Optics in 2021 & 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 2020" feature for thoughts on areas that might advance in 2021.

QUANTUM TECHNOLOGIES

"By leveraging advances in integrated nanophotonics, in the next year we will start to see realization of scalable, manufacturable and portable fully integrated CMOS-compatible platforms for quantum technologies based on atomic systems such as cold atoms and ions, and finally bring them out of a complex free-space optics lab environment."

—Amit Agrawal, *NIST, Gaithersburg, MD, USA*

PHOTONIC CIRCUITS

"In 2021 and beyond, we will see more photonic devices and circuits enabled by inverse design, by continuing to merge modern optimization and artificial-intelligence techniques with high-speed electromagnetic solvers. On the experimental side, the biggest breakthroughs will be in scaling of classical and quantum photonic circuits to much larger numbers of components, enabled by new design approaches, as well as innovative fabrication and hybrid integration of new and old photonic materials."

—Jelena Vučković, *E.L. Ginzton Laboratory, Stanford University, CA, USA*

BIOINTEGRATED PHOTONICS

"Coherent light sources integrated into single cells and live animals have the potential to outperform conventional imaging and sensing techniques. The focus in the coming years lies in the development of biocompatible nanolasers with subcellular dimensions and the implementation of advanced spectroscopic techniques like plasmonic or exceptional-point sensing to increase sensitivity. These steps will strongly widen the scope of biolasers, allowing them to detect minuscule signals deep inside scattering tissue and to track individual cells within whole animals."

—Marcel Schubert, *Centre for NanoBioPhotonics, University of Cologne, Cologne, Germany*

TELECOMMUNICATIONS

"2021 will likely witness the advent of low-loss hollow-core optical fibers outperforming classical solid-core fibers. This will be a revolutionary breakthrough, primarily for longer-distance telecommunications with drastically reduced distortions and crosstalk for a higher density of information—but also for distributed fiber sensing that may enter into a new dimension by exploiting the huge flexibility of a customizable gaseous medium."

—Luc Thévenaz, *EPFL Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*

COMPUTATIONAL IMAGING

"The combination of metasurface nanophotonics and computational imaging is only recently beginning to be explored. In 2021 and subsequent years, a major advance will be the direct integration within image-sensor arrays of metasurfaces with tailored transmission characteristics, distributed on a pixel-by-pixel basis. By independently controlling the properties of the light detected by each individual pixel, and computationally reconstructing the output image, novel advanced capabilities will be enabled for both image sensing and processing."

—Roberto Paiella, *Center for Photonics, Boston University, Boston, MA, USA*

NANOPHOTONIC CAVITIES

"In three to five years, nanophotonic cavities will make groundbreaking contributions to novel types of ultrastrong light-matter interactions owing to the tiny mode volumes they provide. Examples include the realization of forbidden optical transitions, Cherenkov radiation and extremely strong nonlinear effects. Even more tantalizing are prospects for manipulating properties of correlated electron systems, just by the vacuum fields of the cavities. This could unlock a completely new field unveiling new types of out-of-equilibrium phases."

—Frank Koppens, *ICFO–The Institute of Photonic Sciences, Barcelona, Spain*

Photos: courtesy of researchers; Infographic: Alessia Kirkland and John Zavada