DukeBroadband

FITZPATRICK INSTITUTE FOR PHOTONICS / DUKE UNIVERSITY

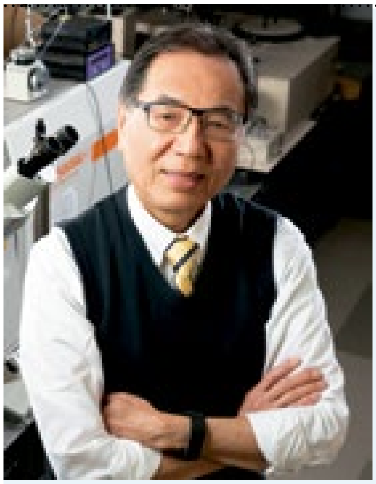
Engineering light to change the world

MAPPING *the* INVISIBLE

Faculty Highlight
Nimmi Ramanujam
See page 18

2024 VOLUME 17 ISSUE 1

DIRECTOR'S WELCOME



WELCOME to the 2024 Issue of *BROADBAND*, the Newsletter of the Fitzpatrick Institute for Photonics (FIP).

The Fitzpatrick Institute for Photonics (FIP) continues its remarkable upward trajectory, a testament to its unwavering dedication to cross-disciplinary research. The driving force behind this success lies in the collective passion and commitment of its faculty, students, and staff, who form the foundation of the Institute's dynamic growth. The FIP has become a powerful testament to interdisciplinary collaboration at Duke, with its influence spanning across an expanding network of partnerships that transcend traditional academic boundaries. This vibrant collaboration underscores the resilience and lasting impact of the faculty's groundbreaking contributions, cementing FIP's relevance in both academic and real-world applications. With a diverse membership of over 150 faculty from more than 40 departments and institutions, the FIP's reach spans a broad array of disciplines. From Chemistry, Physics, Biomedical Engineering, and Material Sciences to medical fields like Oncology, Pathology, and Global Health, the FIP embraces a holistic cross-disciplinary approach from scientific discovery to translational research. The Institute's engagement even extends beyond the sciences, fostering collaboration in areas such as Art, Art History, and Visual Studies. This wide-ranging inclusivity reflects the FIP's commitment to innovation and excellence across all fields, making it a model for how cross-disciplinary research can drive transformative breakthroughs.

An exceptional highlight in this issue of Broadband is the spectacular celebration of Duke University's Centennial, organized by the FIP. On Saturday, April 13, 2024, FIP marked this historic occasion with a groundbreaking event titled ***Engineering Light to Empower the World.*** The celebration was a dazzling fusion of innovation and inspiration, showcasing FIP's visionary achievements in photonics. Three remarkable events amplified the event's vibrancy and excitement:

Lightning Speed Centennial Symposium:
Light in Service of Society
The festivities started with "Lightning Talks" delivered by FIP's faculty. These fast-paced video presentations took attendees on a journey through Duke's rich legacy in photonics research while highlighting the immense societal contributions and future potential of light-based technologies.

Exploring the Wonder of Light –
Lasers, Lenses & Light Outreach
The FCIEMAS Atrium transformed into a hub of exploration, inviting guests to interact with a series of captivating light-based exhibits organized by the Duke Optical Student Chapter. From lasers to lenses, attendees of all ages were captivated by hands-on demonstrations that brought the wonders of photonics to life and showcased how light is shaping our world.

Moving Forward at the Speed of Light
through Space & Time
A fascinating laser show lit up the night, leaving the audience in awe and wonder. The day's festivities culminated in an extraordinary Light Painting session, where the fusion of art, creativity, and technology produced spectacular displays of color and movement. The FIP didn't just commemorate Duke University's 100-year legacy—it lit the way to a brighter future, inspiring everyone to explore the limitless possibilities of light!

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

I send you my very best wishes for a successful, safe, and enjoyable year.

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

ON THE COVER: *The assembly wheel of the Nancy Grace Roman Space Telescope, designed to reflect light extremely efficiently.* **More on page 12**.

CELEBRATING DUKE UNIVERSITY'S 100TH ANNIVERSARY

SAVE THE DATE

MARCH 10-11, 2025

2025 FIP SYMPOSIUM

THE FITZPATRICK INSTITUTE FOR PHOTONICS

DUKE UNIVERSITY DURHAM, NC USA

Frontiers in Photonics Science & Technology

KEYNOTE SPEAKER:

Professor Moungi Bawendi

Nobel Laureate in Chemistry (2023)

Lester Wolfe Professor in Chemistry

Massachusetts Institute of Technology

Duke FITZPATRICK INSTITUTE *for* PHOTONICS

Duke 1924-2024 100

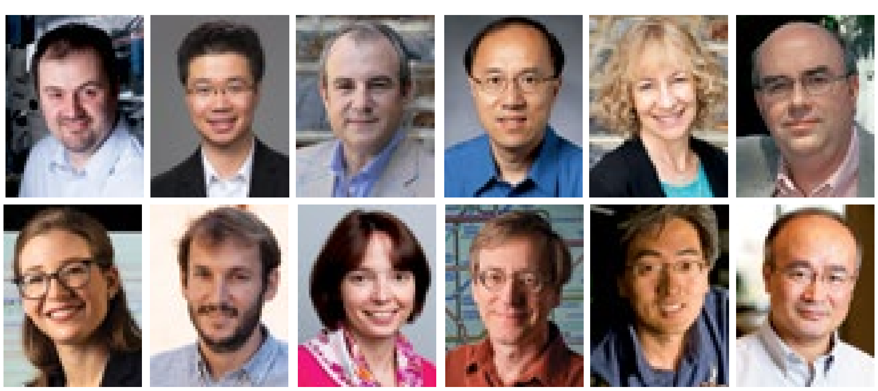
PARTICIPATING DEPARTMENTS AND INSTITUTIONS

150 **Faculty Members** | **40** **Participating Departments, Centers, and Institutions at Duke University**

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

DEPARTMENTS

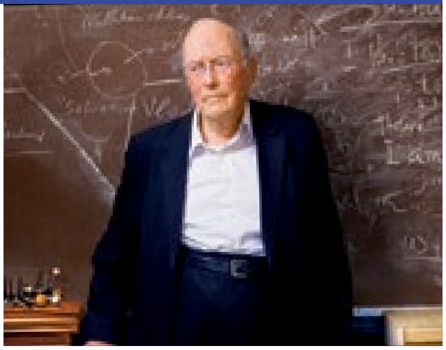
Anesthesiology
Art, Art History & Visual Studies
Biochemistry
Biology
Biostatistics and Bioinformatics
Biomedical Engineering (BME)
Cell Biology
Chemistry
Civil & Environmental Engineering (CEE)
Computer Science
Dermatology
Electrical and Computer Engineering (ECE)
Environmental Toxicology
Gastroenterology
Geriatrics
Immunology
Mathematics
Mechanical Engineering and Materials Science (MEMS)
Molecular Genetics and Microbiology
Neurology
Neurobiology
Neurosurgery
Obstetrics and Gynecology
Oncology
Ophthalmology
Orthopaedic Surgery
Pathology
Pediatrics
Pharmacology and Cancer Biology
Philosophy
Physics
Radiation Oncology
Radiology
Surgery
Urology
Center for Applied Genomics and Precision Medicine
Duke Cancer Institute
Global Health
Nicholas School of the Environment
School of Medicine
School of Nursing



