Scientists Move Optical Computing Closer to Reality

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(PhysOrg.com) -- Scientists at the University of Pennsylvania have theorized a way to increase the speed of pulses of light that bound across chains of tiny metal particles to well past the speed of light by altering the particle shape. Application of this theory would use nanosized metal chains as building blocks for novel optoelectronic and optical devices, which would operate at higher frequencies than conventional electronic circuits. Such devices could eventually find applications in the developing area of high-speed optical computing, in which protons and light replace electrons and transistors for greater performance.

Colleagues in the Department of Bioengineering, Alexander A. Govyadinov and Vadim A. Markel, also of the Department of Radiology at Penn, published the study in a recent issue of the journal *Physical Review B*.

Recent developments in nanotechnology have enabled researchers to fabricate nanoparticle chains with great precision and fidelity. Penn's research team took advantage of this technological advance by utilizing metallic nanoparticles as a chain of miniature waveguides that exchange light.

Currently, the advance is theoretical. But, from a practical standpoint, the creation of a metallic nanochain would provide the combination of smaller-diameter optical components coupled with larger bandwidth, making them optimal wave guiding materials. As the velocity of the light pulse increases, so too does the operating bandwidth of a waveguide.

Increasing the bandwidth helps to increase the number of information channels, allowing more information to flow simultaneously through a waveguide.

Researchers investigated changing the shape of particles in an attempt to increase this bandwidth. Spherically-shaped nanoparticles, the shape used almost exclusively in early research, provide narrow bandwidths of light. As Markel and Govyadinov discovered, shaping the particles as prolate, cigar-shaped or oblate, saucer-shaped, spheroids boosted the velocities of surface plasmon pulses reflecting off the surface to 2.5 times the speed of light in a vacuum.

Reshaping the nanoparticles therefore resulted in an enormous increase in the operating bandwidth of the waveguide. As an additional bonus, constructing the chains from oblate spheroids results in decreased power loss as well.

The exceptional combination of small size, large bandwidth and relatively small losses may make these useful as building blocks for the light-based devices of the future.

Researchers have used light and metal to create special electromagnetic wave of electrons on the surface called plasmons for years. Just as light travels through optical fibers, surface plasmons propagate along a chain of closely spaced, metallic particles with each particle acting like a miniature beacon, receiving a signal from its neighbor and transmitting it further along the chain. Although chains of metallic particles are not practical for long-range communication due to rapid power loss, they are well suited for optoelectronic and optical devices in which achieving a small overall size is important.

Markel and Govyadinov's theory may prove useful in overcoming sizing obstacles that complicate optics. Light cannot travel through an optical fiber if the fiber's diameter is smaller than a micron. A particle chain like the one proposed by Penn researchers, however, could be as thin as 50 nanometers in diameter, a few hundred times thinner than any optical fiber, and still guide the surface plasmon waves.

An interesting conundrum arises from the work. The theory of relativity prohibits anything from moving faster than light.

"But what is a 'thing'?" Markel said. "A very powerful flashlight directed at the moon would theoretically create a bright spot on its surface. By simply turning the flashlight sideways, the flashlight's beam streaks across the sky at speeds far exceeding the speed of light. This evidence has long been known and dismissed, since the bright spot cannot be used for superluminal, or faster-than-light communication, between the earth and the moon. The fast motion of the bright spot is simply a geometrical artifact, similar, in some ways, to the point at which the two blades of closing scissors intersect. The theory of relativity does not concern such purely geometrical objects."

The researchers believe there are, in fact, some superluminal "things" in nature. For example, it has been long theorized, and was demonstrated in a series of experiments in the last quarter of the 20th century, that electromagnetic pulses, or "wave packets," can propagate through material media with an overall velocity which is greater that the speed of light in vacuum. Although the superluminal wave packets cannot be used to transmit energy or information faster than the speed of light, and therefore do not contradict the theory of relativity, they are fascinating objects and can be utilized in optical communications.

The surface plasmon pulses discovered at Penn belong to the same class of superluminal wave packets. It is predicted that the superluminal properties of these pulses are much bolder than anything previously observed.

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