Researchers create faster, more efficient laser for communications

November 8 2005

Because light can carry huge amounts of data, lasers are vital components in modern communications. But to satisfy growing demand, lasers must become faster and more efficient. Current solid-state laser technologies—used in telecommunications and networking equipment—are reaching limits in their speed and efficiency. Now, a new laser technology developed by Stanford researchers could let communications progress shine on. In the Oct. 31 edition of the journal *Optics Express*, electrical engineering Assistant Professor Jelena Vuckovic and doctoral student Hatice Altug report a new type of solid-state laser that wastes less energy than competing laser technologies.

"A single-mode laser that can be turned on at low 'pump' powers, modulated, or turned on and off, at high speeds, and that can produce sufficiently high output powers is crucial for a number of applications," Vuckovic says.

The most immediate application would be in speeding up optical networks, such as those that carry phone conversations between cities or reams of data within corporate networks. The current technology, vertical cavity surface emitting lasers (VCSELs), is comparatively energy-inefficient and cannot generate data (i.e., be modulated) faster than 20 billion bits per second (bps). A telecommunications industry goal is to be able to transfer data at 40 billion bps in the near future. Vuckovic says her laser theoretically can operate at rates exceeding 100 billion bps, easily meeting industry needs.

Vuckovic and Altug also can build lasers that operate at different wavelengths, which could be useful for "multiplexing," or sending several different wavelengths of light—each one transmitting its own stream of data—down the same cable.

Crystal power

The new laser is based on a photonic crystal, a square layer cake of indium phosphide-based material that is 300 billionths-of-a-meter (nanometers) thick and that is etched to create an array of regularly spaced, 400-nanometer-wide holes through the cake. At regular intervals among the holes are areas where no hole has been etched, called microcavities, which trap light. The filling of the layer cake is four layers of indium gallium arsenide phosphide. Each layer is called a "quantum well."

How does the laser work? When Vuckovic shines pulses of light onto the crystal, the energy that the light "pumps" into the quantum wells excites them to emit light of a desired wavelength. That light then bounces around in the microcavities and back into the wells again, setting off a chain reaction of light emission from the crystal that produces a laser beam.

Researchers recently have made lasers using just a single photonic crystal microcavity in an attempt to outdo VCSELs. But single-cavity lasers are way too weak, emitting only a few billionths of a watt (a common light bulb emits 60 watts) when hundreds of millionths of a watt of light is pumped in. Vuckovic and Altug's laser successfully combines 81 microcavities (in a 9 by 9 array) to make it more powerful, and it operates with greater energy efficiency. In fact, in the experiments Vuckovic and Altug describe in the Oct. 31 paper, their laser was about 20 times as efficient as single-cavity lasers, putting out 100 times more power (12 millionths of a watt when pumped with 2.4 thousandths of a watt).

Moreover, the laser is small. About 400,000 lasers could fit within a square centimeter chip. Smaller chips may be less costly to make and easier to integrate into electronic devices.

Vuckovic and Altug still must demonstrate that their laser modulates faster than VCSELs, but there is strong reason to believe it can. In research published earlier in 2005, Vuckovic reported a technique for controlling the duration of light pulses emitted from photonic crystals, meaning she can turn photonic crystal light emission on and off at a rate exceeding 100 billion bps. The next step is to demonstrate that in a photonic crystal-based laser.

Vuckovic and Altug have several other projects ahead. One is improving laser energy efficiency further. They also want to power the laser with electricity rather than pumping it with light. Finally, they want to explore integrating the laser with computer chips to bring optical data transmission into computers, potentially speeding their operation.

"Various applications can benefit from improved lasers, ranging from optical telecommunications and optical computer interconnects to spectroscopic sensing and optical image processing," Vuckovic says. "We hope to see many of them in the near future."

Source: Stanford University (by David Orenstein)