FIP RESEARCH PROGRAMS AND DIRECTORS

(left to right): **Advanced Photonics Systems:** Brenton Hoffman **Biophotonics:** Junjie Yao & Adam Wax **Nanophotonics:** Fan Yuan **Nano & Micro Systems:** Nan Jokerst **Novel spectroscopes:** Warren Warren **Photonics & AI:** Jessilyn Dunn & Roarke Horstmeyer **Photonic Materials:** Natalia Litchinitser **Quantum Optics and Information Photonics:** David Beratan and Jungsang Kim **Systems Modeling, Theory & Data Treatment:** Weitao Yang

Duke 100



Duke Centennial Celebrated at FIP

Echoing the date of Duke University's founding in 1924, Duke launched a year-long 100th birthday party with an extraordinary kickoff event on January 9, 2024. The centennial brings about a historic opportunity to recognize Duke's extraordinary past, highlight the impact of the present and look toward the potential of Duke's future. The year's festivities and events will celebrate athletics, research and innovation, Duke history, and more.

In this spirit, the Fitzpatrick Institute of Photonics pays homage to one of Duke's most impactful and decorated alumni, Charles H. Townes. Townes earned his master's degree in physics here at Duke before eventually working on a team of researchers that eventually led to the invention of the laser, for which they received the Nobel Prize in 1964.

From the historical remarks provided by FIP's various program leaders (page 10), the laser stands as one of the most impactful photonics devices ever invented. Duke was proud to welcome Townes back to campus in 2006 to speak at the annual FIP symposium and continues to be proud to have played a part in shaping the career of such a transformational and influential scientist.

Duke 100

The Fitzpatrick Institute for Photonics Lights Up Duke University's 100th Anniversary with a Spectacular Celebration!

On **SATURDAY, APRIL 13, 2024**, the Fitzpatrick Institute for Photonics (FIP) ignited the spirit of innovation at Duke University's centennial celebration with a truly unforgettable event:

Engineering Light to Empower the World

This extraordinary day was a vibrant showcase of FIP's groundbreaking achievements, featuring the brilliant minds of its leaders, rising innovators, students, and dedicated staff, all united by their passion for light-based technologies.

The program featured three special events:

Lightning Speed Centennial Symposium: Light in Service of Society

The symposium kicked off with electrifying 'Lightning Talks' from FIP faculty, where they dazzled the audience with insights into Duke's illustrious history in photonics research. These rapid-fire presentations spanned the past, present, and future, revealing the immense societal impact of light.

Exploring the Wonder of Light - Lasers, Lenses & Light Outreach

The FCIEMAS Atrium transformed into a playground of discovery, captivating attendees of all ages with interactive exhibits and stunning demonstrations. From the mesmerizing nature of light to its practical applications, this outreach event was a true eye-opener.

Moving Forward at The Speed of Light through Space & Time

The event reached new heights with a dazzling Light Painting session, where creativity met technology in a spectacle of color and motion. For the grand finale, a breathtaking laser show lit up the night, leaving the **audience in awe.**

View Video of FIP Lightning Symposium Talks

The Fitzpatrick Institute for Photonics truly made Duke University's 100th Anniversary Celebration one for the ages, illuminating the path to a brighter future!

Lasers, Lenses & Light: A Showcase of Fitzpatrick Institute Photonics Research for the Community

Institute holds open house as part of Duke Centennial | BY GEOFFREY MOCK

Light is a storyteller, and for a young girl about to roll a giant die, it's telling an important story about treating disease.

The girl is playing a game on the third floor of the Fitzpatrick Center, home to the Fitzpatrick Institute for Photonics (FIP). As she rolls the die, the girl moves a model of a gold nanostar – a tiny synthetic particle -- through the human body to a cancerous tumor. Duke graduate student Joy Li describes how institute researchers use gold nanostars, tiny particles of gold with multiple spikes -like a star- and laser light to signal the presence of specific molecules that serve as red flags to indicate the presence of cancerous cells and potentially other diseases. Then laser light can also be used to heat the gold nanostars and kill the tumor cells that had been identified.

The big idea is that in the future the combination of light and gold nanostars will be able to identify a range of diseases in their earliest stage in a single drop of blood taken from an ostensibly healthy person, even before the individual has symptoms. Early detection of diseases is critical for

FIP SYMPOSIUM 2024

Scenes from the various workstations at the FIP open house, each designed to show the magic and power of light.

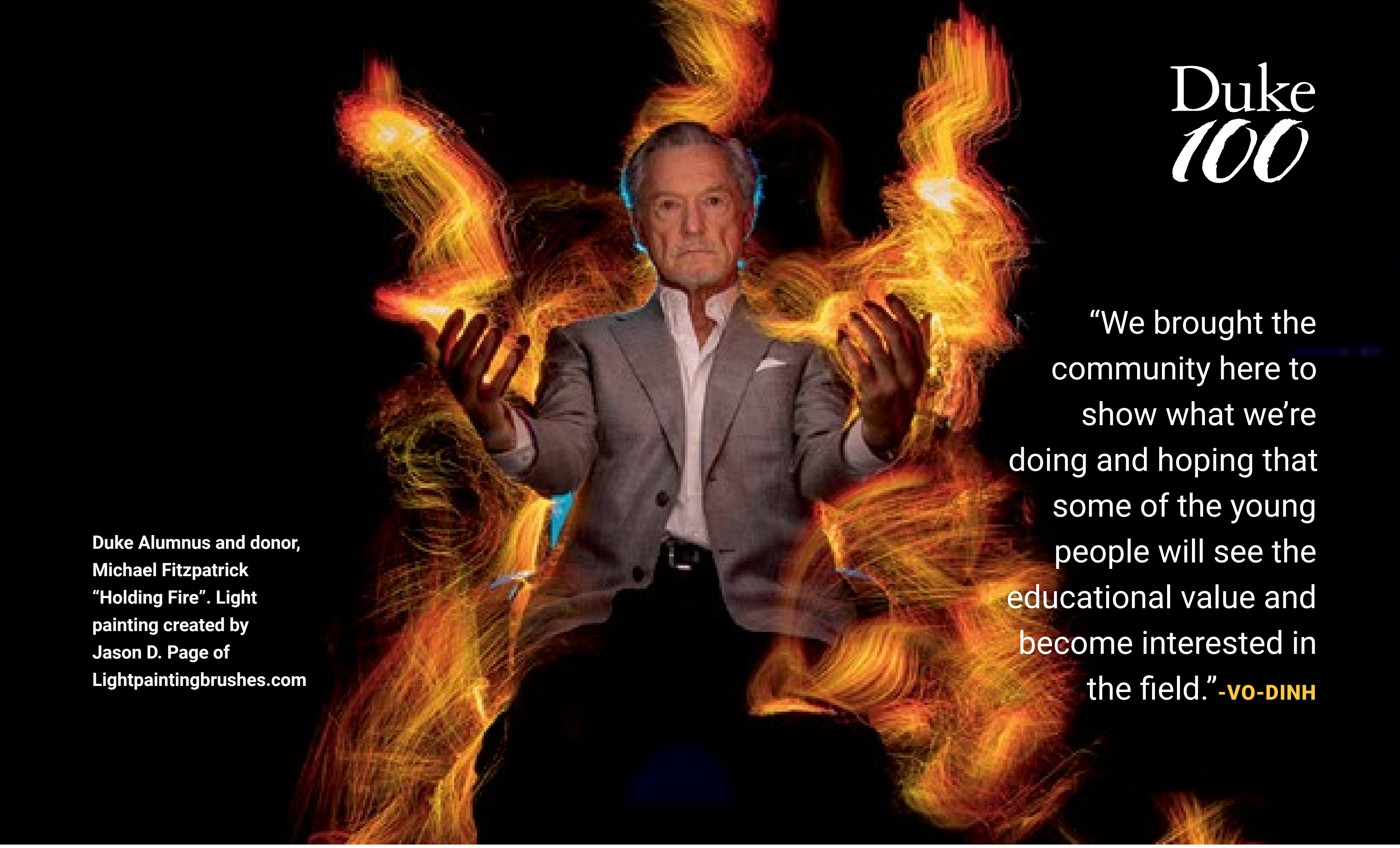
treatment effectiveness, improving survival rates, and enhancing the quality of life for patients.

