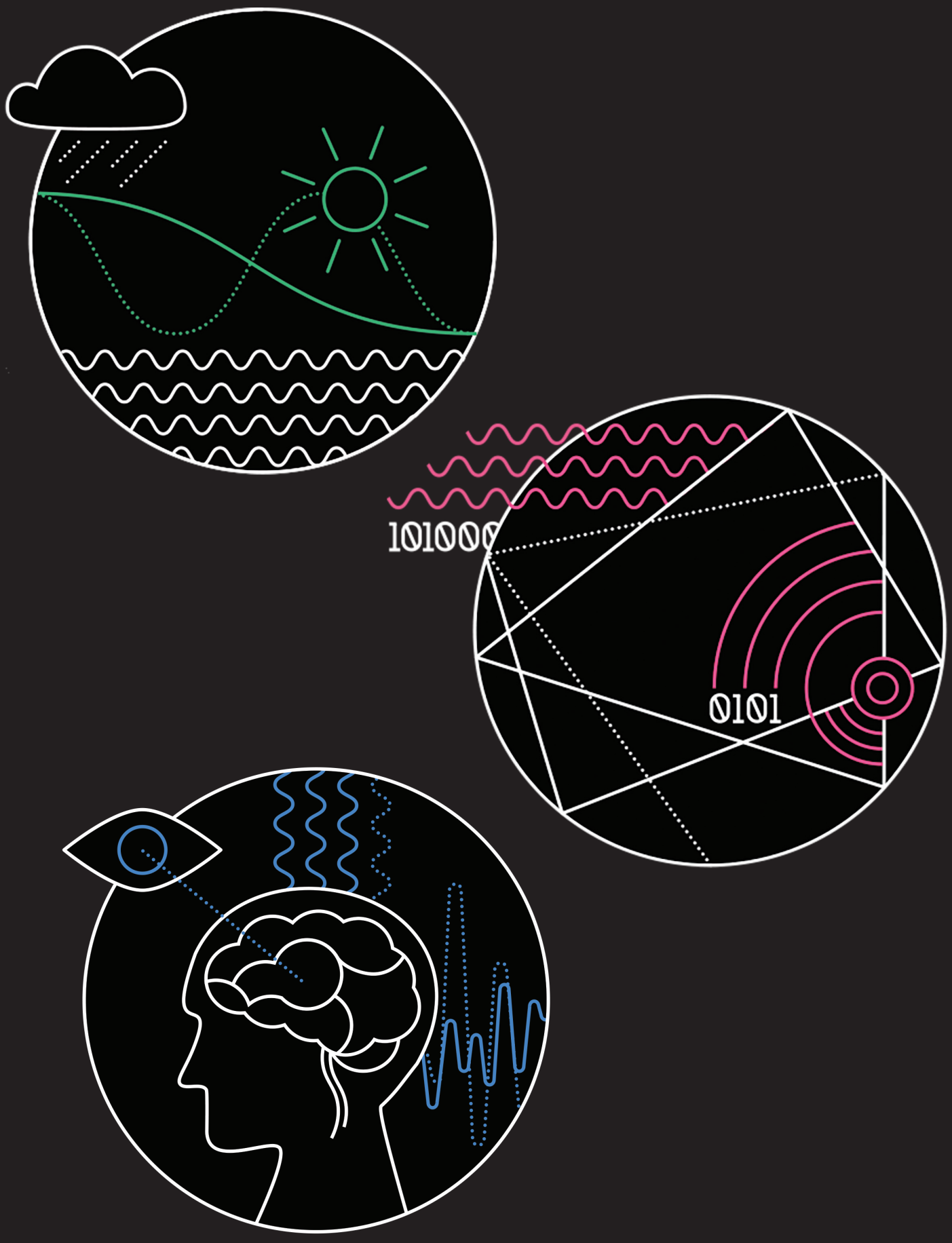
Karen Kwon

Use Photonics. Find a Solution. Change the World.

