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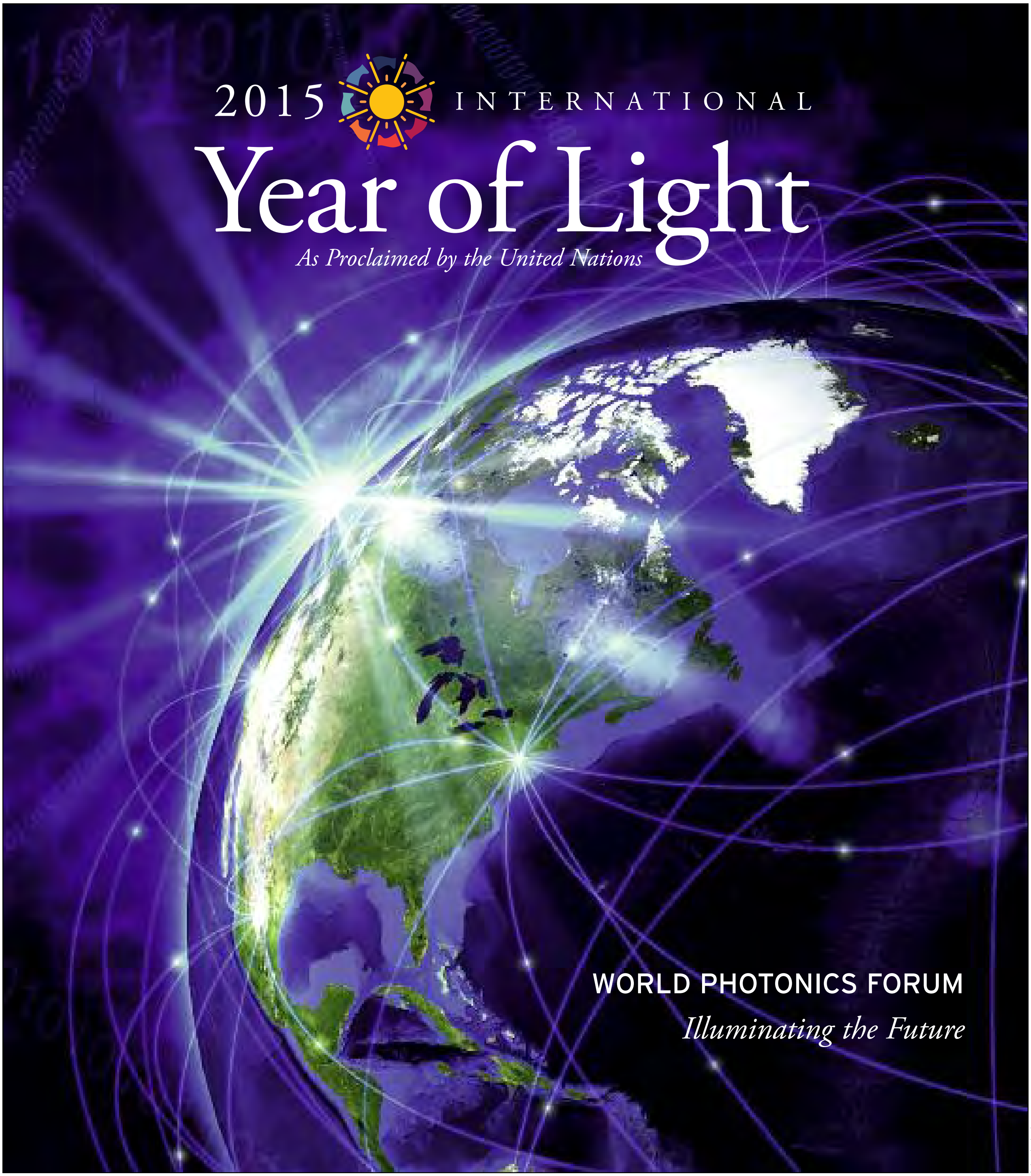

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2015 VOLUME 8 . ISSUE 1

What Is the "International Year of Light"?

The International Year of Light is an official proclamation from the United Nations (UN) for the entire year of 2015 in recognition of photonics and light-based technologies. It's a reflection on the profound impact of the field that the UN recognizes the importance of raising global awareness on how light-based technologies have contributed to human evolution and transformed our lives. For us involved in research and development in the field, it is a once-in-a-lifetime opportunity to reach out and show to the world all the ways that this important research touches people's lives every single day.

Professor Tuan Vo-Dinh

What would you say is the most important light-based discovery that has been made in the past 100 years?

This is a very challenging question because there are so many good answers. You could write an entire book on the topic. In the medical field alone, you can see the progression of how light-based technologies have had a major impact on society. The invention of the microscope gave us the ability to look at the human cell and understand molecular processes of disease on an infinitesimal level heretofore invisible to the human eye. X-ray scans allowed doctors to 'see' inside the human body and detect tumors without having to use a scalpel. And now lasers have led to an amazing array of powerful and versatile enabling tools for many groundbreaking technologies, like DNA sequencers that can read the human genetic code, and 'optical biopsy' technologies that can diagnose cancer instantaneously without surgery, revolutionizing medicine as we know it. And that's just for medicine. That's not even getting into the information revolution where cellular phones can transmit data at the speed of light linking people and civilizations across continents creating the global village of the future.

What would your best guess be as to the photonics discovery that will have the most impact over the next 100 years?

As light-based technologies and their impact on society are growing exponentially, it is impossible to predict, especially for such a long time. However, there are many important fields that photonics and light-based technologies will affect, and faculty at the Fitzpatrick Institute for Photonics are actively involved in many of them. With our vision toward the future, we focus on cutting-edge areas like biophotonics, which integrates optical technologies and medicine; nanophotonics, which investigates light interactions with systems at the nanoscale level; quantum photonics, which explores quantum optics and photon entanglement for designing next-generation computers; and novel materials, such as metamaterials that are artificially engineered to possess exceptional optical properties. We believe these areas will lead to revolutionary breakthroughs at Duke that will bring science to the service of society.

