Optical communication systems serve as the backbone of today's technologies

By **Rahul Rao**

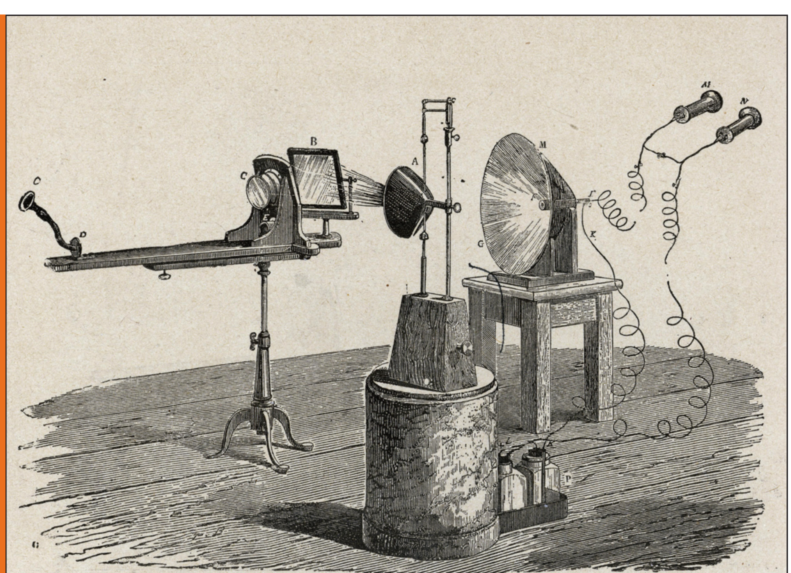
Optical fibers quietly underpin much of the world's Internet and telecommunications infrastructure. Compared to traditional copper cables, bundles of optical fibers transmit signals more quickly, with less attenuation over long distances, and suffer from far less electrical interference; they are also far more difficult to wiretap and far less valuable to scrap thieves. Optical fibers also have widespread use as sensors and in imaging difficult-to-reach spaces.

Generally, optical fibers consist of a dielectric core, often silica glass, nested within a slightly less refractive cladding. Since the core has a higher index of refraction than the cladding, light remains within the core, guided along the core's path. This property is called internal reflection; it is the same property that makes the surface of a body of water mirror-like when viewed from underneath.

Internal reflection had been understood for centuries before the possibility of harnessing it to catch and transfer light was demonstrated in Europe in the mid-19th century. In 1842, Jean-Daniel Colladon found that if he projected light into a stream of water, the light would keep within that stream. In 1854, John Tyndall advanced Colladon's "light fountain" by showing that light would even bend with that stream if it curved.

Tyndall suggested that glass could similarly be used to guide light; by the turn of the century, glass light tubes became commonplace. One inventor, William Wheeler, created a home lighting system that piped light from an electric-arc lamp through reflective-coated glass tubes. Light tubes found widespread use in medical applications: bent glass rods could be used as surgical lamps or to illuminate otherwise inaccessible parts of the body.

Even in the 19th century, some scientists realized that light could be used to carry information. For instance, in 1880, Alexander Graham Bell, four years after being credited with inventing the telephone, created a wireless device called the "photophone." Bell's device could transmit sound, much like a telephone, by modulating a beam of sunlight across air to a receiver. But the photophone never stuck, partly because its aerial transmissions were vulnerable to weather interference.



In 1880, Alexander Graham Bell transmitted a wireless telephone message on his "photophone," a device that allowed for the transmission of sound on a beam of light. Credit: AdobeStock.

Something more like modern fiber optics came in 1930, when a medical student in Munich named Heinrich Lamm wanted to build a better endoscope for viewing internal body parts. Lamm used a comb to arrange several hundred glass tubes into a bundle that could transmit images, each tube effectively transmitting a single pixel. Even though Lamm's image was faint and its quality poor, he'd still created a primitive fiber-optic imaging device. But Lamm was unable to patent his work, and subsequently, it was largely forgotten.

The work on optical transmission that resulted in modern fiber optics only took off after the Second World War. At the Technical University of Delft in The Netherlands, Abraham van Heel began to bundle glass fibers to transmit images, independent from but not unlike Lamm's earlier efforts. But in 1953, van Heel took the step of cladding his fibers in a transparent material, drastically reducing the amount of information that leaked out.

Simultaneously, at Imperial College London, Harold Hopkins and his graduate student Narinder Singh Kapany were working to build an endoscope, again similar to what Lamm had done two decades earlier. Kapany would go on to coin the term "fiber optics" and was largely the figure responsible for placing the subject in scientific conversation.

By the 1960s, the British center of fiber-optics research had moved to Standard Telecommunication Laboratories (STL), located in Harlow, Essex. In a 1966 press release, STL boldly claimed that with optical fiber cables, "it will be possible to transmit very large quantities of information … between say, the Americas and Europe, along a single undersea cable."

