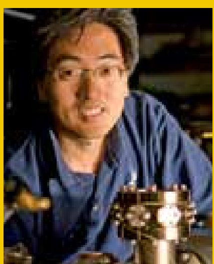
DukeBroadband

FITZPATRICK INSTITUTE FOR PHOTONICS / DUKE UNIVERSITY

Digital Optics and Algorithms

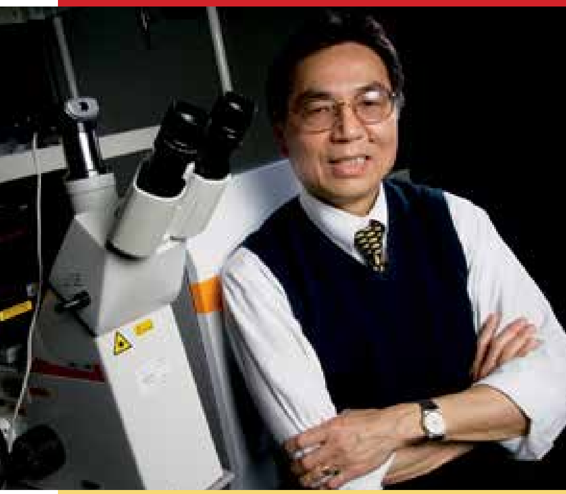
FOR ART CONSERVATION



FACULTY HIGHLIGHT:
Jungsang Kim, p.12

2016 VOLUME 9 ISSUE 1

DIRECTOR'S MESSAGE



Welcome to the Spring 2016 issue of

BROADBAND, the newsletter of the Fitzpatrick Institute for Photonics (FIP). Due to the dedication and contribution of its faculty, students and staff, the FIP has continued to grow in research, education, industrial activities and membership. The membership of the Institute has increased to 110 faculty members belonging to 37 departments and institutions from the Pratt School of Engineering, the Trinity School of Arts & Sciences, and the Duke School of Medicine.

INTERNATIONAL YEAR OF LIGHT 2015

The year 2015 was special for the photonics community worldwide as the United Nations (UN) General Assembly 68th Session proclaimed 2015 as **THE INTERNATIONAL YEAR OF LIGHT** (IYL 2015). Supported by 100 partners from more than 85 countries, the "International Year of Light is a global initiative highlighting to the citizens of the world the importance of light and light-based technologies in their lives, for their futures and for the development of society" [www.light2015.org/Home.html].

To celebrate IYL2015, our institute organized the **2015 World Photonics Forum** (WPF), which was designed to provide a platform for international researchers in science, technology, art and the humanities, and global leaders in management, policy and industry to discuss the challenges, contribution and potential of photonics-related activities and technologies in the next century. These distinguished guests provided their views, discussed and anticipated how photonics will play a critical role by contributing key revolutionary and breakthrough technologies, and reviewed how these critical enabling technologies are at the heart of the scientific convergence that will define research progress in the 21st century. The WPF included several panels on critical and strategic topics of photonics:

- **Fundamental Breakthroughs in Light-based Science Technology** (basic research and applied technologies, convergence of the New Light Age where photons replace electrons, etc.)
- **Light-based Technologies and Societal Impact and Human Development** (education, arts, humanities, happiness, entertainment industries, next-generation global transportation, etc.)
- **Light-based Technologies on Global Economic Development** (global health, global interconnectivity, renewable energies, the reshaping of geopolitics and global economics, etc.)

Technical sessions at the WPF and the Outreach Program organized at the WPF are highlighted in this special issue of *BROADBAND*. The IYL celebration underlines the fact that we are witnessing a very exciting period in the history of photonic science because there is an epochal convergence of many revolutions from the 20th century, such as the quantum revolution, the technology revolution and the genomics revolution. Riding on the crest of this convergence, light-based technologies influence our lives today in new ways that we could never have imagined just a decade ago. As we move into the next century, light will play an even more significant role, triggering a revolution in global photonic communications linking our entire planet, creating nanoscale biosensors to unveil the inner world of the human cell, developing cost-effective medical cures for global health, inventing new energy sources and galvanizing human exploration at the frontiers of the universe.

I invite you to visit our website at **www.fitzpatrick.duke.edu** to learn more about our faculty, research programs and activities.

I hope you have a successful and enjoyable year.

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

NEW FIP FACULTY

Dr. Volker Blum
Associate Professor, Mechanical Engineering and Materials Science

Dr. Ingrid Daubechies
Professor, Mathematics & Electrical and Computer Engineering

Dr. Emily Derbyshire
Assistant Professor, Department of Chemistry

Dr. Henry Everitt
Adjunct Professor, Physics

Dr. Yiyang Gong
Assistant Professor, Biomedical Engineering

Dr. Steve Haase
Associate Professor, Biology

Dr. Jianfeng Lu
Assistant Professor, Mathematics, Chemistry & Physics

Dr. Paolo Maccarini
Assistant Research Professor, Biomedical Engineering

Dr. Zhen-Ming Pei
Associate Professor, Biology

Dr Xiling Shen
Associate Professor, Biomedical Engineering

Dr. Marc A. Sommer
Associate Professor, Biomedical Engineering, Neurobiology

Dr. Tai-Ping Sun
Professor, Biology

Dr. Steve Taylor, MD
Assistant Professor, Division of Infectious Diseases

Dr. Xiaofeng "Steve" Zhang
Assistant Professor, Radiology

Dr. William E. Moerner, Nobel Laureate in Chemistry(2014)
Special Topic Session: *Photonics for Automonous Systems*
2016 FIP Annual Symposium - March 14-15, 2016

"Light: Beyond the Bulb" Photo Exhibit was displayed at the Fitzpatrick Institute for Photonics (FIP) public outreach, symposium and world photonics forum in co-sponsorship with SPIE.

