HOLOGRAMS REDISCOVERED: A CASE STUDY ON THE PRESERVATION OF A HOLOGRAM COLLECTION

John M. Dudley[1], Luc Froehly[1], Maia Carpentier[2], Lucie Vidal[2], Baptiste Cottard[3], Maxime Jacquot[1]

1) Université Marie et Louis Pasteur, CNRS, institut FEMTO-ST, Besançon, France
2) Université Marie et Louis Pasteur, Besançon, France
3) Université Bourgogne Europe, Dijon, France

HOLOCONTROL project

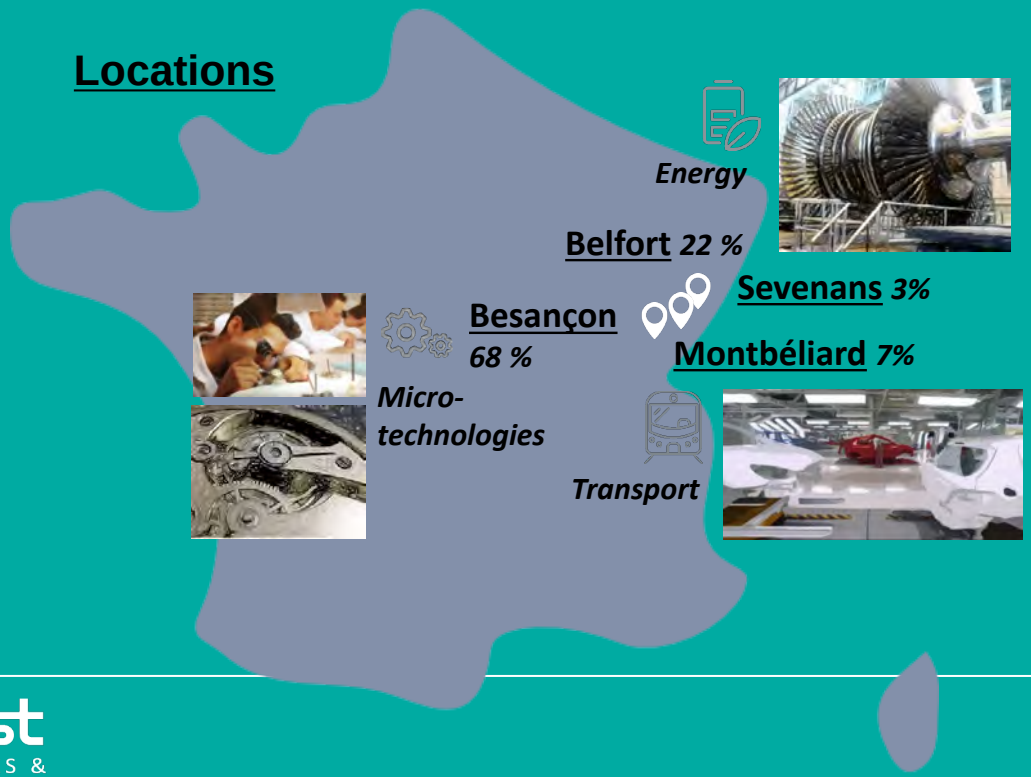


FEMTO-ST Institute

750 members (staff, students, invited)
7 scientific departments (AS2M, DISC, ENERGY, DMA, MN2S, OPTICS, TF)
1 micro-nano- fabrication center (MIMENTO, clean room facilities) and 9 other technological centers
1 R&D business unit for technology maturity growth toward the industry: FEMTO Engineering

Expertise in Engineering Sciences, Information and Communication Technologies
FEMTO-ST gathers these activities within the Bourgogne-Franche-Comté region, France.

Locations



The FEMTO-ST Institute in a nutshell:

Mastering micro & nano technologies, densify functions, integrate intelligence, for components and systems engineering with optimized performances and ambitious societal and economical impact

INTRODUCING THE OPTICS DEPARTMENT @ FEMTO-ST INSTITUTE







History since 1946 / location in Besançon

- The legacy of P.M. Duffieux and many others!
- Birth of the laboratory in 1963
- Founding member of FEMTO-ST in 2004

3 research teams – 85 members (30 staff, 47 Students…)

- Nano-Optics
- Non-linear Optics
- Optoelectronics, Photonics & Optical Telecommunications

