# Breakthrough optics pave way for new class of intriguing technologies

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A new class of fascinating technologies—including optics in computing, telecommunications links and switches, and virtually any other optical component—could be created simply by configuring a mesh of light-controlling devices known as interferometers. This is similar to the way electronic semiconductors can fashion the wide array of digital technologies we have at our disposal today.

Optical technologies have the potential to greatly reduce the power consumption of computers, speed telecommunications, and enhance the sensitivity of chemical and biological sensors. The basic building blocks of traditional optics, however, mirrors and lenses, lack the versatility to readily perform these functions and are difficult to scale to the small sizes needed for many applications.

A fundamentally new approach to designing optical technologies—based on a single device known as a Mach-Zehnder interferometer—could overcome these limitations and lead to a variety of breakthrough applications, thus, paving the way for an entirely new class of technologies that could give optics the kind of versatility we see in electronics.

"Recently, optical researchers have begun to understand that these interferometers can be thought of as universal 'building blocks' that could enable us to construct essentially any optical device we could imagine," said Dr. David A.B. Miller, Stanford University, California, USA and author of a letter describing the potential of interferometers

published today in The Optical Society's new high-impact journal *Optica*.

Previously, this approach would have only been feasible if the Mach-Zehnder interferometers were able to achieve perfect performance—a seemingly unattainable goal.

The new approached described in this paper, however, presents an alternate pathway. Rather than engineering a perfect, single component, researchers propose it's possible to create a mesh, or array, of interferometers that, when properly programmed, could compensate for its less-than-perfect parts and deliver overall perfect performance.

"It's this larger scheme that allows us to use reasonable but imperfect versions of these components," explains Miller.

## Interferometers Building the Foundation of Technology

Interferometers are basically any device that separate and re-combine light waves. Like sound waves, light waves can be combined so their signals add together. They also can "interfere" and cancel each other out. This basic "on/off" capability is what would allow interferometers to be harnessed and configured in a variety of ways.

Mach-Zehnder interferometers are specialized versions of these devices that split light from one or two sources into two new beams and then recombine them. They are already used for some specific applications in science and for switching beams in optical communications in optical fibers.

Their more general use in consumer and other applications, however, has been obstructed because of the way that the light is initially split as it

enters the device. Ideally, the beams would be split in perfect 50/50 symmetry. In reality, however, the split is not nearly so perfect. This means that when the interferometer recombines the signal it cannot be completely canceled, preventing engineers from completely controlling the optical path.

The ability to combine or cancel the signals along a particular path is critical for technology. Researchers realized, however, that if Mach-Zehnder interferometers could be assembled in large meshes and controlled, it would be possible to create a system that achieved the necessary perfect performance. This would allow the meshes to, in principle, perform any so-called "linear" optical operation, much like computers are able to perform any logical application by controlling on/off functions of semiconductors.

## Automatic Control Enables Technology

The final element that enabled this process was the invention of algorithms—essentially the control software—that allowed the meshes to be "self-configuring," adjusting how they directed the light paths based on the signal received by simple optical sensors embedded in the system.

This self-correcting algorithm allowed the researchers to propose meshes of interferometers with some imperfections and then compensate to make them behave as if they were perfect. The algorithms could then control the "phase shifters" in the interferometers, determining if the signals combined or canceled, by simply monitoring the optical power in various detectors.

"With this development, we are starting to do some things in optics that we have been doing in electronics for some time," observed Miller. "By using small amounts of electronics and novel algorithms, we can greatly expand the kinds of optics and applications by making completely

custom optical devices that will actually work."

**More information:** "Perfect optics with imperfect components," David A.B. Miller, *Optica*, Vol. 2, Issue 8, pp. 747 (2015). doi: dx.doi.org/10.1364/optica.2.000747

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