Researchers use semiconductors to set speed limit on light

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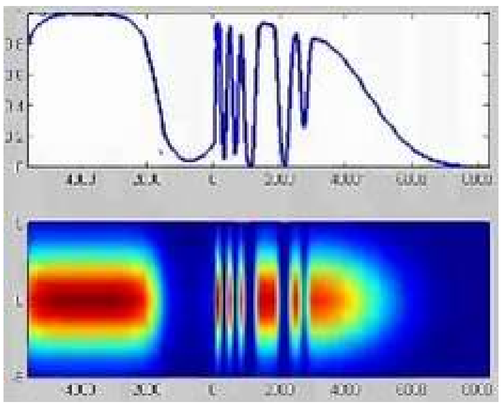

In a nod to scientific paradox, researchers at the University of California, Berkeley, have **slowed light down in an effort to speed up network communication**.

They have shown for the first time that the group velocity of light - the speed at which a laser pulse travels along a light wave - can be slowed to about 6 miles per second in semiconductors. While that speed is not exactly the pace of a turtle, it is 31,000 times slower than the 186,000 miles (or 300 million meters) per second that light normally clocks while traveling through a vacuum.

Image: Simulation of slow light as optical signal enters and exits *semiconductor quantum wells. (Video by Pei-Cheng Ku and Connie Chang-Hasnain)*

"It's about twice as fast as an orbiting space shuttle," said Connie J. Chang-Hasnain, UC Berkeley professor of electrical engineering and computer science and principal investigator of the project. "This achievement marks a major milestone on the road to ever faster optical networks and higher performance communications."

The researchers envision a future of 3-D graphics transmission, high-resolution video conferencing as good as face-to-face encounters and quantum memory chips that could boost the power of supercomputers, including those used for complex climate modeling.

Chang-Hasnain and other researchers at UC Berkeley's Department of Electrical Engineering and Computer Sciences describe their experiment in a paper published Oct. 1 in the journal Optics Letters. Co-authors of the paper include Hailin Wang at the University of Oregon and Shun-Lien Chuang at the University of Illinois at Urbana-Champaign.

Prior experiments in the past five years have demonstrated that light beams can be slowed or accelerated through atomic vapor as well as solid state crystal. Physicists at Harvard University have even managed to stop light particles in their tracks for 10-20 microseconds in rubidium gas.

The UC Berkeley-led team is the first to experimentally demonstrate slow light using thin layers of semiconductors.

"Semiconductors offer a critical bandwidth advantage over atomic vapor and solid state crystal," said Chang-Hasnain, who is also director of UC Berkeley's Center for Optoelectronic Nanostructured Semiconductor Technologies. "Semiconductors have 1 million to 1 billion times broader bandwidth capacity than atomic gas or crystal. This brings real-world practicality to telecommunication and network applications. Another advantage to using semiconductors is the possibility of cost-effective integration into circuitry, specifically photonic integrated circuits."

Currently, optical signals can zip along fiber at over 62,000 miles per second - until they reach one of the many junctions along the way. At that point, the light signals are converted to slower moving electronic data so they can be read by routers. The routers then direct the data to the correct path before converting the signals back to light. This optical-electronic-optical (OEO) conversion is incredibly slow and is expensive to power, the researchers say, resulting in huge bottlenecks and significant cost for the network.

"The routers are like traffic lights at motorway intersections," said Chang-Hasnain. "With OEO conversion, it's as if at every intersection, drivers would have to get out of their cars, speak with a traffic control officer, and fill out different forms indicating their destination before moving on. You would need to have traffic control officers who can speak different languages to communicate with all the different drivers. As a result, you end up with a huge traffic jam at each intersection."

Pei-Cheng Ku, lead author of the paper and a UC Berkeley post-doctoral researcher in electrical engineering at the time of the study, compares controlling light's velocity to installing brakes on a car. "Enabling drivers to adjust their speed is necessary so they can avoid colliding into one another; it's the same with optical signals," he said. "This would eliminate the need for traffic control officers, or electronic routers, by letting drivers stay in their cars."

"Right now, we are not taking full advantage of the 20 terahertz bandwidth that fiber can provide because of the limitations of these OEO switching systems," said Ku. "If we did, we'd be able to send 600 two-hour feature films in about 1 second."

Ku is careful to point out that the experiments do not violate the laws of physics, which state that the speed of light is a physical constant that cannot be changed. What can be, and has been, changed is the speed with which a light wave's amplitude, also known as the "envelope" of a wave, is transmitted.

All the "slow" and "fast" light experiments that have been conducted to date exploit the way light is absorbed and dispersed when it interacts with matter. In a technique called electromagnetically induced transparency (EIT), a "control" laser beam is fired into atomic vapor to interfere with the ability of the atoms to absorb light particles. Researchers then shine a "signal" beam into the vapor, which disperses the light pulses and dramatically slows them down. This is measured by an increase in the refractive index as it passes through the medium.

Other researchers, including the UC Berkeley-led team, have used a second method to demonstrate slow light called coherent population oscillation (PO). This involves simultaneously shining two laser beams - a "pump" beam and a less intense "probe" beam - of slightly different frequencies at a sample. The differing frequencies create a rhythmic beating pattern that creates light-slowing interference.

Semiconductor quantum wells were used as the sample in the UC Berkeley-led experiments. The device consisted of a thin layer of electron-confining gallium arsenide sandwiched between two relatively thicker layers of aluminum gallium arsenide.

The researchers conducted the experiments at the ultra-low temperature of 10 Kelvin, or minus 442 degrees Fahrenheit. They are currently working on using EIT in semiconductors to slow light down at room temperature.

Other researchers on the project are Forrest Sedgwick at UC Berkeley, Phedon Palinginis and Tao Li at the University of Oregon, and Shu-Wei Chang at the University of Illinois at Urbana-Champaign.

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Source: UC Berkeley