1970s technology solution to Internet 'capacity crunch'

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Fibre optical cables

Exactly 50 years ago, Noble prize winner Charles Kao and his colleagues demonstrated the feasibility of using fibre optical cables to transmit information over long distance.

The sudden jump in capacity was so massive that many thought we could not possibly exhaust it. Yet, last year, prominent researchers and policy makers convened at the Royal Society to discuss the imminent "capacity crunch"—a phrase that attracted much attention and is slowly building presence in our common experience as we want better, faster Internet and pervasive, instant connectivity to the global network.

To keep optical communications technology, which carries 99% of global data traffic, ahead of the projected growth in demand for bandwidth, researchers have turned their attention to tackling nonlinear distortions of signals traveling in fibre cables that are now the main showstopper for the continued expansion of data transmission rates. A team of leading researchers in the UK at Aston Institute of Photonic Technologies and UCL, who conduct joint research under the EPSRC funded UNLOC programme, used a technique called "optical phase conjugation" to effectively reduce the undesirable effect of nonlinearities in a very high-capacity transmission link achieving up to a 60% increase in the distance which information could travel and still be successfully received.

"Optical phase conjugation" (OPC) is a method in optics to undo distortions in optical waves introduced by the medium in which they travel. It has been known for several decades, but until now, it had not been tested in optical communication systems with data rates on the order of Tb/s, which are expected for next-generation communications technology and were recently demonstrated by UNLOC. In this study, published in the *Journal of Lightwave Technology*, UNLOC researchers used a single OPC device in a 2,000km fibre link to show for the first time that OPC can successfully deal with nonlinearities, improving signal quality and allowing information to travel much further.

OPC and another technique known as "digital back propagation" (DBP) have recently emerged as the two most promising approaches to minimizing nonlinearities in optical fibres. Each comes with its advantages and disadvantages, but as communication links become more wide-bandwidth, OPC becomes very attractive. "Unlike DBP, which requires massive processing power for high-capacity links, leading to prohibitive increase in energy consumption, a single OPC device can handle large bandwidths and multiple channels simultaneously," said Professor Andrew Ellis, who led this experiment.

The main drawback of OPC is that it requires a symmetry in the transmission link, which is very hard to achieve practically. This symmetry is needed because an OPC device (always installed in the middle of a link) manipulates optical signals in a way that allows them to "erase" distortions and noise accumulated in the first half of the link as they travel through the second, provided that the signals see the same medium along the way. "This is identical to Netwon's prisms, where the first of two identical prisms spreads white light out into a rainbow, and the second inverted prism collects the colours back together again. However, since we don't yet know how to build an "inverted fibre" we need to use a special "mirror," the optical phase conjugator, to perform this trick," said Prof. Ellis.

Current commercial optical communications systems installed at the bottom of the ocean use amplifiers at regular intervals to boost the signal as it travels through the fibre. As they amplify the signal at various points along the fibre, they break the symmetry in a transmission link crucial for OPC to operate effectively. However, as optical amplification technology improves and new types of components like Raman amplifiers, which use the entire cable to provide the amplification, slowly enter the market, it is expected that the symmetry challenge will be largely resolved.

The UNLOC team has also developed an analytical model to analyse OPC performance in multiple system configurations. "The road from here to commercially deployed OPC technology is not that long," said Professor. Ellis. "Some product development is clearly needed, but we are now really only waiting for the market demand to catch up with the technology, which it will within a couple of product cycles."

More information: Andrew Ellis et al. 4 Tbit/s transmission reach enhancement using 10x400 Gbit/s super-channels and polarization insensitive dual band optical phase conjugation, *Journal of Lightwave Technology* (2016). DOI: 10.1109/JLT.2016.2521430

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