From fundamentals to applied research: 3 focused key areas

- New advanced optical features
- Non-linear photonics in intense fields & extreme events
- Control of complex smart systems

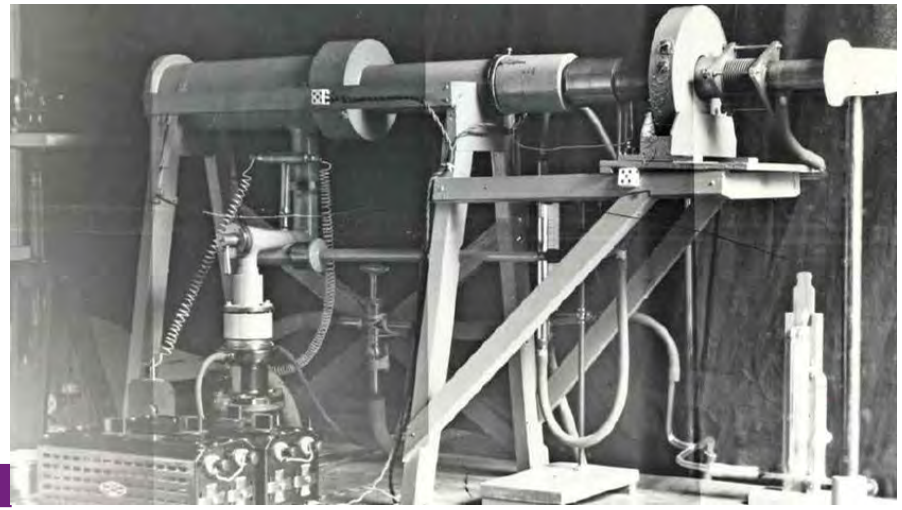
Expertise and historical know-how

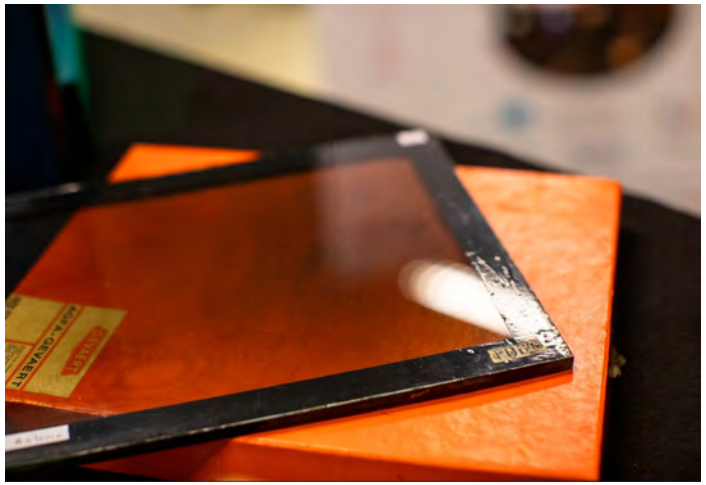
- Background: Optical metrology, lasers, non-linear optics, holography, etc.
- Non-linear photonics, integrated optical components (LiNbO3...), photonics in fibres, nano-photonics, ultra-fast optics, quantum information, non-conventional imaging, photonic AI...

