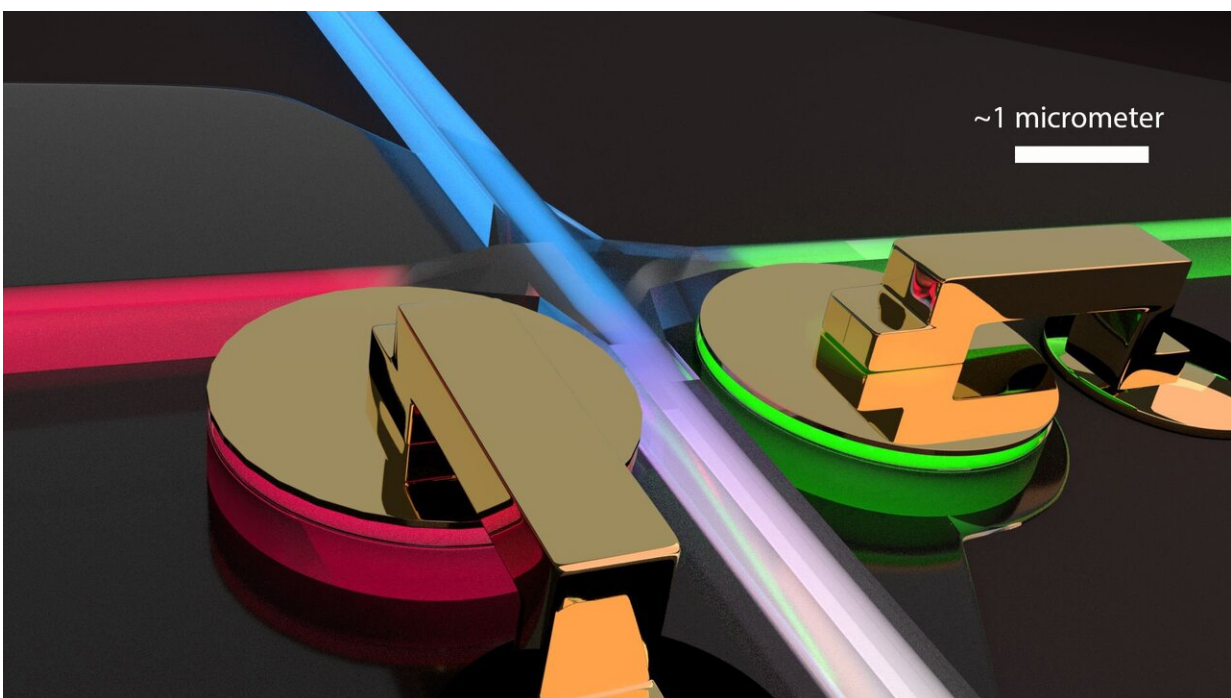


Research team develops tiny low-energy device to rapidly reroute light in computer chips

November 14 2019



Artist's depiction of newly demonstrated nano-opto-electro-mechanical switches as they could be used for future filtering of colors for sensing or communications. In communications, the amount of transmitted information per channel can be increased by carrying data not only by one color but by multiple colors. Yet, the different color channels need to be routed on demand to different end-users. The image shows how this can be achieved on the scale of 1 millionth of a meter (1 micrometer) by using the switches. White light can contain, for example, blue light for voice messages, red for video, and green for text. All of those are filtered by the switches such that red, blue and green color

channels are routed to different designated end-users. By applying tiny voltages researchers can swap colors on demand, controlling which data reaches which end-user. Credit: S. Kelley/NIST

Researchers at the National Institute of Standards and Technology (NIST) and their colleagues have developed an optical switch that routes light from one computer chip to another in just 20 billionths of a second—faster than any other similar device. The compact switch is the first to operate at voltages low enough to be integrated onto low-cost silicon chips and redirects light with very low signal loss.

The switch's record-breaking performance is a major new step toward building a computer that uses light instead of electricity to process information. Relying on particles of light—photons—to transport data within a computer offers several advantages over electronic communications. Photons travel faster than electrons and don't waste energy by heating up the computer components. Managing that waste heat is a major barrier to improving computer performance. Light signals have been used for decades to transmit information over great distances using optical fibers, but the fibers take up too much room to be used to carry data across a computer chip.

The new switch combines nanometer-scale gold and silicon optical, electrical and mechanical components, all densely packed, to channel light into and out of a miniature racetrack, alter its speed, and change its direction of travel. (One nanometer is a billionth of a meter, or about one-hundred-thousandth the width of a human hair.) The NIST-led international team describes the device online today in *Science*.

The device has myriad applications, notes study co-author Christian Haffner of NIST, ETH Zurich and the University of Maryland. In

driverless cars, the switch could rapidly redirect a single light beam that must continually scan all parts of the roadway to measure the distance to other automobiles and pedestrians. The device could also make it easier to use more powerful light-based circuits instead of electricity-based ones in neural networks. These are artificial intelligence systems that simulate how neurons in the human brain make decisions about such complex tasks as pattern recognition and risk management.

The new technology also uses very little energy to redirect [light signals](#). This feature may help realize the dream of quantum computing. A quantum computer processes data stored in the subtle interrelations between specially prepared pairs of subatomic particles. However, these relationships are extremely fragile, requiring that a computer operate at ultralow temperatures and low power so that the particle pairs are disturbed as little as possible. Because the new [optical switch](#) requires little energy—unlike previous optical switches—it could become an integral part of a quantum computer.