2015 FIP Symposium and World Photonics Forum

March 9-10, 2015 Duke University Durham, North Carolina, USA

The 2015 International Year of Light, as proclaimed by the United Nations, was an exciting, historic moment—and the Fitzpatrick Institute for Photonics (FIP) recognized this global event at its 2015 annual symposium.

Key events included a roster of distinguished speakers—including two Nobel laureates, Professor Theodor W. Hänsch, and Professor John L. Hall, Nobel Laureates in Physics (2005). Dr. Hall and his wife, Marilyn Hall, co-creators of the Sci-Teks Discovery Program for Kids, also helped lead a pre-symposium open house to expose the general public to the latest in light-based science and technologies.

In addition to lectures from world-renowned speakers, the symposium included contributed papers and posters by investigators from Duke and other academic and industrial institutions. Additional featured highlights were the International Year of Light poster and technology fair, industry booths, themed lab tours and the 2015 World Photonics Forum of special panel sessions on the influence and contribution of light-based technologies on science, human development and global economic development for the next century. The sessions were represented by our global community. ■

PARTICIPATING DEPARTMENTS AND INSTITUTIONS

121 Faculty Members | **37** Participating Departments

Anesthesiology
Art History
Biology
Biomedical Engineering (BME)
Cell Biology
Chemical Biology
Chemistry
Civil and Environmental Engineering (CEE)
Computer Science
Dermatology
Electrical and Computer Engineering (ECE)
Gastroenterology
Geriatrics
Literature
Mathematics
Mechanical Engineering and Materials Science (MEMS)
Microbiology
Molecular Genetics
Neurobiology
Neurosurgery
Oncology
Ophthalmology
Orthopaedic Engineering
Pathology
Pediatrics
Philosophy
Physics
Radiation Oncology
Radiology
Surgery
Center for Applied Genomics and Precision Medicine
Center for Genomic and Computational Biology
Center for Metamaterials & Integrated Plasmonics
Duke Comprehensive Cancer Center
Duke Human Vaccine Institute
Duke Immersive Virtual Environment (DiVE)
Nicholas School of the Environment

SPEAKERS FOR THE 2015 FIP SYMPOSIUM AND WORLD PHOTONICS FORUM INCLUDED:

Symposium Keynote Speaker
Theodor W. Hänsch, PhD
Nobel Laureate in Physics (2005) Max-Planck-Institut for Quantum Optics, Carl Friedrich von Siemens Professor Chair, Faculty of Physics, Ludwig-Maximilians University of Munich, Germany.

Dr. Hänsch was awarded the Nobel Prize in Physics along with Dr. Hall for their contributions to the development of laser-based precision spectroscopy, particularly the optical frequency comb technique.

Forum Keynote Speaker
John L. Hall, PhD
Professor Nobel Laureate in Physics (2005) JILA, University of Colorado National Institute of Standards and Technology Boulder, Colorado, USA

Dr. Hall was awarded the Nobel Prize in Physics along with Dr. Hänsch for their contributions to the development of laser-based precision spectroscopy, particularly the optical frequency comb technique.

Left to Right: John Hall, Robert Lieberman, Eugene Arthurs and John Dudley all wearing their signature SPIE International Year of Light ties.

Left to Right: Federico Capasso, Michael Fitzpatrick, Theodore Hänsch, Robert Lieberman, Tuan Vo-Dinh and John Hall

World Photonics Panel of fundamental breakthroughs in light-based science technology. Panel members: J. Dudley, F. Capasso, T. Hänsch, A. Forbes, C. Kurachi, P. Russell, T. Vo-Dinh

FIP faculty member Professor Vicky Seewaldt engaging with the World Photonics Forum panel.

Plenary Speakers
John M. Dudley, PhD
Chair, U.N. IYL2015 Steering Committee
President, European Physical Society
Universite of Franche-Comté
Besançon, France

Federico Capasso, PhD
Robert Wallace Professor of Applied Physics
Harvard University
Cambridge, Massachusetts, USA

Forum Special Lecture Speakers
Eugene Arthurs, PhD
CEO SPIE, The International Society for Optics and Photonics
Bellingham, Washington, USA

Philip Russell, PhD
President of Optical Society (OSA) Director,
Max Planck Institute for the Science of Light
Erlangen, Germany

Invited Forum Panel Speakers
Silvia Bruni, PhD
Associate Professor, Analytical Chemistry University of Milan
Milan, Italy

John Edmond, PhD
Co-Founder and Director of Advanced Optoelectronic Technologies
CREE
RTP, North Carolina, USA

Andrew Forbes, PhD
Professor, Chief Research at Council for Scientific and Industrial Research (CSIR),
National Laser Centre
Pretoria, South Africa

Cristina Kurachi, PhD
Professor, São Carlos Institute of Physics University of São Paulo,
Brazil, South America

Robert Lieberman, PhD
President Elect of SPIE President,
Lumoptix, LLC
California, USA

Ulderico Santamaria, PhD
Chief, Scientific Laboratories of Vatican Museums, Professor of Chemsitry for Restoration and Material Science, Department of Cultural Heritage Sciences,
Tuscia University
Viterbo, Italy

