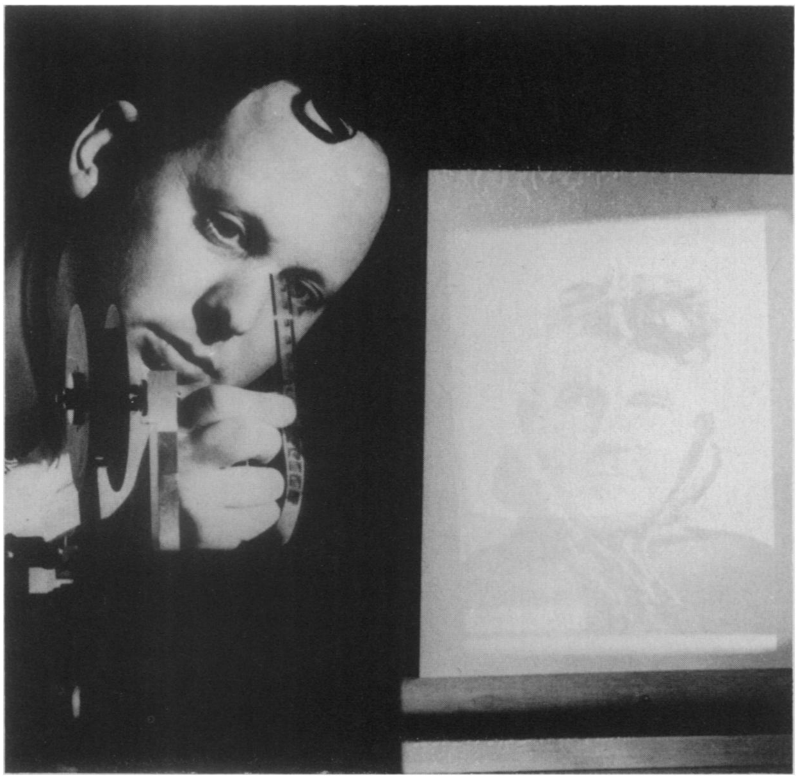
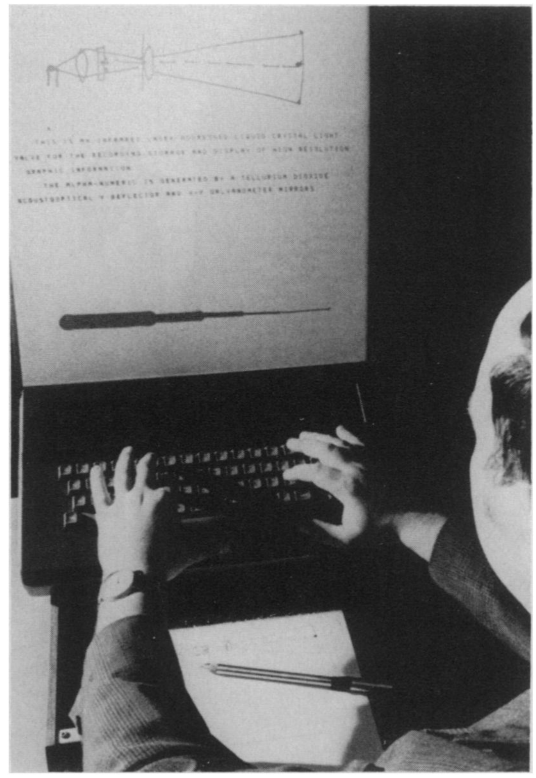


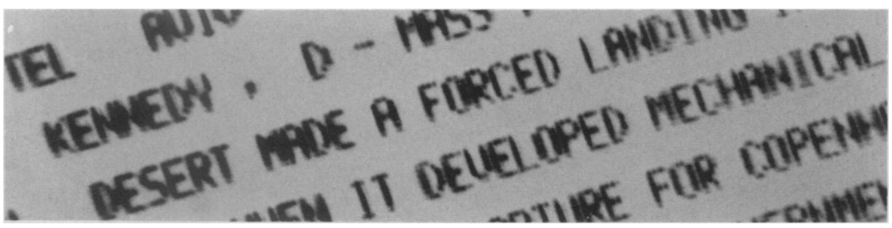
Bell Labs

Dan Maydan of Bell Telephone Laboratories examines images printed in a bismuth layer on a strip of microfilm by beams of laser light directed by an acoustooptical diffraction apparatus.



