for applications in the visible and infrared and allowing the use of ultrashort pulses with considerable spectral width. In pump–probe measurements, the all-optical switch demonstrated a record low switching time of 260 fs as well as an ultra-low driving energy of the control pulse of only 35 fJ, which is the smallest switching energy reported up to now for sub-picosecond opto-optical switches.

However, while the plasmonic waveguide is beneficial to create this ultracompact switch of small footprint with strong light confinement, it also causes one of the major current drawbacks — an insertion loss of about 19 dB — that is mainly attributed to the intrinsic absorption in the metal (ohmic losses) incurred as the light traverses the length of the waveguide. The use of several layers of graphene is a possible way out, since it would enhance the saturable absorption and therefore allow a shortening of the waveguide by keeping the switching contrast up. The shorter propagation within the plasmonic waveguide will directly lead to a reduction in ohmic losses and overall insertion loss in the transmitting state. Alternatively, combination with an amplification process as realized in recently reported polaritonic transistors[8] might help to counteract the reduction in signal strength caused by the losses.

In conclusion, the authors demonstrated that the combination of strong-field confinement in a plasmonic waveguide and a saturable absorber of short carrier relaxation time can lead to a low-energy, ultrafast all-optical switch offering broadband operation. Even if graphene might not finally be the material of choice for applications due to its cumbersome fabrication and/or introduction in the device, the work of Ono and colleagues is an encouraging step to apply the described concept to other saturable absorbers. The problem of the ohmic losses still needs to be addressed and a reduction in the length of propagation in the plasmonic waveguide seems to be the direct way forward in order to achieve the cascadability for several such switches on a chip — a prerequisite for performing optical logic operations[9]. ❐

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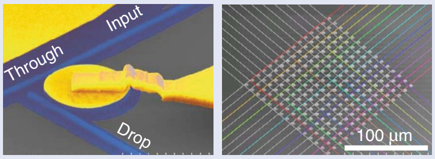
PLASMONICS

Miniature switch fabric

Could the combination of plasmonics and mechanical actuation be the answer for making tiny reconfigurable optical integrated circuits that are compatible with complementary metal–oxide–semiconductor electronics, can switch rapidly and exhibit low optical loss? The recent findings from a collaboration of scientists from Switzerland, Sweden and the US suggest that this is the case. Writing in *Science* (*Science* **366**, 806–864; 2019), Christian Haffner and co-workers report how micrometre-scale disk-shaped plasmonic structures that feature a tiny suspended gold membrane that deforms under electrostatic forces can be used to construct electro-optical switches that route infrared light between waveguides. Importantly, the tiny devices (footprint of ~10 µm^2) feature a low optical insertion loss (0.1 dB through port, 2 dB drop port), rise and fall switching times of 60 and 100 ns respectively, and an optical contrast of 90% between the on and off state.



Credit: From Haffner, C. et al. *Science* **366**, 806–864 (2019). Reprinted with permission from AAAS.

The switch, fabricated on a silica substrate, consists of a 40nm-thick gold membrane partially suspended over a silicon disk forming a small-air-gap plasmonic waveguide. The switch is located at the junction between two orthogonal silicon waveguides to facilitate coupling to each of them. The switching of light from one silicon waveguide to the other only occurs when the plasmonic switch is resonant with the wavelength of the incoming light signal so that coupling occurs, otherwise the light simply continues along its original waveguide. Changing the voltage applied to the device in the range of 0–1.4 V generates an electrostatic force that causes the gold membrane to deform, thus changing the size of the air-gap waveguide and the device's resonant wavelength, thus shifting it into either a resonant or off-resonant state. The electro-optical switch operates at telecommunications wavelengths of around 1550–1560 nm and the estimated electrical power consumption is around 600 nW for a driving voltage of 1.4 V and 12 nW at 0.2 V.

The team believe that it should be feasible to fabricate large arrays of such switches and thereby realize a photonic platform for constructing dense optical switch fabrics for telecommunications or optical neural networks for applications in deep learning. "These switches could form the building blocks of optical field-programmable gate arrays and trigger a technological revolution similar to the one enabled over the past few decades by electrical field-programmable gate arrays", conclude the authors in the final part of their paper. "For instance, 200 switches and their electrical drivers could be integrated on an area as small as the cross section of a single human hair." ❐

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