How will Duke be celebrating the International Year of Light?

We will be celebrating during a special annual symposium being held on March 9-10, 2015, where we will invite distinguished speakers and international experts in the field of photonics and light-based technologies. During the symposium, we will have a special *World Photonics Forum* with luminaries and leading researchers from around the world discussing the next great photonics scientific breakthroughs, the contributions of photonics to the humanities and arts, and the roles photonics plays in global economic development.

We are also planning to have an outreach event before the symposium with high school students and their parents visiting the Fitzpatrick Institute for Photonics featuring hands-on demonstrations and posters. And following the symposium, we'll be hosting a workshop designed to explore areas where the field of biophotonics could contribute to industry, education and research in North Carolina. We are partnering with the Office of Science Technology & Innovation of the North Carolina Department of Commerce in organizing this important post-symposium event.

There will be a lot going on here on campus in early March. We invite anyone interested in learning more or attending to check our website: **www.fitzpatrick.duke.edu/2015-fip-symposium**

We are very excited about the International Year of Light. It will be quite an event!

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

Fitzpatrick Institute for Photonics
Duke University
Durham, NC
March 9-10, 2015

2015 Annual Symposium
Frontiers in Photonics, Science and Technology

featuring

WORLD PHOTONICS FORUM

in celebration of the United Nations proclamation of

The International Year of Light (IYL 2015)

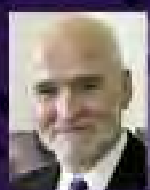
Including special panel sessions on the influence and contribution of light based technologies on science, human development, and global economic development for the next century

Symposium Keynote
Prof. Theodor W. Hansch
Nobel Laureate in Physics
Ludwig-Maximilians University Munich, Germany

Forum Keynote
Prof. John L. Hall
Nobel Laureate in Physics
University of Colorado
National Inst. Standards and Technology

Plenary Lecture
Prof. John M Dudley
Chair, U.N. IYL2015 Steering Committee
President, European Physical Society
Univ. of Franche-Comté, Besançon, France

Plenary Lecture
Prof. Federico Capasso
Robert Wallace Professor of Applied Physics
Harvard University



Forum Special Lecture
Dr. Eugene Arthurs
CEO, SPIE
Bellingham, USA

Forum Special Lecture
Prof. Phillip Russell
Director, Max Planck Institute for the Science of Light
Erlangen, Germany

Invited Forum Panel Speakers

Prof. Andrew Forbes, CSIR National Laser Center, South Africa
Prof. Cristina Kurachi, University of São Paulo, Brazil
Dr. Robert Liebermann, SPIE, USA
Prof. Ulderico Santamaria, The Vatican Museums, Italy
Dr. David Ward, Cisco, USA
Dr. Rachel Pei Chin Won, Nature Photonics, United Kingdom

Duke UNIVERSITY | PRATT SCHOOL of ENGINEERING

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www.fitzpatrick.duke.edu

INTERNATIONAL YEAR OF LIGHT 2015

NEW FIP FACULTY

Dr. Sandeep Dave, MD, Associate Professor
Oncology

Dr. Silvia Ferrari, Professor
Mechanical Engineering and Materials Science

Dr. Katherine Franz, Associate Professor
Chemistry

Dr. Mariano A. Garcia-Blanco, MD, Professor
Molecular Genetics and Microbiology

Dr. Joel Greenberg, Assistant Research Professor
Electrical and Computer Engineering

Dr. Ute Hochgeschwender, Associate Research Professor
Neurobiology

Dr. Sönke Johnsen, Professor
Biology

Dr. David Kirsch, Associate Professor
Radiation Oncology

Dr. Nandan Lad, MD, Assistant Professor
Neurosurgery

Dr. Walter T. Lee, MD, Associate Professor
Surgery, Radiation Oncology

Dr. Bob Malkin, Professor of the Practice
Biomedical Engineering

Dr. David Mitzi, Professor
Mechanical Engineering and Materials Science

Dr. Jennifer L. Roizen, Assistant Professor
Chemistry

Dr. Bill Seaman, Professor
Art, Art History & Visual Studies

Dr. Ganesan Vaidyanathan, Professor
Radiology

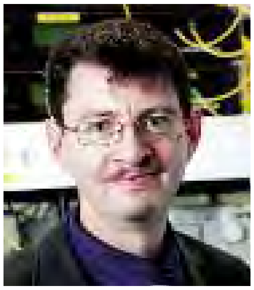
Dr. Michael Zalutsky, Professor
Radiology, Radiation Oncology, Biomedical Engineering and Pathology

"Geometry Ascending a Staircase" designed by artist George Hart and commissioned by Dr. Ingrid Daubechies was a highlight at the FIP symposium as mentioned in the recap on page 14.

PARTICIPATING DEPARTMENTS AND INSTITUTIONS

110 FACULTY MEMBERS **37** PARTICIPATING DEPARTMENTS & INSTITUTES AT DUKE UNIVERSITY:

- Anesthesiology
- Art History
- Biology
- Biomedical Engineering (BME)
- Cell Biology
- Chemical Biology
- Chemistry
- Civil & Environmental Engineering (CEE)
- Computer Science
- Dermatology
- Electrical and Computer Engineering (ECE)
- Gastroenterology
- Geriatrics
- 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
- Division of Infectious Diseases & International Health
- Duke Comprehensive Cancer Center
- Duke Human Vaccine Institute
- Duke Immersive Virtual Environment (DiVE)
- Nicholas School of the Environment



Dr. John Dudley

"An International Year of Light is a tremendous opportunity to ensure that international policymakers and stakeholders are made aware of the problem-solving potential of light technology. We now have a unique opportunity to raise global awareness of this. I would like to congratulate and thank in equal measure the Fitzpatrick Institute for Photonics for organizing the World Photonics Forum. Professor Vo-Dinh was amongst the earliest supporters of the International Year of Light, and in bringing together such an outstanding array of speakers so early in the year, he has shown precisely the kind of initiative that is needed so that the success of the International Year of Light is assured."