David Ward, PhD
Senior Vice President,
Chief Technology Officer and Chief Architect, Development
Cisco Systems, Inc.
RTP, NC, USA

Siavash Yazdanfar, PhD
Manager, Applied Optics Lab
GE Global Research
Albany, NY, USA

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FIP Photonics Pioneer Award

Dr. Theodor W. Hänsch, 2005 Nobel Laureate in Physics (jointly with Roy Glauber and John L. Hall) for his contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique, presented the keynote lecture at the annual Fitzpatrick Institute for Photonics (FIP) Symposium and World Photonics Forum held March 9-10, 2015. During the conference, Dr. Hänsch was recognized for his accomplishments in the field of photonics and awarded the prestigious *FIP Pioneer Award.*

In honor of the momentous occasion of the International Year of Light 2015, the Fitzpatrick Institute for Photonics held a contest for non-Duke students to qualify for free registration to the symposium. The students had to submit a video, sound clip or essay to answer the following question "How have light technologies positively impacted your life?" The winners of the competition were:

1st Place – Kapila Wijayarante, University of Virginia

2nd Place – Sam Migirditch, Appalachian State University

3rd Place – Niranjan Sridhar, University of Virginia

Honorable Mentions:
Ben Migirditch, Appalachian State University and Wenjiang Fan, University of Virginia
Check out their videos and essays on our website:
www.fitzpatrick.duke.edu/fip-international-year-light-contest

CORPORATE AND CONFERENCE PARTNERS

Software Helps Art Conservators Clear the Cradling

North Carolina Museum of Art partners with Duke University to develop an art conservation tool that helps analyze paintings using x-ray images | **By Emily Kowalski, North Carolina Museum of Art**

For decades, art conservators have had a cradling problem. But thanks to some fancy mathematics and computer engineering work, their issues have been laid to rest.

X-ray radiography is a standard technique widely used by art conservators, art historians and curators to discover information about the manufacturing process and the condition of a painting. A long-used preservation technique called cradling, however, often gets in the way of their work.

Cradling is the term used for wooden slats attached to the back of many old paintings executed on wooden panels. While the slats do provide support for the aging art works, it also creates lattice patterns that appear as grids or a series of stripes on an X-ray image. These patterns can obscure the image and distract art conservators from reading the image and analyzing paint layers.

"Cradle patterns in X-ray images have been an ages-old problem for conservators studying collections of Old Master paintings, requiring many hours of tedious Photoshop manipulation or various other techniques that could damage the painting," says William Brown, chief conservator at the North Carolina Museum of Art (NCMA). "We have been fortunate to work with world leaders in the fields of time-frequency analysis, informatics and image processing to come up with a practical solution to a difficult problem."

The cradle pattern problem appeared while **Rujie Yin**, research assistant in Duke University's Mathematics Department, was using X-ray images to research a 14th-century altarpiece by Francescuccio Ghissi for an upcoming exhibition at the NCMA. Yin, attempting to study crack patterns in the altarpiece for an image-processing component of the exhibition, was frustrated at the distracting cradling and decided to use mathematical algorithms to solve the problem.

But she couldn't do it alone.

Yin turned to Noelle Ocon, NCMA conservator of paintings to identify objectives of the project based on art conservators' challenges with X-ray images. Then,

with the help of Duke professors **Ingrid Daubechies** (mathematics and electrical and computer engineering) and David Dunson (statistics), the group developed an algorithm that removed the cradle pattern from the X-ray image. Compared to manually altering the image in Photoshop, the algorithm was not only quicker and more effective, but also much easier for art conservators to use.

