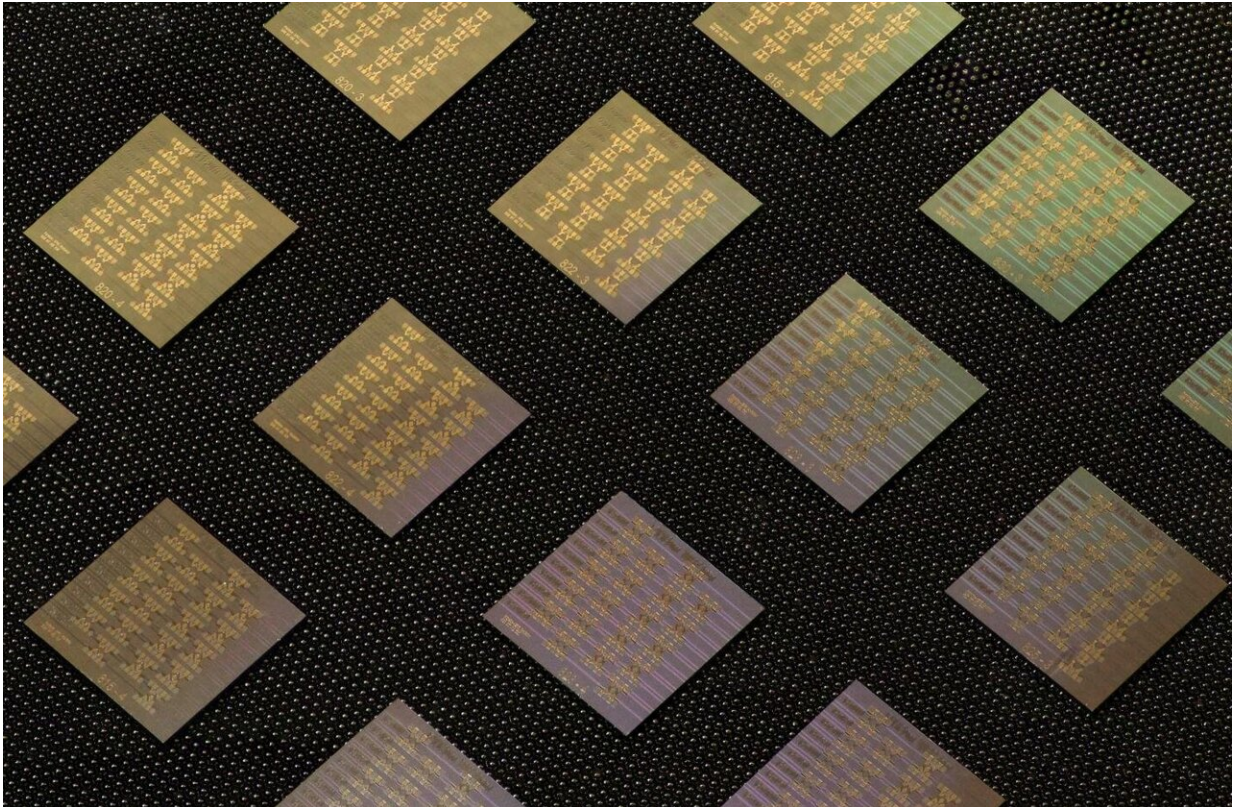


# Shaking light with sound

July 15 2020

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Integrated silicon nitride photonic chips with aluminium nitride actuators.  
Credit: Jijun He, Junqiu Liu (EPFL)

Piezoelectric materials can convert electrical voltage to mechanical displacement and vice versa. They are ubiquitous in modern wireless communication networks such as in cellphones. Today, piezoelectric devices, including filters, transducers and oscillators, are used in billions

of devices for wireless communications, global positioning, navigations, and space applications.

In an article published in *Nature*, a collaboration lead by Professor Tobias J. Kippenberg at EPFL and Professor Sunil A. Bhave at Purdue University has combined piezoelectric aluminum nitride (AlN) technology—used in modern cellphones' radio frequency filters—with ultralow-loss silicon nitride ( $\text{Si}_3\text{N}_4$ ) integrated photonics, demonstrating a new scheme for on-chip acousto-optic modulation.

The hybrid circuit allows wideband actuation on photonic waveguides with ultralow electrical power—a feat that has been so far challenging. The circuit itself was manufactured using CMOS-compatible foundry processes, which are widely used to construct microprocessors, microcontrollers, memory chips, and other digital logic [circuits](#).

