# Experimenter's Corner

By Forrest M. Mims

## THE PHOTOPHONE CENTENNIAL: 1880–1980

HAVE YOU ever talked over a sunbeam? I hope every reader of this column will do just that during 1980, for this is the centennial year of the invention of light-wave communications.

On February 19, 1880, Alexander Graham Bell and Sumner Tainter, Bell's lab assistant, became the first men to transmit voice over a beam of reflected sunlight. One kind of transmitter they developed, shown in Fig. 1, was a thin, silvered mirror attached to one end of a hollow cylinder. Sound waves were directed against the mirror through a speaking tube. The resulting vibrations of the mirror caused a reflected beam of sunlight to become more or less divergent. The net result was an amplitude-modulated light beam.

Bell's receiver consisted of a series of selenium cells mounted in the focus of a parabolic reflector and connected in series with a telephone receiver and a battery. Figure 2 shows one of Bell's early optical receivers.

Bell called his invention the *photophone*. In June of 1880, he and Tainter transmitted intelligible voice from the top of the Franklin School in Washington, D.C. to Bell's laboratory at 1325 L Street, a distance of 213 meters. Later Bell and Tainter were granted several patents covering the photophone and its variations. Until his death in 1922, Bell considered the photophone to be his most important invention, more important even than the telephone.

If you would like more information about the photophone, I've written a detailed paper on the subject which appears in the Spring edition of *Optics News*, a publication of the Optical Society of America (available at well-stocked libraries). Also, if you happen to be in Washington, D.C. this spring or summer, stop by Explorer's Hall, the museum of the National Geographic Society at 17th and M Streets, N.W., to see their excellent photophone centennial exhibit. It was constructed by Bell Telephone Laboratories, and traces the history of light-wave communications from the photophone to today's glass-fiber communication links.

Alexander Graham Bell played a pioneering role in the early history of the National Geographic Society. His grandson, Dr. Melville Bell Grosvenor, is Editor Emeritus of the *National Geographic*. Several years ago, when I met with Dr. Grosvenor to propose a photophone-centennial exhibit, his interest perked up considerably when I pulled a homemade photophone from my briefcase. He scurried out onto the balcony to catch a few rays of sunlight, and we were soon communicating over his grandfather's invention.

That was a very exciting moment for me, and one I hope to share with you by means of this column. You can be "on the air" in a matter of minutes with an aluminum-foil-and-cardboard transmitter and a receiver made from a solar cell and a portable amplifier! With your own photophone, you'll never be without an entertaining and educational gadget to demonstrate for friends, neighbors, scout troops and school classes. Indoors, at night, or when clouds obscure the sun, you can use light from an artificial source. I've used many kinds of flashlights, a helium-neon laser, infrared LEDs and a continuously operating (CW) injection laser with good results. Interested? Here are some details.

**Photophone Transmitters.** Bell and Tainter devised many ways to modulate a light beam, but the simplest is the use of a flexible mirror. My favorite photophone transmitter, shown in Fig. 3, is a 25-mm diameter, ultra-thin glass mirror cemented to one end of a 1" (25.4 mm) diameter aluminum tube. The mirror is catalog number 30,626, available from Edmund Scientific Company (300 Edscorp Bldg., Barrington, NJ 08007).

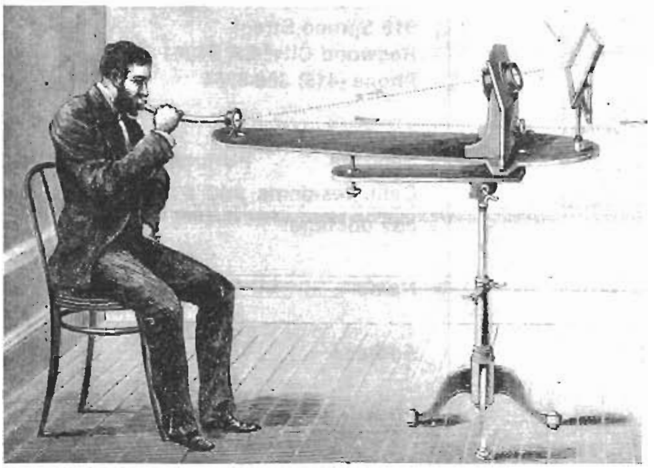
A larger mirror will give more range, but suitable glass mirrors are hard to find and are very fragile. Bell solved this problem by using a system of lenses to collect more light than would otherwise be intercepted by the mirror alone (see Fig. 1). You can take this approach also, but a suitable alternative is the use of a mirror fabricated from aluminum foil or aluminized Mylar.

