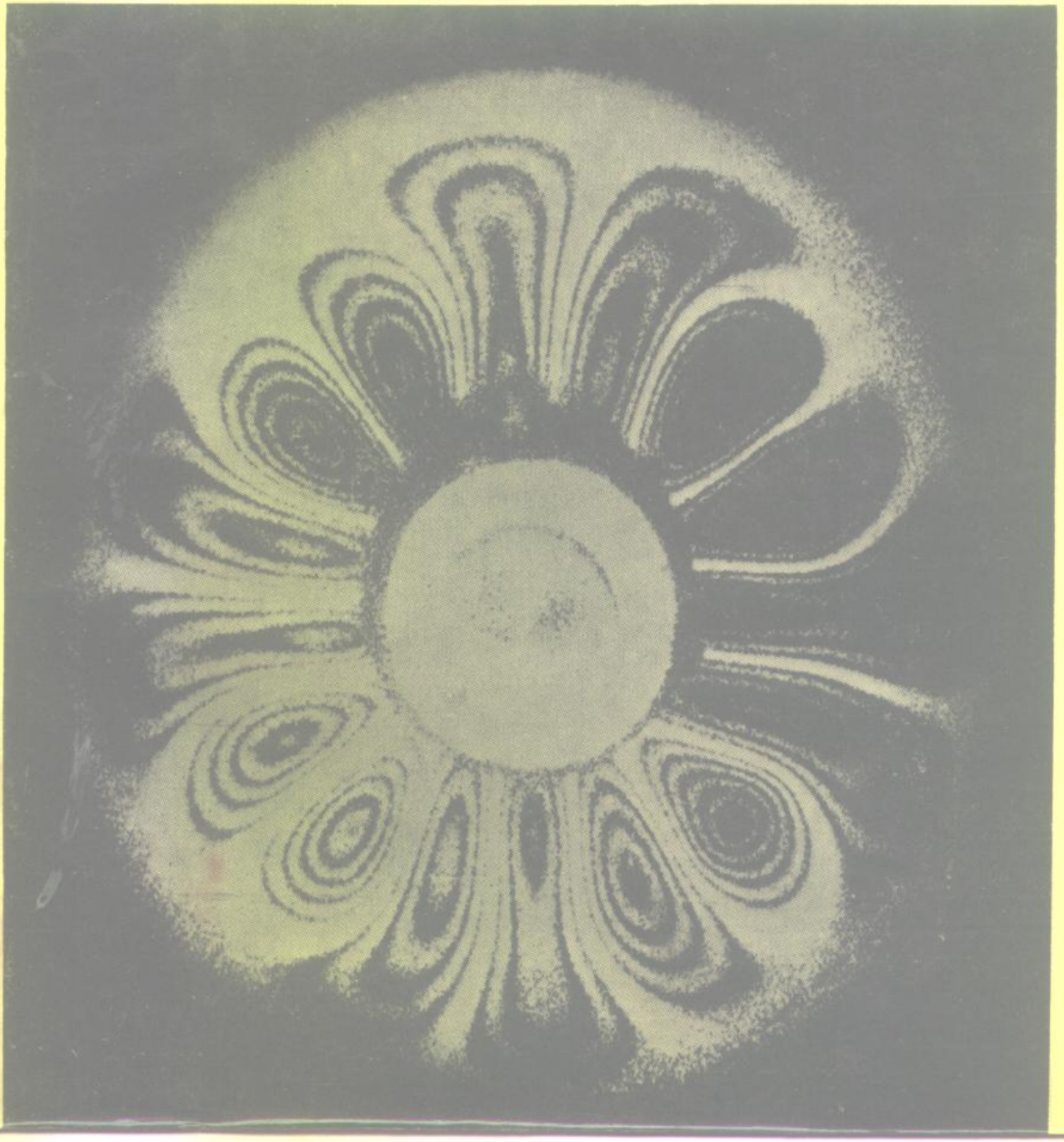
Edited by Ezio Camatini

OPTICAL AND ACOUSTICAL HOLOGRAPHY



OPTICAL AND ACOUSTICA
HOLOGRAPHY

Proceedings of the NATO Advanced Study Institute
on Optical and Acoustical Holography
Milan, Italy, May 24-June 4, 1971

Edited by Ezio Camatini

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PREFACE

When Faraday performed the very first experiments on electromagnetic effects, which form the very foundation of modern civilization since virtually everything electrical utilizes them, he was asked of what use his experiments were. He is said to have replied: "What is the use of a baby?" That reply might also be given to those who asked what was the use of basic research which resulted in the development of the laser and holography.

