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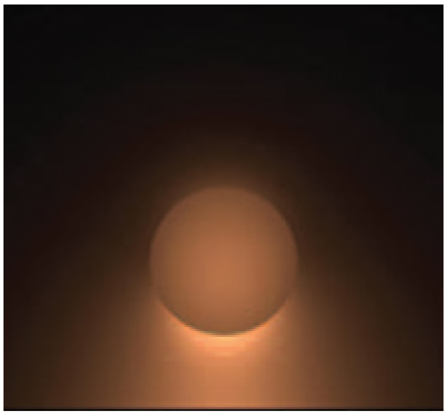
Compressing Light

A new way to confine light could enable better optical communications and computing.

By Lauren Rugani



Guiding light: Light can be compressed between a semiconductor nanowire and a smooth sheet of silver, depending on the nanowire’s diameter and its height above the metal surface. Here, light is confined in a 100-nanometer gap by a nanowire with a 200-nanometer diameter. Credit: Rupert Oulton, UC Berkeley

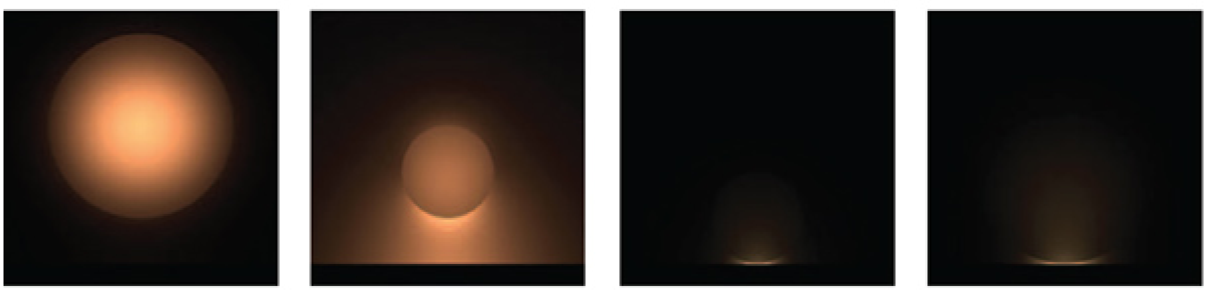
A new way to compress light, designed by researchers at the University of California, Berkeley, could make optical communications on computer chips more practical. The researchers developed computer simulations that suggest that it is possible to confine infrared light to a space 10 nanometers wide. What's more, unlike other techniques for compressing light, the configuration will allow light to travel up to 150 microns without losing its energy, which is key for small optical systems.

Scaling down optical devices is important for future optical communications and computing. Light-based communications use wavelengths on the order of microns to carry information, and they are successful in large-scale applications such as optical fiber networks that span oceans. But to transmit data over short distances, like between circuit components on a microchip, long-wavelength light must be squeezed into tiny spaces.

Previously, scientists have effectively shrunk light by converting it into waves that travel along the surface of metals. But these waves lose their energy before they can successfully carry information useful distances. Optical fiber, on the other hand, carries light over several kilometers without energy loss, but it cannot be miniaturized less than half the size of the wavelength.

The Berkeley researchers combined these techniques to both compress the light and allow it to travel far enough to transmit information on computer chips. They place a semiconductor nanowire, such as gallium arsenide, within nanometers of a thin sheet of silver. Without the nanowire, light converted into surface waves would spread out over the silver sheet, and the light energy would be quickly dissipated. But with the nanowire present, charges pile up on both the silver and the nanowire surfaces, trapping light energy between them. The nanowire has the effect of confining and guiding surface waves, preventing them from spreading out over the metal and dissipating the light energy.

Using computer simulations to tune both the diameter of the nanowire and the distance between the nanowire and the metal, the researchers found an optimal arrangement that would allow light to be squeezed into the smallest space possible while still retaining a sufficient amount of energy: a nanowire with a 200-nanometer diameter placed 10 nanometers above the silver surface would give the best combination of results for communications wavelengths of about 1.5 microns.



Shape shifting: Light is confined to different parts of the waveguide when the diameter or height of the nanowire changes. From left to right: light travels inside a 400-nanometer nanowire placed 100 nanometers above the surface; some light begins to travel between the nanowire and the surface when the diameter is reduced to 200 nanometers; when the nanowire is just two nanometers above the surface, light is trapped in the tiny gap for both 200-nanometer and 400-nanometer nanowires.
Credit: Rupert Oulton, UC Berkeley

This could truly enable a revolution in the [nanophotonics] field," says Marin Soljacic, a physics professor at MIT. For example, the resolutions of sensing and imaging techniques are limited by the wavelength of light they use to measure objects; anything beneath the resolution can't be seen. A device that confines light beyond its natural wavelength, however, could measure and return information about what lies beyond these limits.

The group is cautiously optimistic about its innovation. "This is probably our biggest breakthrough in the last seven or eight years," says Xiang Zhang, a professor of mechanical engineering at UC Berkeley, who led the research. "But we still have a long way to go." The researchers have already started to demonstrate in experimental devices the performance that their simulations predicted. However, they have only tested the devices with visible light frequencies, which are still hundreds of nanometers smaller than the infrared frequencies used in communications. And while a propagation distance of 150 microns is good, says Zhang, they want a distance of at least a millimeter for practical devices on integrated chips.

With continued refinement, the technique could play several roles in optical computing. The setup could be used to steer light through certain paths on chips. The group is even toying with the idea of using the device to produce an ultrasmall light source. Still, any practical devices are several years away. "They will have to master the fabrication," says Soljacic. "But the simulations seem convincing, and I have complete faith that it will work."