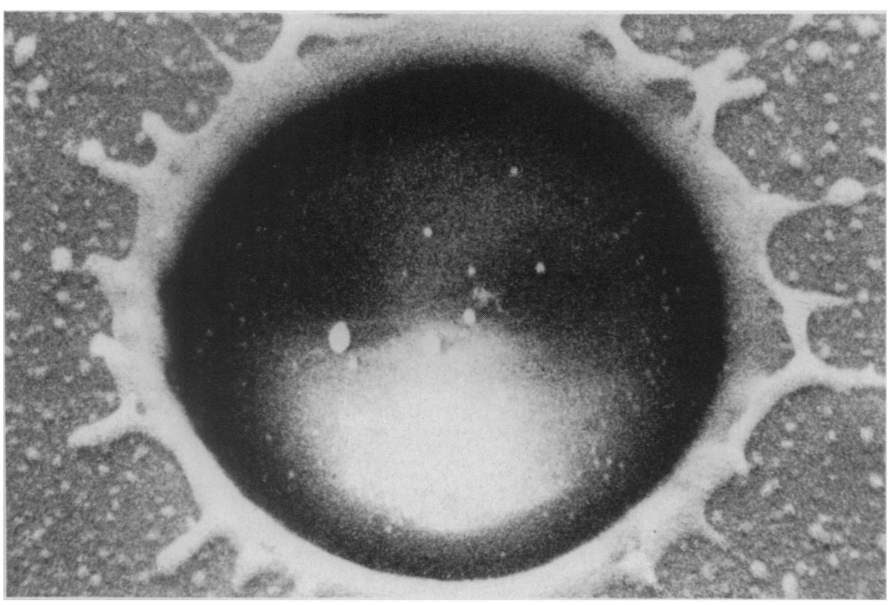
Bell Labs

Information from the typewriter is printed by acoustooptically directed laser light on a liquid crystal slide and is simultaneously projected.



Zenith

Print-out by Zenith character generator from United Press International wire.



Bell Labs

BTL device prints by making holes (1/10 diameter of hair) in bismuth strip.

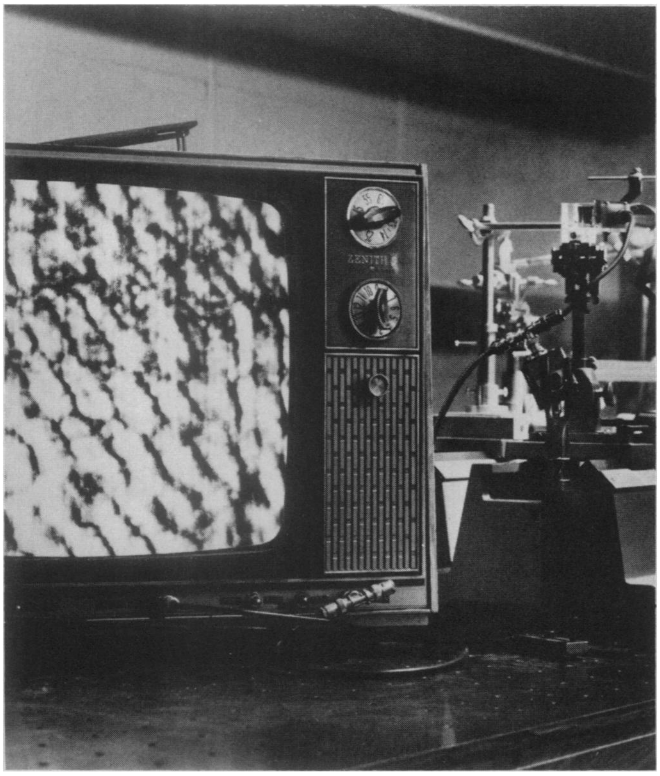
The glittering

by Dietrick E. Thomsen

Light and sound are both vibrations. Yet they are vibrations of two very different kinds. Sound is a mechanical vibration; it causes solids, liquids and gases to vibrate, and it must have a material medium in which to propagate. Light is a vibration of electric and magnetic fields. Although it can pass through many material media, it needs none; it can propagate through a vacuum.

