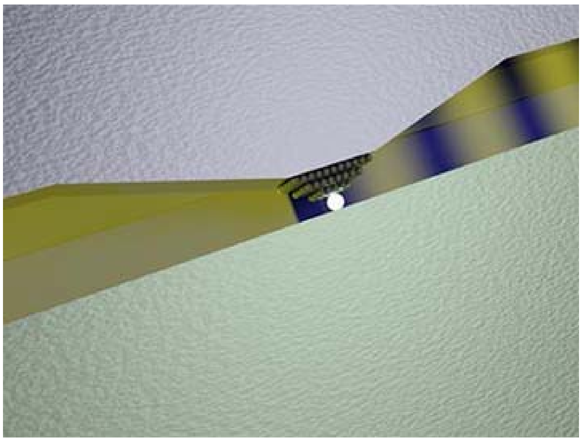
RESEARCH NEWS

# Optical Switching at Atomic Length Scales

Stewart Wills



A slot waveguide, consisting of a silver electrode (gray), tapered to a point, separated from a platinum electrode (green) by a 20-nm gap, allows 1.55-μm light in the waveguide to be converted into subwavelength surface plasmons that can pass through the gap. Applying a voltage differential between the electrons causes the plasmonic flow to be switched off by one or more mobile silver ions (white dot), for an atomic-scale digital switch. [Image: Alexandros Emboras/ETH Zurich]

A Swiss-German scientific team has developed a novel waveguide-integrated device that can act as an in-line digital switch for optical signals—and that uses a single silver atom as the toggle (Nano Lett., doi: 10.1021/acs.nanolett.5b04537 (http://dx.doi.org/10.1021/acs.nanolett.5b04537)). The researchers believe that the setup, which can operate at room temperature, could "lay the foundation for a new integrated photonic atomic scale technology" with applications in communications and quantum devices, once some issues of device speed and manufacturing process are sorted out.

## The ultimate in Moore's Law

One motivation for atom-scale switches and modulators is the need for ever-greater miniaturization and device density in an age of high-performance computing and broadband communications. That need has kept electronics researchers busy designing single-atom switches, transistors and other devices in pursuit of the ultimate Moore's Law payoff—with some early research success.

An atom-scale photonic switch, however, is a much tougher proposition, as common communication wavelengths (roughly 1.55 microns) are orders of magnitude larger than nanometer atomic length scales, and as photon-atom interaction tends to be weak. And, while some cavity-based schemes have demonstrated stronger interactions, they have required cryogenic temperatures and complex setups that would be difficult to package into practical devices.

## Plasmonic intermediary

To find a way around those limitations, the Swiss-German team—led by OSA Fellow Jürg Leuthold from ETH Zurich, Switzerland, along with other scientists at that institution and the Karlsruhe Institute of Technology in Germany—decided to press plasmonics into service.

Plasmonic interactions take advantage of the ability of light, interacting with certain metal surfaces, to excite surface plasmons—localized electromagnetic waves with length scales much shorter than the wavelength of the photons that excite them, and that propagate along the metal-dielectric surface. Six months earlier, another group led by Leuthold had reported using plasmonic techniques to build a Mach-Zender modulator a mere 10 microns in length (Nat. Photon., doi: 10.1038/nphoton.2015.127 (http://dx.doi.org/10.1038/nphoton.2015.127)). Now, they drilled down even further, to determine if plasmonics could also provide a route to an atom-scale photonic switch.

## A silver-atom switch

The team began by overlaying a planar silicon photonic waveguide with a plasmonic slot waveguide fashioned out of two metals: silver on one side, platinum on the



### Recent Headlines

A New Gold Standard for Killing Bacteria? (/home/newsroom/2016/march/a_new_gold_standard_for_killing_bact

New Lens for Terahertz Radiation (/home/newsroom/2016/march/new_lens_for_terahertz_radiation/)

Sugar-Coated Quantum Dots Illuminate Viral Infection (/home/newsroom/2016/march/sugar-coated_quantum_dots_illuminate_viral other. The tiny silver pad was built to taper to a point, and was separated from the platinum by a gap of approximately 20 nm, which was filled with amorphous silicon. As light at telecom wavelengths travels through the optical fiber, interactions with the metal create surface plasmons that can pass through the subwavelength-sized gap and convert back into light on the other side.

The switching is handled by applying a voltage differential between the platinum and silver electrodes. When the voltage is applied, silver ions become mobile and move into the narrow gap between the metallic pads, effectively short-circuiting the system and shutting off the plasmonic flow through the gap. Removing the voltage differential once again allows the surface plasmon, and thus the optical signal, to pass through the gap. The experiments showed that the switch can operate at room temperatures—and at a minuscule power consumption of as little as 12.5 femtojoules per bit.

## A few hurdles to clear

Because the plasmonic flow is either "on" or "off," the result is, according to the team, at truly digital switch. And the atomic size is orders of magnitude smaller than the team's previously reported Mach-Zender modulator —"which," says Leuthold, "I honestly thought would be the most compact modulator that physics would allow us to implement."

The system will require some additional development before commercialization. It is currently relatively slow, operating only at megahertz frequencies, and the fabrication techniques will require some refinements in order to scale to commercial production. The team is working to address both shortcomings, however, and believes it can have a commercializable solution on offer within a few years.

Publish Date: 03 February 2016

### Add a Comment