A powerful transmitter can be made by taping a sheet of foil or Mylar over one end of a metal can from which both ends have been removed. The Mylar is easier to attach and forms a highly desirable flat, drum-like surface. Unfortunately, aluminized Mylar, at least the type which I've used, is not quite as reflective as aluminum foil. A simple test shows that about 5% of incident sunlight passes through the thin film of aluminum deposited on the Mylar and is therefore not available for reflection.

Aluminum foil is almost perfectly reflective, but it tears easily. Another problem with foil is the difficulty of obtaining a perfectly flat surface. Both of these problems can be partially alleviated by crossing strips of masking tape across the dull side of a sheet of foil (use four strips) and centering the shiny side of the foil out over the end of the can. The tape reduces tearing, keeps the foil reasonably flat and improves the sound quality by damping out resonances.

Instead of a metal can, the Mylar or foil can be taped over a 4" to 6" (10-cm to 15.25-cm) diameter hole cut in a square of corrugated cardboard. This method works well with foil because it results in less chance of tearing.

You can experiment with other kinds of transmitters. Several years ago, at a hot-air balloon competition in New Mexico, Otis Imboden, a *National Geographic* photographer, and I experimented with a large foil-covered board he was using to reflect sunlight at balloon crews that were shadowed by the huge bags of hot air rising above them.



Photos courtesy Bell Labs.

*Fig. 1. The photophone transmitter used by Bell and Tainter in their historic experiment of 1880.*

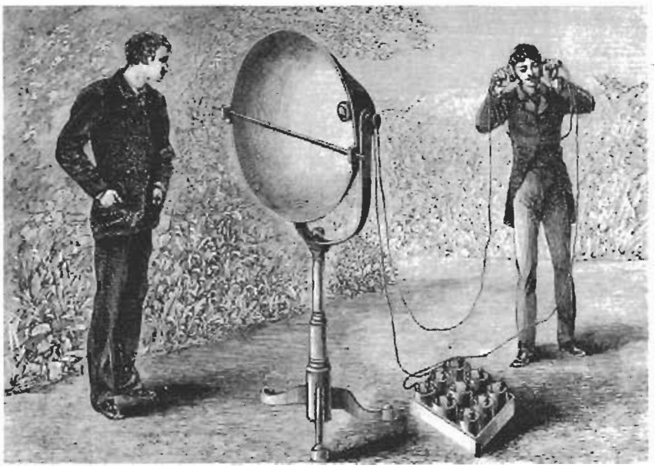


*Fig. 2. A photophone receiver of 1880. The detector is the cylindrical object in the reflector.*

We found that we were able to send voice messages to a nearby receiver simply by talking near the reflector. Later, we gave a receiver to a balloon crew. Otis spoke to the pilot with the help of his reflector while the balloon was in tethered flight.

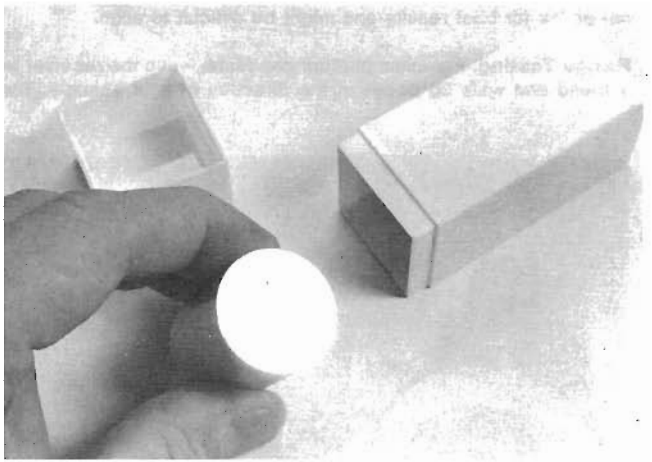


*Fig. 3. A photophone transmitter is easily made using a 25-mm diam. mirror cemented to an aluminum tube.*

