TELEPHONING BY LIGHT, II: THE SYSTEM

Following recent technological breakthroughs in optical components, a commercial communications system now appears possible, but several problems must be overcome.

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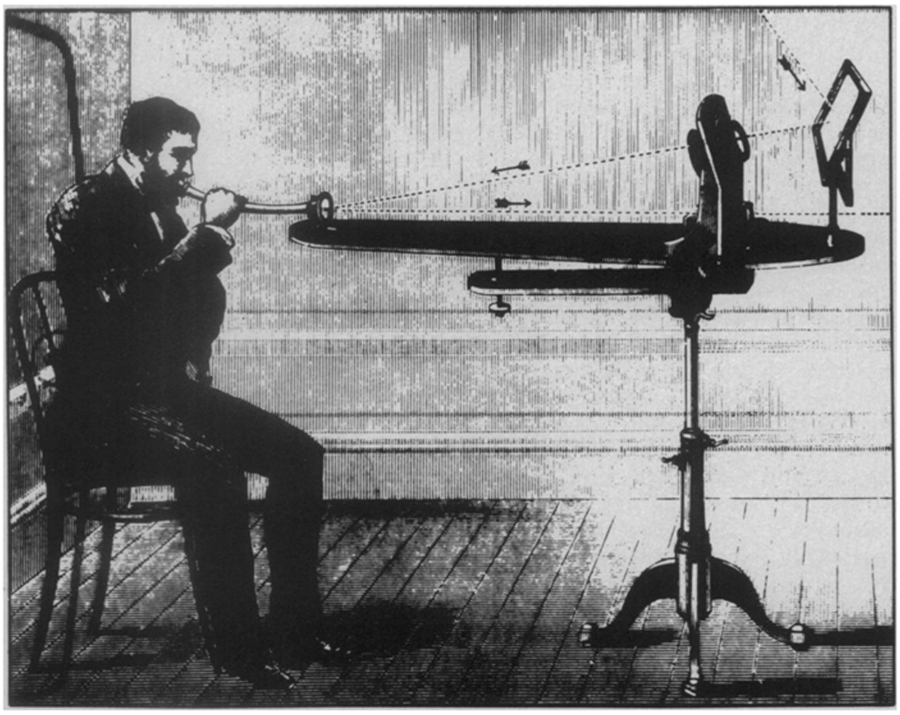
Second of two articles



Photos: Bell Laboratories

Alexander Graham Bell's dream of transmitting voices by light may soon come true.

America's vital communications links are becoming clogged. In central urban areas, installation of new telephone lines is stymied by a simple lack of space in underground conduits, and tearing up the streets to make room for more new lines may cost millions of dollars per mile. Where once wires sufficed, and then a sophisticated system of microwaves, coaxial cables and multiplexed signals, a glut of messages has begun to tax the intrinsic limits of present technology. As inner city populations become even more dense, and demand for open channels rises sharply to fulfill the new needs of data transmission and possibly picture phones, alternative technologies must be found to handle the load.

One of the most promising of these new technologies is optical communications, made possible by a series of recent breakthroughs in solid state physics and materials research (SN: 7/19/75, p. 44). Light-conducting glass fibers can carry many more messages than present-day cables, in a much smaller space. Also, as the price of metals continues to rise, the use of almost inexhaustible silicon to make these noncorroding glass lines will become even more attractive. But first the existing individual optical components must be combined into a competitive, reliable *system*, and several practical problems still stand in the way.

Communicating on a beam of light is not a new idea; Alexander Graham Bell patented one crude method of transmitting a voice signal by light decades ago. But light is a much more difficult medium to handle than electricity or radio, and only recently has increasing demand created a need for light's one great advantage—the inherent capacity to carry many more messages simultaneously than longer wavelength electrical or microwave signals. By thinking of messages reduced to a series of brief flashes, it is easy to see the advantages of a system in which the flashes (consisting of a few wavelengths each) can be packed many times closer together.