The work is complicated, but after 15 minutes, the girl walked away happy with a prize for getting the nanostar successfully to the tumor, and knowing a little bit about how interdisciplinary research at the FIP is using light to impact our lives.

That was the goal of the day-long symposium and open house at the institute on April 13th organized to celebrate the 100th anniversary of Duke University. More than 250 community members and alumni attended the event to hear from FIP faculty and graduate students and get a taste of the innovative ways light is being used in fields from medicine to art.

"We wanted to show the magic and power of light," said Tuan Vo-Dinh, R. Eugene and Susie E. Goodson Distinguished Professor of Biomedical Engineering, Professor of Chemistry, and director of the Fitzpatrick Institute for Photonics. "And we wanted to show how that power is being used by Duke researchers to benefit society. This work is part of the legacy of Duke, as we celebrate our centennial. We brought the community here to show what we're doing and hoping that some of the young people will see the educational value and become interested in the field."

Duke 100



Duke Alumnus and donor, Michael Fitzpatrick "Holding Fire". Light painting created by Jason D. Page of Lightpaintingbrushes.com

"We brought the community here to show what we're doing and hoping that some of the young people will see the educational value and become interested in the field." -VO-DINH

Celebrating Duke Alumni Weekend at our FIP Symposium, where alumni joined in on the fun and got creative with light painting! This alumni requested a vibrant showcase as Laura DelPrato illuminated golden sparkles and Jess Cruger brought the rainbow to life with fiber optics!

Duke has a long tradition as a leader in research on light. One Duke alumnus, Charles Townes, went on to win the Nobel Prize for Physics for his discovery involving lasers. Over the past two decades, the institute has further elevated optical research at Duke to make the university one of the world leaders in the field.

At workstations throughout the open house, photonics graduate students described how work in the FIP's lab is advancing science to benefit society.

Among the sights was a rare glassfrog, which has the unusual ability to conceal its red blood cells in its liver while sleeping. This amazing feat protects them from predators at night but also may provide new tools for imaging technology.

At one station, biomedical engineering graduate student Márcia Cunha Dos Santos described how institute faculty are developing improved imaging to better understand how cancer behaves, creating low-cost medical tools that are transforming care for breast cancer and other diseases in low-resource communities around the world.

Dos Santos also cited the program's ethos of using creative interdisciplinary collaboration with global health scholars to develop tools that are available to many.

"The program is working to bring affordable technology to communities with little resources," she said. "In doing so, people have improved access to better health care. Some of these settings are challenging, so we're doing complex work that requires engineering but also other skills to work with the community so their needs are best met."

Engineering to explore the wonder of light was a common theme at the various stations. At a table on light polarization, graduate student Robert Trout shared his path to studying intraocular surgical imagery, which provides surgeons with real-time images of eye surgery.

"The doctors tell us they need to be able to see something, and it's up to us to engineer a way to let them do that," Trout said. "We are engineering to close a gap. A common theme here at the institute is we are all interested in finding applications that are useful and benefit society."

Finally, an unusual session was held, featuring demonstrations of light painting suitable for all ages. These demonstrations showcased the artistic use of light and culminated in an impressive laser show.

One of the visitors was Michael Fitzpatrick, the Duke alumnus whose gift through the Fitzpatrick Foundation supported the establishment of the Fitzpatrick Center of Interdisciplinary Engineering and Medical Applied Sciences (FCIEMAS) where the event took place as well as the photonics institute. Since its creation two decades ago, the FIP has been the centerpiece of the university's effort to promote cross-disciplinary research involving light-based technologies at Duke.

“We are engineering to close a gap. A common theme here at the institute is we are all interested in finding applications that are useful and benefit society.” **- ROBERT TROUT**

A young attendee brought his imagination to life, transforming into a dinosaur in his light painting portrait!

“For me it’s fun to come back and to see the progress that’s been made and talk about what will be the top advances for the coming years,” Fitzpatrick said. This has evolved so much under Tuan’s leadership. I think what’s been so great is the interdisciplinary aspect that has been very important to us from the very beginning. It just shows how important that is and how much progress can be made when you’re able to get the best of the best from all different types of scholars. It’s far outside of engineering. We’re now working with artists; we’re working with all different forms of disciplines.” ■

200 Years of Photonics Impact

Impressions and Vision….

Photonics research has had an incredible impact on a wide range of fields and disciplines over the years. With nearly a dozen programs focused on different areas, the Fitzpatrick Institute for Photonics in a clear example of that fact. We asked the leaders of the various FIP programs about their thoughts on what the largest impact of photonics has been on their field over the past 100 years—and what they think will be its largest impact over the next 100.

Tuan Vo-Dinh
Director of FIP

Over the past 100 years, photonics has had a transformative impact on medical diagnostics and therapy due to the development and widespread use of laser technology, fiberoptics, and advanced imaging techniques. These advancements have revolutionized how diseases are diagnosed and treated, enabling more precise, minimally invasive procedures and improving patient outcomes.

Over the next 100 years, photonics will transform medical diagnostics and therapy. The convergence of advanced photonic technologies, artificial intelligence, and quantum science will revolutionize healthcare, fundamentally changing how we detect, monitor, and treat diseases.

Roarke Horstmeyer
Photonics & AI

Within the field of imaging, photonics over the past 100 years has shifted our ability to capture and record images into the digital world. Digital image sensors are now everywhere—in our pockets and cars and are a part of nearly every scientific experiment. This has revolutionized not only how we increasingly interact with images and video within our everyday lives, but also how we use images and videos to perform research, communicate ideas and make clinical decisions.