INTERNATIONAL YEAR OF LIGHT 2015

—**Dr. John Dudley**, Chairman of the IYL 2015 Steering Committee

Google Engine Map

THE FITZPATRICK INSTITUTE FOR PHOTONICS has collaborators all over the world from Belgium to Uruguay. Go to **fitzpatrick.duke.edu** to explore all of our **55 collaborators** in over **20 countries** with an interactive map from Google Earth.

Q&A

We asked a group of researchers and students from Duke University what they thought about the way photonics fits in with our day-to-day lives and how it might change the world in the future. Their answers were very enlightening.

How has photonics research affected the day-to-day lives of people around the world?

NJ: Photonics has had a tremendous impact, particularly in the area of "green" technologies. LED lighting uses less power than traditional lighting, and solar cells have the potential to generate electrical energy with lower emissions than coal, natural gas and oil. Imaging and communications, both of which have also had a tremendous impact, involve photonics. The pervasive imaging and sharing of images has had a profound impact upon how we experience the world and world events.

DG: A sizable fraction of the world's population is now globally connected by the high-speed Internet, the backbone of which is enabled by photonics technology.

JM: I think that the most powerful development in photonics is Thomas Edison's long-lasting electric light bulb developed in 1880. Providing a reliable light source, regardless of the time of day, enabled people to work longer and ultimately fueled the industrial revolution, which led to countless advances in technology and improvement in the quality and longevity of human life. While we as a wealthy nation have limited appreciation for the light bulb, visiting low-resource communities where life is dictated by the sun can remind us of the power of light.

HN: The effect of photonics research is almost everywhere in our day-to-day lives. When you are at the office and work on a computer, pictures and text you see on the computer's screen are displayed through millions of tiny pixels. Each pixel can be a light emitting diode (LED) or a liquid crystal pixel, which are results of photonics research. When you click on the computer's screen to print a document, your data is likely transferred to a laser printer where a print head will scan and give you images of the document on paper. This is all possible thanks to advancements in photonics research.

JKP: Probably more than what people could imagine and definitely more than I can imagine. That's why I am working in the field. I'd like to work to broaden its benefit to more people.

YB: The products of photonic research have permeated every corner of our lives and provided people a more comfortable and efficient living manner. As a simple example, the progress in display technologies has driven the revolution in television markets. From high-voltage cathode ray tube display screens to liquid-crystal, plasma and organic light-emitting diode displays, people have been enjoying the more vivid images provided by the new technologies, each triggered by progress made in photonics research. Another example is the development in our daily illumination—from incandescent light bulb to fluorescence lamps, electricity is converted into visible white light in a much more efficient way.

What do you think is the most influential light technology to date?

NJ: The Internet has had a profound impact on how we access and use information, on our productivity and on how people communicate throughout the world. The speed of the Internet is largely enabled by laser and fiber communication technologies, and these, to date, are the most influential technologies. Imaging, for photographic and medical purposes, is a very close second.

DG: This is a difficult choice. Leading candidates are optical telecommunications, digital imaging sensors, lasers and advanced optical telescopes.

FY: Most discoveries on pharmacokinetics of nanomedicine are based on fluorescence microscopy. Many are based on intravital fluorescence microscopy. If contrast agents for microscopy are also part of the light technologies, they are equally important for nanomedicine characterization. In medicine, photodynamic therapy has been used routinely to treat cancer. Optogenetics has been used to control expression of genes or activities of proteins in living tissues.

Respondents, left to right: ***Nan Jokerst****, J.A. Jones Professor of Electrical and Computer Engineering;* ***Dan Gauthier****, Bass Fellow and Professor of Physics;* ***Fan Yuan****, Professor and Director of Master's Studies of Biomedical Engineering;* ***Jenna Mueller****, Chambers Scholar and Graduate Student, Department of Biomedical Engineering;* ***Hoan Ngo****, Fitzpatrick Scholar and Graduate Student, Department of Biomedical Engineering;* ***Jong Kang Park****, Chambers Scholar and Graduate Student, Department of Chemistry;* ***Yusong Bai****, Chambers Scholar, Graduate Student, Department of Chemistry*

JM: In addition to the long-lasting electric light bulb, I believe that the light microscope is the most influential light technology to date. Light microscopy is widely used in clinical practice to diagnose a host of diseases—from malaria and tuberculosis to virtually any type of cancer. Additionally, light microscopy has been instrumental in a vast amount of scientific discoveries, such as the development of antibiotics and vaccines, which have greatly improved human health.

HN: To me, the most influential light technology to date is the optical fiber. It has revolutionized the telecommunications industry. With optical fiber, you can send an email from America to Asia in the blink of an eye or see and talk with your family in another city almost in real time. Those are all possible using a web of lightning-fast optical fiber connecting cities, countries and continents.

JKP: I think that the invention of the laser is the most influential discovery so far in the field of light technology. From a laser pointer to medical diagnostic tools and quantum computing source, the usage of the laser has grown explosively since its invention.

YB: To me, it would be display technologies.

What do you think will be the biggest discovery of light technology in the next 25 years?

NJ: The biggest discovery will be how to provide low-cost, low/no-emission energy to the world using sunlight.

DG: Realization of a scalable quantum computer.