In fact, such a process of digitization—reduction of speech or other signal to binary flashes—is already being used in some high-capacity telephone lines. It operates so effectively that most people are unaware that the familiar voices they hear have been literally chopped up and reassembled. The fastest commercial digital transmission system, developed at Bell Laboratories, is now operating between New York City and Newark, N.J. It sends 1,820 telephone voice channels over a single coaxial tube, using 274 million binary "bits" per second—fast enough to copy a 24-volume encyclopedia, letter by letter, in less than a tenth of a second. An experimental laser-powered system, however, can send a billion bits per second, fast enough to send 4,000 phone conversations over a single optical fiber. And fibers are so small that perhaps a hundred of them could be bundled into a cable the size of a single coaxial tube.

Optical systems are also found superior when one considers the necessity of periodically amplifying and redefining a signal as it passes through a long transmission line. Weakened, smeared-out pulses must pass through a "repeater" that boosts their power and reseparates them. Bell Labs' scientists estimate that using a laser transmitter, the best optical receiver and one of the existing low-loss optical fibers, repeaters would be required only once every 9.0 kilometers. A comparable coaxial system needs repeaters about every 1.8 kilometers.

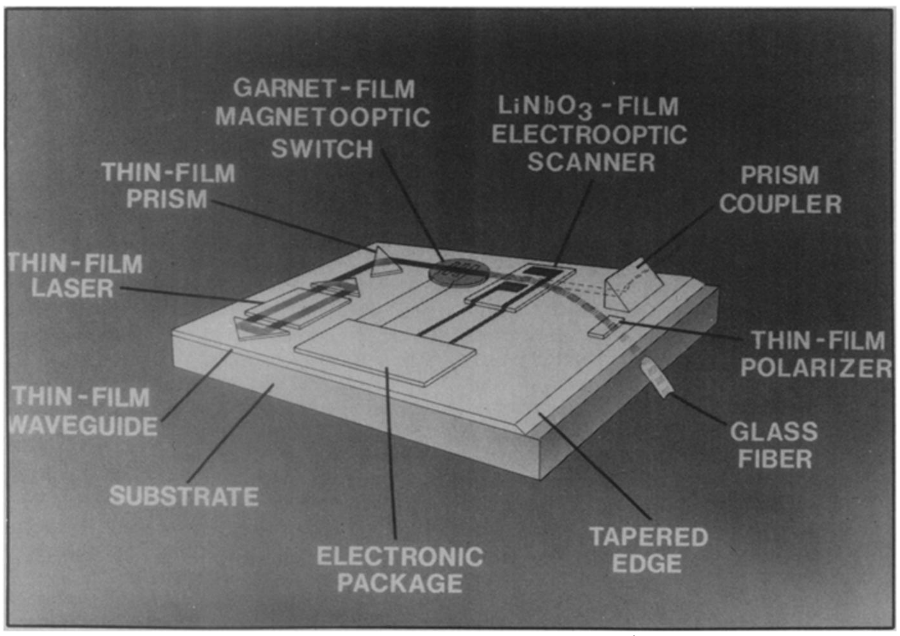
The key to a commercial light communications system, then, is to develop a small, reliable optical repeater. It is here that the great difficulty of processing light signals becomes evident. Simple operations that electricians take for granted—like splicing—suddenly take on peculiar difficulty when one is dealing with hair-thin glass fibers instead of wires. More important, no way now exists to amplify and redefine light directly; it must first be converted to an electrical signal, processed, and then retransmitted as light. Early commercial systems will probably have to rely on this somewhat clumsy method, making repeaters as small as possible by using "integrated" electronic circuits that have all their elements etched on a single semiconductor chip. But another possibility is now generating considerable excitement among experts in the field—the integrated *optical* circuit.

Any integrated circuit starts with a complicated map-like pattern that is reduced and etched onto a small piece of material, either by photolithography or ablation with ion beams focused through a mask. Layers of other materials may be deposited, and after successive etchings, thousands of circuit components are created on a chip the size of a fingernail. In integrated electronic circuits, the elements are usually transistors and diodes, which may be packed as thick as 20,000 to the square quarter-inch. In optical circuits, the elements will be lasers, prisms, photodiodes, lenses and optical switches.

An optical chip will consist of a thin film of transparent material deposited on a glass substrate to give it strength. The film will be only one micron thick and light will travel through it along the same zigzag beams (quantized modes) as in the optical fibers. To make the beams turn a corner, a thin-film prism is created by depositing a triangular region of high refractive index. To focus light, a semicircular region is deposited, which acts like a lens.