The Optica Foundation Challenge enables early-career optics researchers to pursue high-impact ideas.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Courtesy of X. Ji

> “I always hope what I’m doing will actually make a contribution to the real world or solve real-world problems.”
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> —*Xingchen Ji, Shanghai Jiao Tong University, China*

One day in mid-2022, Xingchen Ji was scrolling through his email inbox when, out of the tens of messages that he receives daily, one jumped out at him with an eye-catching subject line: “Use photonics. Find a solution. Change the world.” He immediately clicked on it and saw that the Optica Foundation was launching the Optica Foundation Challenge to commemorate its 20th anniversary.

The foundation sought proposals aimed at tackling global issues in three areas—environment, health and information—via solutions driven by optics and photonics. Ten proposals from early-career Optica members would be selected, the announcement said, with the winners each collecting US$100,000 in seed money to explore their ideas.

Though he was interested in submitting a proposal, “I did hesitate a bit,” says Ji, who is an associate professor at Shanghai Jiao Tong University, China. With only 10 winners, the competition would be fierce. But he decided to follow his mantra, “Don’t be afraid to fail, but be afraid not to try,” and give it a shot. “I always hope what I’m doing will actually make a contribution to the real world or solve real-world problems,” he adds. “So that’s why I decided to try.”

Origins of the foundation

The Optica Foundation was established in 2002, under the name OSA Foundation, to support the education, training and recognition programs of OSA (now Optica).

Funding and support for the foundation have always come directly from the community. Don and Carol Scifres, Joseph and Hon Mai Goodman, The Sawchuk Family Foundation, The Welch Family Fund and Gary and Carolyn Bjorklund provided a base of over US$1 million for its launch. Thanks to the ongoing generosity of Optica’s individual and corporate members, this seed fund has grown to roughly US$30 million in assets leveraged to support students and early-career professionals annually—still the foundation’s primary focus.

As its available funding has grown, so have its impact and global reach. The list of programs has evolved from a handful of education grants and paper prizes to a robust portfolio of scholarships, training programs and schools, and prizes and honors. As of 2022, foundation programs and resources had impacted 140,000 beneficiaries around the world. Plans are underway to expand the program offerings in response to the industry’s keen desire to ensure that the photonics profession attracts the next generation of bright minds.

The Optica Foundation Challenge is latest addition to that roster. Celebrating two decades of the foundation’s existence, the challenge was first announced at the plenary stage of the Conference on Lasers and Electro-Optics (CLEO) in May 2022 by Eric Mazur, chair of the foundation. In October 2022, after considering nearly 100 applications from across the globe, the selection committee announced the winners—which included Ji.

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Miniaturizing OCT

Ji's proposal, "Developing low-cost, portable, integrated OCT [optical coherence tomography] systems using low-loss silicon nitride platform," was one of the three proposals selected as winners in the health category. The other health winners include a project to build a compact, single-shot microscope using flat optics, and an exploration of using holography for high-resolution, noninvasive tissue imaging (see sidebar, right).

Ji decided to focus on OCT because he saw a number of barriers hindering its wider application. For example, a typical OCT system for clinics costs around US$100,000, and its optical parts can easily misalign, he says, requiring a technician to fix. In addition, if a person's condition calls for ongoing monitoring using an OCT system—people with diabetes, for instance, have to get their retinas checked for the signs of diabetic retinopathy, such as macular edema—the person must regularly carve out time to visit their doctor's office. Ultimately, Ji's end goal is to eliminate these inconveniences with a low-cost, portable, integrated OCT system.

Ji plans to achieve this goal by using low-loss Si_3N_4. Compared with silicon, which does not transmit light with a wavelength below 1.1 μm, Si_3N_4 has a broad transparency window, ranging from the visible to the mid-IR. This means that an OCT system using Si_3N_4 can accommodate ophthalmological uses at around 800 nm and 1050 nm as well as dental uses at around 1700 nm. He is also developing the system as a whole, instead of focusing on a single part, by integrating the light source, interferometer and spectrometer all on the same carrier.

