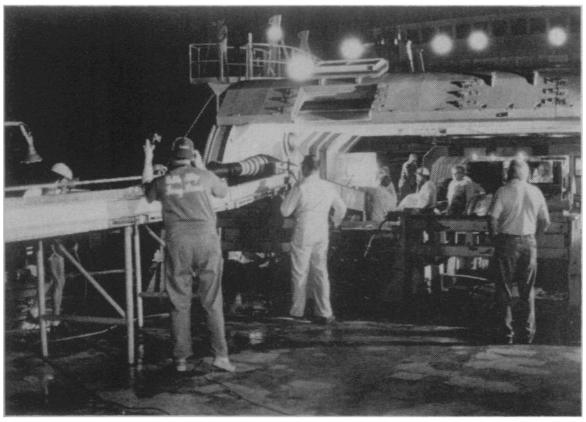
Tomorrow's Telephony: Light and Clear

Digital pulses of light in glass fibers engineered for virtually error-free transmission are bidding to replace electric signals in copper wires



Cable for undersea use made of single-mode fibers was tested on the bottom of the North Atlantic. Here it is being payed off the stern of the cable ship Long Lines.

By DIETRICK E. THOMSEN

"What hath God wrought?" was the first message transmitted by electrical pulses in metal wires between major cities in the United States. It went in 1844 from Washington to Baltimore over Samuel F.B. Morse's telegraph. There were contemporary parallel developments in England, and the English claim priority over Morse for the invention. In any case, these events inaugurated an era in which a large part of the world's long-distance communication came to be carried by electric pulses in copper wires.

Today we may be seeing the beginning of the end of that era. Technology that transmits messages by light pulses moving in glass fibers is now being installed in several of the world's telephone systems, and the day may come when optical fibers have driven electric wires completely out of the field. The basic reason for the change is that light can transmit messages faster and more accurately than can electrical pulses. (Electrical pulses consist of electrons, which have mass and therefore move more slowly and cost more energy to start, stop and reverse direction than the massless photons that make a light pulse.) The fibers and the cables made from them are also much thinner than electric wires and cables, and that is an advantage in high-traffic areas where ducts and rights of way are already stuffed to capacity with cable.

Even as this technology is beginning to be deployed it is undergoing changes toward greater speed and greater efficiency under the pressure of the needs of the business. The trend is toward fibers that transmit only a single vibrational mode of the light rather than the multimode fibers with which the technology began and toward digital transmission of messages rather than the analog transmission traditional in electric telephony. Much of the talk at the recent Topical Conference on Optical Fiber Communications in New Orleans was on these two topics.

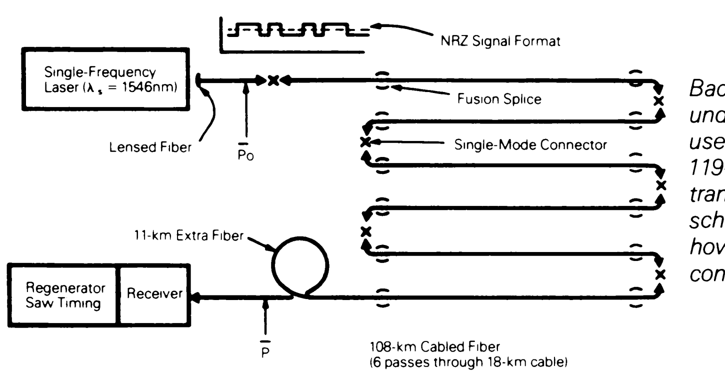
In the 19th century it took 30 years to progress from the dit-dah telegraph to the telephone that was capable of carrying the human voice. The telephone could transmit more complex and more subtle messages faster than the key telegraph and could also give information, such as musical pitch, that the key telegraph couldn't handle. The optical-fiber technology being laid today is designed to be superseded in only a few years by more efficient and versatile systems.

Much of today's important communications traffic consists of computers talking to other computers, and their needs are what is largely forcing the pace. Computers talk digital. Standard voice telephony uses analog signals: the shapes of the electrical pulses imitate the shapes of the acoustic waves that generate them in the telephone mouthpiece. The Morse telegraph was digital — every written symbol was translated to a pattern of dots and dashes, or to put it in modern terms, 1s and 0s. Computers talk the same way, in sequences of 1s and 0s.