Passive transmitters like those described thus far work fine, but you can make an electronic photophone transmitter by cementing a thin glass mirror to the rim of the cone of a miniature speaker. Refer to the Edmund Scientific catalog for suitable mirrors. This technique results in very high quality voice transmission and allows one person to conduct photophone tests unassisted because the transmitter can be driven by signals from the earphone or external speaker jack of a portable radio or tape player.

**Photophone Receivers.** Bell and Tainter experienced considerable difficulty making selenium detectors for their photophone experiments, but today you can purchase for a few dollars a silicon solar cell that's considerably more sensitive and easier to use. I prefer silicon solar cells for photophone receivers because their large surface area (the larger the better) reduces or eliminates entirely the need for collecting lenses or reflectors for short-range experiments. When a lens or reflector is used to increase communications range, the greater area of the detector does away in large part with the alignment difficulties associated with the use of small detectors such as phototransistors.

An ultra-simple receiver can be made by connecting a silicon solar cell directly to the microphone input of an audio amplifier. Figure 4 is the schematic of a circuit with plenty of gain that works quite well. Rather than building an amplifier, you can salvage one from a discarded cassette recorder or purchase a factory-assembled amplifier module from one of the dealers who advertise in this magazine.

Silicon solar cells are very thin and are easily broken. One way to protect a cell is to install it in a clear plastic box or container like that

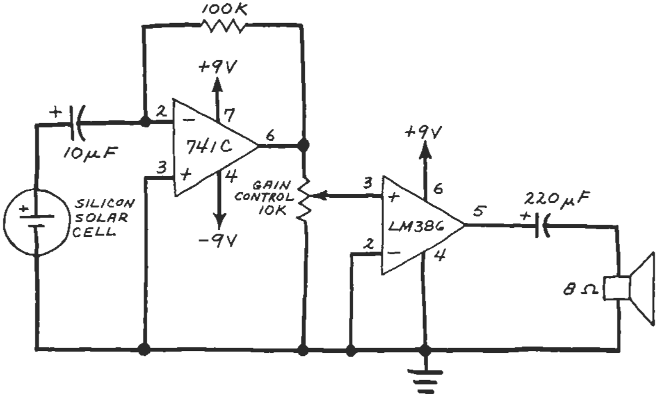


*Fig. 4. Schematic of a high-gain photophone receiver.*

# BATTERY-WRAP

in which a typical cell is packaged when sold. A layer of plastic foam behind the cell will cushion it from shock, and a small notch or hole can be easily formed for the leads.

Some solar cells are supplied with wire leads. Others are not. If you must attach your own leads, use a small, low-wattage iron with a well-tinned tip. For best results, use tinned wrapping wire for leads. Most silicon cells have electrodes on the front and back surfaces. Solder the back electrode first by forming a small puddle of solder near an edge of the cell and then holding the stripped end of a wire lead in the solder until it cools.

The front electrode is usually in the form of a thin strip and requires more care. Touch the tip of the iron to the electrode and, after a second or two, apply enough solder to form a small bump or ridge. Then reheat the solder and position the second wire lead along the electrode. Hold the lead in place until the solder cools.

The leads, particularly the one soldered to the front electrode, must be protected from excessive strain. One way to do this is to attach the leads directly to the cell's protective housing with glue or miniature solder lugs. A shielded cable can then be connected to the leads or lugs.

Your mounting problems will be simplified if you install the cell in a reflector or behind a lens. Alignment of the receiver will be much easier if you use the reflector rather than a lens. Various types of reflectors are available from Edmund Scientific, but I prefer to modify ordinary flashlights. For example, the reflector in a typical 6-volt lantern has plenty of room for two solar cells connected in series and mounted back-to-back. The battery compartment has more than enough space for a modular amplifier, miniature speaker, battery, switch, gain control and phone jack.