The first step in developing a prototype is to optimize the Si_3N_4 fabrication process for the wavelength of 1050 nm, says Ji, as his initial focus is for the device to serve ophthalmological uses. This step will involve trying out different film-deposition methods and optimizing absorption peaks.

At the same time, Ji will explore multiple avenues to miniaturize the three key parts of the OCT system—light source, interferometer and spectrometer—to speed up the prototyping. For example, Ji will look at two approaches for developing and integrating

More health winners

Guangwei Hu
Nanyang Technological University, Singapore

Proposal title: Single-shot, Isotropic and Miniaturized Differential Interference Contrast (SIM-DIC) Microscopy based on computational flat-optics

Hu aims to detect micrometer-sized bio-samples, air pollutants and microplastics that are transparent in the visible spectrum. These subjects can be detected using differential interference contrast (DIC) microscopy, which enhances the contrast of transparent samples, but such systems tend to be bulky and obtain information in 1D. To tackle the issue, Hu plans to develop single-shot, isotropic and miniaturized DIC microscopy using a single-layer metasurface—a flat optical component—made of millions of subwavelength silicon nanostructures. The metasurface helps significantly reduce the overall size of the device by carrying out multiple functions, such as polarization multiplexing and 2D isotropic edge detection.

Florian Willomitzer
University of Arizona, USA

Proposal title: Noninvasive high-resolution imaging through living tissue with single-shot synthetic wavelength holography

Willomitzer's proposal seeks to improve synthetic wavelength holography, an imaging technique that provides a way to "see" through scattering media. The technique typically requires taking multiple images in sequence for an algorithm to subsequently reconstruct a single image of the object that is hidden behind the scattering medium. This poses a problem for medical applications because living tissue is constantly in motion. For the challenge, Willomitzer proposes developing single-shot synthetic wavelength holography, which, he writes, "could have immense impact on future academic research as well as today's billion-dollar industries," such as the areas of autonomous vehicles and virtual reality.

More environment winners

Dismas Choge
University of Eldoret, Kenya

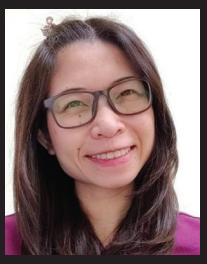
Proposal title: Development of tunable multi-color laser for sensing: case study for hyperspectral detection of water contaminants

Existing techniques for detecting water contaminants, such as atomic emission spectroscopy and mass spectroscopy, require expensive instruments and preparation to obtain results. Choge plans to develop an optical system that will provide faster results while keeping the sample intact.

Ashim Dhakal
Phutung Research Institute, Nepal

Proposal title: Piloting an affordable and real-time Water Assessment System (WAS) for detection of fecal coliforms in drinking water

Dhakal proposes a way to detect fecal contamination in water based on the native fluorescence of tryptophan-based proteins. The proposed system does not require reagents and employs a flat Fresnel lens. According to Dhakal, it will be able to analyze samples in real time and offer a user-friendly reading for a fraction of the cost of current techniques.



Wanvisa Talataisong
Suranaree University of Technology, Thailand

Proposal title: An innovative optical fiber device for micro-pollutants and greenhouse gas monitoring

Talataisong plans to make an optical-fiber device for monitoring micro-pollutants and greenhouse gas. She proposes three options for achieving her goal: A fiberized plasma resonance sensor for compact sensing; a hollow-core fiber fabricated with a unique technique that would present an inexpensive alternative; and a fiber Bragg grating for nanoparticle detection.

the light: using frequency combs based on gain chips and Si_3N_4, which has higher risk but potentially better scalability; and co-packaging a superluminescent diode and Si_3N_4 photonic chip, which is a more conventional approach with lower risk.