FY: Optogenetics will lead to new discoveries in brain and behavior science; super-resolution microscopy may reach the resolution of electron microscopy in some areas of cell biology research, allowing study of living cells at high spatial and temporal resolutions; light microscopes will be combined with various sensors to provide functional information of cells, such as molecular events in cells, mechanical forces, and microenvironment of cells in 3D space; and light technology may also allow surgical procedures on organelles in a single cell.

JM: I believe the biggest discovery will be focused around the development of low-cost, robust devices for diagnosing disease and monitoring health outcomes in low-resource communities. Through mutual collaboration with these communities, I believe that huge advances in health can be achieved in the next 25 years.

HN: In my opinion, the biggest discovery will be using light to detect and cure different diseases including cancer, Alzheimer's and more. One of the main advantages of light technology is to be able to non-invasively diagnose diseases with high spatial and temporal resolution. The same light can also do therapy in controllable ways without affecting adjacent healthy tissues.

JKP: That's an excellent question that I don't know the answer to. I wish I did so that I could be a part of the next big thing.

YB: I think it will be solar energy conversion technology—either new, high-efficiency, low-cost light-to-electricity conversion devices or solar water-splitting technologies.

Charles Gersbach, left, and PhD student Lauren Polstein demonstrate their ability to selectively turn on genes in specific areas of tissue, below. These are human cells genetically engineered to have glow-generating genes turned on after being exposed to light. Any pattern could be used, but this stencil seemed appropriate.

Lighting Up the Genetic **On-Off Switch**

Turning the expression of specific genes on or off has long since moved from science fiction to reality. Current methods to do this using chemical compounds such as drugs, however, have many drawbacks. The process is expensive, the drugs are unstable, there are many potential side effects, the chemicals often target other pathways, and switching genes both on and off at will is challenging.

Perhaps the biggest drawback, however, is the inability to control where the drugs go. For example, researchers can't target one-third of a cell culture or just a particular area of a mouse tissue. But with new techniques using light to control gene expression, all of that may be about to change.

Lauren Polstein

Compounds used to control genes typically have two parts—one part that latches on to a specific DNA sequence and another that either blocks or prompts the expression of nearby genes. **Charles Gersbach**, assistant professor of biomedical engineering at Duke University, had the idea of pulling these two pieces apart and putting a light-sensitive molecule between them.

To do that, Gersbach looked to plants for inspiration. Among their many molecules that respond to light for everything from physical movement to photosynthesis, Gersbach found two proteins in particular that bind to each other in the presence of light and release their grip in darkness. By attaching the DNA-targeting and gene-regulating molecules to each of these plant proteins, researchers can turn on and off specific stretches of DNA with the flash of a light.

The results so far have been promising. Experiments have shown that the technique can target different cell types and provide dynamic control. Not only can the DNA be turned on and then back off again, its activity level can be tuned with the intensity of light.

"We're not working specifically in the area of photonics, but we've incorporated light-regulated gene expression into our toolbox for gene therapy and controlling tissue development and it's looking very promising," said Gersbach. "It just goes to show how far the field of photonics has come in enabling new approaches in diverse fields."

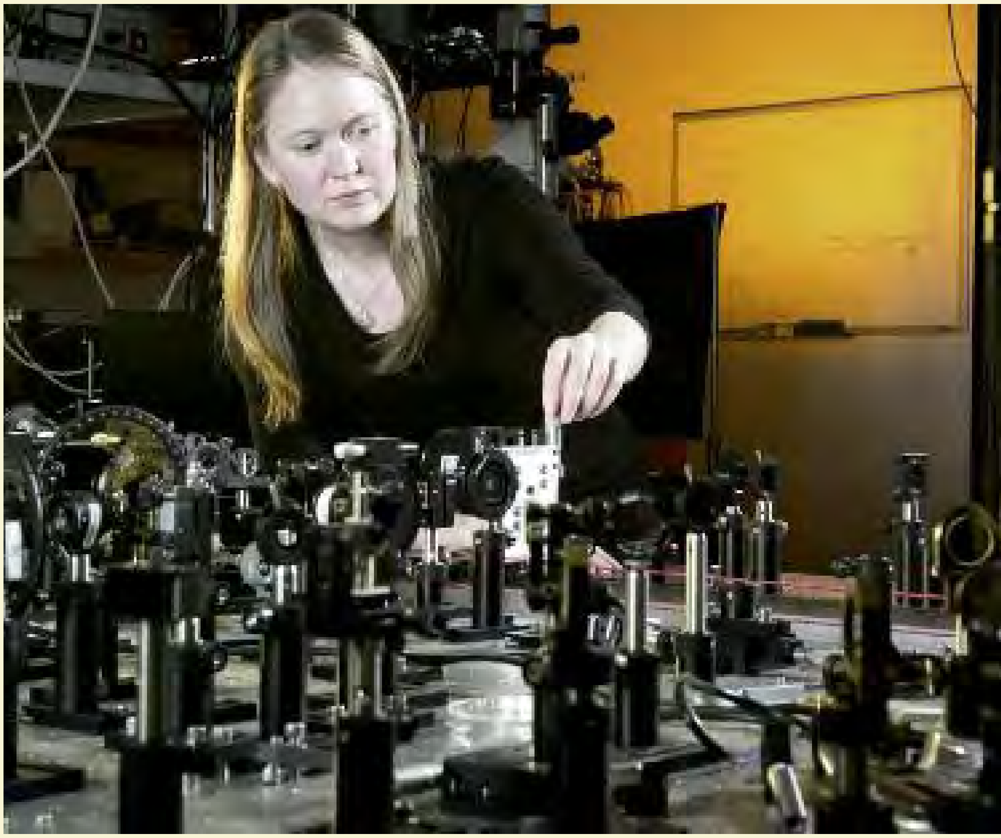
Gersbach hopes to next create a circuit that turns genes on in the presence of light but does not turn them off when the light goes out. With continued improvement, the technique could have many potential applications including controlling the differentiation of stem cells, allowing light-inducible drug release, guiding the growth of blood vessels in vivo, and engineering robust microphysiology systems that mimic human tissue for drug testing.