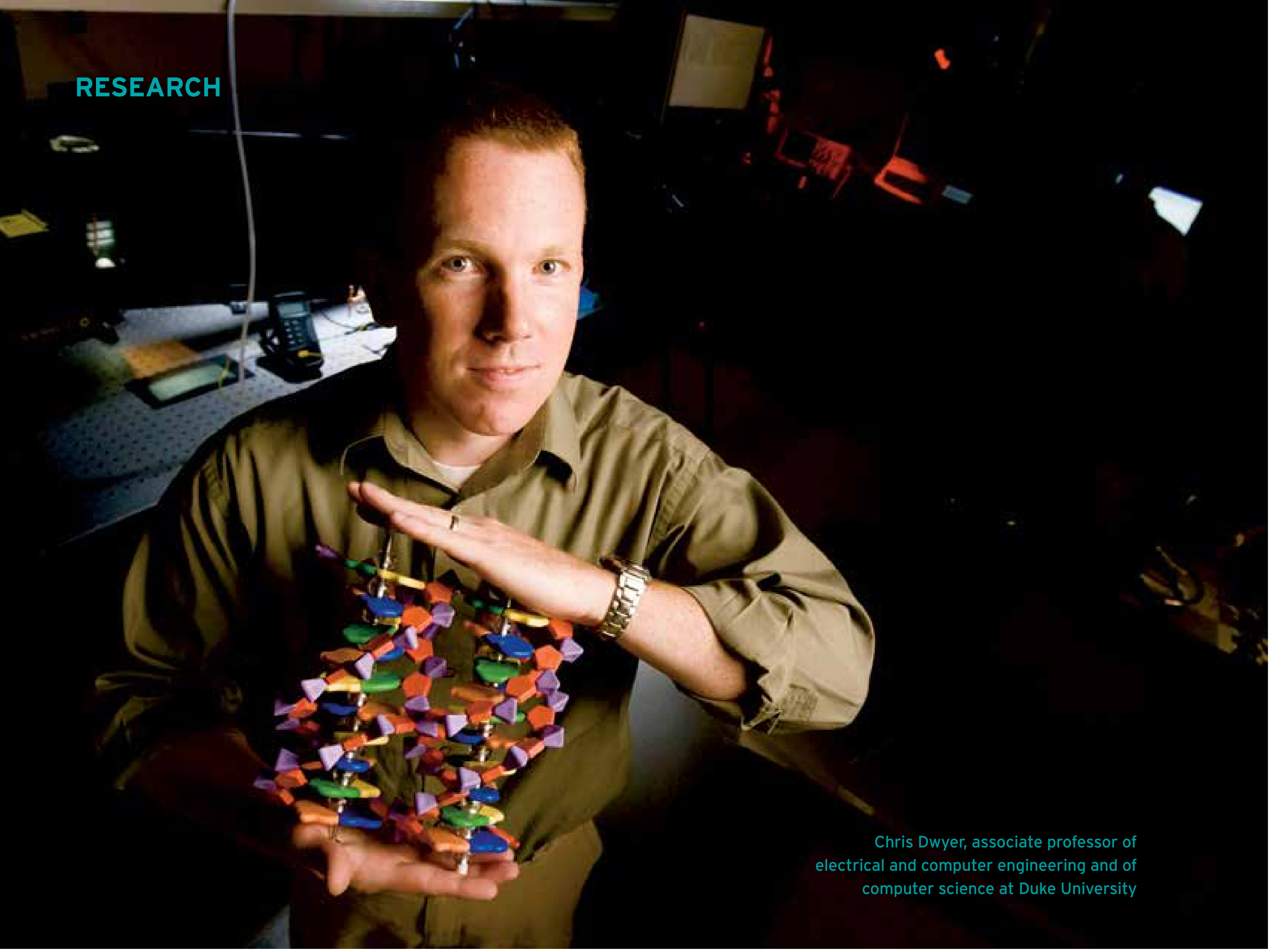
Describing the algorithm, Daubechies explains, "The algorithm consists of a three-stage procedure. First, the cradled regions are located automatically. The second step consists of separating the X-ray image into a textural and image component. In the last step, the algorithm learns to distinguish between the texture caused by the wooden cradle and the texture belonging to the original painted wooden panel."

With the support of a grant from the Samuel H. Kress Foundation, the collaboration was then able to convert the algorithms and coding into a user-friendly Photoshop plug-in tool. Dubbed Platypus, the program was introduced at a workshop in August 2015 attended by national and international art conservators. After receiving feedback from the conservators, the group worked to finalize the software and coding, which is now available free online.

The collaboration between the NCMA and Duke University is part of the NCMA's Art + Science Initiative, which enlists local universities to research issues concerning both art and science, bringing technological advances to art conservation and demonstrating the importance of interdisciplinary studies. The Museum's Conservation Center has partnered with Duke University on other conservation projects, including applying laser imaging technology to research materials used in paintings (designed by **Warren S. Warren**, director of Duke University's Center for Molecular and Biomolecular Imaging).

The project is also part of the Information Initiative at Duke (iiD), an interdisciplinary program designed to increase "big data" (information characterized by tremendous volume, variety and rapid change) computational research and expand opportunities for student engagement in this rapidly growing field. ■

Compared to manually altering the image in Photoshop, the algorithm was not only quicker and more effective, but also much easier for art conservators to use.



Chris Dwyer, associate professor of electrical and computer engineering and of computer science at Duke University

The Genetic Codes That Create Optical Computers

FIP researchers are using self-assembling DNA to form the basic components for optical computing

Researchers at Duke University can use photons instead of electrons to store data, drastically increasing the storage capacity of the optical analog of Blu-Ray discs.

So what are your top 5,000 movies?

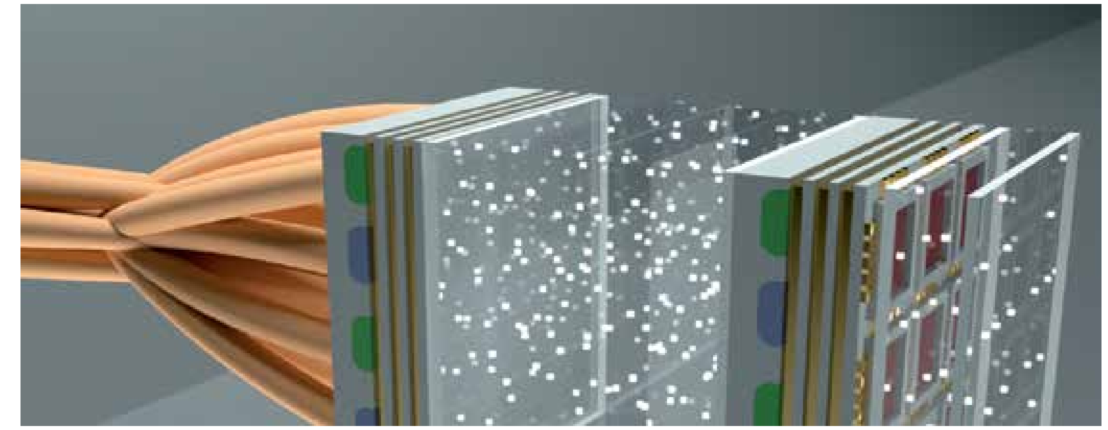
"That's the kind of ridiculous thing we can do, but I don't know how we're going to use it," said **Chris Dwyer**, associate professor of electrical and computer engineering and of computer science at Duke.

