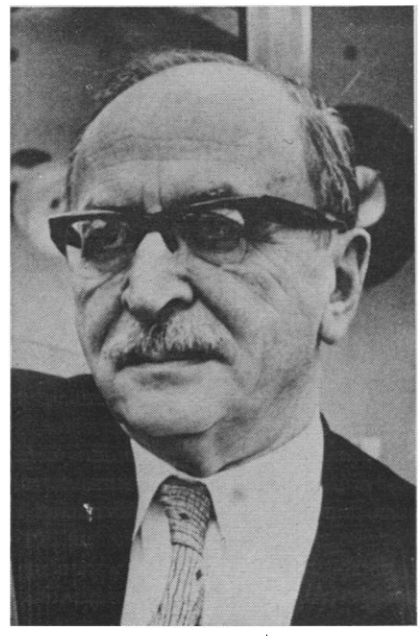
Nobel Prize for Physics: Gabor and Holography

The Nobel Prize in Physics for the year 1971 has been awarded to Dennis Gabor for his discovery of holography, an interferometric wavefront-reconstruction imaging technique first described by him in 1948. Since then, this technique has been applied widely, not only in optics as a three-dimensional lensless system of photography, but also in other fields, such as microwave radar acoustics and seismic exploration. Of his three memorable papers describing the concept, the first appeared in a May 1948 issue of *Nature* (*1*), the second in the 1949 *Proceedings of the Royal Society* (*2*), and the third in the June 1951 issue of the *Proceedings of the Physical Society* (*3*). Because holography requires coherent radiation in order to be of maximum effectiveness, interest in the concept and in its possible applications mushroomed when the laser, first demonstrated in 1960, became widely available. Two University of Michigan scientists, Emmett Leith and Juris Upatnieks, first applied the laser to holography in 1963; the result, a fulfillment of one of Gabor's predictions, was three-dimensional images of very high quality. Leith and Upatnieks were mentioned in the Academy's announcement as "accelerating the use of Gabor's technique."

A Fellow of the Royal Society, Gabor (*4*) was born in Budapest in 1900. He studied electrical engineering and physics at the Technical University in Budapest and at the Technische Hochschule in Berlin, where he received his doctorate. In 1933 he went to England as a research engineer in the Thompson-Houston Company at Rugby. He joined the faculty of the Imperial College of Science and Technology of the University of London in 1949 as a reader, and later became a professor there. He is now a professor emeritus at the university, but he spends most of his time at the Columbia Broadcasting System's laboratory in Stamford, Connecticut.

Gabor is author of over 100 scientific papers and is the recipient of numerous awards: Fellowship in the Royal Society, the Thomas Young medal of the Institute of Physics and the Physical Society, the Cristoforo Columba Medal of the International Institute of Communications, the Albert Michelson Medal of the Franklin Society, the Rumford Medal of the Royal Society, and the Medal of Honor the Institute of Electrical and Electronic Engineers.

Basically, holography is a new and ingenious method for photographically recording a three-dimensional image of a scene. Holography records not only the light waves issuing from the scene (as a normal photograph would), but also a second set of waves (also coherent), called the reference beam. These two sets interfere with each other, and it is this interference pattern which is recorded on the photographic plate. When developed, this recorded pattern acts as a complicated diffraction device, causing a beam of coherent (laser) light to be diffracted in such a way as to "reconstruct" a three-dimensional image of the original scene. This image manifests such vivid realism that the viewer is tempted to reach out and touch the objects of the reconstructed scene. The photographic plate itself resembles a window, with the imaged scene appearing behind it in full depth. To see around an object in the foreground, the viewer simply raises his head or moves it to the left or right. Inasmuch as no lenses are involved in the process, a hologram has none of the depth-of-focus limitations that apply to a camera photograph.



Dennis Gabor

Gabor coined the term "hologram" (holo meaning complete, gram meaning message) to indicate that the hologram captures the entire message of the scene, including its three-dimensionality. Although various words could have been devised to describe the general process—for example, "hologrammetry"—George Stroke (of the State University of New York, Stony Brook, and, since 1963, an extensive contributor to holography) proposed the term "holography," and this has become the generally accepted term.

For his contributions toward extending the usefulness of holography and making it more understandable, one other British scientist, G. L. Rogers, should be mentioned briefly. Rogers noted in 1950 (*5*) the similarity between hologram diffraction and diffraction by optical zone plates. In 1956, he published the results of radio experiments in which he used holography (*6*). Thus Rogers is apparently the first person to have described not only the use of holography in the radar field, but also the basic synthetic-aperture radar process whereby the hologram reference wave is supplied from the transmitter's master oscillator.

The number of applications of holography continues to mount steadily, and dozens of books on the subject are now available. A recent one, *Applications of Holography*, contains chapters by Gabor, Stroke, Winston Kock, and others (*7*). In July, *Science* carried an article, by Gabor, Stroke, and Kock, in which numerous applications of holography were discussed (*8*). Stroke's *An Introduction to Coherent Optics and Holography* (*9*) provides a rigorous treatment of the subject and includes a translation of "Applications of Holography," an article written by Russian scientist I. P. Nalimov.