Over the next 100 years, I expect photonics to increasingly help us not only capture and measure, but also to process and understand information. As the ability to compute and form decisions about the world around us continues to accelerate, photonics will continue to provide critical sensing and processing capabilities to feed upcoming machine learning and artificial intelligence platforms.

Jessilyn Dunn
Photonics & AI

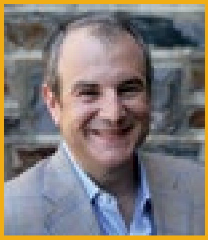
Over the past century, photonics has significantly influenced the field of biosignal monitoring, particularly through the development and integration of optical sensing technologies. Photonics has enabled non-invasive monitoring of various physiological parameters using light-based techniques. These technologies have been miniaturized and integrated into consumer wearables like smartwatches and fitness trackers, making it possible to continuously monitor vital signs in a non-intrusive manner.

Looking forward, the potential impact of photonics on the fields of biosignal monitoring, digital health and wearables is vast. The next 100 years could see advancements in the sensitivity, miniaturization and wavelength spans of photonic devices, leading to even more sophisticated and accurate health monitoring systems, especially ones that monitor a broader range of biomarkers in real-time. The integration of photonics with AI could enable novel devices to analyze complex datasets in real time, providing in-the-moment predictive insights and personalized health recommendations.

Junjie Yao
Biophotonics

Biophotonics, the science of using light to study biological materials, has revolutionized medical diagnostics and fundamental research over the past century. The biggest impact photonics has had on this field is undoubtedly the development of advanced optical imaging techniques as well as the advent of optogenetics. Innovations such as confocal microscopy, fluorescence imaging, and optical coherence tomography have enabled unprecedented visualization of cellular and subcellular structures, transforming our understanding of biological processes and disease mechanisms. Deep tissue imaging has allowed scientists to peer into the depths of biological tissues, revealing insights previously hidden from view.

Looking ahead, the next century promises even greater strides with the integration of photonics, artificial intelligence and robotics. The potential for real-time, high-resolution imaging at the molecular level, coupled with AI-driven data analysis, could lead to revolutionary advancements in personalized medicine. Additionally, the development of non-invasive light-based therapies and diagnostics could transform patient care, making treatments more effective and less invasive.



Adam Wax
Biophotonics

I believe the development of OCT has been the biggest impact of photonics in the field of biomedicine in the past 30 years. If we look back 100 years, it has to be the development of the laser—Charles H. Townes received his master degree at Duke and won the Nobel Prize in 1964.
There have been a number of recent advances in photonics which might produce a large impact in the next 100 years. I believe optogenetics, the ability to manipulate biological systems using light could be the most impactful.

Nan Jokerst
Nano/Micro Systems

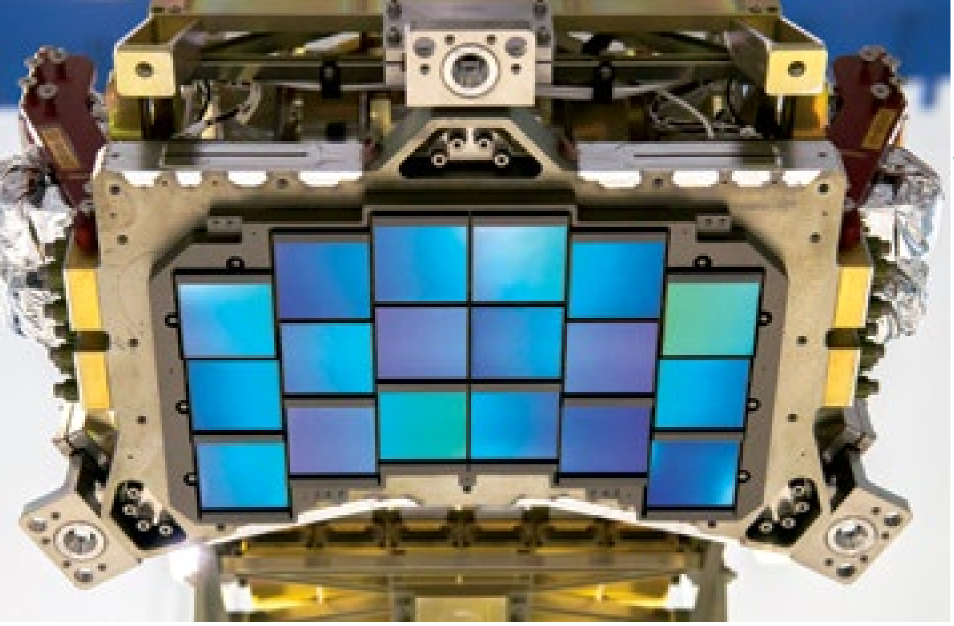
The revolution in lighting, from incandescent to fluorescent to LED, has had dramatic effects on the quality, cost and energy efficiency of a wide variety of indoor, outdoor and indicator illumination. From large displays in Times Square to the displays on your desk and the cell phones and watch faces in your hand, the advance of optical displays has revolutionized how we interact with the world.

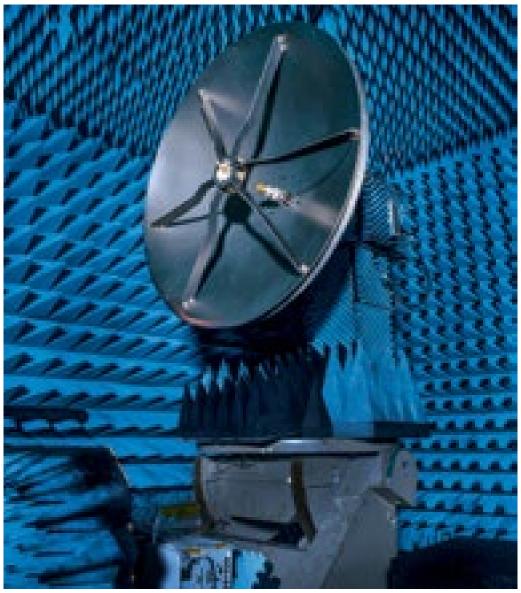
Looking forward, addressing human-induced climate change is a critical challenge for mankind. The dominant power source that drives our planet is light from the sun, and harnessing that light to produce power in an environmentally responsible way is a clear path to renewable energy.