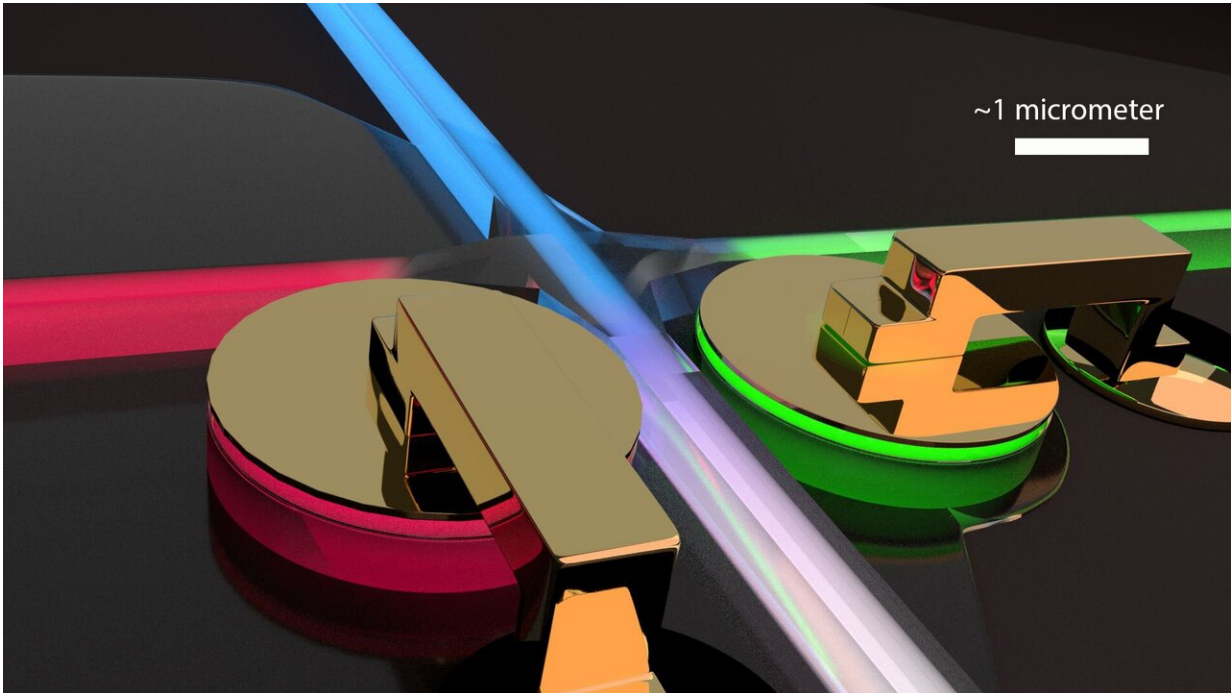
Haffner and his colleagues, who include Vladimir Aksyuk and Henri Lezec of NIST, say their findings may come as a surprise to many in the scientific community because the results contradict long-held beliefs. Some researchers have thought that opto-electro-mechanical switches would not be practical because they would be bulky, operate too slowly and require voltages too high for the components of a [computer](#) chip to tolerate.

The switch exploits the wave nature of light. When two identical light waves meet, they can superpose such that the crest of one wave aligns or reinforces the crest of the other, creating a bright pattern known as constructive interference. The two waves may also be exactly out of step, so that the valley of one wave cancels the crest of the other, resulting in a dark pattern—destructive interference.

In the team's setup, a light beam is confined to travel inside a miniature highway—a tube-shaped channel known as a waveguide. This linear highway is designed so that it has an off-ramp—some of the light can exit into a racetrack-shaped cavity, just a few nanometers away, etched into a silicon disk. If the light has just the right wavelength, it can whip around the racetrack many times before leaving the silicon cavity.

The switch has one other crucial component: a thin gold membrane suspended just a few tens of nanometers above the silicon disk. Some of the light traveling in the silicon racetrack leaks out and strikes the membrane, inducing groups of electrons on the membrane's surface to oscillate. These oscillations, known as plasmons, are a kind of hybrid between a light wave and an electron wave: The oscillating electrons resemble the incoming light wave in that they vibrate at the same frequency, but they have a much shorter wavelength. The shorter wavelength lets researchers manipulate the plasmons over nanoscale distances, much shorter than the length of the original light wave, before converting the oscillations back into light. This, in turn, allows the optical switch to remain extremely compact.

By changing the width of the gap between the silicon disk and the gold membrane by only a few nanometers, the researchers could delay or advance the phase of the hybrid light wave—the point in time when the wave reaches a crest or valley. Even minuscule variations in the width of the gap, which the team accomplished by electrostatically bending the gold membrane, dramatically altered the phase.



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Depending on how much the team had advanced or delayed the phase of the wave, when it recombined with light still traveling in the tube-shaped highway, the two beams interfered either constructively or destructively (see animation). If the light beams match up to interfere constructively,

the light will continue in its original direction, traveling down the tube. But if the light beams interfere destructively, canceling each other out, that pathway is blocked. Instead, the light must move in another direction, determined by the orientation of other waveguides, or routes, placed close to the blocked pathway. In this way, the light can be switched at will to any of hundreds of other [computer chips](#).

Scientists had once thought that a plasmonic system would greatly attenuate light signals because photons would penetrate the interior of the gold membrane, where electrons would absorb much of the light energy.

But the researchers have now proved that assumption wrong. The compactness of the device and a design that ensured that few photons would penetrate the membrane resulted in a loss of just 2.5% of the [light](#) signal, compared with 60% with previous switches. That puts the [switch](#), although still a prototype, within reach of commercial applications.

The team is now working to make the device even smaller by shortening the distance between the silicon disk and the gold membrane. This would further reduce signal loss, making the technology even more appealing to industry.

More information: "Nano–opto-electro-mechanical switches operated at CMOS-level voltages" *Science*, [science.sciencemag.org/cgi/doi...1126/science.aay8645](https://science.sciencemag.org/cgi/doi/10.1126/science.aay8645)

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