There was some use of analog signals in the early days of fiber optics, but the equipment now being installed is all digital, and that seems to be the pulse of the future. Modern digital encoding techniques are so good that they can transmit all the nuances of pitch and dynamics in a human voice pattern (and the subtleties of contrast in a picture). It turns out therefore to be easier to digitize the voice of someone talking to Aunt Minnie in Flin Flon, Manitoba, than to meddle with a computer's output.

Computers also need transmissions with the lowest possible error rates. Errors in a few digits will not make much difference in Aunt Minnie's voice, but they can garble important computer programs, with potentially serious results. Multimode fibers have low error rates, but single-mode fibers promise almost error-free transmission. Transmission in a single-mode fiber is like talking in a room without reverberations. The message comes through clearer and faster with less effort. Where there are many vibrational modes of light taking different paths in a fiber, like reverberations in a room, the pulses tend to tread on each other and garble a certain amount. Because of the clearer transmission, single-mode fibers also permit wider spacing of repeaters, the circuit elements that repair the degradations the signal suffers as it passes through the fiber. This is an important logistical and financial advantage.

Single-mode fibers are more complicated to design than multimode ones. Single-mode fibers must have several concentric layers of slightly different materials. In a review talk authored by himself and V.A. Bhagavatula, Donald B. Keck of Corning Glass Works Research and Development Division in Corning, N.Y., told the New Orleans meeting that five basic designs are under consideration in the various laboratories in the world working on these problems. They range from a simple core and one layer of cladding to multilayer "segmented profiles." The materials in the different layers have different indices of refraction. When a light ray reaches a boundary between materials with different refraction indices, it will be bent. The trick is to design the thickness of the layers and the refraction indices so that the finished fiber selects one vibrational mode of light and transmits it by repeatedly bending it inward when it threatens to escape out the sides of the fiber, while the other modes are bent differ-



Back on land, the undersea cable was used for the record 119-km unrepeated transmission. This schematic shows how the fibers were connected for that test.

ently and get lost.

The simplest single-mode fibers have only one change of refractive index; the more complex ones have several ups and downs between the axis and the edge of the fiber. All of this layering takes place within a characteristic thickness of about a tenth of a millimeter. One goal of the work is to find optimum combinations of power transmission and mechanical properties such as flexibility.

Another goal is high capacity for transmitting information on the carrier wavelengths of particular interest, which are in the infrared between 1.3 and 1.6 micrometers. Both the attenuation of light in the glass and the dispersion or spreading (which alters the shapes of pulses) tend to be minimal for certain wavelengths in that range. The effort is aimed at manipulating the materials to extend those minima so that both those factors will be low enough over the widest possible range of wavelengths. This will permit "wavelength division multiplexing," the sending of several different messages simultaneously in the same fiber on different carrier wavelengths.

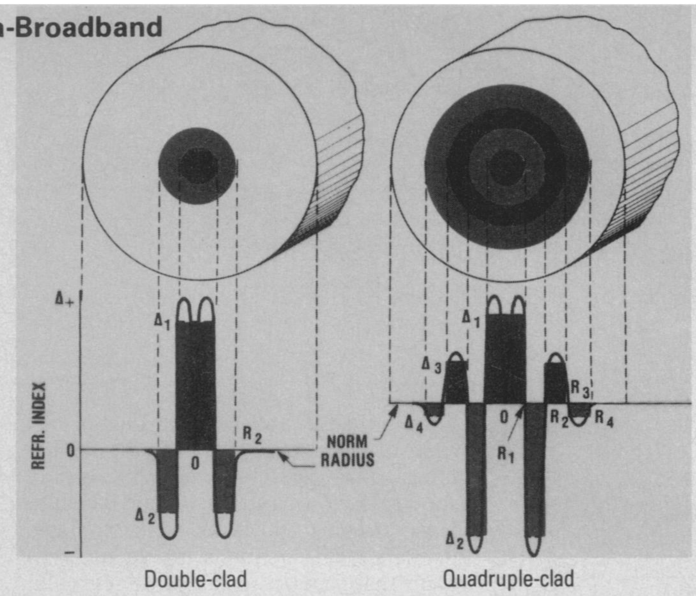
A fiber in which dispersion is kept to a minimum over the entire 1.3- to 1.6-micrometer range, permitting very high rates of information transmission at all those wavelengths, was described at the meeting by Leonard G. Cohen of Bell Telephone Laboratories in Murray Hill, N.J., on behalf of himself, W.L. Mammel of Bell Labs in Holmdel, N.J., and S.J. Jang of the Western Electric Engineering Research Center in Princeton, N.J. It consists of a core and four layers of cladding rather than the two cladding layers of earlier designs. Its ability to keep dispersion low at the high end of the wavelength range is attributed to the extra cladding.