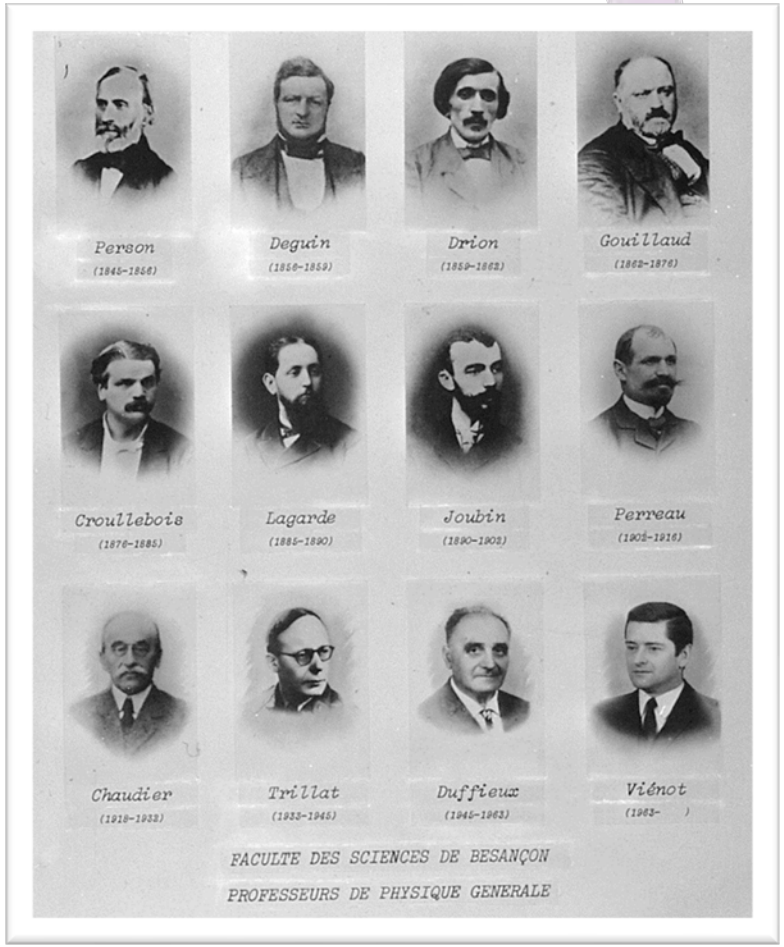
OUR PROJECT AT UNIVERSITÉ MARIE ET LOUIS PASTEUR

In a small university that sometimes struggles to make itself known compared to its larger neighbours, it is important to showcase our own scientific heritage, both internally and externally!

‘One cannot fully understand a science without knowing its history.’ Quote from Auguste Comte, reproduced by P. M. Duffieux (1891–1976) in a letter to Charles Fabry (1867–1945) in 1931.