Creating a switch to pulse the light is a little tougher. One method under consideration involves a region of deposited garnet film, in contact with a tiny electrical circuit. When the circuit is activated, a magnetic field causes light passing through the garnet to be polarized in one direction; when no external field exists, the light is polarized in the other direction. By following the switch with a thin-film polarizer, a sequence of discrete light flashes is created.

Perhaps the most complex element of the circuit—not yet perfected—is the thin-film laser. Generally a laser is created by enclosing a light-emitting region between two mirrors, spaced just right to form a resonating chamber. Photons bounce back and forth between the mirrors, eventually escaping, but meanwhile stimulating the emission of other photons of the same wavelength. Normal-sized lasers can usually be made by sharply cleaving the ends of a light-emitting material so that a partially reflecting flat surface is created. Such cleaving is almost impossible to achieve when working with a microscopic region of a thin film, however, so alternatives are being sought. One favorite idea at present is to bound the lasing region with "corner reflectors," triangular regions in which light is reflected twice and sent back along the direction from which it came.



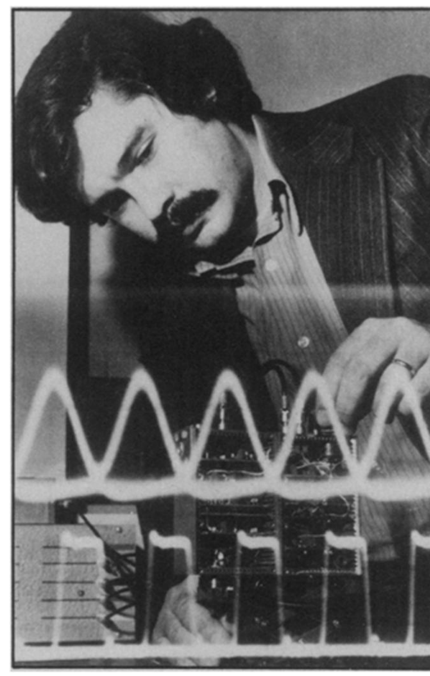
One conception of an integrated optical circuit, with elements deposited on thin film.

Once the various optical components have been demonstrated using materials best for each, ways must be found of compromising in the choice of materials, so that all can be created in a few steps using a common substrate. Some electronic circuitry to control switching will also be needed, so a separate "package" of integrated electronic components must be added to each circuit.

Finally, a sturdy, inexpensive way of attaching the optical circuit to a glass fiber must be found. Since coupling directly to the thin film would be virtually impossible, the light will probably be diverted into the glass substrate by tapering the film edge, and the fiber will then be attached directly to the larger piece of material. For laboratory use, fairly large prism "couplers" placed on top of the thin film may prove more convenient.

Just how far along is optical communication? The question finds many answers: A physicist might say "the rest is just an engineering problem," but an executive might reply "it's still a laboratory dream." In the lobby of Bell Laboratories, a color television set runs all day on light pulses fed through an optical fiber. But this impressive simple model is still a long way from a reliable, commercial optical system that a routinely equipped lineman can fix in the rain.

Before a practical system can be installed, the lifetimes of miniature lasers must be extended several fold. Low-loss optical fibers must be mass-produced and drop considerably in price. Ways must be found to bundle many fibers together into cables without the light escaping from one interfering with messages on another. And splicing must become more efficient—the task now appears like gluing the separate strands of a hemp rope end to end, one at a time, while trying to remember which of the identical-looking fibers go together.



Signal "repeater:" incoming smeared-out waves and redefined outgoing waves.

Incentive to solve these problems is mounting, however. The interstate capacity of the Bell System is expected to triple by 1981, and every available means—including communications satellites, optical fibers and a greatly improved microwave system—will all be needed to fill the demand. Other countries are also joining the competition to create optical systems. Japan is making low-loss fibers and engineering prototypes of optical communications elements. A German manufacturer claims to have found a way to "manageably" splice optical fibers and is talking about combining four separate laser beams onto one fiber. According to a National Science Foundation report, however, the United States is still the "unquestioned world leader in the field." □