Miniaturized Coherent Modulators Break Bandwidth Density Records

Artificial intelligence (AI) is transforming nearly every aspect of modern life, powered by massive computing clusters containing thousands of nodes spread across vast campuses. Optical interconnects provide the essential infrastructure needed to move data at the scale AI demands.

Coherent optical communications dominate long-haul networks thanks to their robustness to link impairments, high transmission capacity and long reach. Yet, until now, coherent systems have remained bulky, power-hungry and difficult to integrate closely with advanced electronics through co-packaged optics (CPO). A key constraint has been the size and complexity of optical modulators.

Microring modulators (MRMs) offer exceptional compactness and energy efficiency,[1,2] making them attractive for AI data center interconnects. However, their inherent frequency chirp has confined their use largely to intensity-modulation/direct-detection links—approaches whose limited reach and sensitivity to impairments restrict scalability as data center clusters continue to grow in size and complexity.

We have developed a novel optical transmitter that addresses these challenges by miniaturizing coherent modulators on a silicon photonics platform.[3,4] Our solution embeds a pair of MRMs within a push-pull Mach–Zehnder interferometer (MZI), effectively counterbalancing chirp. Using this building block, we have, for the first time, constructed an in-phase/quadrature (I/Q) modulator by nesting two such devices.

By leveraging the compact footprint and low-energy operation of MRMs, the resulting coherent modulators are ideally suited for CPO integration with advanced electronics. Achieving this result required an in-depth understanding of MRM coherent dynamics and their interaction with phase modulation.

In laboratory demonstrations, the device achieved a record on-chip shoreline bandwidth density exceeding 5 Tb/s/mm, supported symbol rates up to 180 Gbaud and delivered net bit rates above 1 Tb/s over 80 km of fiber—the fastest MRM-based transmission reported to date—while consuming as little as 10.4 fJ/bit.

In summary, miniaturizing coherent optical modulators with MRMs paves the way for compact, high-capacity and energy-efficient coherent optical interconnects, bridging the gap between performance, footprint and scalability for next-generation AI clusters. OPN

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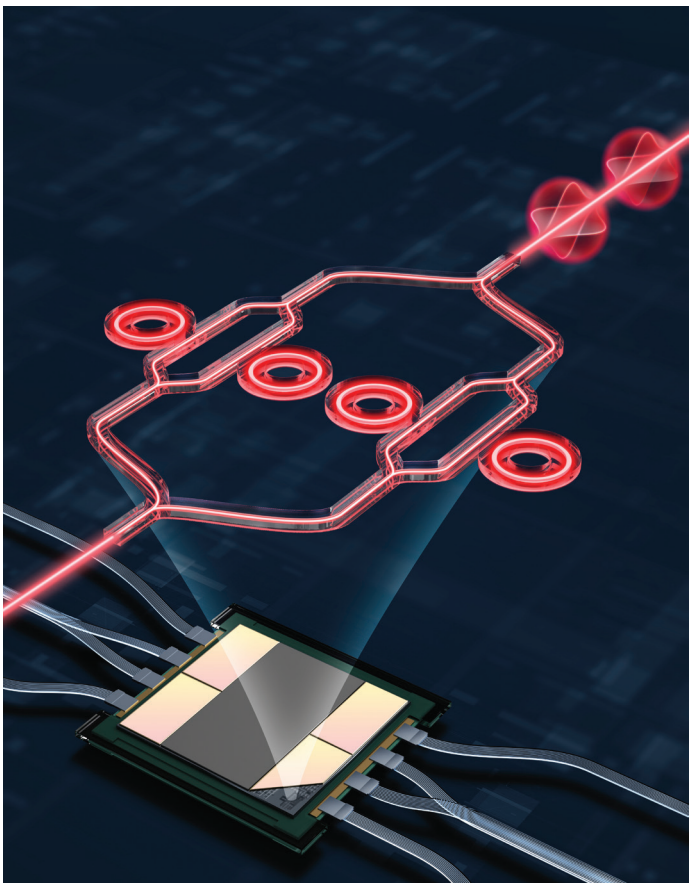

Artistic illustration of an ultra-compact silicon photonic modulator that controls both the amplitude and phase of light to enable fast connectivity for advanced electronics.