Illuminating numerical study on light propagation in nonlinear optical fibers

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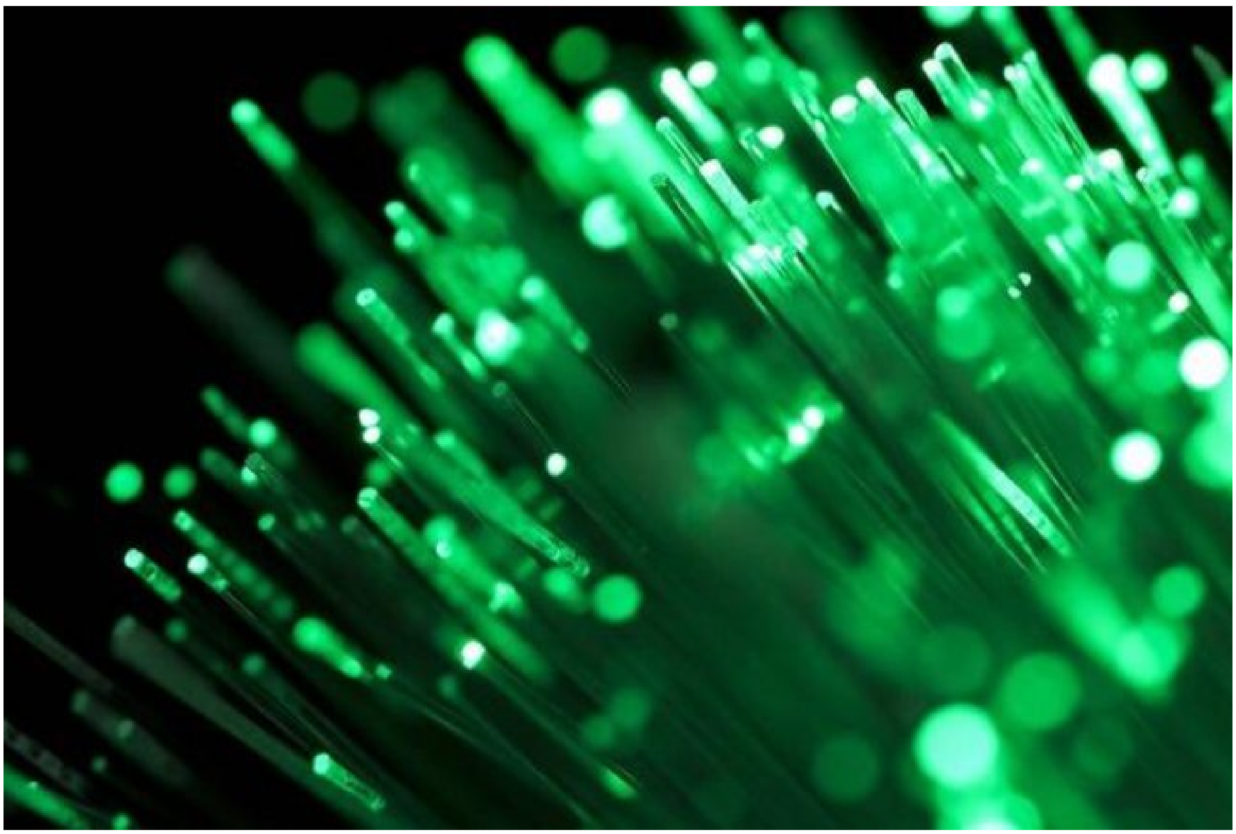

Credit: Eindhoven University of Technology

More than 99% of our Internet data is carried by optical fibers but with our data demands increasing, we are pushing our existing fiber networks to their limits. One way to increase the capacity of fibers is to transmit signals with a higher power, but this is usually avoided as transmissions can become distorted. To help with this, researchers at Eindhoven University of Technology have developed a new mathematical tool to better explore how light propagates through optical fibers in this high power, or nonlinear, regime. This new tool could help in the design of the next generation of data transmission optical fiber networks. Results are published in *Nature Communications*.

Today, large amounts of data are transmitted via optical fibers such as the single mode optical fiber (SSMF). Typically data signals are carried in the low power, or linear, regime. This type of light propagation through fibers can be modeled quite well using the Schrödinger wave equation, a key element of quantum physics. But when signal intensity is increased to transmit signals over further distances, nonlinear effects become an issue. Existing mathematical tools cannot provide reliable solutions for signal transmission, so researchers currently have a poor understanding of what happens to light in the nonlinear regime.

"When light moves through optical fibers such as SSMFs in the nonlinear regime, we must contend with nonlinear and dispersion effects", says Vinícius Oliari from Eindhoven University of Technology. High intensity light can change the refractive index of the fiber, which is responsible for the nonlinear effect known as self-phase modulation, while dispersion is the spreading out of light over time as it moves through a fiber, which can be a serious issue over large distances. Nonlinear effects can also increase signal bandwidth, which could increase the costs of many fiber systems.

Guiding future designers

Oliari and Alex Alvarado from the Department of Electrical Engineering, along with Erik Agrell at Chalmers University of Technology in Gothenburg, Sweden, have developed a new mathematical model that can accurately describe the propagation of light signals in fibers subject to nonlinear effects. "In the future we will need low cost, reliable receivers that can handle large amounts of data transmitted in the nonlinear regime. Our model can help engineers to design devices that function best in this regime", says Oliari.

Their model applies regular perturbation theory, which can be used to solve complicated equations by starting with the solution to a similar equation. To test the accuracy of the model, the researchers focused on fiber lengths up to 80 kilometers. "An optical fiber length between 20 and 40 kilometers can be found in passive optical networks that deliver broadband signals to homes, while 80 kilometer is the typical distance between amplifiers used in long distance transmission", adds Oliari.

Major step

The researchers compared their model with three other models used to simulate light propagation in optical fibers and found that their model more accurately captured highly nonlinear and weak dispersive effects on signals.

While the application of the model is limited to cases with low dispersion and fiber lengths less than 80 kilometers, the model can have far reaching implications for fiber networks. The authors also point out that this model can be applied to other systems where the nonlinear Schrödinger equation can be used. "Before we can start taking advantage of the nonlinear regime, we need to further our understanding. This model is a major step in that direction", according to Oliari.

More information: Vinícius Oliari et al. Regular perturbation on the group-velocity dispersion parameter for nonlinear fibre-optical communications, *Nature Communications* (2020). DOI: 10.1038/s41467-020-14503-w