Revving Up Luminescence
for Superfast LEDs

This year's Nobel Prize in physics was awarded for the discovery of how to make blue LEDs, which enabled advances from more efficient light bulbs to video screens. While the discovery has had an enormous impact on lighting and displays, the slow speed with which LEDs can be turned on and off has limited their use in light-based telecommunications.

In an LED, atoms can be forced to emit roughly 10 million photons in the blink of an eye. Modern telecommunications systems, however, operate nearly a thousand times faster. To make future light-based communications using LEDs practical, researchers must get photon-emitting materials up to speed.

Maiken Mikkelsen, assistant professor of electrical and computer engineering and physics at Duke, specializes in plasmonics—the study of the interaction between electromagnetic fields and free electrons in metal. Through her work, Mikkelsen is trying to set new speed records in molecular fluorescence.



Maiken Mikkelsen, assistant professor of electrical and computer engineering and physics at Duke, adjusts mirrors and lasers in her experiment to speed up fluorescence.

In a recent experiment, her group manufactured 75-nanometer silver nanocubes and trapped light between them, greatly increasing the light's intensity. When fluorescent molecules are placed near intensified light, the molecules emit photons at a faster rate through an effect called Purcell enhancement.

The researchers found they could achieve a significant speed improvement by placing fluorescent molecules in a gap between the nanocubes and a thin film of gold. To attain the greatest effect, Mikkelsen's team used computer simulations to determine the exact gap size needed to tune its frequency to match the color of light that the molecules respond to.

That gap turned out to be just 20 atoms wide. But that wasn't a problem for the researchers.

"We can select cubes with just the right size and make the gaps literally with nanometer precision," said Gleb Akselrod, a postdoc in Mikkelsen's lab. "When we got the cube size and gap perfectly calibrated to the molecule, we saw a record 1,000-fold increase in fluorescence speed."

This illustration created by Gleb Akselrod, a postdoc in electrical and computer engineering, depicts a silver nanocube and gold film sandwiching fluorescent molecules (red) to speed up their fluorescence.

The researchers believe they can do even better by building a system with an individual fluorescent molecule placed precisely underneath a single nanocube. According to Akselrod, they can achieve even higher fluorescence rates by standing the molecules up on edge at the corners of the cube.

"If we can precisely place molecules like this, it could be used in many more applications than just fast LEDs," said Akselrod. "We could also make fast sources of single photons that could be used for quantum cryptography. This technology would allow secure communications across vast distances that could not be hacked—at least not without breaking the laws of physics."

Nico Hotz, assistant professor of mechanical engineering and materials science at Duke, stands with a catalytic prototype that produces hydrogen by reforming fuel at much lower temperatures than conventional methods.

Generating Hydrogen with Sunlight

(EFFICIENTLY.)

Duke engineers have, for the first time, used sunlight to thermally activate the catalytic reaction necessary to generate hydrogen—an advance that has the potential to greatly increase fuel efficiency, lower costs and save resources.

Most hydrogen used in industry today is produced through fuel reforming, which involves adding water to methanol and heating the mixture to produce a hydrogen-rich gas. The process, however, often uses inefficient combustion of fuels to heat the catalyst in excess of 1200° F and must also heat a bulky containment and reaction vessel.

"At those elevated temperatures, there's a lot of heat loss, and about half of the fuel ends up being wasted," explained **Nico Hotz**, an assistant professor of mechanical engineering and materials science. "Another option is photoelectric water splitting that requires large areas of solar cells to get little hydrogen—and at the moment, that lack of efficiency is a show-stopper."

Led by Hotz and **Tuan Vo-Dinh**, Goodson Professor of Biomedical Engineering and director of the Fitzpatrick Institute for Photonics, the Duke team instead turned to methanol, nanoscale plasmonic structures and sunlight to come up with something completely new and different.

"Instead of generating hydrogen with electricity, we've generated it from sunlight and biofuels without having to burn any of our precious carbon-based fuel," says Hotz, who brought this idea to Duke when he arrived in 2010. "We've been able to make nanoscale solar-thermal 'collectors' that can concentrate sunlight and locally heat up to about 250 degrees Celsius, which is high enough to react methanol and water to generate hydrogen."

The innovation enables the efficient heating of the methanol-water mixture using just a 10 cm^2 reactor filled with millions of plasmonic nanoparticles. The structures absorb sunlight efficiently due to localized surface plasmon resonance, which creates an enhanced interaction between surface and light and—in localized spots—heats up better than macro-scale structures.

"The idea is to tap into those localized spots where a lot is happening," said Hotz.

The team has shown the first proof of principle that the technique does in fact work and produces methanol steam-reforming cavities on the plasmonic structure.

A screen capture from the generative work s_traits | The Many Senses Engine *by Bill Seaman with Todd Berreth.*

Connecting Disparate Thoughts

(WITH LIGHT.)

Bill Seaman, professor of visual and media studies

Many people's best ideas come when they stop focusing on the problem at hand and allow their brain to wander. Counterintuitively, it is this ability to connect seemingly disparate thoughts that often leads to "eureka" moments.

Professor **William Seaman** of Duke's Department of Art, Art History & Visual Studies (AAHVS) and the new Media Arts + Sciences program has an innovative way of bringing such connections literally to light. Along with assistant professor John Supko, Seaman heads the Media Arts + Sciences Emergence Lab where they focus on generative arts—image, music and text. Seaman also explores recombinant informatics—a discipline he describes as a multi-perspective approach to inventive knowledge production.

"Recombinant informatics uses a database of 'media objects,' texts, URLs, and actions that are navigated, mined, and explored by the user," he says. "It's designed to enable researchers to discover relevant conceptual territories that they might not normally come across."

