Team lets there be leisurely light

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Increasing interest has focused recently on ways of drastically slowing light or, more precisely, the speed of laser data pulses - and a joint USC/Duke University team has just reported improvements in a way to do this in a flexible and controlled manner.

The team was co-led by Alan Willner, a professor in electrical engineering at the University of Southern California Viterbi School of Engineering who specializes in photonics, the study of using light to carry and process information. The results appear in the current issue of the *Journal of Lightwave Technology*.

The key parameters are slowness of the light, maximum data modulation rate, and control of the delay. The new system, says Willner, "uses simple optical fiber and can potentially accommodate much higher data rates than the previous work using exotic atomic vapors. The slowing process in fiber can be readily controlled and can be compatible with ordinary transmission fiber."

"Beyond these advantages," continued Willner, "the experiments led to deeper understanding of the tradeoffs involved in slowing light without simultaneously distorting the data bits themselves."

The stakes are potentially huge. Laser light can carry an enormous volume of information optically via high-bandwidth optical fibers, but such signals invariably have to be converted back into electronic bits for most kinds of signal processing functions, such as data equalization, buffering, synchronization, and multiplexing.

"Photonics usually can't compete with electronics when it comes to processing data," says Willner, "because silicon transistors are extremely cheap and can perform processing operations that have long been very difficult to do with light."

But controlled slow light could alter this equation. European researchers Luc Thévenaz and Miguel Gonzalez-Herraez, who used a similar method that Willner explores, recently wrote that slow light could lead to "all-optical delay lines... Such devices could have important consequences for optical telecommunication and computer networks. If the complex functions of timing and routing could be performed all-optically, this would drastically boost performance and bridge the first gap towards all-optical logic functions and computation."

That light can be slowed has been known for centuries, Willner points out. Refraction, used to create lenses, is based on the fact that light travels more slowly in glass than it does in air. But the dramatic slowdown created by Willner's new techniques works on a relative slowdown of one wave relative to other waves.

Willner's system takes pulses of light lasting 75 picoseconds and delays them so they arrive 46 picoseconds later than they would untreated (1 ps = 1 trillionth of a second. 1 ps : 1 sec :: 1 sec : 31.688 years).

The slowing was achieved by controlling a phenomenon described 80 years ago by the French physicist Leon Brillouin, who noted that acoustic vibrations in transparent materials change the frequency of a light wave traveling through it. And the speed of a light wave in a material can be dependent on its frequency.

The USC/Duke collaboration employs a technique that makes use of a basic wave phenomenon: when two waves (of water, for example) overlap, they will "add" where both waves are high and produce a high peak water pulse. The velocity of this specific "addition point" pulse will slow down if the speeds of the individual water waves are not the same.

"In optical communications," explained Willner, "we can think of the data information as being represented by a series of light pulses. Each light pulse is really made up of many individual light waves, and the Brillouin effect ensures that each individual wave is traveling at a slightly different speed, thus making the specific 'addition point' data pulse slow down relative to the original waves."

The rate of optical data pulses in the Thévanez /Gonzalez-Herraez experiment was several hundred megabits per second. The USC/Duke result slowed the light for data rates of 14 gigabits per second, more than a 20-fold increase. They found that broadening the frequency bandwidth of the Brillouin-inducing beam could greatly increase the bandwidth of the slow-light process.

As noted, most previously published techniques for slowing light involved exotic and difficult conditions -- large chambers full of vapors of certain atoms, ultrachilled atoms of others, and exotic cryogenic crystal structures. Willner notes that while these remain interesting theoretically and can achieve dramatic slowing they are expensive, difficult to control and also unlikely to even potentially be part of useful real-world information systems.

By contrast new scattering method pursued by the USC/Duke team and others can take place in an enclosed module at room temperature.

Source: University of Southern California