Cohen told SCIENCE NEWS that channels separated by 100 nanometers (a tenth of a micrometer) could be handled by the equipment that puts the signals into one end of the fiber and separates them at the other end. This would mean up to four channels per fiber. Although 20 kilometers of this fiber have been made, it is still a laboratory experiment. It could be some years before it becomes commercially available. Even when it does, its full capacity may not be immediately needed, but, says Cohen, it would be "nice to put in a fiber that can accommodate future needs."

Two-channel wavelength division multiplexing has been tested in a single-mode fiber system intended for intercity use. The system was assembled in late 1982 in Atlanta. Two parallel 1-kilometer cables were spliced together. Lasers emitting at 1.275 micrometers and 1.335 micrometers were used as light sources. Individual fibers in the cables could be connected to each other to form light paths that ran many times back and forth along the length of the cables. Repeaterless distances of 65 km at an information rate of 432 million bits per second and 75 km at 144 million bits per second were achieved in this way. The conclusion of the experimenters, S.S. Cheng and P. Kaiser of Bell Labs in Holmdel, W.B. Gardner of Bell Labs in Norcross, Ga., and C.J. McGrath of Bell Labs in North Andover, Mass., is that the system, which was "tested in an environment that closely resembles field conditions, ... has great promise for high capacity intercity transmission."

"Experience on single-mode systems is still limited," says G. Pellegrini of the Centro Studie Laboratori Telecommunicazioni in Torino, Italy, who reviewed worldwide field trials, but what has been learned seems good. Laying fiber cable is not much more difficult than laying copper coaxial cable. Optical repeaters are simpler than those for copper and can be several times farther apart. Because of the complex structure of single-mode fibers, "splicing was considered a main problem," Pellegrini says. However, experience shows otherwise. Pellegrini cites only 5 failures in 3,093 splices. Prices are coming down, too. Fiber that sells for 10¢ per meter now sold for $5 to $10 per meter in 1970. "Economic savings by using optical fiber are already achieved," he concludes.

Single-mode fiber, with its potential for long unrepeated distances, is particularly promising for undersea use, according to I.W. Stanley of British Telecom Research Laboratories in Ipswich (Suffolk), England. Stanley's talk was devoted to describing the "advantages of digital optical techniques over analog copper." Over the years since the first transatlantic telephone cable went into service in 1956, copper cable diameter has increased and repeater spacing has decreased. "The change to optical reverses both trends," he says. For systems carrying between 274 million and 400 million bits of information per second in 1.3-micrometer single-mode transmission, the cable diameter should be half that for copper and the repeater spacing 30 to 35 km, three to four times that for copper.



Cross-sections and refractive index profiles of double-clad and quadruple-clad single-mode fibers from Cohen et al.

Illustrations: Bell Labs

In fact, the longest unrepeated transmission yet recorded was done in single-mode fibers in a cable prepared for undersea use by Bell Labs and tested on the bottom of the Atlantic (SN: 3/12/83, p. 166). Back on land R.E. Wagner and ten others from Bell Labs at Murray Hill and Holmdel linked together individual fibers in about 20 km of the cable and succeeded in making an unrepeated transmission at 420 million bits per second, virtually error-free over 119 km. For good power concentration they used a laser that produced only one mode of 1.55-micrometer light (SN: 4/23/83, p. 260).

Such long unrepeated distances are not likely to appear in commercial use for some time. According to Russell G. de Witt of Continental Telephone Co. (which serves portions of 37 states including Alaska and Grand Bahama Island), use of single-mode fibers could soon yield repeater spacings up to 30 miles, which is competitive with the spacing of antennas in the microwave radio lines that are now used for some long-distance telephonic transmissions.

"Never in the history of technology has a new development come at a more opportune time," says de Witt. "Optical fiber comes as telephone systems are being converted to digital switching. It solves all problems with past systems." Except at least one. De Witt acknowledges that hunters take potshots at aerial optical cable as they do at aerial copper cable, so it all may have to be buried. But above ground or underground, de Witt says, "I can foresee the day when all our trunks will be carried on lightwave guides." □