Figure 5 shows a photophone receiver and a LED voice transmitter installed in 6-volt lanterns (Burgess "Dolphin" brand). I made the receiver in 1966, and it's worked fine ever since. The solar cells are secured in place, perpendicular to the axis of the reflector, by wrapping their leads around the protruding shoulder at the small opening in the reflector. While this mounting method might appear to be very flimsy, my cells have survived a trip around the world (including a one-year stint in Vietnam) and numerous field tests of various light-wave communications devices. The cells simply bounce upon their leads when the receiver is dropped or jostled.

I recommend one or more silicon solar cells for your photophone receiver, but you can use selenium cells, phototransistors or photodiodes instead. Keep in mind that small detectors will require external optics for best results and might be difficult to align.

**Range Testing.** For initial photophone tests, leave the receiver with a friend and walk 25 paces in the direction of your shadow. Then, while facing the receiver, point the transmitter toward the ground in front of you until the sun's reflection is visible as a bright spot. It's a simple procedure to slowly move the spot toward the receiver by following the spot of light along the ground.

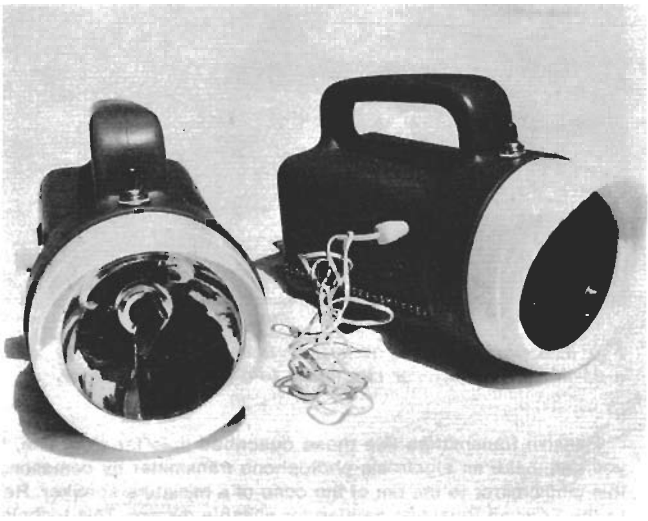


*Fig. 5. Photophone receiver (left) and LED voice transmitter installed in 6-volt lantern lights. Note the position of the two back-to-back solar cells in the receiver's reflector.*

It's helpful to place the receiver in a shaded location so the reflected spot will be easier to see. A trick I usually employ is to place a large red bicycle reflector next to the receiver. When the reflector lights up, the transmitter is on target. Here's another tip: placing the receiver *inside* a building and directing the transmitter beam through a window makes for an impressive demonstration because the voice of the person at the transmitter can be heard only via the light beam and *not* by the propagation of sound waves through the air.

While testing a photophone, you'll soon discover some difficulty in keeping the reflected spot of sunlight trained on the receiver. One way to stay on target is to rest the transmitter against a fixed object like a tree, fence post, or building. A better way is to mount the transmitter on a photographer's tripod. Of course, the receiver must be kept in a fixed location. You'll also need to make frequent adjustments to compensate for the earth's rotation, which manifests itself as the apparent continuous motion of the sun.

Once you have an operational photophone, you'll probably want to determine its maximum transmitting range. For long-range tests, a tripod is essential. An electronic transmitter (i.e., a speaker with attached mirror) is very helpful also, because one person can perform the test unaided. It's very easy to achieve a range of 100 meters or more. For ranges of one kilometer or more, the photophone receiver I described in the February 1976 issue of POPULAR ELECTRONICS is ideal. This receiver uses a large glass reflector installed in a special cabinet complete with amplifier and solar cell. Though very difficult to align, the receiver has exceptional sensitivity. If you don't have this article in your back issues, you can find it at a library. It's also in the 1980 ELECTRONIC EXPERIMENTER'S HANDBOOK.

**In Conclusion.** The photophone will allow you to explore the fascinating world of light-beam communications. However, remember one word of caution. Always avoid staring at the bright reflection of sunlight from photophone transmitters! Protect your eyes by wearing sunglasses with optical-quality glass lenses and by looking away from the transmitter mirror. ◇