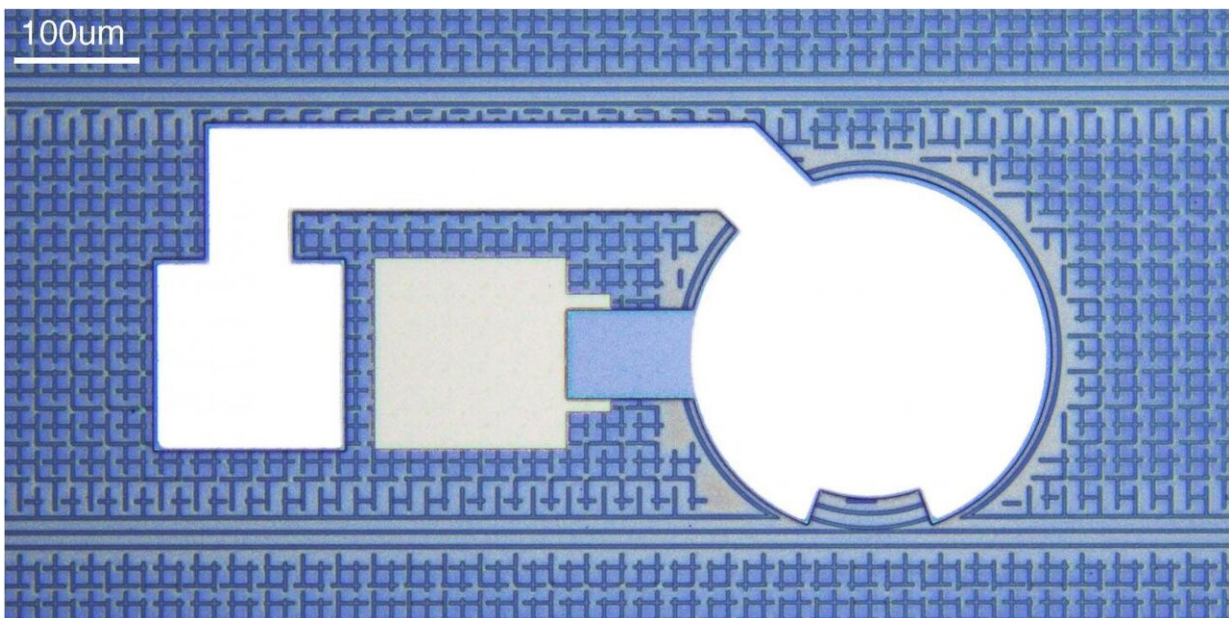
## Light and sound

To build the circuit, the scientists used  $\text{Si}_3\text{N}_4$ , which has emerged as a leading material for chip-scale, microresonator-based optical frequency combs ("microcombs"). Microcombs are used in a range of precision-demanding applications, including coherent communications, astronomical spectrometer calibration, ultrafast ranging, low-noise microwave synthesis, optical atomic clocks, and most recently, parallel coherent LiDAR.

The researchers fabricated piezoelectric AlN actuators on top of the ultralow-loss  $\text{Si}_3\text{N}_4$  photonic circuits, and applied a voltage signal on them. The signal induced bulk acoustic waves electromechanically, which can modulate the generated microcomb in the  $\text{Si}_3\text{N}_4$  circuits. In short, sound shakes light.

A key feature of this scheme is that it maintains the ultralow loss of

$\text{Si}_3\text{N}_4$  circuits. "This achievement represents a new milestone for the microcomb technology, bridging integrated photonics, microelectromechanical systems engineering and nonlinear optics," says Junqiu Liu, who leads the fabrication of  $\text{Si}_3\text{N}_4$  photonics chips at EPFL's Center of MicroNanoTechnology (CMi). "By harnessing piezoelectric and bulk acousto-optic interactions, it enables on-chip optical modulation with unprecedented speed and ultralow power consumption."



Microscope image showing the piezoelectric actuators covering the silicon nitride photonic circuits. Credit: Junqiu Liu, Rui Ning Wang

## Two new applications

Using the new hybrid system, the researchers demonstrated two independent applications: First, the optimization of a microcomb-based massively parallel coherent LiDAR, based on their previous work also

published in *Nature* recently. This approach could provide a route to chip-based LiDAR engines driven by CMOS microelectronic circuits.

Second, they built magnet-free optical isolators by spatio-temporal modulation of a  $\text{Si}_3\text{N}_4$  microresonator, which was published recently in *Nature Communications*. "The tight vertical confinement of the bulk acoustic waves prevents cross-talk and allows for close placement of the actuators, which is challenging to achieve in p-i-n silicon modulators," says Hao Tian, who fabricated the piezoelectric actuators at the Scifres cleanroom in Purdue's Birck Nanotechnology Center.

The new technology could provide impetus to microcomb applications in power-critical systems, e.g. in space, datacenters and portable atomic clocks, or in extreme environments such as cryogenic temperatures. "As yet unforeseen applications will follow up across multiple communities," says Professor Kippenberg. "It's been shown time and again that hybrid systems can obtain advantages and functionality beyond those attained with individual constituents."

"I recently read a *Scientific American* article that really resonated with me," adds Professor Bhawe. "It is called, "Why Science is Better When it's Multinational." Our results would not be possible without this multidisciplinary and inter-continental collaboration."

**More information:** Liu, J., Tian, H., Lucas, E. et al. Monolithic piezoelectric control of soliton microcombs. *Nature* 583, 385–390 (2020). [doi.org/10.1038/s41586-020-2465-8](https://doi.org/10.1038/s41586-020-2465-8)

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