Like his Fitzpatrick Institute for Photonics colleague Jungsang Kim (page 10), Dwyer is working to bring an entirely new type of computer hardware into our day-to-day lives. But unlike Kim's, his technology isn't based on the quantum state of individual atoms.

Optical computing has been around for decades, but the physical properties of light have limited its use to large scales. Wave guides that interact with and manipulate light have to be of the same order of magnitude in size. And for photons, that means nothing can be much smaller than a micron, which is huge compared to conventional silicon systems.

Dwyer, however, and others in his field have found a way around this problem—excitons.

When individual molecules called chromophores interact with light, they quantum-mechanically absorb some of its energy, which gets turned into an exciton. And when that little nugget of energy moves from chromophore to chromophore in specific patterns, it creates light-based computational components.



Left: A rendering of a hypothetical stack placed at the end of an optical fiber bundle. The sparkles are DNA+RET logic and the square elements are photocollectors.

Below, left: An illustration of one of the structures Dwyer's laboratory works with. Each "waffle board" holds an array of logic elements that use so-called "excitons."

Below, right: A computer rendering of a nanoparticle system (the ball on the left) that is assembling some Luciferase enzymes (the curly proteins) into a system with a DNA-based "exciton" wire.

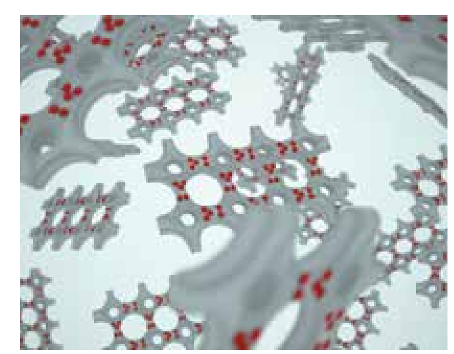
"For my group, it's about applying this kind of photoluminescence to building memory systems, sensors and computational logic," said Dwyer. "And we build these components with self-assembling nanostructures using DNA."

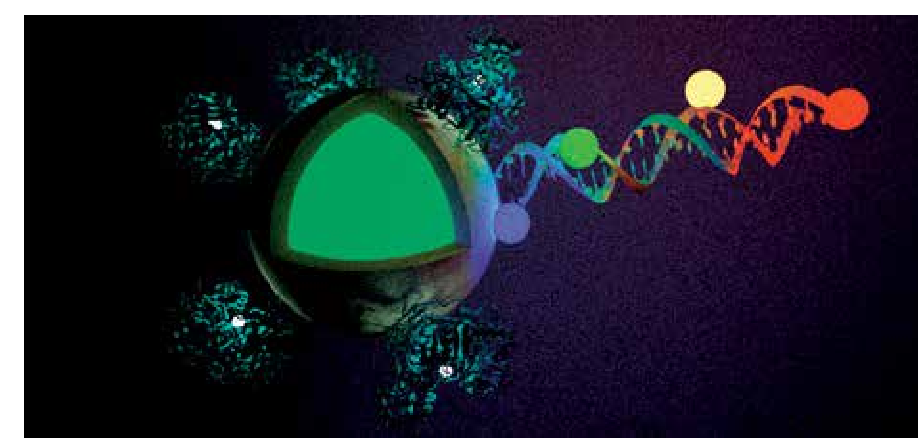
This approach has several benefits.

For one, Dwyer and his group can use DNA structures to piece together logic gates just two nanometers wide. This leads to memory systems that are very dense. And the way light propagates also means that the amount of energy required to perform an operation is radically lower than a conventional computer.

Or at least it could be, once Dwyer's group gets all of the components talking to one another. They can currently build logic gates and memory elements and network them together, but they still have to figure out how to optimize these devices so that they can compete with electrical silicon technologies.

"These devices blow silicon processors out of the water on paper, but getting the real world in line with the theory is easier said than done."





"These devices blow silicon processors out of the water on paper, but getting the real world in line with the theory is easier said than done," said Dwyer. "On the flip side, we can figure out how to use these devices just as they are in spaces where conventional technologies can't go."

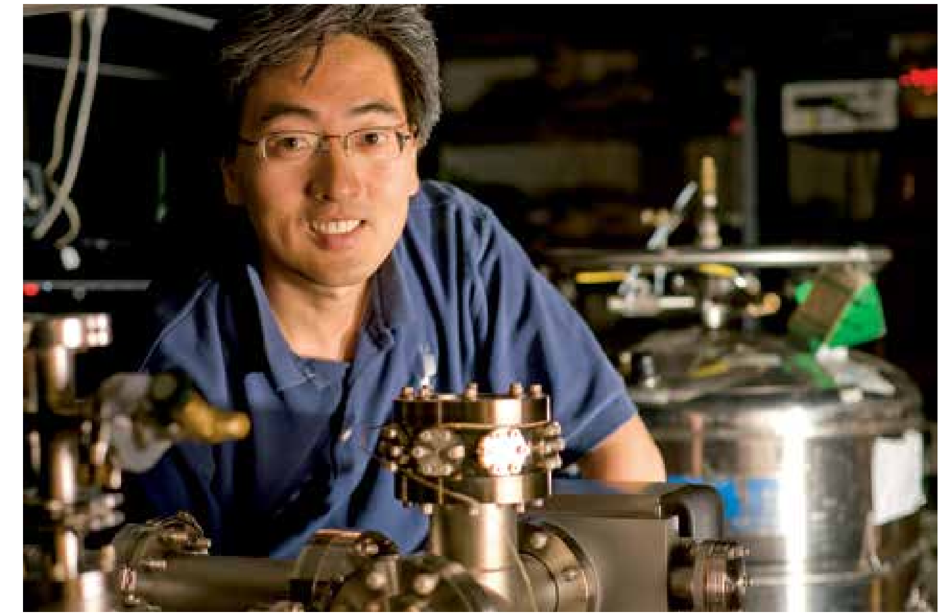
For example, being made out of DNA, these tiny computational networks are biologically compatible. Perhaps scientists could put some computing power on a diagnostic assay inside the body—a feat which would greatly reduce the costs of such tests. Or in a future science fiction world, maybe scientists could conduct computations inside the bloodstream itself.