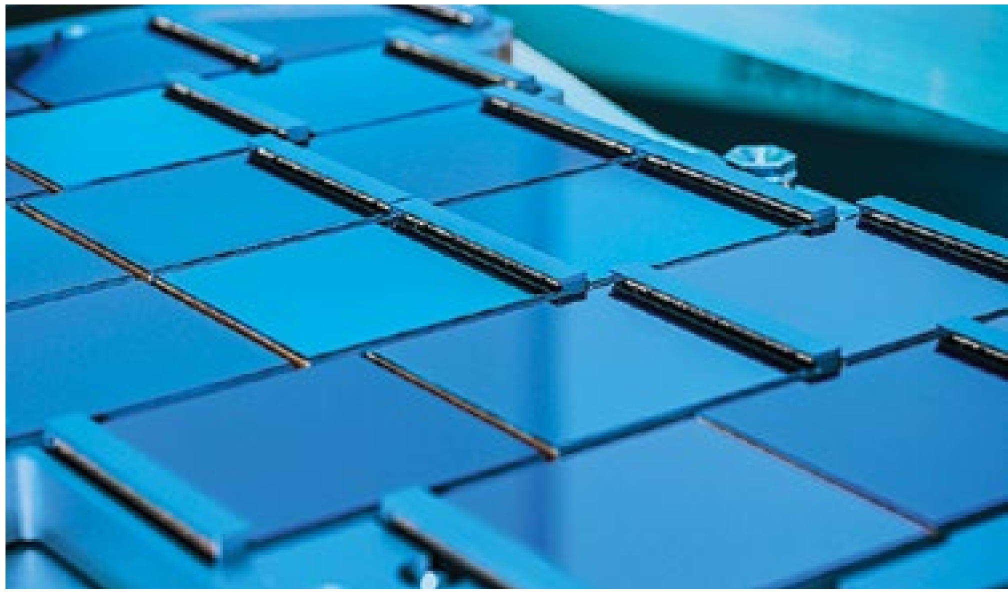
Natalia Litchinitser
Photonics Materials

Photonics has been essential for the fundamental science discoveries starting from the discovery of the photoelectric effect by Einstein, or Raman and Compton effects, to more recent laser cooling and trapping, super-resolution microscopy, and generation of attosecond light pulse generation, as well as a plethora of technological developments that we nowadays use in our lives, including high-speed optical fiber communications and chirped pulse amplification, holography, charge-coupled device (CCD) sensor arrays, novel light sources such as lasers, laser diodes, or light-emitting diodes.

I strongly believe that photonics will make a huge impact in medicine in the coming decades. My most recent passion is a very ambitious project aiming at fundamentally improving the tools for neurosurgery, where the ability to "see" as well as possible is more important than probably anywhere else. While many advanced imaging modalities have been developed or adapted for neuroimaging, there are many directions in which advanced photonic technologies can further improve or even revolutionize this field. ■







Mapping the Invisible

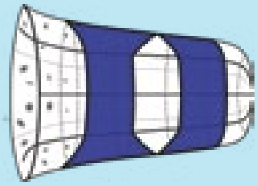
Duke researchers are gearing up to take advantage of the new Nancy Grace Roman Space Telescope to explore the history (and present) phenomena of our galaxy

BY JUNWOO KIM FOR THE 2024 DUKENGINEER MAGAZINE

It's a rite of passage for Pratt undergraduates—physics. Known for its challenging weekly quizzes and grueling labs, it's no surprise the two-semester Introductory Physics sequence (Physics 151L + 152L) often results in a collective sigh of relief post-final exam. The students leave with a false sense of confidence that they've mastered the material.

In reality, they've covered less than 5% of the subject. This is because the content learned in classes like Introductory Physics or Optics and Modern Physics (Physics 264L) covers the physics of normal matter. However, according to NASA, normal matter composes less than 5% of the universe in mass, while the other 95% is made up of dark components, called dark energy and dark matter.

One Duke faculty member hoping to uncover the mysteries of the dark universe is Michael Troxel, a professor in the Department of Physics and a member of the Fitzpatrick Institute for Photonics (FIP), an interdisciplinary center aiming to advance photonics and optical sciences. Troxel's research focuses on a technique called "gravitational lensing" to map the locations and sizes of dark matter masses. Gravitational lensing revolves around the idea that the path of light can be bent by the gravitational pull of an object of



large enough mass. Thus, the size and location of massive objects like galaxies and dark matter can be determined by observing how the light path bends around them. The location of dark matter can then be isolated by identifying the locations where no visible mass is present.

Another Duke Physics professor and FIP member shining light on dark matter is Daniel Scolnic, whose research hinges on the concept of "cosmic expansion," which relies on the light generated by exploding stars—supernovae—to chart the expansion of the universe because of dark energy. The light emitted from one supernova is roughly equal to that of half a billion stars, so the location of a supernova can be pinpointed by identifying areas where the light captured is considerably greater than it was previously. By measuring the apparent brightness, scientists can determine the distance of the supernovae from Earth and use it to understand how dark energy is causing the universe to accelerate in its expansion.

In 2016, to more deeply understand dark energy, dark matter, and other celestial mysteries, NASA approved the development of the Nancy Grace Roman Space Telescope. Tuan Vo-Dinh, a professor of biomedical engineering and chemistry who directs the FIP, says that Roman's mission is unique.

"These two intrepid scientists and members of FIP are preparing to embark on a journey with the future NASA Nancy Grace Roman Space Telescope as their explorer vessel, charting the celestial map to unveil the secrets of planetary systems and illuminate the enigmatic realms of dark energy, exoplanets and infrared astrophysics," Vo-Dinh said.

The Roman Telescope is considered a successor to the famous Hubble Space Telescope, while sharing some characteristics with the more modern James Webb Space Telescope (JWST). Its main similarity with Hubble is its sensitivity — the extent to which it can determine faint sources of light. While this may seem like devolution considering the exceptional sensitivity of the JWST, the purpose of Roman is to survey large plots of the night sky, not hone into one celestial system.

"The data that Roman will take in its survey mission would take Hubble or the James Webb Space Telescope 1000 years to gather," said Troxel.

For both Troxel and Scolnic, capturing a wide field of view is critically important. In gravitational lensing, for instance, it's crucial to capture as much light as possible; the bending of one path of light does not mean that dark matter is present; rather, it's the bending of many paths of light in a single area that indicates the presence of dark matter. In addition, for the cosmic expansion method to be effective, finding as many supernovae as possible is a priority. Supernovae, however, are few and far between. "We estimate supernovae at the rate of one per galaxy per century," said Troxel.

> "The data that Roman will take in its survey mission would take **Hubble** or the **James Webb Space Telescope** 1000 years to gather." **- MICHAEL TROXEL**

Thankfully, Roman's imaging cameras can capture a field of view 100 times larger than those of the Hubble, allowing the efficient mapping of dark matter.

Troxel and Scolnic have been working with NASA on their respective research for years. Even before coming to Duke, both worked as a part of the Roman's Science Investigation Team (SIT), which performed initial research to determine the space telescope's design and instruments on board. When the SIT contract ended after the telescope entered "Phase C" (NASA jargon for telescope construction), both professors were chosen to implement their respective research in the Project Infrastructure Teams, which is building the infrastructure to make the gathered data usable, supported by $12.5 million in grants over five years.