Seaman also creates generative poetic works—ever-changing because of their algorithmic nature—such as his light-art work *An Engine of Many Senses* (with programming by Todd Berreth) and *A China of Many Senses*, installed at Duke's Nasher Museum of Art in 2012.

"I make decisions with the code about the objects that are chosen, their qualities, and the parameters of what I want to have happen with those objects," he explains.

Poetic technology can be used at the intersections of a wide variety of disciplines for a virtually endless number of artistic works, Seaman says, and the recombinant-informatics software he developed has great potential for didactic use.

"There are many different ways of looking at things and each has its own qualities, but when you bring them all together in a lateral way, you have a richness that you don't have from looking at something from just one perspective," he says.

"As today's scientists get more specialized, they also need to communicate across disciplines more than ever before to bridge with new fields. Recombinant informatics allows people to tap into and share a whole world that's based on their interaction with this 'intelligent system.'

"This is a visual, conceptual, and artistic way of knocking down silos and bringing these disciplines together to get a more comprehensive view of something. Since Duke is such a multidisciplinary institution, it's perfect for creating these kinds of collaborations and putting this technology into practice."

Lighting Up the Seas

It's only been in the last 200 years that humans invented the light bulb—but many animals figured out how to make their own light eons ago. **Sönke Johnsen**, a professor of biology at Duke University, is trying to learn as much from them as he can.

"These animals produce light very efficiently, and learning their secrets is an interesting chemical problem that could be useful anywhere you need a little light for as little energy as possible," said Johnsen. "You just never know where this type of research could be useful."

One example of bioluminescent research's usefulness is GFP—the number-one fluorescent marker used for biological research. Researchers mutate cells to exhibit GFP to track them under a microscope. The Navy is interested in how organisms exhibit bioluminescence because vessels tend to churn up bioluminescence in their wake, making it difficult to move unseen. And then there's the entire fishing and game industry, who are always looking for new ways to bring in their catch.

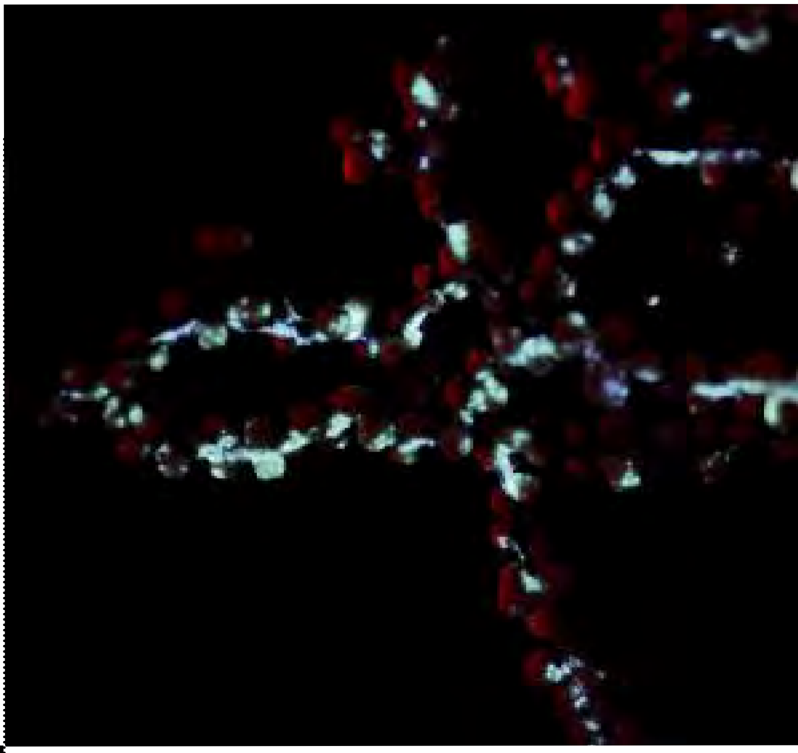
Animals in the wild have very different uses for their bioluminescence, though. One is counter-illumination. It is very difficult to hide your silhouette in the ocean—with light shining down from above, a big black splotch is pretty obvious. Some animals use bioluminescence on the underside of their body to try to blend in.

Sönke Johnsen, Duke University

"The way contrast propagates in the ocean, you can see a silhouette a long way away, which makes an animal very vulnerable," said Johnsen. "But photophores can match the light in spectrum, intensity and angular distribution. They really do it quite well."

All bioluminescence is achieved in the same basic way. You need some energy from ATP, some oxygen, a specially evolved molecule and an enzyme to catalyze the whole process. The exact mechanisms different species use to carry out this reaction, however, can vary widely.

There are three general categories of how animals achieve this reaction. Look at some examples of an animal from each while learning about the different methods.



Brittle stars and some corals, like the ones shown here, carry all the materials necessary to produce light inside their own cells.

LET THERE BE LIGHT

A photophore carries out the illuminating chemical reaction inside its very own body—think firefly. It can be a process as simple as mixing the chemicals together inside a cell or as nuanced as a special structure with biological lenses, mirrors and filters.

"These structures can easily be as complicated as an eye," says Johnsen. "They can shape light, change its spectrum, aim it in a specific direction or change its intensity—they're actually quite sophisticated."

