# Daring to dream

The origins of optical fibre communications lie with a paper published 50 years ago.

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This month marks the 50th anniversary of the publication of a visionary paper that was pivotal to the birth of long-distance optical fibre communication, earning Charles Kao one half of the 2009 Nobel Prize in Physics.

Paper 5033E 'Dielectric-fibre surface waveguides for optical frequencies' by Charles Kao and George Hockham (pictured), two scientists from the Standard Telecommunications Laboratories (STL) in Harlow, UK, was first published in the July edition of the Proceedings of the Institution of Electrical Engineers (IEE)[1].

The paper ultimately became an important landmark because it formally presented the concept and transmission properties of core-clad dielectric waveguides for carrying light — in essence, providing the blueprint for modern-day optical fibres. Today, optimized, ultralow-loss versions of these fibres circumnavigate the world in a vast web of glass that supports the global Internet and makes high-quality voice and data connectivity an expectation that everyone takes for granted.

Significantly, Kao and Hockham provided a theoretical analysis of transmission properties of their core-clad waveguides at optical frequencies including loss, dispersion, modal behaviour, power handling and information capacity, and a discussion of how they could be fabricated. The paper made the bold claim that such fibres held true potential as a practical means of communication by light if their transmission loss could be reduced to around 20 dB km$^{-1}$.

Hockham and Kao presented some preliminary optical experiments with short lengths of their core-clad fibres with cores ranging in size from 3–13 μm using narrowband light from a red (632.8 nm) HeNe laser and a gallium arsenide semiconductor laser as sources of an optical signal. The experiments clearly demonstrated the existence of patterns of propagating modes supported by the fibres, showing that they were guiding light as predicted. In what turned out to be a visionary statement, the paper's conclusions predicted with startling clarity and foresight the birth of optical fibre communications.

"Theoretical and experimental studies indicate that a fibre of glassy material constructed in a cladded structure with a core diameter of 100 lambda represents a possible practical optical waveguide with important potential as a new form of communication medium. The refractive index of the core needs to be about 1% higher than that of the cladding," stated Kao and Hockham.

Encouraged by the paper's results, which were presented at an IEE meeting on 27 January 1966, STL decided to issue a press release. At this stage, the paper was still undergoing review and revision prior to its publication that summer (it had been originally submitted to the IEE in November 1965).

The press release stated that these prototype fibres "exhibited an information-carrying capacity of one Gigacycle, which is equivalent to about 200 television channels or over 200,000 telephone channels." It also stated in a footnote "when these methods are perfected, it will be possible to transmit very large quantities of information (telephone, television, data, etc.) between say, the Americas and Europe, along a single undersea cable."

Interestingly, the press release appeared to largely fall on deaf ears and received little attention and acclaim at the time.

"When the Kao and Hockham paper finally appeared, it also made no discernible mark even in the technical press," wrote Jeff Hecht in his extensively researched and beautifully written book *City of Light: The Story of Fiber Optics*[2], which charts the origins and development of optical fibre communications. "After all, in 1966 satellites were the future of telecommunications."

The true impact of optical fibres didn't really materialize until the optical loss was substantially reduced from the initially enormously high value of the order of 1,000 dB km$^{-1}$. It was left to intensive research from other labs around the world, in particular at the US glass maker Corning, inspired by the work at STL, to improve the quality of the glass used in the fibres and their fabrication process. By 1970, Bob Maurer, Peter Schultz and Donald Keck at Corning had managed to make a single-mode fibre from glass with a loss of just 16 dB km$^{-1}$ by doping with titanium. Two years later, the same Corning team improved this to just 4 dB km$^{-1}$ using Ge doping and had identified traces of water as being a major source of the remaining loss. By the end of the 1970s, the Japanese national telecom company, NTT, was successful in fabricating a fibre with a loss of just 0.2 dB km$^{-1}$ at a wavelength of 1,550 nm.

Combined with the developments in the laser diode as a convenient and practical source of light for carrying data signals, the seeds for the dawn of the optical communications revolution had been sown. The invention of the erbium-doped fibre amplifier — a fibre device that could directly amplify optical signals once they were weak — in the late 1980s by scientists at the University of Southampton, UK, and independently at Bell Labs, US, was the final piece of the jigsaw. The era of the optical Internet had arrived. ❐

### References


1. Kao, K. C. & Hockham, G. A. *Proc. IEE* **113,** 1151–1158 (1966).
2. Hecht, J. *City of Light: The Story of Fiber Optics* (Oxford Univ. Press, 2004).