The telescope is set to launch in 2027, and rest assured the Duke and space communities will be watching with anticipation to see what Troxel, Scolnic, and the whole Roman team can achieve. "Their pioneering research and interdisciplinary, trail-blazing spirit will reshape our understanding of the universe in the decades to come," said Vo-Dinh. ■

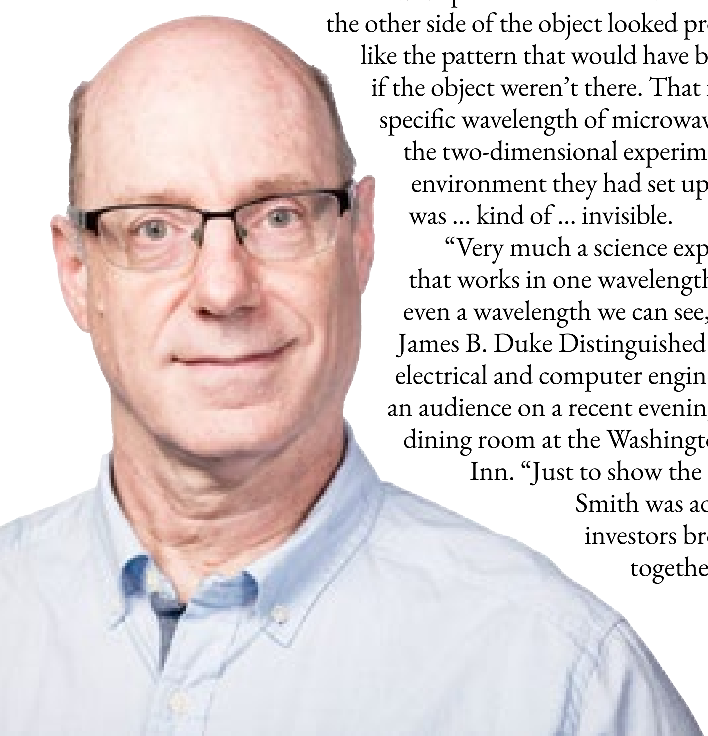
Assembly pieces of the Nancy Grace Roman Space Telescope, which is designed to help researchers explore dark energy, dark matter, and other celestial phenomena.

Aaron Diebold Ph.D. '20, Divya Pande Ph.D. '23, and Michael Boyarsky Ph.D. '19 explore one of the potential uses of metamaterials—faster and more accurate security scanners.

Weird Science

David Smith's investigations into metamaterials has led to a dozen startups and counting

BY SCOTT HULER FOR DUKE MAGAZINE



Invisibility casts a long shadow.

In 2006, physicist David Smith and colleagues at Duke and elsewhere published a paper about an experiment they had conducted. They used metamaterials to direct microwaves around an object so that the wave pattern that reached a receptor on the other side of the object looked pretty much like the pattern that would have been received if the object weren't there. That is, to that specific wavelength of microwaves and in the two-dimensional experimental lab environment they had set up, the object was … kind of … invisible.

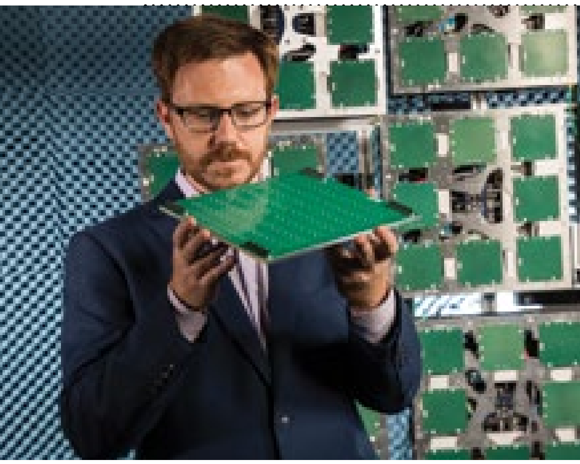
"Very much a science experiment that works in one wavelength," and not even a wavelength we can see, Smith, the James B. Duke Distinguished Professor of electrical and computer engineering, told an audience on a recent evening in a private dining room at the Washington Duke Inn. "Just to show the science of it."

Smith was addressing investors brought together by Duke Capital Partners (DCP), an organization created by Duke to provide Duke student and faculty entrepreneurs with the resources they need – and to find them investors, largely from the Duke alumni community.

From that initial basic science demonstration, Smith started toward a different mission. "I really said, 'OK, I'm going to turn my attention now to try to make this useful.' I really wanted to see this go somewhere."

Smith's lab has spun out more than a half-dozen companies since 2012, most highly capitalized, producing antennas and sensors that use metamaterials to do things that physically ought not to be possible. Another half-dozen companies are in the works. Smith's lab has become a center point of metamaterials research—Duke is probably ground zero for metamaterials worldwide. "I don't think there's really any place that has as much work associated with metamaterials as Duke," he said later. "Certainly on the commercialization side. This is a singularity in that space."

A look at what some of those companies and other metamaterial labs at Duke are doing gives a sense of the



"I don't think there's really any place that has as much work associated with **metamaterials** as Duke. Certainly on the commercialization side. This is a singularity in that space." **- DAVID SMITH**

Michael Boyarsky analyzes a metasurface antenna designed for satellite imaging of Earth.

rapid advance of this new science. Take, for example, Steve Cummer, professor of electrical and computer engineering, who worked on that invisibility experiment with Smith.

It's along the lower parts of the electromagnetic spectrum where the freaky stuff happens, and it's not just invisibility. Willie Padilla, professor of electrical and computer engineering, works with metasurfaces, which he called "simply the 2D equivalent of metamaterials." Working as a postdoc, he recalled, "we found that a planar surface was enough to achieve a lot of these novel effects and potential applications" of metamaterials. They are another implementation of metamaterials and they enable scientists to change the direction of microwave beams rapidly and fluidly, using small and inexpensive flat metasurfaces instead of enormous and costly antenna dishes. This is of enormous interest throughout the communications world.

Then there is the lab of Natalia Litchinitser, who is using metamaterial design to multiply the capacities of microscopes through hyperlenses, using what she calls hyperbolic metamaterials. She's also working on using extremely thin metamaterial films to manipulate beams of light into the kind a doughnut-shaped beam, which "you just twisted into a knot, what people call an optical knot," which may be a good thing for using light to transmit information through water "because people claim that may be more stable in turbulence."

Once you're tying light into knots, you may be forgiven if you have neared the limit of your understanding. The research grows more fascinating by the year; but the people who came out to the Washington Duke were there to hear how metamaterials were turning from amazing ideas into amazing things—and creating companies that could get those things out into the world. Metamaterials, Smith said, has "turned into an engineering platform." It's a tool kit for manipulating waves and making them do your bidding. Padilla said, "It's really like designer electromagnetic materials."

That sounds like work, and the companies that have rolled out of Smith's lab have done that, concentrating on applications within the metasurface area Litchinitser and Padilla described, focusing largely on communications and sensors. More than a decade ago, Smith's work started getting the attention of investors such as Bill Gates and the Invention Science Fund of investment incubator Intellectual Ventures, founded by Microsoft technology veteran Nathan Myhrvold.

