Tiny “nanolaser” could change face of computing, telecom

Aug. 31, 2009
Courtesy UC Berkeley
and World Science staff

Researchers say they have created the world’s smallest semiconductor laser, a device that can generate visible light in a space smaller than a protein molecule.

“This work shatters traditional notions of laser limits, and makes a major advance toward applications in the biomedical, communications and computing fields,” said Xiang Zhang, head of the University of California, Berkeley research team behind the work.

Both pictures show a bright point of light from a single plasmon laser emanating from the optical setup used by UC Berkeley researchers. These semiconductor lasers -- the world's smallest -- are extremely efficient, so the small amount of scattered light is clearly visible, even in ambient room lighting. Camera saturation of the bright laser light gives the impression of a larger spot. (Credit: Courtesy of Xiang Zhang Lab, UC Berkeley)

The scientists said their work could help lead to applications such as tiny lasers that can probe, manipulate and measure properties of DNA molecules; optics-based telecommunications many times faster than current technology; and optical computing in which light replaces electronic circuitry, with a resulting leap in speed and processing power.

The findings were described in an advance online publication of the journal *Nature* on Aug. 30.

Light is an electromagnetic wave—an oscillation of the electric and magnetic fields that also drive the motions of electric currents.

It was long thought that an electromagnetic wave, including laser light, can’t be focused, or compressed, beyond the size of half its wavelength—literally the length of a wave in a series, from one wave peak to the next.

But researchers have previously found a way to compress light further, down to dozens of nanometers, or billionths of a meter. This was done by linking light to the electrons, or charge-carrying subatomic particles, that oscillate collectively at the surface of metals.

This interaction between light and oscillating electrons is known as surface plasmons.

Scientists have been racing to construct surface plasmon lasers that can sustain and utilize these tiny optical fluctuations. But the resistance inherent in metals makes these surface plasmons dissipate their energy very quickly, preventing the buildup of electromagnetic field necessary for lasers to be created.

Zhang and his research team took a new approach by pairing a wire of cadmium sulfide, 1,000 times thinner than a human hair, with a silver surface, the wire and surface being separated by an

insulating gap of 5 nanometers, the size of a protein molecule.

In this structure, the gap region stores light within an area 20 times smaller than its wavelength. Because light energy is largely stored in this tiny non-metallic gap, energy loss is greatly reduced, Zhang explained. The researchers could then work on amplifying the light, the key step to making a laser.

Fortunately, the tiny wire, or nanowire, "acts as both a confinement mechanism and an amplifier," said Rupert Oulton, a research associate in Zhang's lab who first theorized this approach last year and is the study's co-author.

Trapping and sustaining light in such tight quarters creates such extreme conditions that the very interaction of light and matter is strongly altered, the study authors explained. An increase in the spontaneous emission rate of light is a telltale sign of this altered interaction, they added; they measured a six-fold increase in the spontaneous emission rate of light in the gap.

Recently, researchers from Norfolk State University in Virginia reported lasing action of gold spheres in a dye-filled, glasslike shell immersed in a solution. The dye coupled to the gold spheres could generate surface plasmons when exposed to light.

The Berkeley researchers used semiconductor materials and fabrication technologies commonly used in modern electronics manufacturing. Semiconductors are materials whose ability to conduct electric charge is somewhere between that of metals and that of non-conductors, or insulators.

By engineering surface plasmons in the tiny gap between semiconductors and metals, they were able to sustain the strongly confined light long enough that its oscillations stabilized into the "coherent," or synchronized, state characteristic of a laser.

Scientists hope to eventually shrink light down to the size of an electron's wavelength, which is about a nanometer, so that the two can work together on equal footing. "The advantages of optics over electronics are multifold," added Thomas Zentgraf, a post-doctoral fellow in Zhang's lab and another co-lead author of the Nature paper. "For example, devices will be more power efficient at the same time they offer increased speed or bandwidth."