle2, Masoud Panjehpour4, Joseph Galanko7, Ryan D. Madanick2, Evan S. Dellon2, Ana Bennett5, John Goldblum5, Bergein F. Overholt4, John T. Woosley3, Julie K.M. Thacker8, John Migaly8, Cynthia Guy9, Christopher R. Mantyh8, Nicholas J. Shaheen2 and Adam Wax1
1 Department of Biomedical Engineering, Duke University, Durham, North Carolina;
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3 Department of Pathology, University of North Carolina, Chapel Hill, North Carolina;
4 Thompson Cancer Survival Center, Knoxville, Tennessee;
5 Department of Pathology, Cleveland Clinic, Cleveland, Ohio;
6 Oncoscope, Inc., Durham, North Carolina;
7 Department of Medicine, University of North Carolina, Chapel Hill, North Carolina
8 Department of Surgery, Duke University, Durham, North Carolina
9 Department of Pathology, Duke University, Durham, North Carolina

Poster # 18 **Evidence of Plasmonic and Charge Transfer coupling in Non-Noble Plasmonic Gallium Nanoparticles/Graphene/SiC**
Congwen Yi,1 Tong-Ho Kim,1 Wenyuan Jiao 1 Yang Yang 1, Maria Losurdo,1,2 April Brown1
1 Department of Electrical and Computer Engineering, Duke University, Durham, 27708 NC, USA
2 Institute of Inorganic Methodologies and of Plasmas, IMIP-CNR, via Orabona, 4, 70126, bari Italy

Poster # 19 **High resolution vital fluorescence imaging and analysis of tumor microanatomy for surgical margin assessment**
Jenna Mueller1, Zachary Harmany2, Jeff Mito3, Stephanie Kennedy1, Yongbaek Kim4, Joseph Geradts5, David Kirsch3, Rebecca Willett2, Nimmi Ramanujam1, J. Quincy Brown1
1Dept. Biomedical Engineering, Duke University; 2Dept. Electrical and Computer Engineering, Duke University; 3Dept. of Radiation Oncology, Duke University School of Medicine; 4Dept. of Population Health and Pathobiology, North Carolina State University College of Veterinary Medicine; 5Dept. of Pathology, Duke University Medical Center

Poster # 20 **Contra-directional coupling with metamaterials : the light wheel and beyond**
Guy Lipworth (1), Antoine Moreau (1,2), Remi Polles (2) and Alec Rose (1)
(1) Electrical and Computer Engineering, Duke University
(2) LASMEA, Blaise Pascal University, France.

Poster # 21 **Optical Pattern Formation and Self-Organization of Cold Atoms**
Bonnie L. Schmittberger, Joel A. Greenberg, Daniel J. Gauthier
Fitzpatrick Institute for Photonics, Physics Department, Duke University

Poster # 22 **Pump-probe microscopy of pigments used in historical artwork**
Prathyush Samineni,1 Martin C. Fischer,1 Jesse W. Wilson,1 and Warren S. Warren2,
1Department of Chemistry, Duke University, Durham, NC 27708, USA
2Departments of Chemistry, Radiology, and Biomedical Engineering, Duke University, Durham, NC 27708, USA

Poster # 23 **Increasing entropy of quantum communication systems using pulse position modulation of single photons**
Hannah Guilbert, Yunhui Zhu, Meizhen Shi, Daniel J. Gauthier, Department of Physics, Duke University and the Fitzpatrick Institute for Photonics

Poster # 24 **Optimized Shapes of Femtosecond Laser Pulses for Detection of Nonlinear Optical Contrast in Dye-Free Microscopy.**
*Baolei Li,1 Kevin Claytor, 1 Warren S. Warren2, and Martin C. Fischer,3,**
1Department of Physics, Duke University, Durham, NC 27708, USA
2Department of Chemistry, Radiology, and Biomedical Engineering, Duke University, Durham, NC 27708, USA
3Department of Chemistry, Duke University, Durham, NC 27708, USA
**Corresponding author: martin.fischer@duke.edu*

