A LOOK AHEAD

Optics in 2022 & Beyond

Each December, OPN looks at interesting research results of the past year. But what about the year ahead? We asked several contributors to our "Optics in 2021" feature for thoughts on areas that might advance in 2022.

ADAPTIVE MULTIMODE LASERS

"Highly multimode lasers are complex nonlinear dynamic systems that can display diverse behaviors. In 2022 and beyond, we will see active, precise control of such lasers to generate arbitrary light fields in space, time, spectrum and polarization. The adaptive, on-demand lasers will enable novel techniques for microscopy, spectroscopy, holography, as well as communication, computing and sensing applications.

Hui Cao, *Yale University, New Haven, CT, USA*

TOPOLOGICAL PHOTONICS

"In 2022 and beyond, a big advance in topological photonics will be the ability to fine-tune the spatial profiles of topological defects and domain walls to create robust modes with tailored volume, group velocity and polarization. We will see the first topological lasers and slow-light photonic-crystal waveguides outperforming their conventional counterparts. It will be exciting to see the integration of topological components into high-performance quantum photonic circuits.

Daniel Leykam, *Centre for Quantum Technologies, NUS, Singapore*

SECURE FREE-SPACE OPTICS

"Free-space optics, involving the communication between two devices using light to carry information, is a promising technology for achieving high-speed communication. Mid-infrared photonic chaos provided by quantum cascade lasers offers unique conditions for more privacy. In the near future, we can envision long-range secure transmission, with strong immunity to atmospheric conditions. Moreover, mid-infrared wavelengths imply stealth, as the background radiation is in the same optical domain, thus strengthening privacy.

—**Frédéric Grillot**, *Télécom Paris, Institut Polytechnique de Paris , France*

METAFORM OPTICS

"Freeform and flat/meta-optics, with close to 10 years of pushing the TRL through concurrent engineering from design to manufacturing, are poised within the next 10 years to permeate consumer (e.g., augmented-reality glasses) and compact precision technologies (e.g., SmallSats for Earth imaging). Their combination—the Metaform—will create solutions where no one has gone before, leveraging existing and new photonic materials, deep-learning design methods, aberration theory, and process chains for complex, scalable manufacturing.

Jannick Rolland, *University of Rochester, NY, USA*

TERAHERTZ OPTOELECTRONICS

"2022 and years beyond will witness realization of scalable, chip-scale terahertz system platforms with new functionalities by leveraging advances in nanotechnology and integrated photonic devices, expanding the scope and potential uses of terahertz waves from laboratory environments to real-world application settings. On the application side, artificial intelligence and quantum technologies will transform the functionalities of terahertz imaging, spectroscopy and communication systems.

Mona Jarrahi, *University of California Los Angeles, CA, USA*

HYPERSPECTRAL DUAL-COMB IMAGING

"We have just witnessed the very first demonstrations of direct hyperspectral dual-comb imaging. In the next years we will start to see how this technique can be employed to surpass many of the limitations faced by current hyperspectral technology, thus opening new application opportunities. Even though several technological challenges are still to be addressed, fields [such as] chemical mapping, optical metrology, nondestructive testing and inspections could be greatly benefited by the advent of this new method.

Farid Ullah Khan, *Universidad Carlos III de Madrid (UC3M), Spain*

Photos: Courtesy of the researchers
Infographic: John Zavada and Alessia Kirkland