Ji believes that within three months he will be able to demonstrate a working low-loss platform. Around the six-month mark, a few parts should be ready, allowing him to acquire OCT images. By the end of the year, he should have all the pieces together and should be able to demonstrate a working prototype.

Overall, Ji predicts, the resulting system would be several orders of magnitude smaller and lighter than current ones—at about a hundredth of the cost. He imagines a future in which an OCT system would work like Google Glass: wear it on your face, take images and upload them to the cloud. Then you could send the OCT images to your doctor, allowing daily monitoring of your health.

Ji argues that advances in the OCT system parts, such as the spectrometer and interferometer, will benefit not only the OCT technology itself but also other, completely different fields. For example, improving and miniaturizing a light source could have an impact on augmented- and virtual-reality research. Or developing a robust, low-cost, high-performance spectrometer could help chemists who perform spectroscopy. "I'm hoping the integrated photonics can serve a lot of communities, helping them benefit from this excellent platform," Ji adds.

From heat to electricity

Michela Florinda Picardi, a postdoc at the Institute of Photonic Sciences (ICFO), Spain, knows that, to some, her work might seem a little "out there"—too niche, too different from the current way of thinking. So when she heard about the Optica Foundation Challenge, which called for breakthrough plans to transform the world, "I thought it was the perfect place to try and share my idea," she says.

Her proposal, "THUNDER: THermal UNpolarized radiation Design for Energy Recycling," was one of four selected in the environment category. The other three included an optical system to quickly detect water contaminants; a method to

ICFO

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>
> —*Michela Florinda Picardi, Institute of Photonic Sciences (ICFO), Spain*

sense fecal contamination using native fluorescence of tryptophan-based proteins; and an optical-fiber device for monitoring micro-pollutants and greenhouse gases (see sidebar, p. 38).

Picardi's idea started with a simple fact of life: every process, industrial or natural, generates heat as a byproduct. According to Picardi, 67% of all energy that we produce is lost as waste heat. She proposes converting the waste heat into light, which can then be turned into more useful electricity or mechanical energy.

