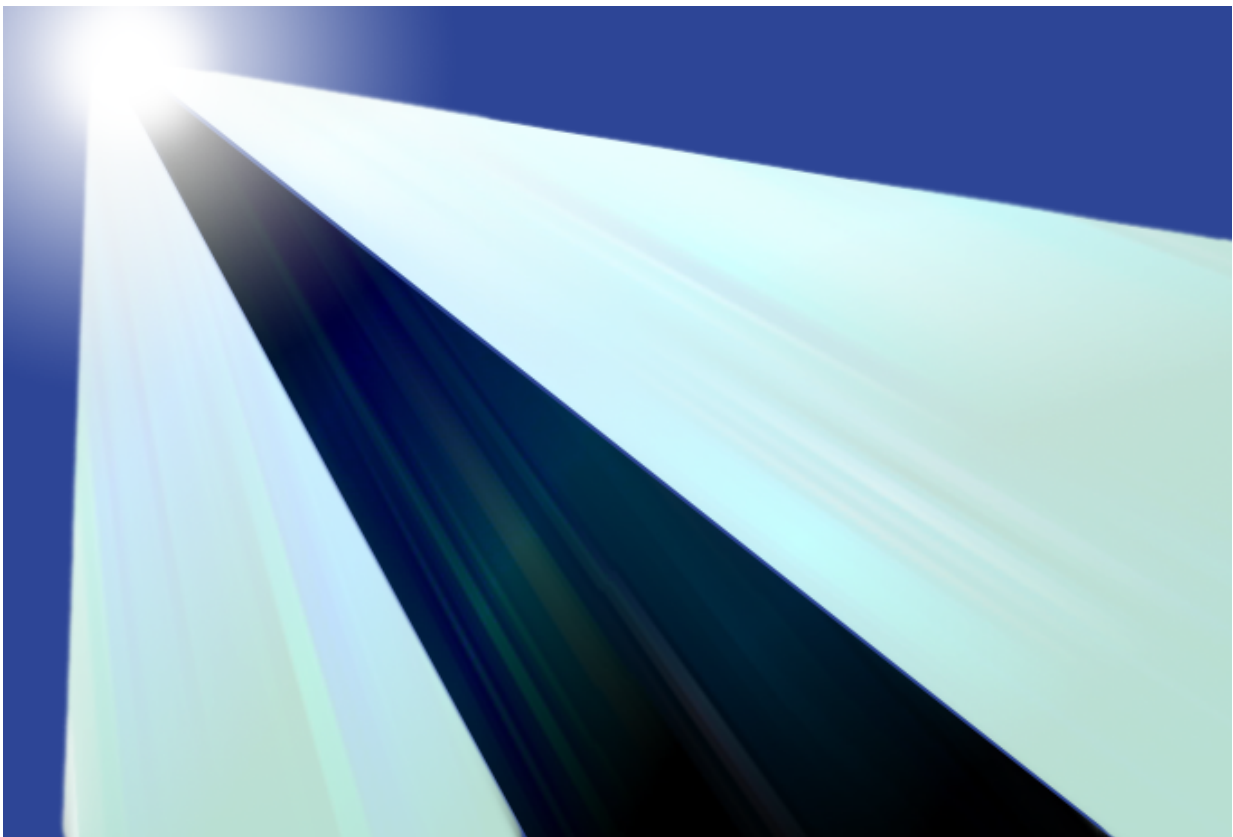


Opening a new route to photonics: Researchers find way to control light in densely packed nanowaveguides

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In this adiabatic elimination scheme, the movement of light through two outer waveguides is controlled via a "dark" middle waveguide that does not accumulate any light. Credit: Zhosia Rostomian, Berkeley Lab

A new route to ultrahigh density, ultracompact integrated photonic circuitry has been discovered by researchers with the Lawrence Berkeley National Laboratory (Berkeley Lab) and the University of California (UC) Berkeley. The team has developed a technique for effectively controlling pulses of light in closely packed nanoscale waveguides, an essential requirement for high-performance optical communications and chip-scale quantum computing.