Dwyer also notes the idea of an encryptable drug, which would have a cryptographic algorithm run by a molecular-scale computer that would render it ineffective if it wasn't presented with the correct challenge or response.

"I spent a great deal of my career trying to simply replace silicon in computing technology," said Dwyer.

"It probably took me the better part of six years, or half my career in academics, to figure out that a much better use of this technology is to bring computation to every niche of the physical world where silicon can't go. I think that's a much better use of our technology." ■

A micro-fabricated ion trap built on a silicon substrate and packaged in a standard ceramic pin-grid array (CPGA). The trap was used by Kim's laboratory in their quantum computing experiments and was fabricated by Sandia National Labs in a collaborative effort.



Jungsang Kim, professor of electrical and computer engineering, Duke University has been awarded a major multi-year award by IARPA in partnership with University of Maryland and Georgia Tech.

Building the World's First Quantum Computer

FIP researchers work to integrate proven components into the world's first quantum processor

In a building full of advanced photonics research, the laboratory of **Jungsang Kim** just might have the most complicated optical setups. After all, not many engineering challenges involve controlling the frequency of a laser to within a millionth of a percent.

But building the world's first quantum computer does.

"I think we're getting close."

This is the next big goal for Kim, a professor of electrical and computer engineering at Duke University. And he's not too far from achieving it.

"Back in the 1940s, researchers were just discovering how to use vacuum tubes as simple switches," explained Kim. "These switches could then form logic gates, which could be linked together to form the first logic circuits. That's where we're at now with quantum processors. We have verified that all the components work. The next step is to engineer the smallest, yet most interesting circuit possible."

According to David DiVincenzo, a prominent computer scientist at IBM, researchers must meet five criteria to create a true quantum computing device.

First, Kim needs a **well-defined system that can represent different states.** For example, classical computers use small electrical switches made out of semiconductors to indicate a 1 or a 0. But because an atom's quantum spin can point in an infinite number of directions, controlling its state with a high degree of reliability is very difficult. Kim's group has demonstrated this feat with an accuracy on par with anyone in the world.

Once an atom's quantum state can be controlled, the system must be made **quantum-mechanically coherent.** If the atom interacts with the outside world even a little bit, it loses its "quantumness," which is bad. Again, Kim's laboratory has demonstrated this ability.

They have also demonstrated the ability to initialize their system to **a well-defined starting state**. For example, in a laptop, each bit starts in the same place—a zero—until data is written to the chip.

Fourth, a quantum processor needs enough components to **produce a universal set of gates**, which allows one to implement arbitrary computational tasks. Kim's setup combines a simple two-quantum-bit gate with the ability to control each quantum bit's state to accomplish that.

Last but not least, a quantum computer needs to have the **ability to report its solution**. To do that, there must be good quantum measurements, which again, Kim's laboratory has already demonstrated.

"All of these criteria our system meets pretty much as well as anybody else's can," said Kim. "But those are just the components. If you want to build a computer, you have to put a large number of these things together in a way that you can control them and interact with them at will. And that system integration is something that we are currently working on."

After scientists in the 1940s put together the first string of vacuum tubes, it wasn't long before they filled rooms with tens of thousands of them to create the first digital computer. Kim hopes to demonstrate the first small string of "quantum vacuum tubes" within a year. After that, it will be up to the cutting-edge technologies developed for semiconductors and telecommunications to scale the system up.

"We do all of these quantum manipulations with atomic ions trapped on silicon chips, so we could actually start to think about systems where we have 100 atomic ions," said Kim. "That's a small processor, but we have ways of connecting multiple units to build large-scale systems. The result would be similar to data processing centers with thousands of processors linked together."

"The challenge is getting today's telecommunications technologies to work with our quantum systems, because they operate on different wavelengths," Kim added. "I think we're getting close. And if successful, not only could we make scalable quantum computing clusters, but also quantum networks that communicate over long distances." ■

Steve Cummer

High speed video sequence of a lightning bolt descending from the cloud and striking the ground. At 200 microseconds per frame this process happens much faster than can be seen with the unaided eye.

Tracking Electrical Storms with a New Light

FIP researchers are using radio waves to track miles of unseen channels of lightning to learn more about the common but enigmatic phenomenon

The flash of light streaking between the ground and sky that catches onlookers' attention is literally just the tip of the lightning bolt. During a typical strike, less than 10 percent of the total electrical activity is visible. The rest is hidden from view within different layers of the cloud extending for miles through the storm.

This presents a major hurdle for studying lightning's many enigmas that still confound researchers to this day. Because movements of electricity are hidden from view, scientists must turn to different portions of the electromagnetic spectrum for insights.