Brigadier General Leo A. Kiley, Commander, Office of Aerospace Research, USAF, in his remarks before the Society of Photo-Optical Instrumentation Engineers at the opening ceremony of the Seminar on Holography held at San Francisco, California, in May 1968, declared, "It has been said that in the twenty-first century at least half of the jobs that will exist then do not exist today. But be that as it may, I am sure that holography will be commonplace."

And later "Even in its embryonic state today, the concept of holography is providing real world applications to the scientific community and I feel that continued rapid growth can be predicted."

Now, only three years after these statements, the development of holography is extraordinary on the scientific side and very promising from the point of view of proven and potential applications. Holography looks like an emerging technique, a valuable tool for engineers.

In this connection, the Advanced Study Institute on Optical and Acoustical Holography held in Milan (Italy) from May 24 to June 4, 1971 has proved to be very fruitful as a stimulating meeting between physicists and engineers for a free discussion, in the most informal way, of the present state-of-art-and-technology of holography as a science and as a technique.

Further progress is linked to two efforts. One is the investigation of the fundamentals of holography. The other main effort

is to extend the range of situations in which holography can be employed by introducing variations in the holographic techniques. Of course, each effort enjoys a feedback from the other, so that only the combined work of scientists and engineers will solve the many technological problems connected with holography and its application.

In this line, the proceedings of the Institute appear to be a basic text and a powerful tool for all people working in the field of holography and a valuable contribution to a greater knowledge and to the development of this new technology.

The material in these proceedings covers four main topics: the general theory of holography, optical holography, microwave holography, and acoustical holography. The first topic is introduced by the contribution of Professor Gabor, some historical remarks concerning holography. Optical holography deals with the following subjects: the fundamentals of optical holographic techniques, experience with optical holography, holographic interferometry and mechanical analysis, optical data processing, and such specific problems as the correction of optical aberrations, recording media, information storage, and the application of holography to NDT (nondestructive testing).

As Scientfic Director of the Advanced Study Institute on Optical and Acoustical Holography and editor of these proceedings, my gratitude goes to the Scientific Affairs Division of NATO, which sponsored the seminar and made possible the publication of this volume.

I also wish to thank the lecturers for their papers, which made this book a valuable document of the Institute.

My best congratulations are conveyed to Professor Dennis Gabor, C.B.E., F.R.S., Prix Holweck, "the Father of Holography," who has been very recently honored with the Nobel Prize in recognition of his contribution in the field of holography.

Finally, I am greatly indebted to Mrs. Valeria Sarchi, without whose enthusiastic and extensive help in the organization of the seminar and in the publication of this volume the editor could not have accomplished his task.

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PREFACE

When Faraday performed the very first experiments on electromagnetic effects, which form the very foundation of modern civilization since virtually everything electrical utilizes them, he was asked of what use his experiments were. He is said to have replied: "What is the use of a baby?" That reply might also be given to those who asked what was the use of basic research which resulted in the development of the laser and holography.

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Further progress is linked to two efforts. One is the investigation of the fundamentals of holography. The other main effort

It is peculiar that in order to observe objects our retina does not need wavefronts or rays but needs what we call an image, that is a particular cross section of a wavefront where the uncertainty in directions of wave vectors is maximum and, on the contrary, the spread in a bundle of rays coming from a point of the object is minimum. As our eyes, so our photographic plates need such particular cross section in order to record an image of an object which can be in turn reproduced on our retina observing the photography.

At this particular section of a bundle of quasi monochromatic rays we have a resolution of the order of the wavelength which allows immediately the evaluation of the information capabilities of a given area of the image. (One should also take into consideration the number of brilliance steps distinguishable in any independent area λ^2).

The same information is present at any other cross section of the bundle of rays considered but, in order to reconstruct the bundle of rays, one needs the double of information elements than needed in the focal plane; furthermore, he needs to know, not only amplitudes but phases also.

This is just what holography does by mixing techniques with carryer beams using as nonlinear elements, photographic plates or photocromic materials.