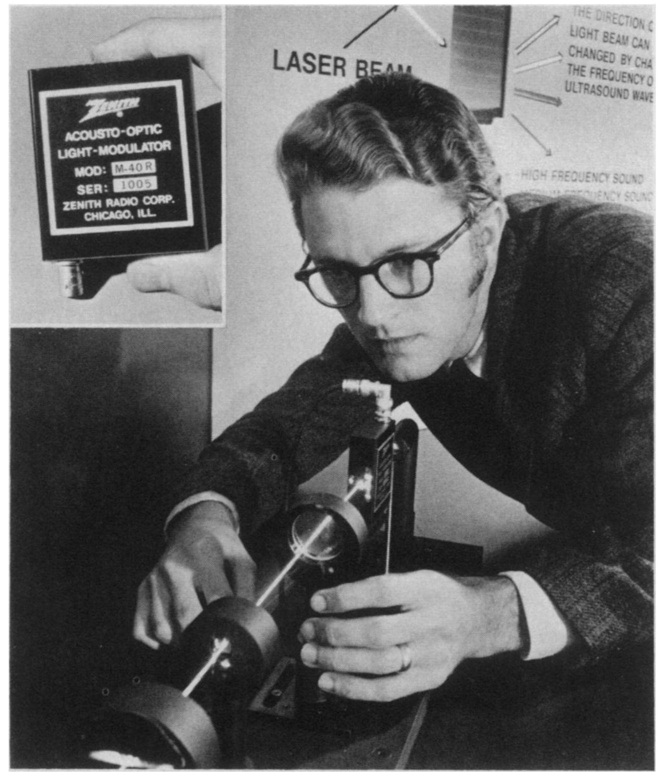
These two types of vibration can influence each other. Sound can be used to modulate light. This property is now providing new tools for scientific investigations and leading to the invention of a variety of devices that promise to have great use in communications technology.

The sound in this case is really ultrasound, high-frequency vibrations in the hundreds of millions of hertz, thousands of times the frequencies of audible sound. The passage of the sound, through a material or along its surface, causes variations in density in the material. When light is shined on them the density variations act like a diffraction grating: They diffract or bend the light. This acoustooptic interaction can be



Zenith

Acoustical image of onion skin cells magnified 400 times is displayed on television screen. Information comes from Zenith Corp.'s acoustooptic microscope.



Zenith

Zenith scientist William Watson adjusts acoustooptic character-generator system capable of printing up to 400,000 letters a second. It uses sound to modulate light.

future ahead for acoustooptic technology

used to change the direction of a light beam. The angle of deflection can be varied by changing the frequency of the sound. Changing the sound frequency changes the spacing of the grating, and that changes the angle of deflection of the light.

This interaction was theoretically predictable years ago, but practical operations with it awaited the advent of lasers, with their narrow beams and precise control of wavelengths. If the light were a mixture of wavelengths, the diffraction would send each one in a different direction.

One of the great scientific advantages of acoustooptic interaction is that it permits the use of a light beam to probe the acoustical properties of many materials. From superconductivity to melting, the way solids behave is often related to their acoustic qualities. With the light beam one can determine what happens to ultrasonic pulses in various materials—how the sound beam may spread, how its energy may be attenuated and how fast it goes. "The advantage of being able to follow the ultrasonic wave, point by point, inside the (transparent) transmitting medium is very important," says Richard W. Dixon of Bell Telephone Laboratories. It enables investigators to isolate the influence of local imperfections and of the surfaces of the sample on the acoustic beam.

