A LOOK AHEAD

Optics in 2024 & 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 2023" feature for thoughts on areas that might advance in 2024.

ELECTRO-OPTIC DEVICES

Electro-optic (EO) devices are needed for high-speed data communications and for wide-bandwidth analog signal processing. EO modulators have achieved high bandwidths and low drive voltages by using thin-film materials, and another jump in performance may be anticipated in the not-too-distant future. In 2024 and beyond, we will see the combination of EO and nonlinear optical (NLO) devices for solving special sensing and computation challenges. It is also likely that future quantum computers will utilize both EO and NLO effects in irreplaceable ways and will require integrated photonics.

Shayan Mookherjea, *University of California San Diego, La Jolla, CA, USA*

PHOTONIC BUILDING BLOCKS

Photonic van der Waals (vdW) integration fuses the concepts of photonic crystals with emerging functional nanomaterials and their heterostructures. The advent of epitaxy and layer lift-off nanofabrication techniques enables a wide spectrum of 2D materials and 3D single-crystalline freestanding thin films, powering up diverse optical functionalities. Various and hybrid vdW building blocks can robustly be assembled into metaphotonic architectures. Such combination introduces unprecedented freedom in engineering and realizing exotic nanophotonic phenomena at mixed-dimensional vdW interfaces.

Cheng-Wei Qiu, *National University of Singapore, Singapore*

ADVANCES IN STRUCTURED LIGHT

In the short term, I expect to see significant movement in controlling and applying mixed degrees of freedom in structured light—for instance, combining time and space for spatio-temporal light. In the longer term, I think nonlinear optics will emerge as a significant tool for advances in quantum structured light, reinventing itself with new selection rules and enhanced efficiencies through novel structured matter.

Andrew Forbes, *University of the Witwatersrand, Johannesburg, South Africa*

OPTICAL QUANTUM TECHNOLOGIES

Optical and quantum technologies will flourish in a unique win–win relationship. Quantum technologies are on the brink of revolutionizing future technological developments in a variety of fields, such as computing, communication and sensing, to name just a few. Optical and quantum-optical technologies will serve as the key means to interface the quantum with the classical world. The first applications will demonstrate the advantage of quantum technologies in the coming years.

Gerhard Birkl, *Technische Universität Darmstadt, Darmstadt, Germany*

SOFTWARE-DEFINED OPTICS

Through the collaborative design of optical front-ends and computational back-ends, we will explore novel imaging modalities with substantial reductions in size, weight, power and latency. These innovations include ultra-thin machine-vision cameras, large-aperture imaging systems for space applications, and coherent imaging systems. Leveraging advanced manufacturing techniques, these optics will entail a hybrid assembly approach that combines flat and conformal elements of refractive and subwavelength diffractive optics.

Arka Majumdar, *University of Washington, Seattle, WA, USA*

NEW COMB SOURCES

Within the next five years, a new generation of integrated broadband multifrequency-comb sources is likely to thrive, as a consequence of novel nonlinear phenomena molding the spatiotemporal soliton physics at the micron scale. Broadband microcomb spectroscopy, optical clocks and computing are among the most important applications to directly benefit from these advances. 2D microcavities will unlock exotic light propagation regimes, offering unprecedented means to operate multifrequency combs and multidimensional solitons.

Carles Milián Enrique, *Universitat Politècnica de València, València, Spain*

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