EXTERNAL CHEMISTRY SET

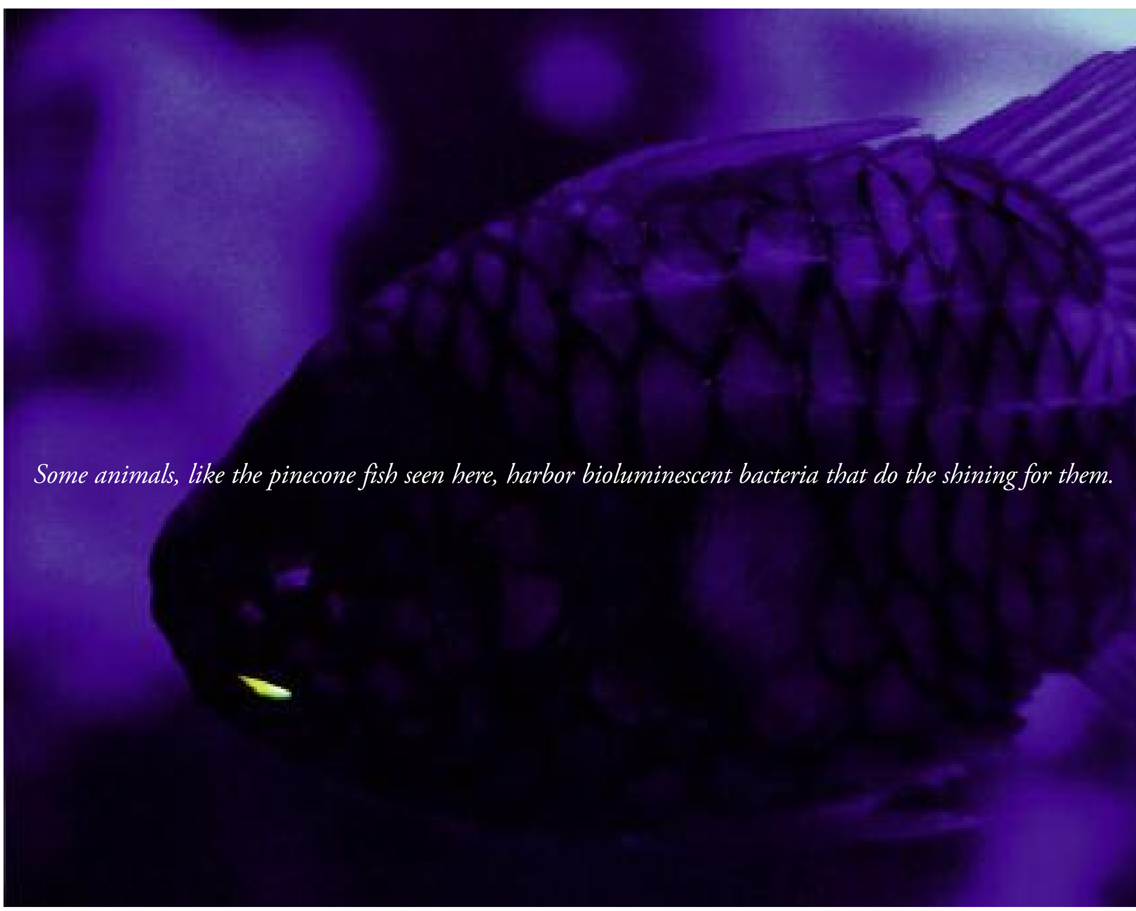
Some animals make all the chemicals necessary to produce light on their own but choose for an external reaction rather than an internal one. They have glands that can emit enzymes, ATP and bioluminescent chemicals into their surrounding area.

"They're basically vomiting light," said Johnsen. "It works like those glow sticks you buy at the Fourth of July, where breaking a little glass tube mixes the chemicals and starts the reaction. It dies down over time and there is little control, but it is dramatic."

Other animals mix the necessary chemicals together in a mucus before shooting it into their surroundings. Sort of like the blue ink that explodes out of a bag of money to mark a thief, this method can mark a predator in a way they don't want.

Some sea anemones and shrimps spew chemicals into the water around them to produce light.

Sönke Johnsen, Duke University



Some animals, like the pinecone fish seen here, harbor bioluminescent bacteria that do the shining for them.

Edith A. Widder, Ocean Research & Conservation Association

I'LL SCRATCH YOUR BACK IF YOU LIGHT UP MINE

Some animals can't produce light on their own, but instead rely on symbiotic relationships with other photophores. For example, some squids keep bioluminescent bacteria distantly related to cholera inside a pouch. The bacteria need the pouch to get nutrients, and the squids need the bacteria's light for self-defense.

"Both animals need each other—it's a beautiful example of symbiosis," said Johnsen. "The bacteria actually glow all the time, but the squid have developed a muscle that acts like a shutter that can aim the light in different directions."

A delicate tarsal pad, the menacing tarsal claws and fine, hooked hairs allow the horsefly (Tabanus sulcifrons) to grip and hold on to animal fur. This scanning electron microscope image of the tarsal claw of the horsefly juxtaposes the complexity and simplicity of 'nature's velcro'. Photo submitted by Valerie Tornini, Duke University at Mahato's "Envisioning The Invisible" Exhibit.

The 2014 FIP Symposium navigated a new direction focusing on arts and humanities. The Special Topic *"Visualization Across The Spectrum from Engineering to Humanities and Medicine"* brought artists, biologists, chemists, engineers, neurobiologists, oncologists, philosophers, physicists, radiologists and surgeons together to discuss their broad work and how photonics is a common theme that connects professionals across disciplines.

Highlights of the meeting included Plenary Speakers, *Dr. Steven Block*, Stanford University and *Dr. Daniel Morse*, University of California, Santa Barbara as well as invited lecturers *Dr. Thomas Cronin* (University of Maryland-Baltimore), *Dr. Dorothy Erie* (University of North Carolina, Chapel Hill), and *Dr. Steven Haddock* (Monterey Bay Aquarium Research Institute).

