Engineers study whether 'light on a wire' is wave of future for circuitry

16 March 2005

If data drove itself around in cars, photonics would be a roomy minivan and electronics would be a nimble coupe. Photonic components such as fiber optic cables can carry a lot of data but are bulky compared to electronic circuits. Electronic components such as wires and transistors carry less data but can be incredibly small.
A problem holding back the progress of computing is that with mismatched capacities and sizes, the two technologies are hard to combine in a circuit. Researchers can cobble them together, but a single technology that has the capacity of photonics and the smallness of electronics would be the best bridge of all. A new research group in Stanford's School of Engineering is pioneering just such a technology—plasmonics.

Surface plasmons are density waves of electrons—picture bunches of electrons passing a point regularly—along the surface of a metal. Plasmons have the same frequencies and electromagnetic fields as light, but their sub-wavelength size means they take up less space. Plasmonics, then, is the technology of transmitting these light-like waves along nanoscale wires.

"With every wave you can in principle carry information," says Mark Brongersma, assistant professor of materials science and engineering and head of the new plasmonics Multidisciplinary University Research Initiative (MURI), which earlier this month received an additional $300,000 round of funding from the Air Force Office of Sponsored Research (AFOSR). "Plasmon waves are interesting because they are at optical frequencies. The higher the frequency of the wave, the more information you can transport." Optical frequencies are about 100,000 times greater than the frequency of today's electronic microprocessors.

The research is a prime example of work at the forefront of two strategic initiatives of the School of Engineering: information technology and photonics, and nanoscience and nanotechnology. The school's other two initiatives are in bioengineering, and environment and energy.

Making plasmons work

Supported by a $2.3 million grant received last October from the AFOSR, the goal of the MURI is to demonstrate plasmonics in action on a standard silicon chip. Brongersma and about 20 MURI partners, including David A. B. Miller, the W. M. Keck Foundation Professor of Electrical Engineering, and electrical engineering Assistant Professor Shanhui Fan, have made working plasmonic components and have had their first journal article accepted for publication in an upcoming issue of Optics Letters. The next step will be to integrate the components with an electronic chip to demonstrate plasmonic data generation, transport and detection. A success would be the first of its kind anywhere.

Plasmons are generated when, under the right conditions, light strikes a metal. The electric field of the light jiggles the electrons in the metal to the light's frequency, setting off density waves of electrons. The process is analogous to how the vibrations of the larynx jiggle molecules in the air into density waves experienced as sound.

Plasmon waves behave on metals much like light waves behave in glass, meaning that plasmonic engineers can employ all the same ingenious tricks—such as multiplexing, or sending multiple waves—that photonic engineers use to cram more data down a cable.

Meanwhile, because plasmonic components can be crafted from the same materials chipmakers use today, Stanford engineers are hopeful they can make all the devices needed to route light around a processor or other kind of chip. These would include plasmon sources, detectors and wires, which the lab already has made, as well as splitters and even transistors.

While an all-plasmonic chip might be feasible someday, Brongersma expects that in the near term, plasmonic wires will act as high-traffic freeways on chips with otherwise conventional electronics. Local arrays of electronic transistors would carry out the switching necessary for computation, but when a lot of data needs an express lane to travel from one section of a chip to another, electronic bits could be converted to plasmon waves, sent along a plasmonic wire and converted back to electronic bits at their destination.

Barriers and frontiers

The potential of plasmonics right now is mainly limited by the fact that plasmons typically can travel only several millimeters before they peter out. Chips, meanwhile, are typically about a centimeter across, so plasmons can't yet go the whole distance.

The distance a plasmon can travel before dying out is a function of several aspects of the metal. But for optimal transfer through a wire of any metal, the surface of contact with surrounding materials must be as smooth as possible and the metal should not have impurities.

For most wavelengths of visible light, aluminum allows plasmons to travel farther than other metals such as gold, silver and copper. It is somewhat ironic that aluminum is the best metal to use because the semiconductor industry recently dumped aluminum in favor of copper—the better electrical conductor—as its wiring of choice. Of course, it may turn out that some kind of alloy will have even better plasmonic properties than either aluminum or copper.

Another classic semiconductor industry issue that MURI researchers will have to address is heat. Chipmakers are constantly battling to ensure that their electronic chips don't run too hot. Plasmonics also will likely generate some heat, but exactly how much is not yet known. Even if plasmonics run as hot as electronics, Brongersma points out, they will still have the advantage of having a higher data capacity in the same space.

Electronics face fundamental physical barriers to their data-carrying capacity, but the demands placed on them never seem to stop. "There is a great need for transporting more information around on chips," Brongersma says.

Source: Stanford University

APA citation: Engineers study whether 'light on a wire' is wave of future for circuitry (2005, March 16) retrieved 17 October 2021 from https://phys.org/news/2005-03-wire-future-circuitry.html