Nathan Kundtz M.S.E.'08, Ph.D.'09 had worked in Smith's lab, and Intellectual Ventures invited him out to Bellevue, Washington, to work on identifying directions to pursue. Kundtz had been using metamaterials that manipulate light waves, and "I postulated that we could use that to do electronic beamforming, which is kind of the holy grail of antenna design." He worked on that with them and ultimately spun out a company called Kymeta Corp., which creates low-power satellite antennas that use metamaterials to enable them to instantly adjust their beams, connecting moving vehicles to moving satellites in real time. Kymeta has raised $525 million in capital and is an industry leader.

That was 2012. Since then five more companies have spun out of Smith's lab, and another five are in development. Duke has created Duke Capital Partners to provide guidance to Duke entrepreneurs and connect them to sources of capital in the alumni community. Smith himself co-founded Metacept, a metamaterials accelerator, in 2018, and it spun out its first startup in 2019.

Those applications are where the fun is for Smith right now, and he and the other scientists are thrilled that their work is finding actual use.

"You'd like to believe that the work you're working on has impact," Smith said. "And certainly the people we're training here have been pivotal in those companies. But also, when these companies are created, they have hundreds of employees. And these employees now are practicing a technology they may not even realize came from Duke. But they are now all aware of this engineering. And just the fact that they are doing metamaterials is amazing to me." ■

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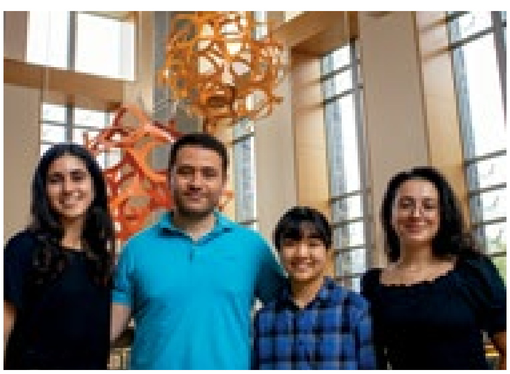


Duke Optical Student Chapter Officers

Sarah Mekha (Events Coordinator), Deniz Acil (President), Yuruo Zheng (Treasurer), Marcia Cunha dos Santos (Outreach Coordinator). Not pictured are: Morgan McCloud (Vice President) and Trey Highland (Secretary)

The Duke Optical Student Chapter (DOSC) are an instrumental part of the Fitzpatrick Institute for Photonics. They act as the student chapters of Optica and SPIE promoting optics and science education in our local community.

Color Vision Initiative at Duke

The Fitzpatrick Institute for Photonics (FIP) of the Pratt School of Engineering is launching a color vision initiative to improve color accessibility for all Duke students, staff, and faculty.
To make this vision a reality, FIP is partnering with
**Duke Office of Information and Technology's "The Link"*
**Duke Accessibility and Accomodating Services*
**EnChroma*

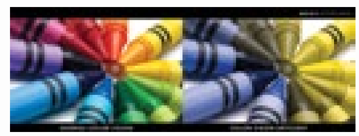
Duke FITZPATRICK INSTITUTE *for* PHOTONICS

Color Blind?

Not sure? You can ***take a quick test*** to see if you are color blind:
Scan QR code or
goto: enchroma.com/pages/test

Ask to ***Borrow EnChroma Glasses*** for Color Blindness at The Link in Perkins Library.

Definition of Color Blindness
What is color blindness? Color blindness is a reduced ability to distinguish between colors when compared to the standard for normal human color vision. When a person is color blind, also called color vision deficiency (CVD), they usually have difficulty distinguishing between certain colors such as yellow and orange, green and brown, pink and gray, or blue and purple. These confusions are typical of what is called "red-green color blindness," which includes protan-type CVD (protanomaly and protanopia) and deutan-type CVD (deuteranomaly and deuteranopia).
https://enchroma.com/pages/what-is-color-blindness



Data from National Eye Institute, NIH:
https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/color-blindness

What do colors look like to individuals with color deficiencies?
We have taken a few images around campus and the images below can be similar to what an individual may see with red-green color blindness. In many cases, Green looks more gray or tan and red looks more brown.

For additional questions about Color Blindness, please feel free to reach out to:
Duke Accessibility & Accomodating Services
DAAS@duke.edu or 919-668-1267
or
Fitzpatrick Institute for Photonics
august.burns@duke.edu

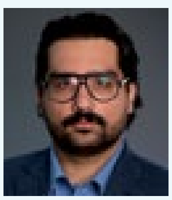
FIP FELLOWS & SCHOLARS


THE FELLOWS PROGRAM, used as recruiting tool for the top candidates, provides incoming graduate students a one year fellowship program, which awards $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.

2024-25 Chambers Fellows *(left to right)*

Peter Lu, BME Phd Student in Professor Adam Wax's Lab
Chunming He, BME PhD Student in Professor Sina Farsiu's Lab





THE SCHOLARS PROGRAM provides existing Duke graduate students within the FIP full funding 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.

2023-2025 Chambers Scholars *(clockwise)*

Amit Narawane (Chambers Scholar), BME PhD Student (*formerly in Professor Izatt's Lab*) in Professor Hafeez Dhalla's Lab
Clare Cook (Chambers Scholar), BME PhD Student in Professor Roarke Horstmeyer's Lab
Hooman Barati Sedeh (Chambers Scholar), ECE PhD Student in Professor Natalia Litchinitser's Lab


2024-26 Chambers Scholars *(left to right)*

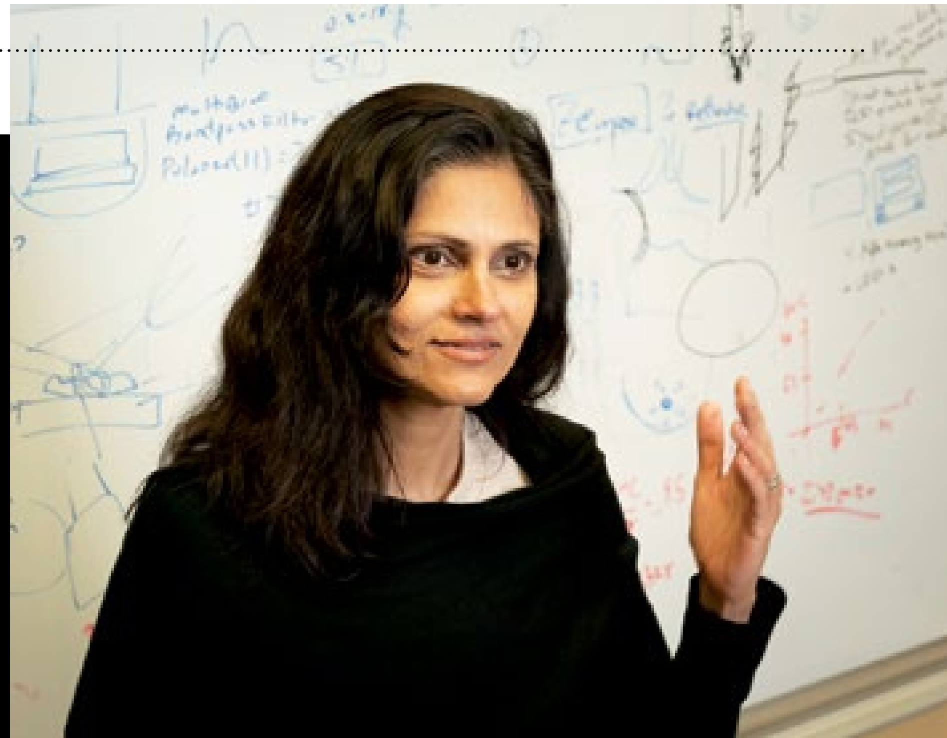
Max McWhorter, Chemistry PhD Student in Professor David Mitzi's Lab
Harvey Shi, BME PhD Student (*formerly in Professor Izatt's Lab*) in Professor Roarke Horstmeyer's Lab