Poster # 25 **Sulfur-Doped Zinc Oxide (ZnO) Nanostars: Synthesis and Simulation on Growth Mechanism**
*Jinhyun Cho1, Qiubao Lin2,3, Sungwoo Yang2 , Jay G. Simmons Jr.2, Yingwen Cheng2, Erica Lin2, Jianqiu Yang2, John V. Foreman4, Henry O. Everitt4,5, Weitao Yang2, Jungsang Kim1 and Jie Liu2,**
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2Department of Chemistry, French Family Science Center, Duke University, Durham, North Carolina 27708, USA
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4 U.S. Army Aviation & Missile Research, Development, and Engineering Center, Weapons Sciences Directorate, Redstone Arsenal, AL 35898
5 Department of Physics, Duke University, Durham, NC 27708

Poster # 26 **Time resolved imaging refractometry of microbicidal films using quantitative phase microscopy**
Matthew T Rinehart a, Tyler K Drake a, Francisco E Robles a, Lisa Rohanb, David Katzc, and Adam Waxa
aDuke University, Department of Biomedical Engineering, Fitzpatrick Institute for Photonics, Durham, North Carolina 27708
bUniversity of Pittsburgh, School of Pharmacy, Magee Womens Research Institute, Pittsburgh, Pennsylvania 15213
cDuke University, Department of Biomedical Engineering, Center for Biomolecular and Tissue Engineering, Durham, North Carolina 27708

Poster # 27 **MEMS-based beam steering for individual addressing of trapped ions**
Stephen Crain, Emily Mount, Caleb Knoernschild, Taehyun Kim, Soyoung Baek, Peter Maunz, and Jungsang Kim
Electrical and Computer Engineering Department and Fitzpatrick Institute of Photonics, Duke University, Durham, NC 27708

Poster # 28 **Active Metamaterials Loaded With A Negative Differential Resistance Element**
John Barrett and Steven Cummer, Duke University

Poster # 29 **Controls in Trapped Ion Shuttling**
Daniel Gaultney, Taehyun Kim, Peter Maunz, Emily Mount, Rachel Noek, and Jungsang Kim
Electrical and Computer Engineering Department and Fitzpatrick Institute for Photonics, Duke University, Durham, NC 27708

Poster # 30 **Direct and Rapid Determination of Tissue Hemoglobin Concentration from Diffuse Reflectance Spectra**
Fang-Yao Hu, Karthik Vishwanath, Janelle E. Phelps, Vivide T. C. Chang, and Nimmi Ramanujam
Department of Biomedical Engineering and Fitzpatrick Institute for Photonics, Duke University, Durham, NC 27708

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Dr. Tuan Vo-Dinh
Director, The Fitzpatrick Institute for Photonics
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August Burns
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The Fitzpatrick Institute for Photonics

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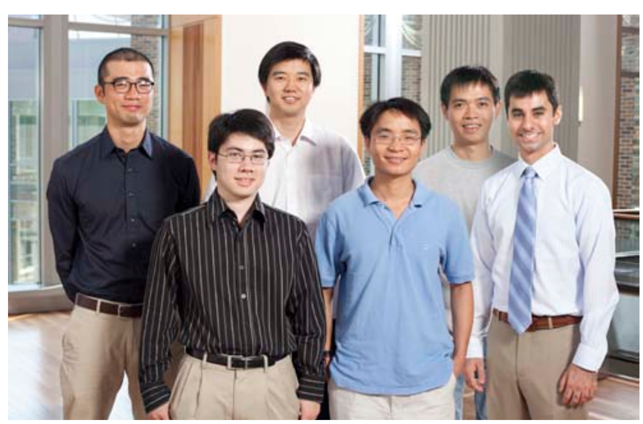
The Fitzpatrick Institute for Photonics (FIP) was able to award several graduate student fellowships through the continued support and generosity of the Fitzpatrick Foundation and John Chambers. Each candidate was nominated by a FIP Professor and judged on the criteria of research accomplishments, research potential, personal qualities and collaborative potential.