"If you have a really good high-speed imaging system, you can see all of this amazing, intricate detail in lightning flashes," said **Steve Cummer**, professor of electrical and computer engineering. "But even with that technology, there are some things you can't see that lightning does because it's in the cloud. So you need some kind of non-optical way to see it."

> "...there are some things you can't see that lightning does because it's in the cloud. So you need some kind of non-optical way to see it."

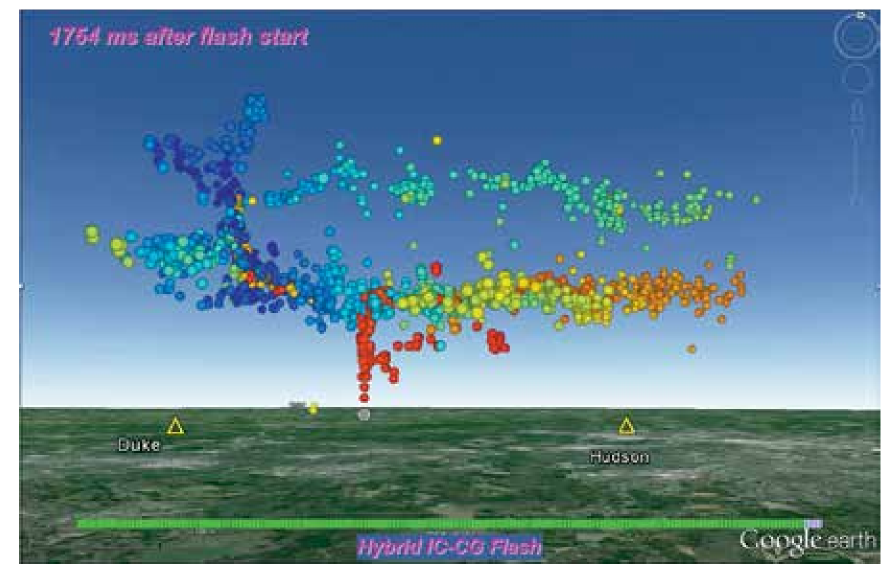
To study an electrical storm's internal wiring, researchers watch for either Very High Frequency (VHF) waves caused by the breakdown of air in front of a bolt's path or radio waves produced by the movement of electrons.

Cummer is pursuing the latter.

Along with postdoctoral associate researcher Fanchao Lyu, Cummer has devised a ground sensor system and data processing system that can track the sources of radio wave emissions with more precision than ever before. The system works by cross-correlating radio wave signals from two stations during a 350-microsecond window to determine the difference in the waves' time of arrival. The time window is then slid 50 microseconds and the process is repeated.

Because the radio waves travel at the speed of light, the difference in time it takes them to reach each sensor is extremely small—but it is detectible. That difference constrains the point from which the waves could have originated. And after getting time-of-arrival differences from seven different stations for a single event, the source of the radio waves can be pinpointed.

While this method has been used before, the greater number of sensors and the way the data are processed make Duke's system more sensitive than any previously deployed, giving good mapping results on both continuous emissions and fast processes within the cloud. The tracking allows Cummer and Lyu to image more processes during a lightning strike than ever before, providing a more complete image of the event.



Besides giving new insights into basic aspects of lightning that are still not understood—like how lightning channels form across tens of miles of sky—the system can also help investigate some of the more extraordinary and rare phenomena produced by electrical storms.

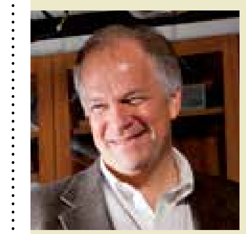
"Right now I am obsessed with terrestrial gamma-ray flashes, which is the process in which thunderstorms act as particle accelerators and launch very high-energy gamma rays out into space," said Cummer. "The challenge is that the only terrestrial gamma-ray flashes ever detected are the ones that just happen to be seen by astronomy satellites."

Because they are thousands of miles away from the source of terrestrial gamma-ray flashes, the satellites rarely manage to spot one. And when they do, they can't directly image the processes at work.

They can, however, measure some details of the lightning flashes that produce the bursts of gamma rays. Cummer hopes that by matching some of the characteristics of storms that produce terrestrial gamma-ray flashes with events he's captured on his new radio wave system, he can begin to tease out the inner workings of the phenomenon. ■

FACULTY SPINOFFS

In June 2015, microscopy and imaging systems company Leica Microsystems acquired Bioptigen, Inc., a company hatched by Joseph Izatt, the Michael J. Fitzpatrick Professor of Engineering at Duke. Formed in 2004, Bioptigen has become a leader in optical coherence tomography (OCT), an imaging technique that uses light to capture extremely high-resolution, three-dimensional pictures of the eye.



During the past decade, the company has secured more than 60 patents in OCT technology, many of which were licensed from intellectual property developed by Izatt, his students, and collaborators at Duke and Case Western Reserve University.

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CHECK OUT THIS PROGRAM!

Master of Engineering Photonics and Optical Sciences

fitzpatrick.duke.edu/education

CURRICULUM: Core industry prep courses in business fundamentals and management with technical courses focused within a chosen engineering discipline. Also includes an industry internship project or equivalent experience.

