Guest Editorial

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Holographic Applications

Little in science has created as much interest, excitement, and controversy in the past decade as holography. Holography, or wavefront reconstruction as it was first called, was invented by Dennis Gabor in 1948 in an attempt to improve the resolution of images obtained with an electron microscope. Although Gabor was unable to demonstrate his technique with electron waves, he was able to do so with visible light. The most serious problems Gabor and other early holography experimenters encountered was the presence of a twin image and the absence of a light source suitable for making holograms. Within a decade after its invention, holography appeared destined for obscurity. However, in the early 1960's Leith and Upatnieks at the University of Michigan demonstrated a new approach to holography based on communications theory techniques that made it possible to eliminate the twin image and hence gave higher resolution images than previously available. At about the same time lasers were being developed that provided the coherent light required for making holograms. By 1964 or 1965 holography was causing much interest in the scientific community, and investigators at numerous universities and industries began studying and inventing new holographic techniques. Between 1964 and 1968 more than 500 papers and articles were written on holography. Unfortunately, many of the early predictions on the use of holography failed to materialize, and by 1968 much of the glamor earlier associated with holography began to disappear, contracts were no longer awarded simply because the title contained the word "hologram," and many of the investigators began to study other fields.

Some of the early investigators will always be interested in holography as a hobby because of the excitement that is generated when a three-dimensional image is produced by illuminating with a laser beam what appears to be a cloudy piece of glass. Other investigators have continued working in holography to improve its applications. While it is no longer an invention a day, the studies performed during the past five years have been much more thorough and complete than most of the early studies. While many of the early predicted applications of holography did not materialize, many very useful applications have been developed, and it is the purpose of this special feature on "Holographic Applications" to give state-of-the-art discussions of many of these applications.

In this issue's first paper, which begins with a brief review of the "holographic process," J. D. Trollinger describes the first practical application of holography, the three-dimensional recording and imaging of particle fields. This important area of particle field holography is the only method by which high-resolution viewing of moving particles through a volume can be achieved. When the object to be observed is small, high magnification is required in the microscope, and hence the depth of field is small. With holography it is possible to record the entire volume of interest at the desired instant and later, at leisure, microscopically examine the three-dimensional image throughout its volume.

The most serious problem facing holography at the present time is the lack of the ideal recording material. The ideal material would have high sensitivity and resolution, low noise, and linear recording characteristics. The recording should persist over an indefinite amount of time, although the material should have erasibility and reusable capability. The material should provide for high diffraction efficiency and easy processing. Although the ideal recording material will probably never exist, improved recording materials, or in some cases recording devices, are being developed. The second paper by R. L. Kurtz and R. B. Owen gives a review of the ideal recording material and the materials currently available.

Although the early prediction of three-dimensional holographic television and books never materialized, holography has produced spectacular displays for educational, commercial, scientific, and artistic purposes. The article by S. A. Benton on "Holographic Displays" examines the prospects for larger, brighter, cleaner, deeper,and more colorful displays.

Another application of holography that shows much promise is the use of holograms as optical elements. The article by D. H. Close is a survey of the characteristics, technology, and applications of holographic optical elements.

It is not expected that holographic optical elements will replace conventional optical elements, but rather they will be used in applications where their special feature make it possible to perform functions that conventional optics cannot perform. As described by D. H. Close, the use of holographic elements in several types of laser systems appears to be both advantageous and technically and economically feasible. A particular type of holographic optical element that is already finding much use is the holographic diffraction grating. As described in the article by G. S. Hayat, J. Flamand, M. Lacroix, and A. Grillo, the plane holographic diffraction grating offers improvements in stray light levels and higher groove densities, whereas the concave holographic grating offers, in addition, improvement in aberration correction with fewer optical components. The use of holographic diffraction gratings will certainly be one of the most important applications of holography.

A type of holographic optical element is a computer-generated hologram. As described in the article by O. Bryngdahl, information about arbitrarily shaped wavefronts, which can be described only mathematically and never need exist previously, can be recorded by means of computer-generated holograms. These holograms can be applied to accomplish phase transformations, geometrical transformations, and combinations of phase and geometrical transformations.

The review article on "Optical Subtraction" by J. F. Ebersole describes techniques for optical subtraction of photographic imagery. Some of the techniques are holographic; while other techniques are not strictly holographic, they all fall into the general category of coherent optics. Among the many applications for optical subtraction are earth resources studies, metrology, automatic surveillance and/or inspection, pattern recognition, urban growth studies, and bandwidth compression.

Photogrammetry is an old, well developed science; however, new methods for improving or in particular increasing the speed of making contour measurements are always in demand. The article on "Holographic Applications in Photogrammetry" by N. Balasubramanian discusses the role holography is playing in improving photogrammetry techniques.

The paper on "Holographic Memories" by G. R. Knight describes recent work in holographic storage. The various holographic systems proposed are compared with more standard technologies such as semiconductors and magnetic disks. Both read-only and read-write-erase memories are described. As described by G. R. Knight, the associative nature of holographic storage is expected to make holographic memories very attractive for parallel search and perhaps parallel processing operations for large data bases.

Probably the most useful application of holography to date has been in the area of interferometry. Holographic interferometry involves the formation and interpretation of fringe patterns that appear when a wavefront generated at some earlier time and stored in a hologram is later reconstructed and interfered with a comparison wavefront. The storage or time delay aspect of holographic interferometry gives a unique advantage over conventional optical interferometry. This storage feature gives holographic interferometry the unique property that an arbitrarily shaped, rough scattering surface, which is subject to stress, can be interferometrically compared with its normal state. In the article by J. E. Sollid, the application of holographic interferometry to the analysis of structural components is discussed. Both strain and vibration analysis is described. J. D. Trolinger in his article on "Flow Visualization Holography" describes the use of holographic interferometry for determining gas density or observing density gradients and their movement throughout a volume. In addition to using the holographically stored wavefront for interferometric purposes, holography improves other methods of flow visualization such as photography, shadowgraphy, and schlieren photography.

While speckle photography or interferometry is not holographic interferometry per se, it owes its origination to holography. Speckle interferometry involves using laser speckle, the universal nuisance of holography, for measuring object motion or change. During the past five years or so, much research has been performed in the area of speckle interferometry, and the paper by K. A. Stetson describes many of the different techniques that have been developed, pointing out their simularities and differences.

Holography or holographically related techniques are expected to yield useful applications in the area of medicine. Some of these applications are already being realized. In the paper by R. G. Simpson, H. H. Barrett, J. A. Subach, and H. D. Fischer, an improvement in the reconstruction technique for annular coded images is suggested. The technique is expected to be useful in nuclear medicine where one is interested in forming an image of the distribution of radiopharmaceuticals that emit gamma rays within a patient.

Another area in medicine where holographic techniques are being used is medical diagnosis in which acoustical holography is in an advanced state of development and is approaching the point where commercial systems will soon be available. The paper by B. B. Brendon describes the application of acoustical holography to medical imaging as well as to industrial testing, seismic holography, and undersea imagery.

The last paper in this special feature on "Holographic Applications" is on microwave holography by N. H. Farhat. Microwave holography is of particular interest because it provides a means of seeing through optically opaque dielectrics by the use of centimeter and millimeter wavelengths. In his paper, N. H. Farhat describes the principles of scanned transmitter-receiver and scanned object microwave holography and their use in high-resolution microwave imaging.