Branching out to art in photonics brought with it the excitement of visual exhibits on display including a feature exhibit by **Dr. William Seaman** from the Department of Art, Art History & Visual Studies at Duke. His exhibit, **"An Engine of Many Senses,"** was a generative computational work projected onto two 72" plasma screens exploring the history and potential future of the computer using a series of media elements. Lights were also brought in to spotlight a permanent exhibit in the atrium, **"Geometry Ascending a Staircase,"** a mathematical sculpture designed by artist *George Hart* and commissioned by **Dr. Ingrid Daubechies**. The final exhibit, **"Envisioning the Invisible,"** used lights to highlight and bring to life a photo exhibit in the atrium, a memorial that honors the memory and life of *Abhijit Mahato*, a graduate student at Duke who believed in bridging the gaps between science, engineering, social sciences, and humanities through photography.

INDUSTRY

FIP Silver Corporate Partner

At **Cisco** customers come first and an integral part of our DNA is creating long-lasting customer partnerships and working with them to identify their needs and provide solutions that support their success. The concept of solutions being driven to address specific customer challenges has been with Cisco since its inception. Husband and wife Len Bosack and Sandy Lerner, both working for Stanford University, wanted to email each other from their respective offices located in different buildings but were unable to due to technological shortcomings. A technology had to be invented to deal with disparate local area protocols; and as a result of solving their challenge, the multiprotocol router was born. Since then Cisco has shaped the future of the Internet by creating unprecedented value and opportunity for our customers, employees, investors and ecosystem partners and has become the worldwide leader in networking, transforming how people connect, communicate, and collaborate.

FIP PHOTONICS PIONEER AWARD

Dr. Roger Y. Tsien, 2008 Nobel Laureate in Chemistry and one of the scientists attributed with the discovery of the green fluorescent protein (GFP), presented the keynote lecture at the annual Fitzpatrick Institute for Photonics (FIP) Symposium "Frontiers in Photonics Science and Technology" held March 11-12, 2014. During the conference, Dr. Tsien was recognized for his accomplishments in the field of photonics and awarded the prestigious *FIP Pioneer Award*.

Check out these programs!

Master of Engineering Photonics and Optical Sciences

fitzpatrick.duke.edu/education

Certificate In Photonics for MS and PhD students

Curriculum: Photonics courses focused on technical areas of interest, a research presentation, and attendance at a minimum of four FIP seminars.

Ideal candidates: Doctoral students in any technical field who wish to gain greater depth of skill and exposure to photonics and optical sciences.

Duration: Flexible. Courses can be taken at any time during the student's tenure at Duke while working towards a primary degree.

CHAMBERS FELLOWS

Where Are They Now?

After completing her PhD in electrical and computer engineering at Duke in 2010, **Sabarni Palit** became a GE Global researcher in New York working on harsh environment optical and optoelectronic sensors.

Her time as a Chambers Fellow helped her land the position by pushing her to work with many people in different fields and getting out of her comfort zone. She became comfortable working on her piece of the project and delegating other pieces to colleagues with expertise in unfamiliar fields.

Palit now uses this experience to work with both government and private industry collaborators on aspects from packaging to the business side of health care. She is the electrical engineering lead on developing photonic devices for medical imaging.

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 $44,000 each year towards 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 towards 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 2014 academic year!

Left to Right: *Han Sang Park (Chambers Fellow), Robert Morhard (Chambers Fellow), James Polans (Chambers Scholar), Brenton Keller (Chambers Fellow), Callie Woods (Chambers Fellow), Daniel Salo (Chambers Fellow), Ye Jin (Chambers Fellow), Weifeng Huang (Chambers Fellow), Bridget Crawford (Chambers Fellow), Yusong Bai (Chambers Scholar) and Hoan Ngo (Fitzpatrick Scholar). Not pictured: Yang Zhao (Chambers Fellow).*

2014-2016 - Fitzpatrick Foundation Scholars

Hoan Ngo (BME- Professor Vo-Dinh)

2014-2016 - Chambers Scholars

Yusong Bai (Chemistry- Professor Therien)

James Polans (BME- Professor Izatt)

2014-2015 Chambers Fellows

Bridget Crawford (BME- Professor Vo-Dinh)

Weifeng Huang (ECE- Professor Liu)

Ye Jin (Chemistry- Professor Beratan)

Brenton Keller (BME- Professor Izatt)

Robert Morhard (BME- Professor Ramanujam)

Han Sang Park (BME- Professor Wax)

Daniel Salo (BME- Professor Ramanujam)

Callie Woods (ECE- Professor Jokerst)

Yang Zhao (BME- Professor Izatt)

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DukeBroadband

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FIP FACULTY: 110 faculty members from 37 departments and institutes at Duke

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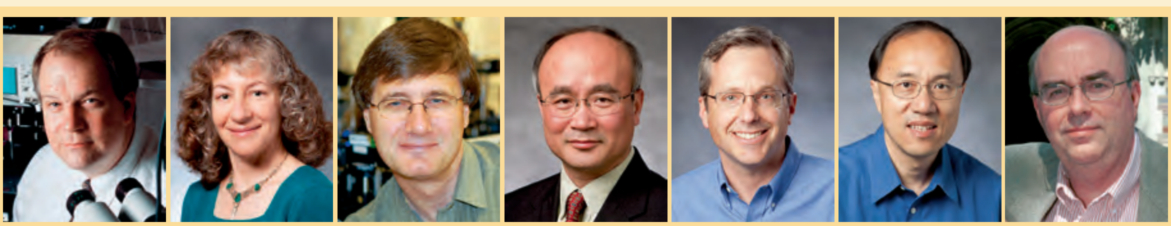

FIP Research Programs and Program Directors, left to right: **Biophotonics:** Joseph Izatt / **Nano & Micro Systems:** Nan Jokerst / **Quantum Optics and Information Photonics:** Daniel Gauthier / **Systems Modeling, Theory & Data Treatment:** Weitao Yang / **Photonic Materials & Advanced photonics systems:** Steven Cummer / **Nanophotonics:** Fan Yuan / **Novel spectroscopes:** Warren Warren