2023-2025 Fitzpatrick Foundation Scholar

Kerry Eller, BME PhD Student in Professor Nimmi Ramanujam's Lab

Kerry Eller is a 4th year biomedical engineering PhD candidate in the Center for Global Women's Health Technologies at Duke University. She also plans to complete an MS in bioethics and science policy. During her undergraduate education at Northeastern University, Kerry completed a B.S. in bioengineering with a minor in political science to develop her expertise in both engineering and policy. Throughout her time at Northeastern, Kerry conducted health research on meniscal tears, assays for visual impairment models in zebrafish, and the musculoskeletal effects of obesity. In Santiago, Chile, she also worked to track vector-borne illness and monitor pesticide exposure in agricultural workers. For her doctoral research under the mentorship of Dr. Nimmi Ramanujam, Kerry is designing tools that will make cervical cancer screening more accessible, comfortable, and empowering for all people who have a cervix. Towards this goal, she is developing a speculum-free colposcope for self-use and a sensor that will measure the biomarkers of HPV in cervical mucus.

CENTENNIAL TRAILBLAZER
IN PHOTONICS AND WOMEN'S GLOBAL HEALTH



Musician, entrepreneur, educator – Nimmi Ramanujam has done it all.

Ramanujam, the Robert W. Carr Professor of Engineering and professor of cancer pharmacology and global health, grew up in Malaysia, where she said in a 2020 interview that her gender limited her prospects.

"I grew up with this whole idea that I didn't have anything meaningful to say," she recalls. "People told me I wasn't very good at academics. At one point she considered a music career. She played the veena, a South Indian instrument resembling the sitar, and often performed on the radio with her mother, a talented musician.

However, her mother insisted she pursue an education. So, at 16, she was sent to the U.S. to study engineering at the University of Texas at Austin.

While there, she was diagnosed with carcinoma in situ in her cervix, a breast lump, and an ovarian cyst, all in quick succession. That was when her studies became personal, and she decided a healthcare career could have greater meaning in her life and the lives of others.

She went on to spend five years as a postdoctoral fellow and then assistant professor at the University of Pennsylvania, five more as an assistant professor at the University of Wisconsin, Madison before landing at Duke in 2005.

In 2013, Ramanujam founded the Center for Global Women's Health Technologies to make cancer prevention and treatment more accessible for women worldwide.

She and her research team created the Pocket Colposcope, and a sister device the Callascope, lightweight, handheld devices which bring improved cervical cancer screening to settings where these capabilities have not been available. Today, more then 100 devices have been deployed in 11 countries impacting more than 8,000 women.

In 2023, she won the Institute of Electrical and Electronics Engineers Biomedical Engineering Technical Field Award. ■

"Access to health care in clinical deserts is a global problem BUT it also presents an opportunity. We as engineers are poised to transform the way health care is delivered – moving care from hospitals and physicians to communities and health care workers. I am proud to be a part of the movement, and I am excited for the next generation to create solutions yet unimagined."

Nimmi Ramanujam, Robert W. Carr, Jr., Distinguished Professor of Biomedical Engineering And Director of Center for Global Women's Health Technologies

dukegwht.org

Remembering OCT Pioneer

BY REBECCA FAN, ORIGINALLY PUBLISHED IN THE DUKE CHRONICLE

Joseph Izatt, chair of the department of biomedical engineering and Michael J. Fitzpatrick professor of engineering, is remembered as an exceptional pioneer in biomedical optical coherence tomography and an inspiring mentor.

Izatt, 61, died on April 7 after suffering a medical emergency while flying a private airplane. The only other passenger on board with Izatt made an emergency landing at the Raleigh-Durham International Airport. The landing had no impact on airport operations.

Izatt was a "lovely, honorable and humble man," according to Sina Farsiu, Anderson-Rupp professor of biomedical engineering. Farsiu was co-advised by Izatt during his time as a postdoctoral researcher and had been a close colleague and friend of Izatt's for 17 years.

Izatt first joined the BME department at Duke in 2001. Throughout his 23-year tenure, Izatt received the 2008 Capers and Marion McDonald Award for Excellence and Advising from the Pratt School of Engineering and the 2017 Dean's Award for Excellence in Mentoring from the Duke Graduate School.

As a skilled researcher and inventor, Izatt pioneered the development of optical coherence tomography, which helps inform diagnosis and treatment decisions for retinal diseases and conditions.

Izatt was always extremely motivated, curious and passionate about the field, according to Farsiu.

"If [he] found a scientific problem he had to solve, or he liked to solve, even if he was originally not at all qualified or educated to do that, he would pursue it over and over and put the time and effort to become the best in that field," said Farsiu.

Izatt displayed an impressive work ethic and consistent motivation throughout his career. Even during the COVID-19 pandemic, he was known for always being in his office.

"He told me he hated sitting at home. The moment he could come in, he [would come] for eight hours a day because he liked being in his office," said Ashutosh Chilkoti, Alan L. Kaganov professor of biomedical engineering and acting chair of the department.

Beyond his academic contributions at Duke, Farsiu added that Izatt was known for his humility "despite being one of the most brilliant minds that has ever graced this earth."

"I never saw him once show irritation [with] anybody. I don't think you'd find anybody to say anything negative about him," Chilkoti said. "Everybody respected him. When he spoke, people listened because he was just so thoughtful."

"He embodied all that is best not just [about] Duke, but universities." - CHILKOTI

Izatt's impact spans well beyond Duke.

Through his research, Izatt held more than 75 US patents and was elected to the National Academy of Inventors in 2017. With Cynthia Toth, Joseph A.C. Wadsworth distinguished professor of ophthalmology, he co-founded Bioptigen in 2006 — a medical device company that specializes in high-resolution imaging devices for non-invasive diagnosis of eye diseases and other medical applications.

Today, the OCT imaging systems produced by Bioptigen are used in a wide range of clinical ophthalmology and preclinical research applications in the biomedical field.

Izatt earned a bachelor's degree in physics, a master's and a doctorate from the Massachusetts Institute of Technology, finishing his studies in 1991. In the three decades since, he has educated generations of professors and scientists at different universities, people who "are leading the boundaries of science in the fields of imaging and photonics," according to Farsiu.

Chilkoti said. "he was a scholar, he was a mentor. He was a wonderful human being. And I hope that's how he will be remembered. As a person, as a scholar, as a teacher, as a mentor, as a researcher — he excelled in all of those things." ■

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