Practical applications of acousto-optics are showing up in many areas where laser light may be used to gain or transmit information. "The greatest application is where a laser does a job that nothing else can do," says George Hrbek of the Zenith Radio Corp. An example is the manufacture of integrated optics (similar to integrated circuits in electronics) for transmission of information. "The most compelling and economically significant motivation for going to optics is the potential for extremely high information-carrying capacity on long distance channels," says Lawrence Kuhn of IBM. Kuhn and others at IBM have been working on the use of both ruled gratings and acousto-optic ones for coupling light beams in and out of thin film waveguides.

But even when electronics does the actual communicating from point to point, acoustooptic read-out methods can greatly enhance the speed with which material is presented. An acoustically modulated laser beam can be made to scan a screen or microfilm or special printing paper (as the electron beam in a television tube scans its screen) and print out material conveyed to it. Zenith recently demonstrated a print-out machine that can print 400,000 characters a second. Theoretically the system could transmit one volume of the Encyclopedia Britannica from New York to London in about 18 seconds—or the whole 24-volume set in about 7 minutes.

Bell Labs has an acoustooptical printer that can reproduce pages of type or illustrations. It can scan a typical newspaper page in four seconds—one-sixtieth of the time needed by conventional wire methods. In the Bell Labs device the laser beam is directed onto a plastic film coated with a layer of bismuth. The light burns holes in the bismuth, the diameter of which varies according to the intensity of the light. Since the light intensity is determined by the relative grayness of the original, the device makes a black-white-gray transparency in one swoop without requiring the development

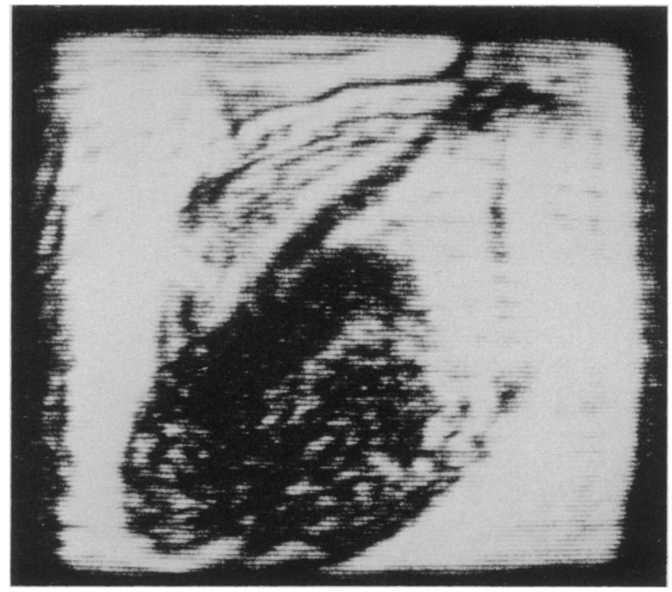


Image of a fish by acoustical holographic apparatus developed at University of California, Santa Barbara. Head and viscera show up dark.

UCSB

processes that photographic methods need. Bell Labs also has a system that uses a liquid crystal between glass plates as a transparency. The crystal becomes frosted where the heat of the laser light strikes it. The image can be projected by an ordinary slide projector.

Acoustooptic read-out systems also are able to keep up with the thinking of a computer. Computers nowadays have storage bins where information is held because the mechanical printer cannot keep up with the computer's thought processes. A computer equipped with acoustooptic read-out could print out as fast as it thought.

Zenith, which has won two awards for its work in acoustooptics, has developed acoustooptic television systems in which a scanning laser beam prints the picture on a wall screen. The signal from the television station controls a beam of ultrasound which modulates the brightness of the laser beam. A second beam of ultrasound is made to vary periodically in frequency according to the synchronizing pulses put out by the station. The laser beam, diffracted by this second ultrasonic beam, scans the screen to produce the picture. Zenith's first system was monochrome. More recently the company has developed a color system in which one laser is used to produce light in the three primary colors that make up the color picture.