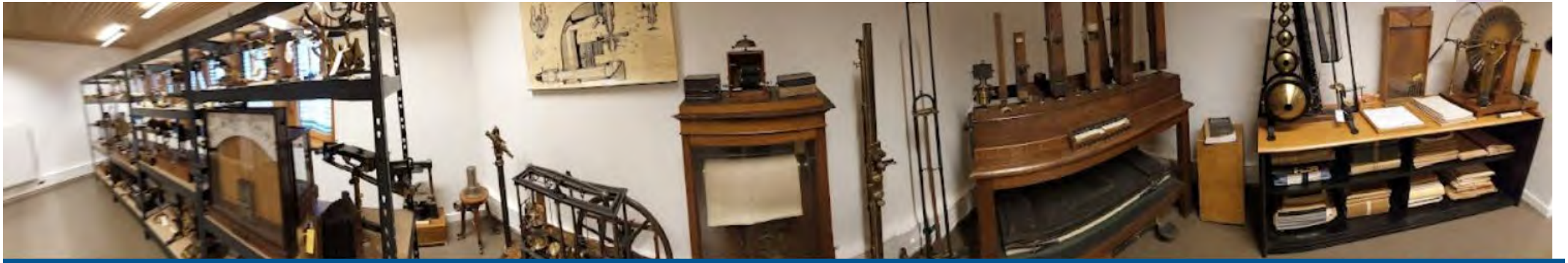


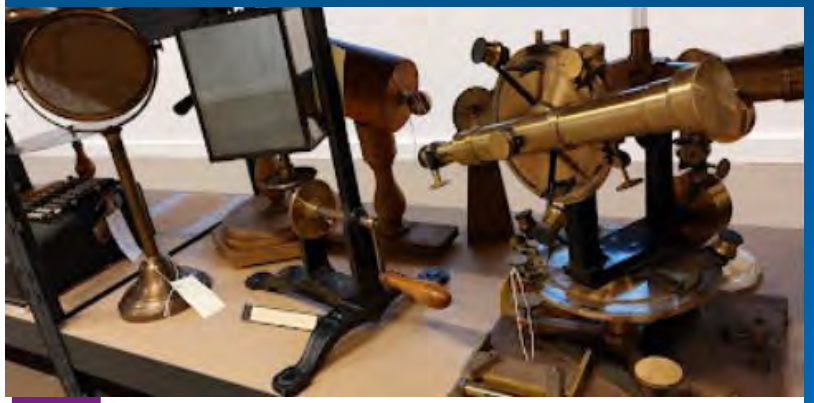


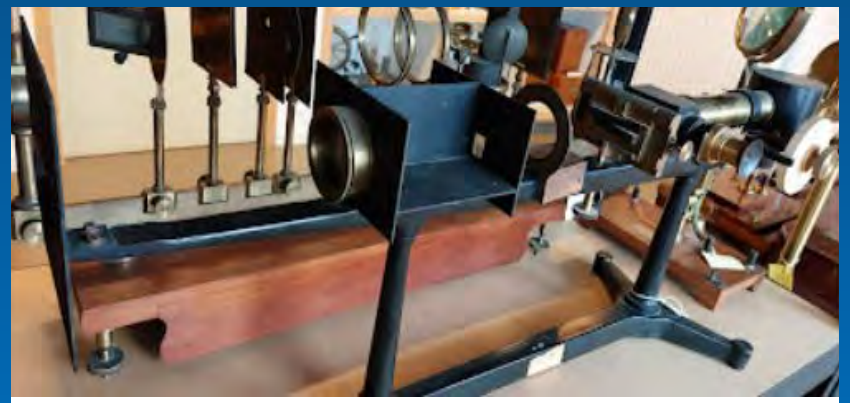


SCIENTIFIC HERITAGE

Fortunately, the optics department has preserved much of its scientific heritage, including numerous optical instruments dating back to the 19th century.





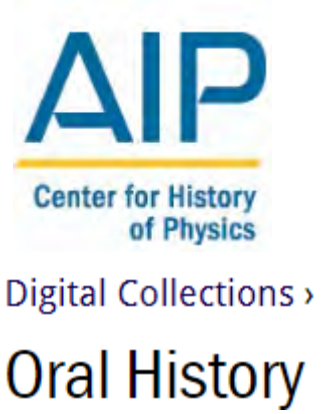




EXISTING INITIATIVES AIMED AT PRESERVING THE HISTORY OF OPTICS

Academic societies play a key role in recording historical events.











However, these archives tend to focus on the most prominent scientists, who enjoy international visibility.

Who records the history of scientists who have had a more local and national impact?
Who ensures the long-term archiving of this information?

For example, many video links of pioneers speaking at Laserfest in 2010 are now inaccessible....

SCIENTIFIC HERITAGE

Fortunately, the optics department has preserved much of its scientific heritage, including numerous optical instruments dating back to the 19th century.
Since 2021, we have been engaged in a systematic exercise to identify and showcase this heritage.

We have now catalogued more than 200 objects of historical value and **close to 250 holograms**.



BACKGROUND

Optical research has a very long history in Besançon, dating back to the founding of the Faculty of Science in 1845.

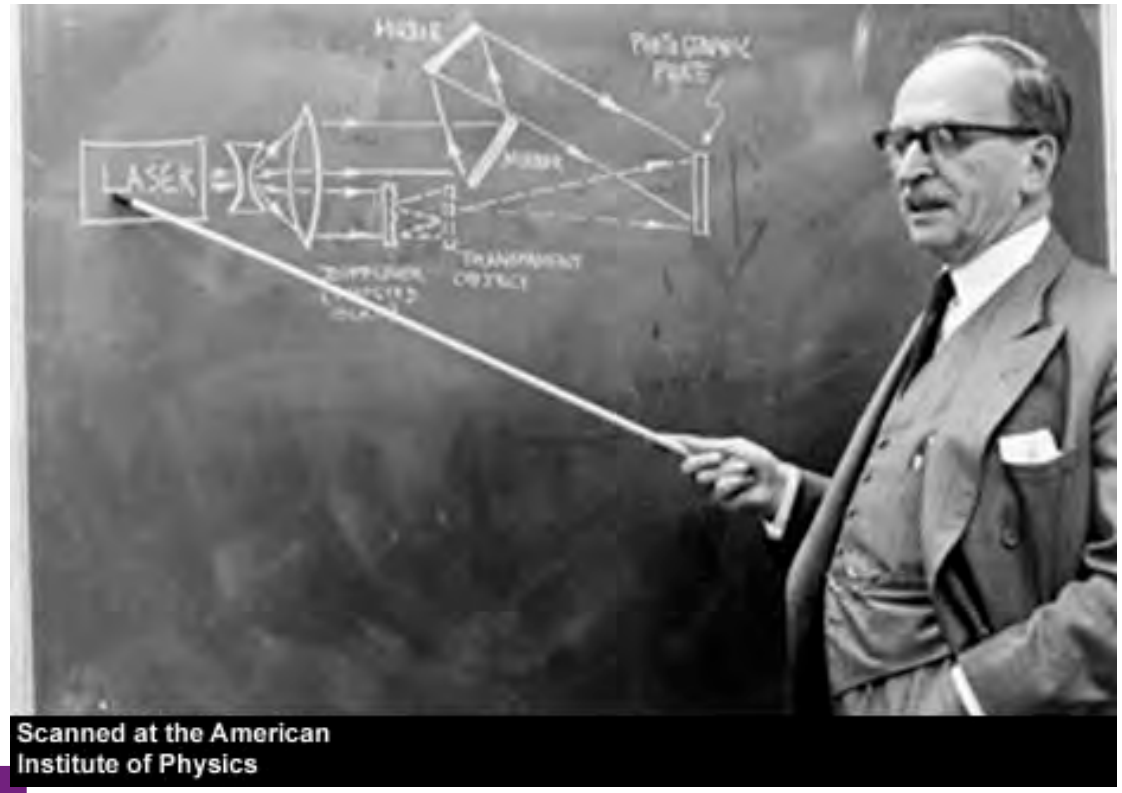
A major theme since the 1940s has been the development of image formation methods and optical measurement, used today in all optical devices.