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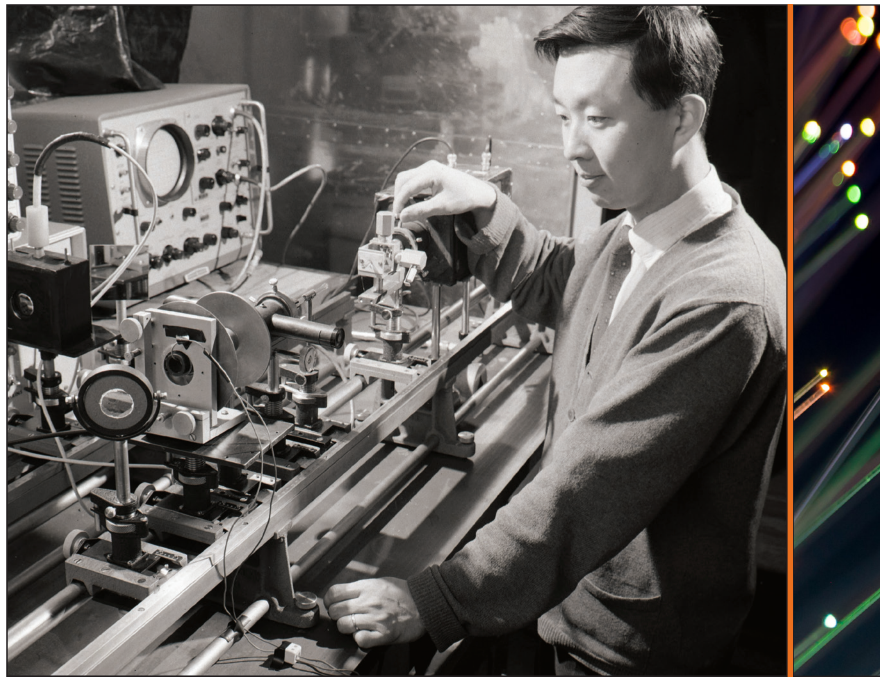
But the optical transmission system still faced a major obstacle: signal loss. The optical fibers of the early 1960s lost one decibel every meter or 1000 decibels every kilometer. This was adequate for short-range applications, such as medical imaging, but to achieve STL's dreamy ambitions of transmitting signals across oceans, optical fibers needed standards several orders of magnitude higher: under 20 decibels of loss per kilometer.

Researchers at the time believed much of the loss was because of the fundamental physics of transmitting signals through glass, but Charles Kao, the leader of STL's optical communications research, believed that much of the signal attenuation could be eliminated by eliminating impurities in the glass itself.

Kao pinpointed fused silica, a high-purity form of glass ideal for optical transmission, as a potential material. In 1970, after several further years of experimentation, a team at Corning created a fused silica fiber, its core doped with titanium to make it more refractive. The resultant fiber had a signal loss of 17 decibels per kilometer—matching Kao's specifications. For his involvement in the process, Kao would later earn the 2009 Nobel Prize in Physics.

Within several years, fiber-optic communications would leave the laboratory far behind. One of optical fibers' earliest commercial adopters was the Dorset Police in the United Kingdom, who in 1973 installed a fiber link in their headquarters as a replacement for an older communications system that had been destroyed by lightning. In 1977, the first live telephone fiber links were installed in several locations, including Turin, Italy, Long Beach, Calif., USA, and downtown Chicago, Ill., USA.



In 1965, Charles Kao conducted early experiments on optical fibers at the Standard Telecommunication Laboratories in Harlow, Essex, UK. Credit: Nano Technology Science Education (NTSE).

Despite an early attempt at laying a seafloor cable in the Canary Islands failing because sharks ate part of the cable, it would only take until 1985 for an undersea link between the United Kingdom and Belgium to begin transmission. The goal of a transoceanic fiber-optic cable was finally achieved in 1988, when TAT-8 was laid across the North Atlantic, linking France, England, and New Jersey.

By the early 1990s, TAT-8 would soon become a key backbone linking the North American and European areas of the fledgling Internet—effectively placing the first of many such backbones that exist today. □

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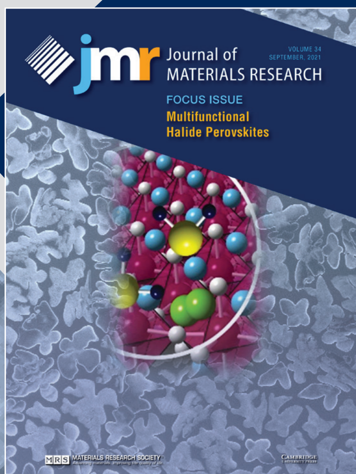

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