Photonics

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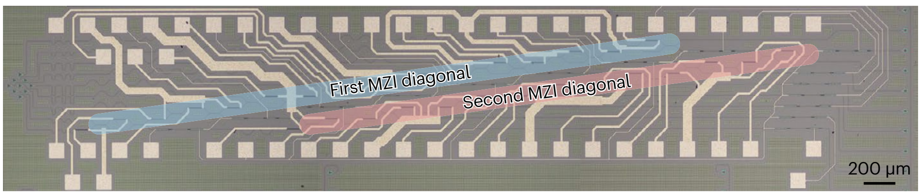
Interferometer meshes for low-crosstalk scalable optical chips



Integrated photonic processors with numerous optical components built on chips leverage light to perform computations. In optical computing, efficient transmission of information between the components and chips is crucial for optimal performance. However, in many practical scenarios, such as sending signals through turbulent environments, navigating multimode optical fibres, imaging through scattering media or conducting remote sensing, efficiency suffers due to deviations of the wave trajectory, end-to-end power loss and mixing or crosstalk among the waves.

Now, writing in *Nature Photonics*, Francesco Morichetti and colleagues present a photonic integrated platform based on two chips hosting Mach–Zehnder interferometer (MZI) meshes that enables efficient and low-crosstalk information transmission through any optical media.

The MZI is a type of optical interferometer in which the light travels two different paths and then recombines, producing an interferogram dependent on the phase difference between the two paths and on the intensity and phase of the incoming light at MZI's input ports. Hence, it can sensitively detect any changes in refractive index and phase difference arising from structural imperfections, material inhomogeneities, and other obstacles in the optical media.

Using a standard silicon photonics platform, the researchers fabricated two identical chips that consist of MZI meshes with thermo-optic phase shifters, single-mode waveguides, and arrays of grating couplers working as integrated optical micro-antennas. The two chips work in pairs, each containing two diagonal lines of MZIs, where each line is used to handle a specific information transmission channel. If a light is shone into the upper input port on one side of the chip, it goes into the first diagonal line of MZIs, during which the phase shifters are set arbitrarily. As a result, some light appears out of each of the nine output ports on the other side of the chip, emerges from the gratings, and finally enters the optical media. The resulting light is collected by the gratings at the inputs to the second chip and moves through the corresponding diagonal line of MZIs. The final output light is collected by the free-space optical fibre. The MZIs in the second chip act as a self-aligning beam coupler, manipulated by a progressive algorithm to route inputs to assigned output ports efficiently. The efficiency of the end-to-end transmission between the two chips can be optimized through several forward-and-backward iterations of the progressive algorithm applied to the pair of MZI meshes.

The second information transmission channel can be created by applying the above procedure to the other diagonal line of MZIs. Therefore, this MZI mesh pairing technology can be scaled up for applications in large-scale photonic computing. In addition, in the presence of obstacles or perturbations in the optical media, the researchers obtain crosstalk below −30 dB between optimal channels in the MZI mesh chip. "Our chips integrate photonic analogue processors designed for rapid and energy-efficient calculations using light. With respect to digital electronic processing, making basic algebraic operations, such as sums and multiplications, directly in the optical domain presents several benefits, including high energy efficiency and an extensive bandwidth surpassing 5 THz," says Morichetti.

"Using optical processors for analogue computing has a vital role in various application scenarios, such as mathematical accelerators for neuromorphic systems, artificial intelligence, quantum computing, and so on — in general, in all systems demanding very high-speed processing of extensive datasets," adds co-author Marc Sorel.

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