After the invention of the laser in 1960 in US and laser holography in 1962, researchers in Besançon were ideally placed to quickly contribute to laser-related research and produce their own holograms – the first in 1966.

The inventor of holography, Denis Gabor, in his Nobel Prize speech in 1971, quoted a book by the director of the Besançon laboratory, J.-Ch. Vienot.

BACKGROUND

« To record an image
in amplitude and in phase »

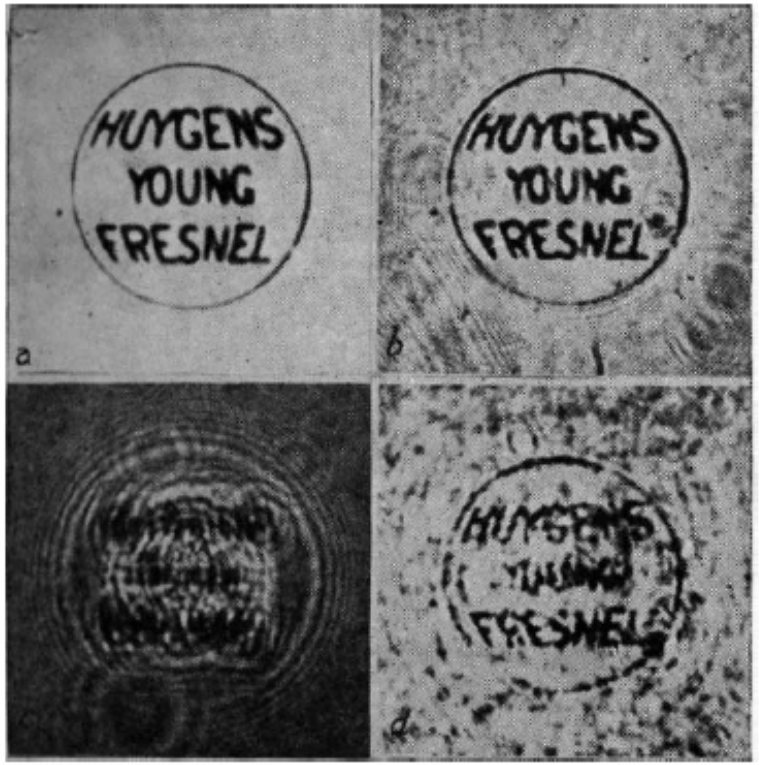


Scanned at the American Institute of Physics

No. 4098 May 15, 1948 NATURE

A NEW MICROSCOPIC PRINCIPLE

By Dr. D. GABOR
Research Laboratory, British Thomson-Houston Co., Ltd., Rugby



BACKGROUND

The reality is more complex...