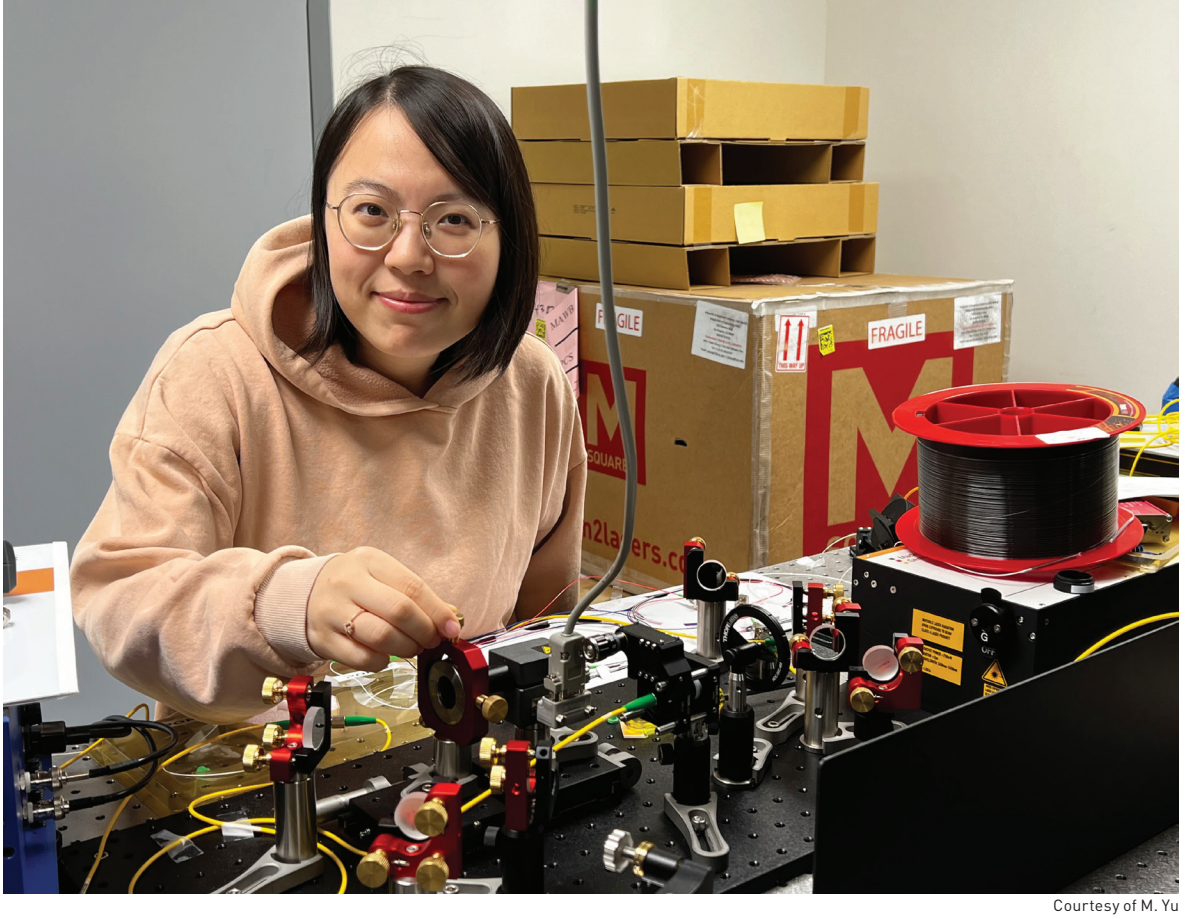
"So, we can get to a place where we generate energy for free, using that waste heat," Picardi says. "Every process could become a source of energy. It could be groundbreaking."

Picardi's previous work was in theoretical nanophotonics, primarily focused on applications in communications, but environmental concerns drove her to pivot to energy production. Since then, she has been asking herself questions such as, how do we produce energy more efficiently? How do we use all the excess heat generated in the process? How do we stop ourselves from overheating the planet?

Picardi plans to harvest waste heat using thermal emitters, which will convert heat into radiation with specific wavelengths useful to photovoltaic cells. More specifically, she aims to devise directional emitters that rely on spin-momentum locking or on a large reactive power, based on her previous work with coherent nanophotonic designs. She also plans to explore light's other degrees of freedom such as Poynting vector, chirality and angular momentum. She hopes that this method will also have applications in radiative cooling.

The first step, says Picardi, is to develop a theoretical framework. "It's something that, we know how it should look, but we don't have the formalism to describe yet," she adds. She plans to enlist help from her advisor and other theorists in the field to come up with a formalism because "it does require developing some parts of physics that haven't been unequivocally defined yet." She imagines this first step will take about six months.

Once the formalism is completed, it will open the door to testing the science by writing code and designing simulations. Though her primary goal is



Courtesy of M. Yu

> “We all believe optics and photonics can transform our world, can offer next-generation discoveries and breakthroughs in all aspects in our life.”
>
> —*Mengjie Yu, University of Southern California, USA*

to apply the theoretical framework to energy production and radiative cooling, she adds that, once developed, the theory can be applied anywhere. “It’s gonna get extremely fun,” Picardi says.

Improving free-space communications

Mengjie Yu considers Optica her second home. The first conference she attended as a Ph.D. student was CLEO, which Optica co-sponsors with the American Physical Society and IEEE Photonics Society, and she also won her first student paper competition award there.

These experiences led her to serve as an Optica ambassador beginning in 2020 and to head Optica’s integrated-photonics technical group from 2019 to 2021—the first leadership role she held outside her school. So when she became an engineering professor at the University of Southern California, USA, in January 2022, she thought that it would be cool if her first grant as a principal investigator came from the Optica Foundation.