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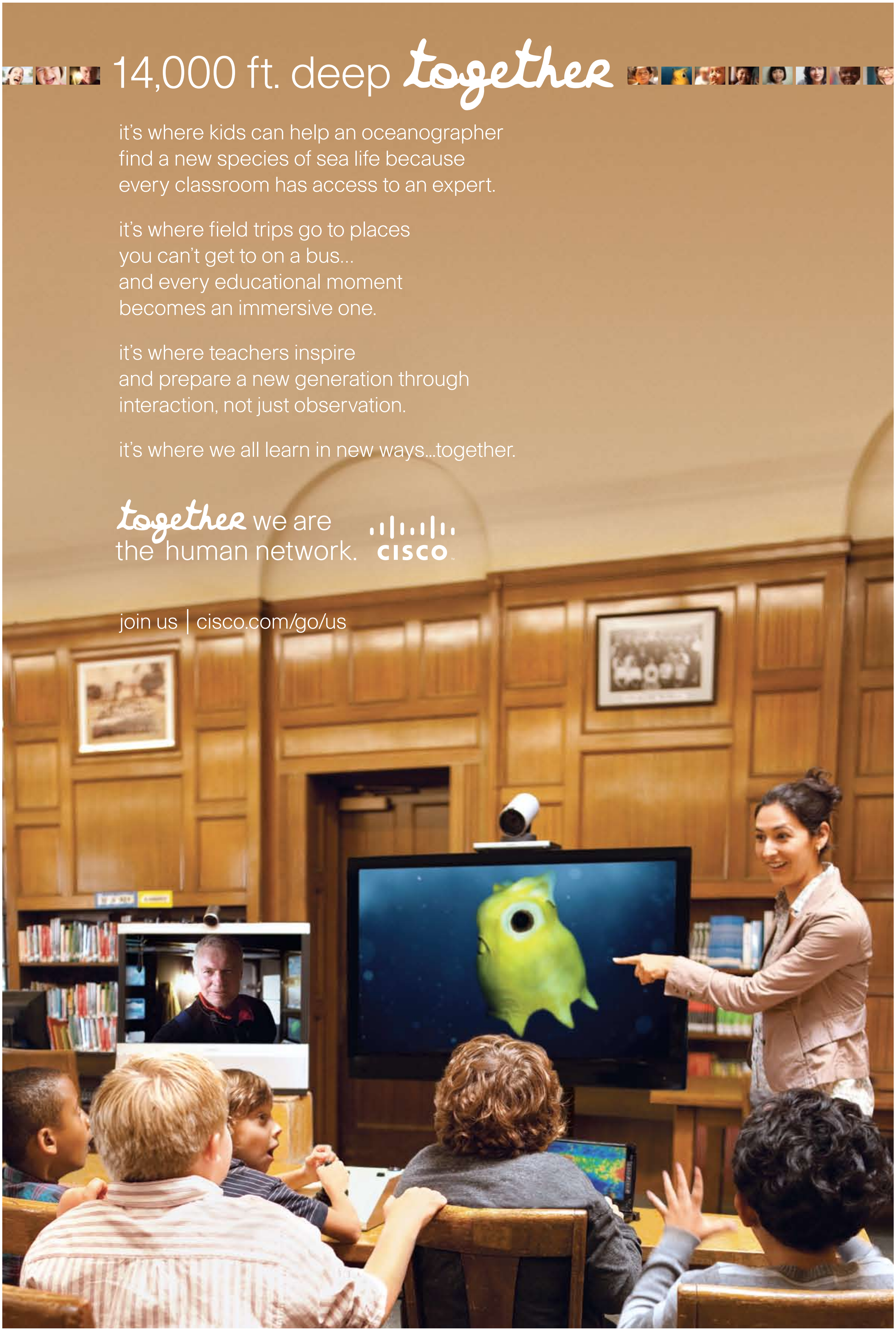
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find a new species of sea life because
every classroom has access to an expert.
it's where field trips go to places
you can't get to on a bus...
and every educational moment
becomes an immersive one.
it's where teachers inspire
and prepare a new generation through
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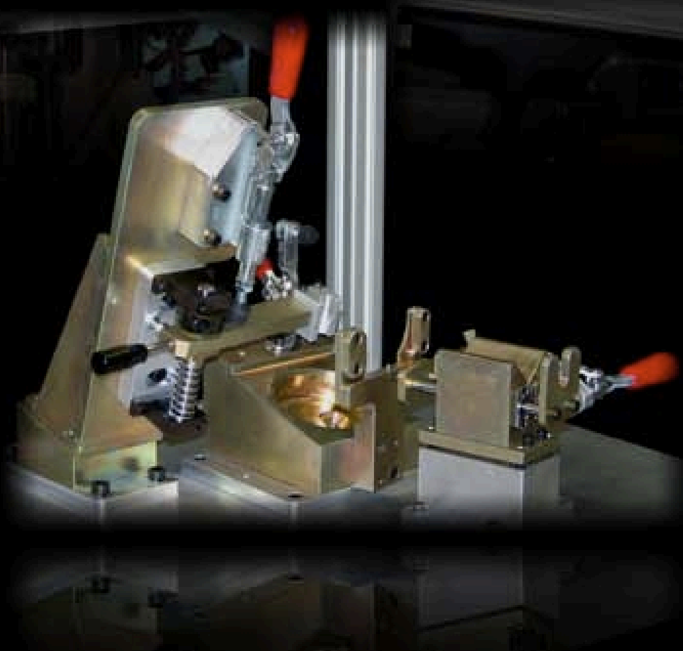