Xiang Zhang, director of Berkeley Lab's Materials Sciences Division, led a study in which a mathematical concept called "adiabatic elimination" is applied to optical nanowaveguides, the photonic versions of electronic circuits. Through the combination of coupled systems—a standard technique for controlling the movement of light through a pair of waveguides—and adiabatic elimination, Zhang and his research team are able to eliminate an inherent and vexing "crosstalk" problem for nanowaveguides that are too densely packed.

Integrated electronic circuitry is approaching its limits because of heat dissipation and power consumption issues. Photonics, in which electrical signals moving through copper wires and cables are replaced by pulses of light carrying data over optical fibers, is a highly touted alternative, able to carry greater volumes of data at faster speeds, while giving off much less heat and using far less power. However, the crosstalk problem in coupled optical nanowaveguides has been a major technological roadblock.

"When nanowaveguides in close proximity are coupled, the light in one [waveguide](#) impacts the other. This coupling becomes particularly severe when the separation is below the diffraction limit, placing a restriction on how close together the waveguides can be placed," Zhang says. "We have experimentally demonstrated an adiabatic elimination scheme that effectively cuts off the cross-talk between them, enabling on-demand dynamical control of the coupling between two closely packed

waveguides. Our approach offers an attractive route for the control of optical information in integrated nanophotonics, and provides a new way to design densely packed, power-efficient nanoscale photonic components, such as compact modulators, ultrafast optical signal routers and interconnects."

Zhang, who also holds an appointment with the Kavli Energy NanoSciences Institute (ENSI) at Berkeley, is the corresponding author of a paper describing this research in *Nature Communications*. The paper is titled "Adiabatic elimination based coupling control in densely packed subwavelength waveguides." Michael Mrejen, Haim Suchowski and Taiki Hatakeyama are the lead authors. Other authors are Chih-hui Wu, Liang Feng, Kevin O'Brien and Yuan Wang.

"A general approach to achieving active control in coupled waveguide systems is to exploit optical nonlinearities enabled by a strong control pulse," Zhang says. "However this approach suffers from the nonlinear absorption induced by the intense control pulse as the signal and its control propagate in the same waveguide."

Zhang and his group turned to the adiabatic elimination concept, which has a proven track record in atomic physics and other research fields. The idea behind adiabatic elimination is to decompose large dynamical systems into smaller ones by using slow versus fast dynamics.

"Picture three buckets side-by-side with the first being filled with water from a tap, the middle being fed from the first bucket through a hole while feeding the third bucket through another hole," says co-lead author Mrejen. "If the flow rate into the middle bucket is equal to the flow rate out of it, the second bucket will not accumulate water. This, in a basic manner, is adiabatic elimination. The middle bucket allows for some indirect control on the dynamics compared to the case in which water goes directly from the first bucket to the third bucket."

Zhang and his research group apply this concept to a coupled system of optical nanowaveguides by inserting a third waveguide in the middle of the coupled pair. Only about 200 nanometers separate each of the three waveguides, a proximity that would normally generate too much cross-talk to allow for any control over the coupled system. However, the middle waveguide operates in a "dark" mode, in the sense that it doesn't seem to participate in the exchange of light between the two outer waveguides since it does not accumulate any light.

"Even though the dark waveguide in the middle doesn't seem to be involved, it nonetheless influences the dynamics of the coupled system," says co-lead author Suchowski, who is now with the Tel Aviv University. "By judiciously selecting the relative geometries of the outer and intermediate [waveguides](#), we achieve adiabatic elimination, which in turn enables us to control the movement of light through densely packed nanowaveguides. Until now, this has been almost impossible to do."

More information: Adiabatic elimination-based coupling control in densely packed subwavelength waveguides, *Nature Communications* 6, Article number: 7565 [DOI: 10.1038/ncomms8565](https://doi.org/10.1038/ncomms8565)

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