A Pure Laser for Clean Communications

Fiber optics, the technology of sending messages by light pulses in tiny glass fibers, is now beginning to be used in several of the world's telephone systems, particularly the American system. But the technology that is now the latest thing is already being superseded in the laboratory. In this business the shadow of the future moves forward rapidly.

First there was the development of monomode fibers, fibers engineered to transmit a single vibrational mode — that is, a single ray configuration — of the light. These are expected to supersede the currently used multimode fibers that transmit several rays. To go with them Bell Telephone Laboratories now announces development of a tiny solid-state laser that produces ultrapure single-frequency light. The new laser is also tunable: it will produce light with a very pure frequency at several points on the spectrum.

The present fiber-optic technology, with multimode fibers and somewhat impure lasers and light-emitting diodes can send signals unboosted (or unrepeated) over longer distances than the traditional technology of electric waves in copper wires and do it with very low error rates. If the combination of monomode fibers and pure frequency lasers can be made to work in the field, it promises even longer unrepeated transmissions at very high information rates with virtually no errors. Low error rates are extremely important to conversations between computers, which are a fast-growing part of present telephonic traffic.

Ordinary lasers emit a certain spread of frequencies. In principle all the atoms of a lasing substance ought to emit a precise frequency. In real life the atoms are never exactly still. For various reasons they are all slightly in motion, and so the emissions all have slight Doppler shifts and are a little off the frequency they would emit if they were all at rest. What comes out is a spread of frequencies. The mirrored cavity, in which the lasing material lies, and which sets up the conditions for amplification and coherence, can also accommodate part of this spread, and so the laser as a whole emits a spread of frequencies.

The new development, called a cleaved coupled-cavity laser (c^3), is an application of the coupled-cavity idea that Bell Labs patented in 1965. Which of the emitted frequencies a given cavity will amplify depends to some extent on its length. If two cavities of slightly different length can be coupled optically so that the light has to go through both of them, a situation can be engineered in which each cavity suppresses the other's permitted range except for a single frequency common to both of them.

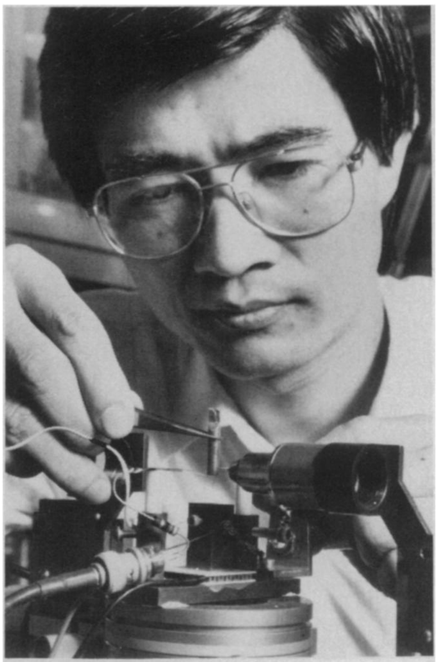
This is what the c^3, invented by Won-Tien Tsang of Bell Labs, does. It is a semiconductor laser that has been precisely cut in two and then rejoined along the cleaved surface. The two cavities are optically coupled but electronically isolated from one another. The optical properties of the material can be changed by changing the electric current applied to it. So by independently varying the currents applied to the two pieces, their optical properties can be manipulated to change the single frequency they will jointly amplify. Thus the c^3 can be tuned from one ultrapure frequency to another. The whole thing is about half the size of a digit in the date inscribed on a United States one-cent piece.

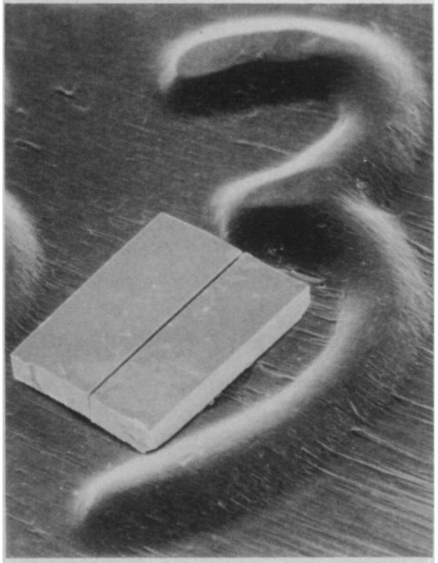
The c^3 laser was designed to emit at the frequencies to which the fibers are most transparent, around 1.5 microns in the infrared. It was used with a monomode fiber for the longest unrepeated fiber-optic transmission yet recorded, 119 kilometers. That fiber was in a cable designed for undersea use that had been tested (with another laser) on the bottom of the Atlantic (SN: 3/12/83, p. 166). The c^3's characteristics could not be described at that time because the journal in which they were to be published, Applied Physics Letters, imposes an embargo on prepublication publicity. The c^3 is described in its April 15 issue.

The c^3 laser can switch rapidly among its frequencies. It has been tested over ten frequencies at a switching rate of a billion times a second. By using such switching in predetermined patterns, several messages can be encoded on a single beam of light, a technique called frequency shift keying. Or several of these lasers emitting at different frequencies can supply carrier waves for different messages sent in the same fiber, a technique called wavelength division multiplexing. Both techniques increase the amount of information that can be sent in one fiber.

Sending as much information as possible fast and error free is the goal. In the multimode fibers pulses have a certain tendency to tread on each other and garble things. With pure frequencies in monomode fiber there is much less of that. Arno Penzias, Bell Labs' vice president of research, points out that the error rate for the 119-km record transmission was one in a billion bits of information. At the transmission rate of 420 million bits per second that they used, he says, the entire text of a 30-volume encyclopedia could be sent in one second with only one error — that is the equivalent of a letter somewhere in the 30 volumes being upper case when it should have been lower case.

—*D. E. Thomsen*





Photos: Bell Labs

Top: Won-Tien Tsang of Bell Labs, inventor of the cleaved coupled-cavity laser, tests the device, which can be tuned to emit a range of ultrapure frequencies.
Below: c^3 on a penny.