Ten times more throughput on optic fibers

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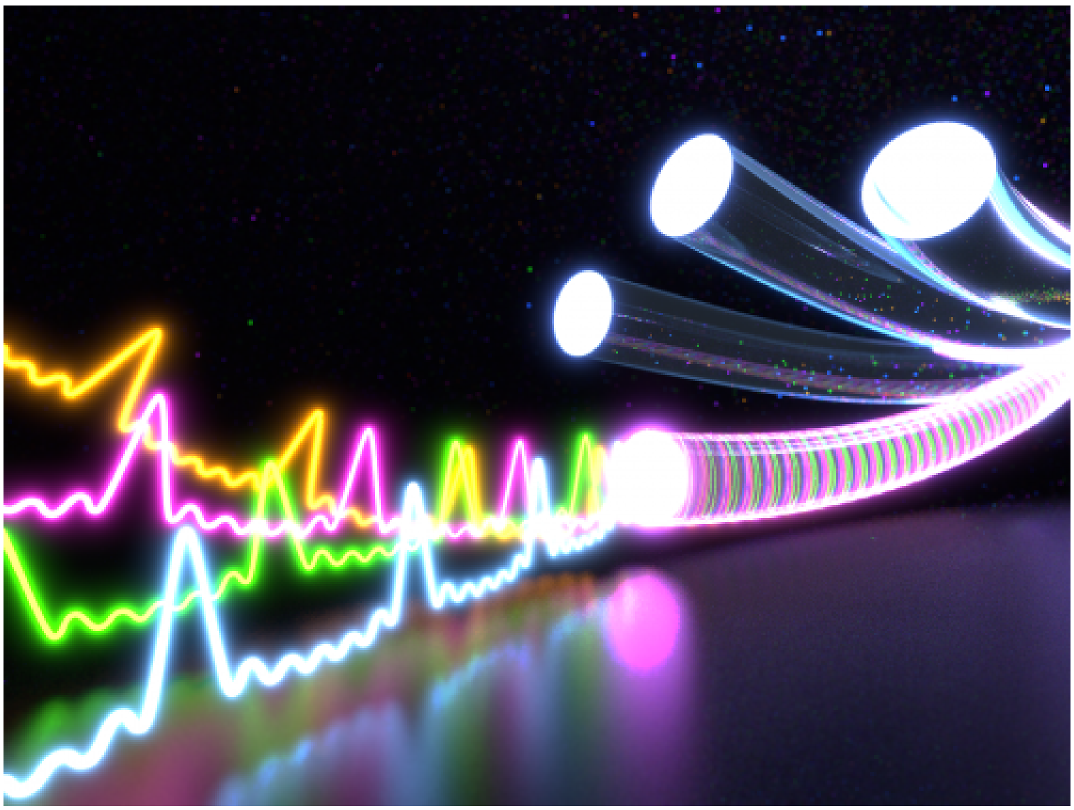

This is a graphical illustration of square-shaped light signals sent through an optic fiber for 10x-enhanced data throughput. Credit: Jamani Caillet / EPFL

Optical fibers carry data in the form of pulses of light over distances of thousands of miles at amazing speeds. They are one of the glories of modern telecommunications technology. However, their capacity is limited, because the pulses of light need to be lined up one after the other in the fiber with a minimum distance between them so the signals don't interfere with each other. This leaves unused empty space for data in the fiber.

EPFL's Camille Brès and Luc Thévenaz have come up with a method for fitting pulses together within the fibers, thereby reducing the space between pulses. Their approach, which has been published in *Nature Communications*, makes it possible to use all the capacity in an optical fiber. This opens the door to a ten-fold increase in throughput in our telecommunications systems.

Fiber optics at a crossroads

"Since it appeared in the 1970s, the data capacity of fiber optics has increased by a factor of ten every four years, driven by a constant stream of new technologies," says Camille Brès, of the Photonics Systems Laboratory (PHOSL). "But for the last few years we've reached a bottleneck, and scientists all over the world are trying to break through."

There have been several different approaches to the problem of supplying more throughput to respond to growing consumer demand, but they often require changes to the fibers themselves. That would entail pulling out and replacing the existing infrastructure. Here, the EPFL team took a different approach, looking at the fundamental issue of how to process the light itself, i.e., how best to generate the pulses that carry the digital data. This approach would not entail a need to replace the entire optical fiber network. Only the transmitters would need to be changed.

Traffic problems on the information superhighway

In modern telecommunications exchanges, for example when two cell-phones are communicating with each other, the data are transported between the two antennae on optical fibers, by means of a series of light pulses that form codes.

Simply put, an "on" pulse corresponds to the number 1, while an "off" pulse corresponds to 0. The messages are thus sets of ones and zeros. These codes are decoded by the receiver, providing the initial message. The problem with this system is that the volume of data transmitted at one time can't be increased. If the pulses get too close together, they no longer deliver the data reliably. "There needs to be a certain distance between each pulse, so they don't interfere with each other," says Luc Thevenaz, of EPFL's Fiber Optics Group (GFO). However, the EPFL team noticed that changes in the shape of the pulses could limit the interference.

Pulses that fit together like a jigsaw puzzle

Their breakthrough is based on a method that can produce what are known as "Nyquist sinc pulses" almost perfectly. "These pulses have a shape that's more pointed, making it possible to fit them together, a little bit like the pieces of a jigsaw puzzle lock together," says Camille Brès. "There is of course some interference, but not at the locations where we actually read the data."

The first to "solve" the puzzle

The idea of putting pulses together like a puzzle to boost optic fibers' throughput isn't new. However, the "puzzle" had never been "solved" before: despite attempts using sophisticated and costly infrastructures, nobody had managed to make it work accurately enough - until now. The EPFL team used a simple laser and modulator to generate a pulse that is more than 99% perfect.

Fine-tuning the system

Practically speaking, the shape of pulse is determined by its spectrum. In this case, in order to be able to generate the "jigsaw puzzle," the spectrum needs to be rectangular. This means that all the frequencies in the pulse need to be of the same intensity. Professors Brès and Thévenaz had this in mind when modulating their lasers.

Simple lasers are generally made up essentially of just one color - i.e., one optical frequency - with a very narrow spectrum. This is rather like a violin that has only one string. However, a laser can be subtly modulated (using a device called a modulator) so that it has other colors/frequencies. The result is a pulse composed of several different colors, with a larger spectrum. The problem is that the pulse's main color generally still tends to be more intense than the others. This means the spectrum won't have the rectangular shape needed. For that, each color in the pulse needs to be of the same intensity, rather like getting the strings of a violin to vibrate with the same force, but without making any other strings nearby vibrate.

The team thus made a series of subtle adjustments based on a concept known as a "frequency comb" and succeeded in generating pulses with almost perfectly rectangular spectrum. This constitutes a real breakthrough, since the team has succeeded in producing the long-sought-after "Nyquist sinc pulses." Professor Thévenaz recounts how it all started: "Camille and I were talking with a Visiting Professor at the University of Leipzig, and we realized that by teaming up we might be able to develop this new approach."

The technology is already mature

The new pulses could well generate interest among many telecommunications-industry market participants. The technology is already mature, as well as 100% optic and relatively cheap. In addition, it appears that it could fit on a simple chip. "It almost seems too good to be true," says Prof. Thévenaz.

Provided by Ecole Polytechnique Federale de Lausanne

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