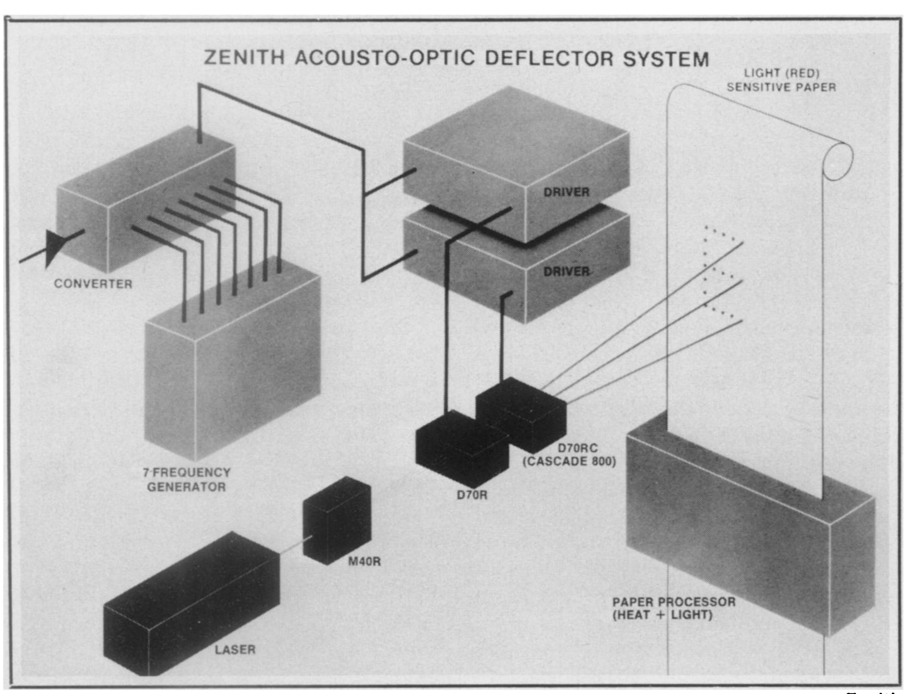
Another technological possibility is acoustic holography. An object is irradiated with ultrasound, which then transfers its information to laser pulses that produce an image. Zenith has developed an acoustooptic microscope that uses this principle. The body to be examined is submerged in water that serves as a medium of transmission for the ultrasound. The sound wave goes through the target, and then, carrying spatial information about the specimen, it strikes a plastic mirror. The sound causes ripples in the surface of the mirror that amount to a dynamic acoustical hologram of the object. The mirror is scanned by a laser beam, and the laser beam is recorded by a photodiode. The information is then imaged on a television monitor.

The frequency of sound now being used in the microscope is 100 million hertz. At this level the smallest detail the sound can resolve is about one-thousandth of an inch. In later versions frequencies 10 to 50 times greater will be used, at which point the acoustical microscope will have a resolving power approaching that of optical microscopes. However, the resolution is not as important as the fact that the sound waves, being able to penetrate where light does not, bring out information that an optical microscope does not. The device is therefore a complement to optical and electron microscopes rather than a replacement.

To use acoustooptical holography to investigate biological specimens lower frequencies are desirable. In many applications of nondestructive testing frequencies in the tens and hundreds of millions of hertz are usable, but to image biological specimens more than one centimeter thick, the absorption is so great that unacceptable power levels are required. John Landry, Hormozdyar Keyani, Glen Wade and John Powers of the University of California at Santa Barbara have been working in this area.

An acoustic imaging system for biological use would have to operate at frequencies below about five million hertz. It was difficult to make an operational system at such low frequencies; the diffraction angle is so small that the image was receiving a large part of the light that was scattered forward by minute particles in the acoustooptic interaction medium, and this scattered light degraded the image. The problem was solved by using a Mylar isolation membrane between the specimen tank and the acoustooptical interaction medium. The Santa Barbara group now has a system working at 3.58 million hertz which is capable of imaging the bone structure in a human hand with acoustic power densities of 100 milliwatts per square centimeter or less.

Sound and light are the two media by which people have communicated with other people since the human race began. Combined now, in ultramodern technological form, they seem likely to provide us with the next breakthrough in communications technology. □



Zenith

Schematic of Zenith's high-speed acoustooptical laser-light print-out system.