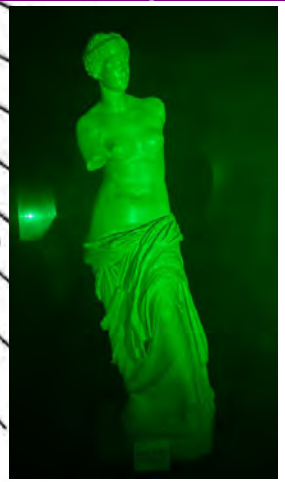
Holography in reflection, volume hologram, white light/colour: Yuri Denisyuk, (1962)



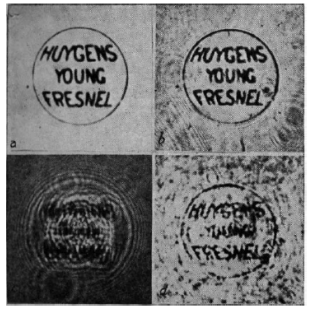


In-line holography in transmission, Denis Gabor (1948)

Off-axis holography in transmission: Leith – Upatnieks (laser, 1962), S. Benton (rainbow/white light, 1968)





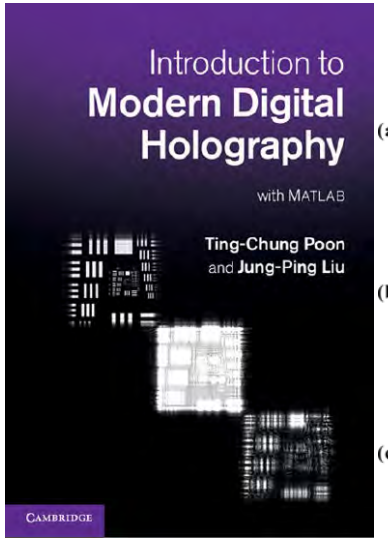


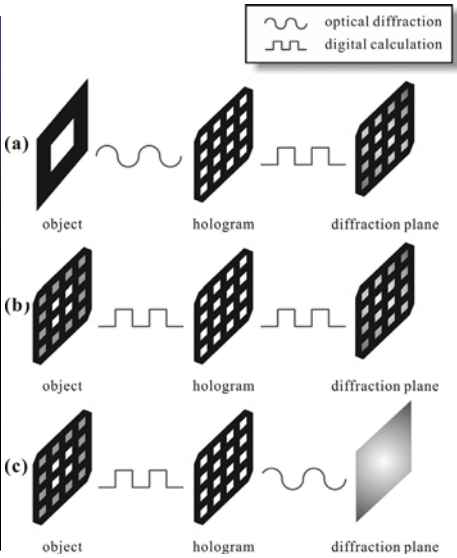
[1] Gabor, D. A New Microscopic Principle. *Nature* **161**, 777–778 (1948)
[2] E.N. Leith and J. Upatnieks, "Reconstructed wavefronts and communication theory," J. Opt. Soc. Amer. 52, pp. 1123-30 (1962).
[3] Denisyuk Y.N., Photographic Reconstruction of the Optical Properties of an Object in its Own Scattered Radiation Field (p.pp 1275-1279), Doklady Academii Nauk SSSR, 1962--, n° Vol. 144
[4] Benton SA, (1969), Hologram reconstructions with extended incoherent sources, J. Optical Society of America, 59: 1545-1546

HOLOGRAPHY TODAY

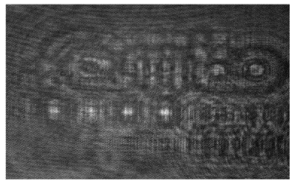
Holography has turned digital:

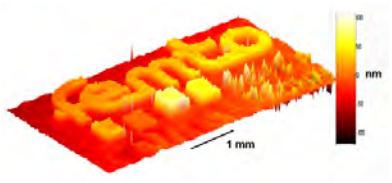
- Computational imaging
- Quantitative phase microscopy
- Optical tweezers
- Beam shaping
- All-optical neural networks...