It was fitting, therefore, that she was selected as one of the anniversary challenge winners in the information category, with her proposal titled, “Integrated high-speed mid-infrared electro-optic modulator for free space optical communication.” Other winners in the category included a design for a photonic neural network and IR wave-shaping technology using pixel-based nanoscale antennas (see sidebar, p. 41).

Free-space optical communications have been a major focus of industry research and development, with Global Market Insights predicting the field’s rise to a US$2 billion market by 2027. And the mid-IR wavelength range between 3 and 5 μm is an ideal optical carrier for free-space communications because it has a higher tolerance to scattering than the near-IR, as well as low atmospheric absorption.

According to Yu, there's a huge technology gap in device development between conventional telecommunications wavelengths and the mid-IR. Currently, the only practical solution that can yield a meaningful data transmission rate in the mid-IR region is the direct current modulation of a quantum cascade laser, says Yu. But such a laser requires cryogenic temperatures to get to 20-GHz modulation speed, as room-temperature operation can support only up to a few GHz. And the heart of the problem, Yu argues, is the lack of a low-loss, high-speed electro-optic modulator for the mid-IR region.

To fill that void, Yu plans to design and create a low-loss integrated electro-optic modulator on thin-film lithium niobate. First, she will develop a practical route to achieving a photonic platform that can support low-loss transmission with high-speed data rates in the mid-IR. Yu hopes that the first prototype will be ready to be characterized in the lab in six months.

Yu says she appreciates everything that Optica and the foundation have offered her so far—training her to become a leader, providing inspiration and motivation to continue with her career and connecting her with her peers. "I think [Optica's] influence on me is huge."

"We all believe optics and photonics can transform our world, can offer next-generation discoveries and breakthroughs in all aspects in our life, including health, information and environment," Yu adds. "I firmly believe that statement."

Future plans

Moving forward, the winners will be checking in with the challenge's selection committee, which also serves as an advisory committee, at the 6-month, 1-year and 18-month marks to report their progress and receive guidance. According to the Optica Foundation, the next in-person check-in date is 26 June, during CLEO/Europe-EQEC. The foundation also plans to run a second challenge round this year—the application opens on 16 May 2023, the International Day of Light.

An overarching goal of the challenge is to highlight exceptional young minds, providing them resources and mentorship as they explore ideas that will one day change the world. "Pooling the inspirational ideas from a group like this could lead to exceptional impact," says Alan Willner, chair of the selection committee and 2016 president of OSA (now Optica). OPN

Karen Kwon is OPN's associate editor.

More information winners

Chaoran Huang
Chinese University of Hong Kong, China

Proposal title: Integrated photonic neuromorphic processor enabled intelligent, energy-efficient signal processing for the next-generation communication systems

In the next 10 years, optical communication systems will require 10 times the current capacity to match the rising need. This increased capacity will demand a processor that can provide high processing speed while consuming only a small amount of power. Huang argues that we need new technology to solve this problem. Her solution? A photonic neural network, which is a hardware realization of a deep-learning model. Her design will exploit the strength of the intrinsic properties of photonics, deep-learning architectures and integrated-photonics technologies, enabling faster and more power-efficient processing of optical communication signals.

Mark Lawrence
Washington University in St. Louis, USA

Proposal title: Fast, low-power, and high-resolution meta-reflect-arrays for massive space-division-multiplexing

To improve free-space optical communications, Lawrence proposes to build IR wave-shaping technology that is extremely energy efficient, capable of updating on microsecond timescales and equipped with spatial resolution approaching the diffraction limit. His research focuses on designing, fabricating and testing nanoscale antenna-based pixels made of silicon and sensitive to small changes in their local environment. Within six months, Lawrence projects he and his team will be able to demonstrate a device with hundreds of pixels that can be switched independently with high speed and high efficiency.