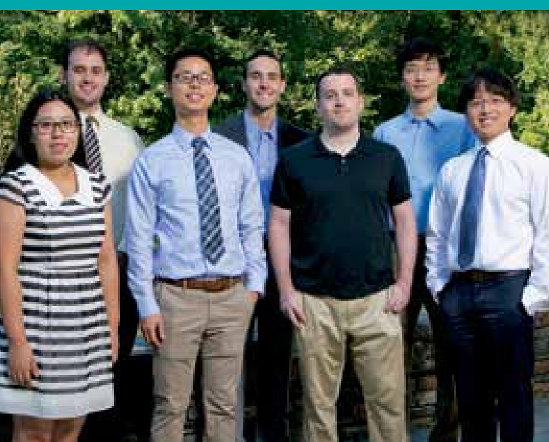
IDEAL CANDIDATES: Recommended for students in the earliest stages of their careers who are interested in a practicing engineering position with a focus on product design and innovation.

DURATION: 18-24 months

Fitzpatrick Institute for Photonics | **Fellowships**

The Fitzpatrick Institute for Photonics (FIP) is able to offer several graduate student fellowships through the continued support and generosity of the Fitzpatrick Foundation and John T. Chambers.

The Scholars program provides existing Duke graduate students within the FIP approximately $46,000 each year toward their stipend, tuition remission, grad school fees and health insurance for two years. This program is designed to reward the most outstanding individuals within FIP for their accomplishments and potential. Each candidate, nominated by a FIP Professor, was judged on the criteria of demonstrated excellence in their academic studies, research and projects that involved inter-group or interdisciplinary research stimulating new collaborations among FIP faculty.



The Fellows program, used as a recruiting tool for the top candidates, provides incoming graduate students a one-year fellowship program, which awards a $10,000 top-up on their stipend and $1,000 toward educational travel. Each candidate is nominated by a FIP Professor and judged on the criteria of research accomplishments, research potential, personal qualities and collaborative potential.

The Fitzpatrick Institute for Photonics (FIP) is pleased to announce and introduce the recipients of the Fitzpatrick Foundation Scholars, John T. Chambers Scholars and John T. Chambers Fellows for the 2015 academic year!

Left to right: Jiani Huang (Scholar), Zachary Steelman (Fellow), Yangbo "Abel" Xie (Scholar), Jon William Stewart (Fellow), David Cunefare (Scholar), Xin Zhang (Fellow), Kevin Zhou (Fellow).

2015-2017 Fitzpatrick Foundation Scholars

Yangbo "Abel" Xie, Prof. Steven Cummer - ECE

2015-2017 John Chambers Scholars

David Cunefare, Prof. Sina Farsiu - BME
Jiani Huang, Prof. Maiken Mikkelsen - Physics

2015-2016 John Chambers Fellows

Zachary Steelman, Prof. Adam Wax - BME
Jon William Stewart, Prof. Maiken Mikkelsen - ECE
Xin Zhang, Prof. Harold Baranger - Physics
Kevin Zhou, Prof. Joseph Izatt - BME

CHAMBERS FELLOWS

Where are they now?

After completing his Ph.D. in biomedical engineering at Duke in 2010, **Vivide Chang** first worked as a life sciences consultant at L.E.K. Consulting and has recently joined Genentech in their Market Analysis and Strategy group. His research project was developing a minimally invasive optical device for cervical cancer screening, which culminated in testing the device initially at DUMC and later Leogane, Haiti. Vivide's time as a Chambers Fellow allowed him to work at the intersection of biophotonics and medicine, which required him to quickly ramp up on biomedical knowledge (coming from an engineering physics in undergrad) and collaborate effectively with physicians and other researchers. These skills have enabled him to transition to a management consultant helping life sciences clients with their strategic business problems. Most recently, Vivide is a Market Planning Manager at Genentech helping to develop strategies for the Avastin cervical and brain tumor indications.

The Duke **OSA/SPIE Student Chapter** (DOSC) brings together undergraduates, graduates and postdocs from many departments at Duke to facilitate outreach, mentorship and learning. Several times a year, DOSC members bring the excitement of optics to local high schools, including the North Carolina School of Science and Math and Durham Academy.

DOSC member Andres Aragoneses teaches students at NCSSM about refraction and reflection using an OSA Light BLOX kit.

Additionally, DOSC helps to match high school students with optics faculty for summer research projects. Past research projects have included construction of a laser beam profiler and design of a GUI for X-ray scatter imaging for security applications.

A group of Open House visitors explore the six-sided 3D immersive virtual environment of Duke's DiVE.

Exploring light technologies

A community celebration of the science and power of light - **Sunday, March 8, 2015**

The United Nations proclaimed 2015 the International Year of Light to raise global awareness about how light-based technologies promote sustainable development and provide solutions to global challenges in energy, education, agriculture and health.

Hundreds of adults and children joined Duke's Fitzpatrick Institute for Photonics for an **Open House** celebration that explored the fun and fascinating science and power of light!

To see videos and more details about last year's event, please go to our website: http://www.fitzpatrick.duke.edu/march8

Center: Dr. Janna Register, Duke rostdoctoral researcher, uses the Optical Society of America's (OSA) Lightblox kit to teach basic concepts of light including refraction. The OSA Lightblox kits were then raffled off and donated to K-12 teachers in attendance, thanks to OSA's sponsorship. *Bottom:* Jenna Meuller, a Duke PhD student and Chambers Scholar, demonstrates "how light helps us see up close." She used a High-Resolution Endoscope to teach how doctors can peer inside the body with this light-based visualization tool.

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DukeBroadband

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FIP Faculty: 121 faculty members from 37 departments and institutes at Duke

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