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- Professional networking events on campus and at conferences
- Outreach programs to local schools
- Support optics-related extracurricular projects
- Interact with visiting professors in small groups
- Assist with FIP breakfast poster sessions

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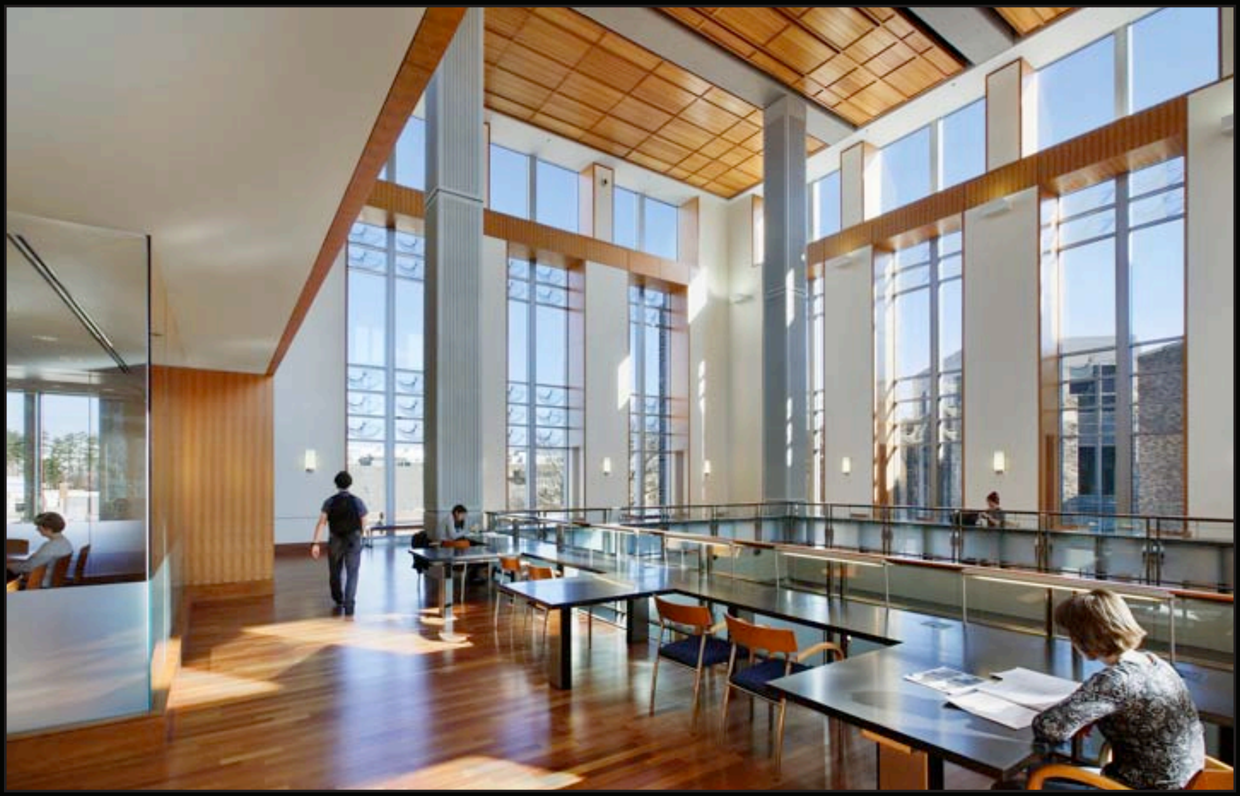

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The Fitzpatrick Institute for Photonics business office has achieved the **Duke Green Workplace Certification**.

Duke Green Workplace Certification is a program created by Sustainable Duke to help staff reduce the environmental footprint of their workplace. The program helps to train and foster staff sustainability leaders within a department and provides resources to guide the process of greening your workplace.

The Fitzpatrick Institute for Photonics supports and promotes Duke Sustainability.
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