A LOOK AHEAD

Optics in 2027 & Beyond

Each December, OPN looks at interesting research results of the past year. But what about the year ahead? We asked several optics researchers for thoughts on areas that might advance in 2027 and beyond.



SUSTAINABLE PHOTONICS

Over the coming years, I foresee breakthroughs in sunlight-driven lasers and quantum photonics. Recent demonstrations of high-quality polarization entanglement from incoherent sunlight and advances in efficient solar lasers offer unprecedented opportunities for sustainable photonic technologies. Innovations in solar concentration and integrated photonics, alongside growing start-up interest in space-based solar energy harvesting, are accelerating progress. These advances could enable solar-driven autonomous quantum communication, interplanetary links, and information and energy transfer for future lunar settlements, even under challenging conditions.

Hanieh Fattahi, *Max Planck Inst. for the Science of Light, Germany*



SENSING AND COMMUNICATION

The seamless integration of distributed acoustic sensing (DAS) and passive optical networks (PONs) provides a state-of-the-art integrated sensing and communication (ISAC) paradigm for transforming global PON infrastructures into weak-vibration-sensing-enabled optical networks for security monitoring. Future ISAC-PONs will be able to provide both broadband communication and multipurpose sensing services, including monitoring of PONs, earthquakes, infrastructure, perimeter security and traffic, etc., enabling the next generation of all-optical access networks.

Yunjiang Rao, *University of Electronic Science and Technology of China, Chengdu, China*



TOPOLOGICAL OPTICS

Over the next year, I expect advances in modular integrated architectures for topological and higher-dimensional structured light in the quantum and classical regimes. Over three to five years, I see the expansion of information processing with topological structured photons as particularly promising. Encouraging demonstrations of communication schemes and elementary computational operations provide a foundation, but practical and deployable end-to-end solutions remain to be perfected. Bringing these pieces together could enable practical computing and communication schemes that exploit the distinctive properties of topological light.

Isaac Nape, *University of the Witwatersrand, South Africa*



AI-DESIGNED COMPUTATIONAL OPTICS

Over the next few years, I foresee breakthroughs in AI-designed optical instruments that embed computation directly into sensing and imaging through programmable diffraction. Rather than merely recording light for subsequent digital processing, these systems will shape optical fields to extract task-relevant information at the point of measurement. Joint advances in diffractive computing, precision nanofabrication, spatial light modulators, and hardware-aware co-design will enable compact, scalable, application-specific instruments with substantially lower latency, energy consumption and hardware complexity.

Aydogan Ozcan, *University of California, Los Angeles, USA*



GRAVITATIONAL-WAVE DETECTION

Frontier gravitational-wave detectors, such as the US Laser Interferometer Gravitational-Wave Observatory (LIGO), will achieve the capability to precisely maintain a constant thermal state in their massive 40-kg optics through a new offline laser-heating approach currently under development. This will have a significant impact on the operational stability and sensitivity of the interferometers, driving LIGO toward a record 500 kW of circulating laser power and the most expansive view yet of the gravitational-wave universe.

Jonathan Richardson, *University of California, Riverside, USA*



STRUCTURED LIGHT

One of the hottest topics in photonics is the generation of structured light with spatially varying polarization distributions. Such light is already finding applications in communication and biomedicine, supported by advances in modulating spin and orbital angular momentum. Future research will increasingly focus on engineering optical fibers that can not only generate vector beams at the fiber facet but also collect/receive complex polarization fields and preserve the corresponding vector modes during propagation.

Diana Galiakhmetova, *Aston University, Birmingham, UK*

Photos: Courtesy of the researchers