Kuen Charles Kao

(1933–2018)

Engineer who proposed optical fibre communications that underpin the Internet.

Today, fibre-optic cables carry more than 95% of all digital data around the world, underpinning the Internet. In 1966, it was Kuen Charles Kao (Charlie to his colleagues) who proposed the use of optical fibres as a universal medium for communication, and calculated how it might be done. Given the rudimentary technology available at the time, it was a leap of imagination, bordering on science fiction. For this work, Kao won a share of the Nobel Prize in Physics in 2009.

Kao was born on 4 November 1933 into Shanghai high society, to an academic lawyer father and poet mother. Introverted and geeky, Kao was educated at home with his younger brother Timothy before going to French- and English-speaking schools. In 1953, he moved to England to study at Woolwich Polytechnic (now the University of Greenwich in London).

Graduating in electrical engineering in 1957, he joined Standard Telephones and Cables, part of the conglomerate International Telephone & Telegraph (ITT). There he met his wife, fellow engineer Gwen Mae-wan Wong. He turned down a lectureship at Loughborough Polytechnic, UK, to do an industrial PhD in the company's research arm — the Standard Telecommunication Laboratories (STL) in Harlow, UK. Similar to Bell Labs in the United States (although less well funded), STL was a nursery for future academic and industrial leaders, heady with creativity, camaraderie and resourcefulness. Kao joined the group of Toni Karbowiak, working alongside another British telecommunications pioneer, Alec Reeves.

At the time, telecommunications used coaxial electronic cables or broadcast radio signals in the megahertz frequency range. Growing demand for information transfer meant moving to higher, microwave frequencies (gigahertz), with major research programmes set up around the world to find a way to guide signals from source to destination. The front-runner technology was hollow metal waveguides, pioneered in the 1950s by Harold Barlow, Kao's external PhD supervisor at University College London. Costly and impractical, these metal tubes needed to be laid in straight lines. Karbowiak, a seasoned microwave engineer and former PhD student of Barlow, knew that new ideas were needed.

In the early 1960s, just as the laser came about, Karbowiak asked Kao to look at an optical analogue of a microwave waveguide. Optical signals have an even higher frequency (hundreds of terahertz), and so can carry

more information. The idea of making a waveguide for the transmission of light over hundreds of kilometres was breathtaking. It meant shrinking the waveguide from a few centimetres across to something as thin as a human hair, just 100 or so micrometres wide. Glass was the most optically transparent material known, and had the advantages of being potentially flexible and resistant to lightning. But could it be made pure and clear enough? George Hockham, a talented young theorist, was assigned to help Kao.

They started pragmatically; given the power available from the earliest lasers of the time, the sensitivity of detectors, and the distance between UK telecommunications switching centres, they calculated that a signal could afford to lose only 20 decibels (a logarithmic measure of power) per kilometre travelled — equivalent to a 99% power loss after 1 km. This was an ambitious target: the best glasses at the time had losses some 10^{98} times greater, of around 1,000 dB km^{-1}. Kao systematically analysed the absorption, reflection and scattering of different glasses, while Hockham did waveguide-dimension calculations. Their landmark 1966 paper concluded that the task, although difficult, was theoretically possible (K. C. Kao and G. A. Hockham *Proc. Inst. Electr. Eng.* **113**, 1151–1158; 1966).

The paper went almost unnoticed, except at the research labs of the UK General Post Office (the telecommunications arm of which later became British Telecom, now BT) and the Ministry of Defence. Both organizations set up research programmes in this area, attracted by the idea of a lower-cost alternative to microwave waveguides.

But there was much scepticism — the gap between theory and practice was huge. To convince others, Kao measured the losses in the purest glasses he could find, now aided by Mervin Jones (Hockham left to start his own antenna-technology research group in 1967). They devised a complex and elegant set-up to measure very low values of loss in rods of fused silica glass about the length of a ruler. They published their results in 1969 (M. W. Jones and K. C. Kao *J. Phys. E Sci. Instrum.* **2**, 331; 1969). The following year, Robert Maurer's group at US firm Corning Glass broke the 20 dB km^{-1} limit in optical fibres of around 1 km long. Together with reports of the first continuous-wave room-temperature semiconductor laser in 1970, this convinced the doubters, sparking research efforts worldwide.

The optical fibre revolution had begun. Much of the work was done at STL and at the Post Office research labs in Britain, in fierce competition with Bell Labs and the US telecommunications firm AT&T. In 1977, the UK Post Office was the first to install optical fibres in its telecommunications network. The first transatlantic system followed in 1988.

From 1970 to 1974, Kao set up the electrical engineering department at the Chinese University of Hong Kong (CUHK), returning to STL in the holidays to keep abreast of research. In 1974, Kao went to work for ITT in the United States, where he rose to director of corporate research in 1985. In 1986, he returned to CUHK as its vice-chancellor, where, for nine years, he used his connections to strengthen the university's research base and make it internationally competitive.

In the mid-2000s, Kao developed Alzheimer's disease. He attended the 2009 Nobel award ceremony and celebrations afterwards, always bearing a smile, but his Nobel speech was read by his wife Gwen. He died in Hong Kong on 23 September.

Kao's legacy is hard to overestimate. Today, his 1966 predictions have been exceeded by six orders of magnitude, with fibre losses of less than 0.15 dB km^{-1}. Kao's determination inspired those of us who worked at STL right up to its closure in 2009. The site, now a technology business hub, is named Kao Park in honour of its most famous resident. ■

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