One final note is called for concerning the economic importance of this new technology. According to a study conducted by *Fortune* magazine, holography has grown into a worldwide business that grosses several hundred million dollars a year; it is being used in medicine and in many areas of industry. During the summer of 1971,

airborne hologram radar was used by the Aero-Service Corporation to "photograph" (extremely clearly, in spite of an extensive cloud cover that would have blocked ordinary photography) 3 million square miles of the Amazon River basin in South America. Another example of the myriad uses of holography now being explored involves attempts to understand more fully extremely small objects. Holographic techniques have been used, for example, to clear up electron photomicrographs of molecular structures.

Optics is not the only field of specialization for Gabor. His papers on communication theory, written in the 1930's and 1940's, are now considered classics in the field. These contributions to information theory (the information content in wave fields) were noted in the Academy's announcement. In addition, he has written numerous papers on cathode-ray oscillographs, electron devices, and gas discharges.

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References and Notes

1. D. Gabor, *Nature* **161**, 777 (1948).
2. D. Gabor, *Proc. Roy. Soc. Ser. A* **197**, 464 (1949).
3. D. Gabor, *Prcc. Phys. Soc.* **64** (part 6), 303 (1951).
4. Gabor prefers to have the first syllable of his name accented—that is, Gá-bor.
5. G. L. Rogers, *Nature* **166**, 237 (1950).
6. G. L. Rogers, *ibid.* **177**, 613 (1956).
7. E. S. Barrekette, W. Kock, T. Ose, G. Stroke, J. Tsujiuchi, Eds., *Applications of Holography* (Plenum, New York, 1971).
8. D. Gabor, W. E. Lock, G. W. Stroke, *Science* **173**, 11 (1971).
9. G. Stroke, *An Introduction to Coherent Optics and Holography* (Academic Press, ed. 2, New York, 1969). See also W. Kock [*Lasers and Holography* (Doubleday, New York, 1969)] for an elementary treatment of holography.

NEWS AND COMMENT

The Open University: Breakthrough for Britain?

Britain's Open University (OU), perhaps the most ambitious venture in extramural higher education ever undertaken, is completing its first academic year. Politically, the future of the OU is something of an open question. Educationally, a lot of issues will remain unsettled, even after the results of current final examinations are in. But in terms of momentum and morale, the OU can fairly claim a successful first year.

Called "the university of the second chance" by its partisans, the OU now offers part-time students 21 years of age and older the opportunity to work for bachelor of arts degrees. In the first year, the faculties of arts (the American equivalent is humanities), social science, science, and mathematics offered first-level courses; two new faculties, technology and educational studies, will offer first courses, starting in January. Second-level courses have been readied for the new academic year, and third- and fourth-level courses are in the works. Advanced courses, including "postexperience" courses and programs leading to graduate degrees, are being contemplated.

Instruction at OU is based on a mix of media, and although the heart of the curriculum is a big package of course material requiring written assignments from students, the OU appears to have beaten the stereotype of a "correspondence college." Not only is teaching by television and radio an integral part of all OU courses, but students have regular access to tutors and counselors through some 280 local study centers scattered around Britain. Students also are required to attend 1-week summer school sessions that are held at universities.

Along with its unique characteristics, the OU has many attributes of a traditional university—a royal charter, the right to grant degrees, administrators and professors of its own, a campus. It even has a crest, which on close examination proves to be a mod heraldic combination of the initials OU. The campus, near Bletchley in Buckinghamshire, lies an hour's train journey from London and near Britain's main north-south motorway, the M1. The OU buildings are going up on a 70-acre site on a country estate, Walton Hall, on the edge of the village of Walton. The campus is in an area which before too long will be part of the projected new city of Milton Keynes (named for the poet and the economist), which is to provide a new population center in crowded southern England.

The campus is, as one professor describes it, "an educational factory," where computers are used to process written assignments and handle complex academic and administrative dealings with students. Senior faculty is headquartered there, and Walton Hall is the center for curriculum development. If plans materialize, the campus is expected ultimately to accommodate everything from comprehensive educational publishing facilities to advanced research. At present, work goes on in the first new brick university buildings—in functional but not unattractive style—and in rows of one-story temporary buildings. A common misconception is that the OU is run by the BBC (British Broadcasting Corporation). The OU-BBC partnership is actually based on an understanding under which the BBC is reimbursed for production of television and radio programs.

The idea of the OU evolved in the mid-1960's while the Labour Party was in office. The then Prime Minister, Harold Wilson labeled the idea "University of the Air", which its backers feel gave it an erroneous and unfortunate image. The project was launched in 1969 and last year survived, if narrowly, the change in government. The Conservative government has remained skeptical of the OU, but has given it a 3-year grace period to prove itself. An observer wryly noted that one thing which recommends the OU to the government is its cost effectiveness. It is estimated that, even if only 20 percent of those enrolled in the first year earn degrees, the investment per graduate will be about half that for graduates of conventional universities. (About $12 million will have been spent on plant and equipment by 1973, and the operating budget for 1971 was about $15