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Nanolasers Sneak Past Diffraction Limits

Yvonne Carts-Powell

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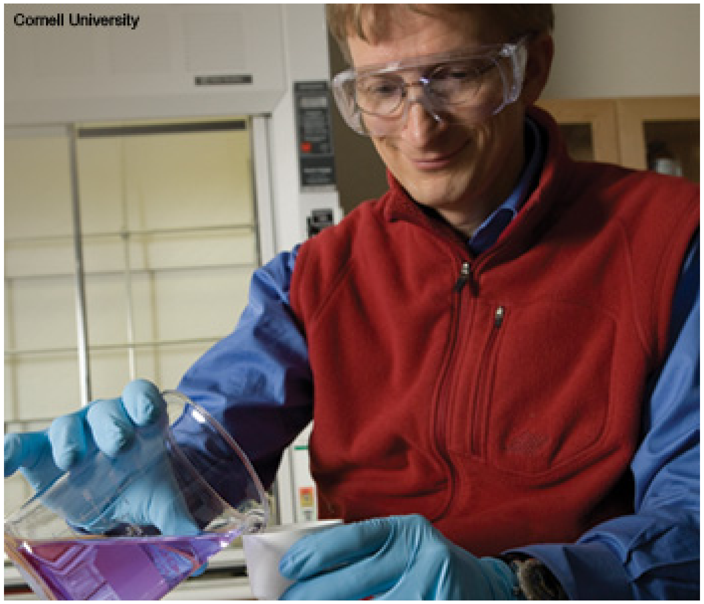
Within a month, two groups demonstrated visible-light lasers generated from devices far smaller than the light's wavelength. The area of the laser spot with either scheme is nearly 100 times smaller than the smallest spot to which a laser of this wavelength could be focused.



Ulrich Wiesner is part of a team of Cornell researchers who developed a tiny laser in collaboration with investigators from Purdue and Norfolk State.

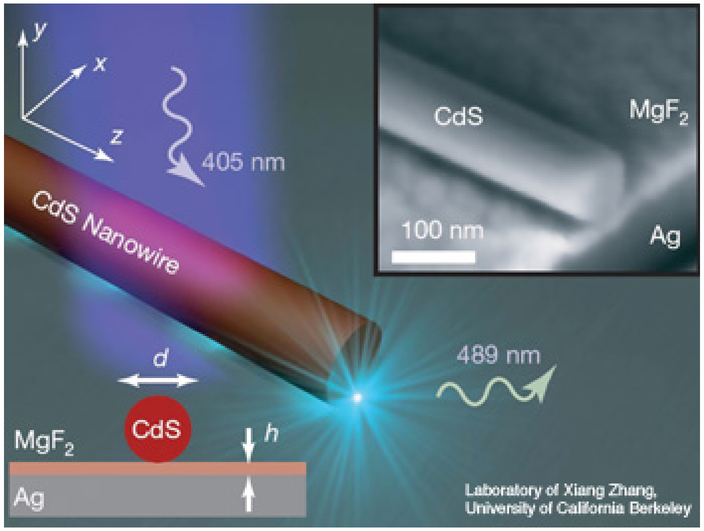
Such tiny lasers offer the potential to build optical devices on the same scale as the smallest electronics. They could be used for sensors, imagers and pieces of optical computers on the nanoscale. "We have demonstrated the feasibility of the most critical component—the nanolaser—essential for nanophotonics to become a practical technology," said OSA Fellow Vladimir M. Shalaev of Purdue University (U.S.A.).

The minimum physical size of conventional lasers (and the optical mode size) is limited to more than half the wavelength of the laser light. Surface plasmons, by contrast, can store optical energy in the electron oscillations at the interfaces of metals and dielectrics. The field is tightly confined to the surface—propagating fields are limited to a much smaller area than, say, optical fields can be restricted within waveguides. But amplifying plasmons has been difficult because of absorption in the metal. While theoretical papers have suggested ways of producing gain in the dielectric to overcome these losses, the current research experimentally demonstrates coherent stimulated emission from plasmons.

The group of researchers from Norfolk State, Purdue and Cornell (U.S.A.) recently demonstrated devices that can generate coherent plasmonic fields, analogous to the way a laser generates stimulated emission of coherent photons (Nature **460**, 1110). The "spaser" uses nanoparticles suspended in solution and pumped with visible light.

Co-author Shalaev explains that, in their setup, "the optical cavity is confined to the nanoscale in a sphere of 22 nm radius." Each nanoparticle includes a gold core, which provides the plasmon modes, surrounded by a silica shell doped with a green fluorescent dye, which provides optical gain.

The oscillating surface plasmon mode provides for the feedback needed to generate localized surface plasmons—in the researchers' terminology, a spaser. Furthermore, when the surface plasmons coupled out of the cavity, they turned into propagating photonic modes: visible coherent light at 531 nm.



Nanolasing occurs in the 5-nm gap—smaller than a protein molecule—between a nanowire and underlying silver surface. Inset: Electron-microscope image of the design.

Rupert Oulton and others at the University of California at Berkeley (U.S.A.), Lawrence Berkeley National Laboratory (U.S.A.) and Peking University (China) took a different approach (Nature **461**, 629). Instead of spheres in solution, they confine the field in two dimensions in a cadmium sulfide semiconductor nanowire. The wire end was placed within a few nanometers of a silver film, and the hybrid surface plasmon laser occurred between the two. Plasmon gain occurred in the nanowire—largely away from the metal. This arrangement allowed them to reduce the wire dimensions and the volume of the optical mode.

The next challenge will be electrically pumping the nanolasers, a task for which the semiconductor device may have an advantage over the nanospheres-in-solution approach.

Plasmon nanolasers could be used as smaller versions of conventional lasers for communications or computing. But they also present new possibilities. "Light that is generated and trapped within such tiny spaces can do interesting things," says Xiang Zhang of Berkeley. "For example, the interaction between light and matter can be strengthened. This means we could detect very weak effects—for example, detecting single molecules—allowing extremely sensitive bio-detection."

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2010 Massachusetts Ave., NW • Washington, DC 20036 USA
Phone 202.223.8130 • Fax 202.223.1096 • Monday-Friday, 8:30 a.m.-5:00 p.m. EDT
E-mail: opncomments@osa.org