In the perception process:

Object - Light wave - Image

holography breaks the process in two processes by freezing first the light wave in a recorded hologram:

Object - Light wave, Carrier wave - Hologram.

The reconstructed light wave can be seen or photographed as if it were the original one.

It is interesting to note that the most general monochromatic wave

has at the most, without any quantum mechanics consideration, ∞^2 degrees of freedom: i.e. amplitude and phases at a given plane; and, therefore, it is able to carry on information about surfaces and not about volumes. We generally look at surfaces of objects and, when we think to see them three dimensionally, we think to surfaces in a three dimensional manifold. If we have to look at volumes, we must put a lot of a priori information in our evolution or try to introduce other variables: for instance, different wavelengths or colours in order to distinguish different depths.

The only purpose of the above review of some basic concepts is to introduce the main subject of this Seminar that will engage you for two weeks in a very stimulating meeting and for which I wish a fruitful work.

WELCOME TO MILAN!

E. Camatini

Politecnico di Milano, Italy

Scientific Director of the NATO Advanced Study Institute on Holography

It is my pleasure to welcome you to Milan and to express in advance the deepest gratitude for your valuable contribution, as lecturers or participants, to this Advanced Study Institute on: DEVELOPMENT OF LASER: OPTICAL AND ACOUSTIC HOLOGRAPHY

Holography is something which sounds like a magic name to most people and when you try to explain to them that hologram means "entire recording", from the Greek word "holos", they still do not understand, nor show any gratitude to Prof. Gabor, the Father of Holography, who invented that name.

This situation is typical of any other when we speak about a new science or technique.

Some years ago, on the door of a laboratory in California I saw a picture from a popular magazine of a light beam blasting a missile from the sky, boldly titled "The incredible Laser". Few years later, on the same door a second legend has been added: "For credible Lasers see inside".
That defaced picture neatly summarizes the brief history of the Laser, one of the most exciting discoveries of modern physics.

Today, many people are familiar with Laser. It might be that within few years holography become so popular that we shall see the tourist to use the holographic equipment instead of the traditional camera to take shots of Scala Theater or something else.

Holography with Laser is a very recent development and much research is still currently in progress. It is therefore hard to

judge the relative importance of its application, but many of those already under development promise to have widespread use in the future.

Applications of holography include information storage, recording of images in depth, the use of holograms as optical elements, and as a means of performing precise interferometric measurements on three-dimensional objects of any shape and surface finish.

However, of the many fascinating possibilities for holograms none seems to hold greater promise than that as a tool for scientific research.
The computer has given the scientist a remarkably powerful tool for analysing immense quantities of data, and to match its abilities and exploit its power to the full, the scientist needs single systems for gathering very large amounts of data at minimum inconvenience to himself.

Holography promises to provide one such system: a single means for gathering data that can then be analysed by a complex system.

Although still in the experimental stage of development, acoustic holography appears destined to play an important future role in such areas as medical diagnosis, non distructive testing, underwater viewing and underground exploration. Its full utilization must await development of certain key components for the imaging system and sophistication of the over-all technology involved.

However, we are not here to deal with the proven and potential applications of holography only; aim of the Seminar is a free discussion, in the most informal way, on the present state-of-the art-and-technology of holography, that means as a science and as a technique.
In other words, the Institute will be very successful if only a stimulating meeting be promoted between plysicists and engineers and the scientific and technical aspects of the subject be dealt with in a balanced way.
In this line, your cooperation, both of lecturers and participants, will be highly appreciated; personally I do not want to interfere at all with your work, therefore the success of the Seminar will mean your success and the merit of this success will be yours, and yours only.

Before the Seminar is declared officially open, please let me express the deepest gratitude to the Scientific Affairs Division of NATO, from which this Institute has been sponsored, and to the FAST, which hosts the meeting and puts at our disposal its very efficient organization: in particular, to the President of FAST, ing. Rossari, and to the President of the Cultural Committee of FAST, prof. Dadda.

I am also indebted to Professors Caldirola and Gatti for their encouragement during the organization of the Institute; to Professors Vienot and Sona, whose contribution to the finalization of the programme was extremely precious; to the lecturers, who bring into the Seminar the high contribution of their science and experience; to the participants, who came here with the scope of promoting a constructive discussion with the lecturers.
To all of you I cordially wish a pleasant stay in Milan and a fruitful work.