Holography: 50th Anniversary of Dennis Gabor's Nobel Prize. Part I. A historical perspective

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Abstract: A historical review of the origins of holography is presented. Special emphasis is placed on the contributions of Gabor, Denisyuk and Leith to the development of holography, to motivate and inspire students and young researchers.

1. Introduction

In 1971, the Hungarian engineer Dennis Gabor was awarded the Nobel Prize in Physics "for the invention and development of the holographic method." To commemorate the 50th anniversary of this award two papers are presented, both of them related to the cycle of online conferences organized by the Spanish Society of Optics in May 2021 within the framework of the International Day of Light events. The first conference [1] is summarized in this paper (Part I) in which a historical approach to the origins of holography is presented. The second conference is summarized in Part II, which is related to volume holographic scatter.

2. Dennis Gabor and the wave-front reconstruction

Dennis Gabor (Figure 1) was born in Budapest (Hungary). He obtained a Diploma in Electrical Engineering in 1924 and the degree of Doctor of Engineering (Dr-Ing.) in 1927 at the Technical Hochschule Berlin-Charlottenburg [2,3]. In the same year he joined Siemens & Halske AG, Berlin, and in 1934 he went to England, where he got a job with the British Thomson-Houston Company in Rugby, where holography began to take its first steps in 1947. Gabor was working on improving the electron microscope, whose main limitation was related to the spherical aberration of the magnetic lenses of the microscope. To solve this problem Gabor asked himself: "Why not take a bad electron picture, but one which contains the whole information, and correct it by optical means?" [4].

Gabor came up with the answer to this question considering a two-step process. In the first stage, the recording, the interference pattern between a coherent electron beam (object wave) and a "coherent background" (reference wave), is recorded on a photographic plate. Gabor called this interference pattern "hologram", from the Greek word "holos", the "whole", because it contained the whole information (amplitude and phase) of the object wave. In the second stage, the reconstruction, the hologram is illuminated with visible light and the original wavefront is reconstructed, so that the aberrations of the electron optics can be corrected by optical methods.

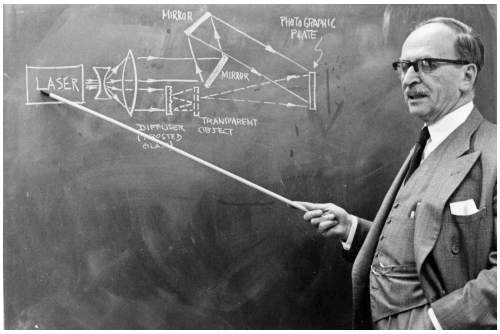

Fig. 1. Dennis Gabor (1900-1979). AIP Emilio Segrè, Visual Archives, Physics Today Collection.

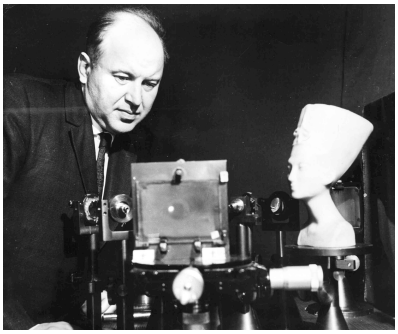

Fig. 2. Yuri Denisyuk (1927-2006). S.I. Vavilov State Optical Institute. AIP Emilio Segrè Visual Archives.

To obtain contrast interference fringes, it is necessary to use a light source of high coherence, which did not exist in times of Gabor (the laser was invented in 1960). Due to this, Gabor made his first hologram in 1948 using a light source that consisted of a mercury arc lamp with a narrow-band green filter, one of the best coherent light sources before the laser. The object was a tiny circular transparency (1.4 mm diameter) of opaque lettering on a clear

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background containing the names of Huygens, Young and Fresnel. However, the reconstruction step of the hologram was imperfect. Gabor's method produced an in-line hologram whose quality is poor due to the overlap of the virtual image and the real image or conjugate. In 1955, after investigating various optical set-ups to minimize the effect of the conjugate image, Gabor abandoned his research about holography.

3. Yuri Denisyuk and wave photography

Yuri Denisyuk (Figure 2) started working for the Soviet Navy in the field of optical instrumentation at the Vavilov State Optical Institute in Leningrad (in the former USSR). In 1962 he published his results on what we now know as a reflection hologram and that he called wave photography [2]. Denisyuk placed the object next to one side of the photographic plate and illuminated the other side with light from a mercury lamp. The light wave, after passing through the plate, is reflected by the object and interferes with the incident wave, giving rise to a standing wave pattern that can be recorded on the photographic plate. This plate, once developed, is illuminated with a beam of white light and the object appears in its original position and in the color of the light used in the recording.

4. Emmett Leith, lensless photography and Dennis Gabor's Nobel Prize

In his Nobel Prize Lecture [5], Gabor stated that around 1955 holography went into a long hibernation until the invention of the laser in the early 1960s. However, this statement is not entirely correct. Emmett Leith (Figure 3) pointed out that it was wrong to think that holography research had disappeared between 1955 and 1962, but that in fact it was carried out clandestinely in two separate laboratories: the Vavilov Institute in Leningrad, where Denisyuk worked on his wave photography, and the Willow Run Laboratories at the University of Michigan, near Ann Arbor (USA), where Leith made the 3rd independent formulation of holography, which he called lensless photography [2].

In 1960 Juris Upatnieks (Figure 3) started working as Leith's assistant and they both repeated Gabor's experiments, first using a mercury lamp as a light source and then a He-Ne laser. They had an advantage over Gabor and Denisyuk in that by the early 1960s, lasers had been invented and highly coherent light was already available. Leith and Upatnieks solved the twin image problem that had plagued Gabor so much and came up with the tilted reference beam technique: they had just invented the off-axis hologram.

Fig. 3. Juris Upatnieks (1936-) and Emmett Leith (1927-2005). AIP Emilio Segrè Visual Archives, Physics Today Collection.

Many developments in holography originated rapidly in the United States in the 1960s after the invention of the laser in 1960 and thanks to the contributions made by Leith and Upatnieks – who made the first hologram of a three dimensional object in 1964 – and other researchers from the Willow Run Laboratories. This holographic explosion put Gabor on top, and he won the Nobel Prize in Physics in 1971 "for his invention and development of the holographic method."

Gabor finished his Nobel Lecture, *Holography, 1948-1971*, recognizing that the contributions of other researchers helped him to win the Nobel Prize [3,5]: "I am one of the few lucky physicists who could see an idea of theirs grow into a sizeable chapter of physics. I am deeply aware that this has been achieved by an army of young, talented and enthusiastic researchers, of whom I could mention only a few by name. I want to express my heartfelt thanks to them, for having helped me by their work to this greatest of scientific honors."

5. Acknowledgements

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