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Nobel Prize in Physics 1971

Dennis Gabor

The Nobel Prize in Physics 1971 was awarded to Dennis Gabor *"for his invention and development of the holographic method"*.

RESEARCH INFORMATION:

Our five senses give us knowledge of our surroundings, and nature herself has many available resources. The most obvious is light which gives us the possibility to see and to be pleased by colour and shape. Sound conveys the speech with which we communicate with each other and it also allows us to experience the tone-world of music.

Light and sound are wave motions which give us information not only on the sources from which they originate, but also on the bodies through which they pass, and against which they are reflected or deflected. But light and sound are only two examples of waves which carry information, and they cover only very small parts of the electromagnetic and acoustic spectra to which our eyes and ears are sensitive.

Physicists and technologists are working continuously to improve and broaden the methods and instruments which give us knowledge about waves which lie outside our direct perception capacity. The electron microscope resolves structures which are a thousand times smaller than the wavelength of visible light. The photographic plate

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preserves for us a picture of a fleeting moment, which perhaps we may make use of over a long time period for measurements, or it transforms a wave-field of heat rays, X rays, or electron rays to a visible image.

And yet, important information about the object is missing in a photographic image. This is a problem which has been a key one for Dennis Gabor during his work on information theory. Because the image reproduces only the effect of the intensity of the incident wave-field, not its nature. The other characteristic quantity of the waves, phase, is lost and thereby the three dimensional geometry. The phase depends upon from which direction the wave is coming and how far it has travelled from the object to be imaged.

Gabor found the solution to the problem of how one can retain a wave-field with its phase on a photographic plate. A part of the wave-field, upon which the object has not had an effect, namely a reference wave, is allowed to fall on the plate together with the wave-field from the object. These two fields are superimposed upon one another, they interfere, and give the strongest illumination where they have the same phase, the weakest where they extinguish each other by having the opposite phase. Gabor called this plate a hologram, from the Greek holos, which means whole or complete, since the plate contains the whole information. This information is stored in the plate in a coded form. When the hologram is irradiated only with the reference wave, this wave is deflected in the hologram structure, and the original object's field is reconstructed. The result is a three dimensional image.

Gabor originally thought of using the principle to make an electron microscope image in two steps: first to register an object's field with electron rays in a hologram, and then to reconstruct this with visible light to make a three dimensional image with high resolution. But suitable electron sources for this were not available, and also for other technical reasons the idea could not be tested. However, through successful experiments with light Gabor could show that the principle was correct. In three papers from 1948 to 1951 he attained an exact analysis of the method, and his equations, even today, contain all the necessary information.

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Holography, as this area of science is called, made its break-through when the tool, which had so far been missing, became available, namely the laser as a light source. The first laser was successfully constructed in 1960, and the basic ideas were rewarded by the 1964 Nobel Prize in physics. The laser generates continuous, coherent wave-trains of such lengths that one can reconstruct the depth in the holographic image. At about the same time a solution was discovered to the problem of getting rid of disturbing double images from the field of view. A research group at Michigan University in the United States, led by Emmett Leith, initiated this development.

The fascinated observer's admiration when he experiences the three dimensional space effect in a holographic image is, however, an unsufficient acknowledgement for the inventor. More important are the scientific and technical uses to which his idea has led. The position of each object's point in space is determined to a fraction of a light wave-length, a few tenthousandths of a millimetre, thanks to the phase in the wave-field. With this, the hologram has, in an unexpected way, enriched optical measurement techniques, and particularly interferometric measurements have been made possible on many objects. The shape of the object at different times can be stored in one and the same hologram, through illumination of it several times. When they are reconstructed simultaneously, the different wave-fields interfere with each other, and the image of the object is covered with interference lines, which directly, in light wavelengths, correspond to changes of shape between the exposures. These changes can also be, for example, vibrations in a membrane or a musical instrument.

Also, very rapid sequences of events, even in plasma physics, are amenable to analysis through hologram exposures at certain times with short light flashes from modern impulse lasers.

Gabor's original thought to use different waves for both steps within holography, has been taken up in many connections. It is especially attractive to use ultra sound waves for exposures, so that, in the second step, a sound field is reconstructed in the shape of an optical image. Despite significant difficulties there is work, with a certain amount of progress, being done in this area. Such a method should be of value for medical diagnosis, since the deflected sound field gives different information from that in X ray radiography.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1971/press.html#