Digital Holographic Microscopy & Phase imaging





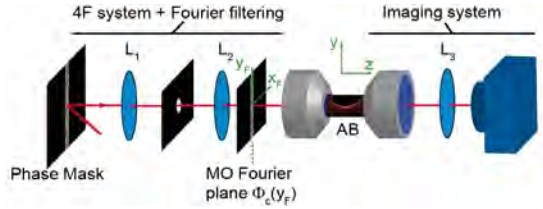

nature machine intelligence

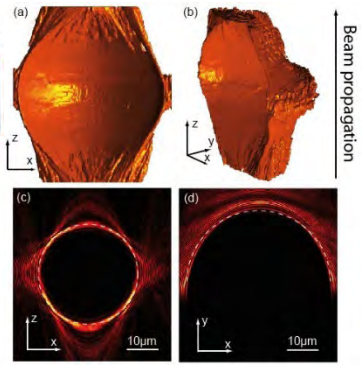
Article

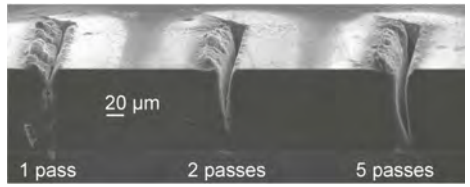
Deep learning based on parameterized physical forward model for adaptive holographic imaging with unpaired data

Chanseok Lee[1,2], Gookho Song[1,2], Hyeonggeon Kim[1,2], Jong Chul Ye[3] & Mooseok Jang[1,2]

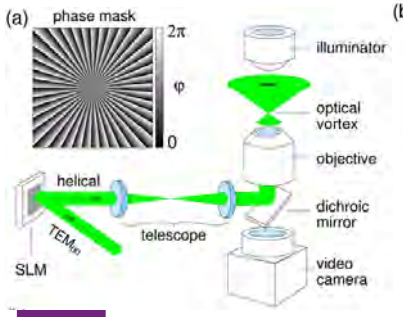
Spherical shaping of light & laser nanoprocessing

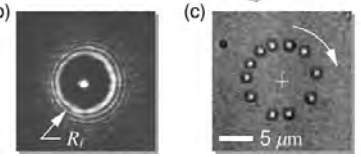


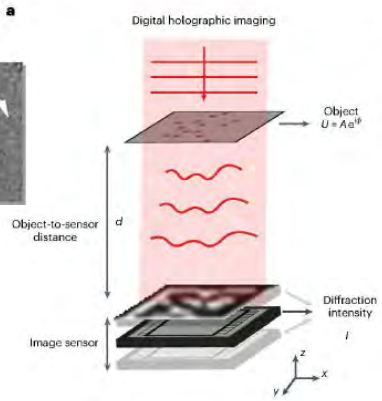


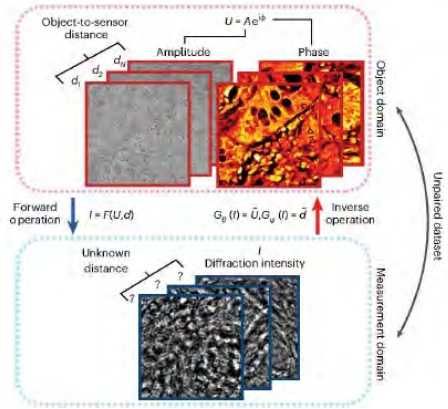


Holographic Optical Tweezers (HOT)









From http://physics.nyu.edu/grierlab/vortex5c/

SPECIAL FEATURES OF OUR HOLOGRAM COLLECTION IN BESANÇON

Among the first holograms produced in France. In some cases, we have photographs taken at the time of their creation.

Numerous technical innovations – improved brightness, 3D reconstruction behind and in front of the holographic plate, animated holograms, etc.

Collaborations between art and science, and in 1977 the creation of a start-up called ‘Hololaser’ from a fundamental science laboratory, pioneering initiatives in the areas of ‘science and society’ that are of concern to the scientific community today.

Research results that continue to inspire developments in many areas of modern photonics today.

HOLOGRAMS COLLECTION IN BESANÇON

Our collection of holograms is of both scientific and artistic importance.

LEONARDO, Vol. 22, No. 3/4, pp. 349–352, 1989

Holography and Art in a Research Laboratory: A Retrospective

Claudine Bainier and Gilbert Tribillon

G. Tribillon and J. M. Fournier, "Large-sized Holographic Interferometry in Real Image", *Optica Acta* **24**, No. 8 (August 1977).

N. Aebischer and B. Carquille, "White-Light Holographic Portraits (Still or Animated)", *Applied Optics* **17**, No. 23 (December 1978).

N. Aebischer and C. Bainier, "Multicolor Holography of Animated Scenes by Motion Synthesis Using a Multiplexing Technique", in Proceedings of the SPIE, *Three-Dimensional Imaging* **402** (April 1983).





HOLOGRAMS COLLECTION IN BESANÇON

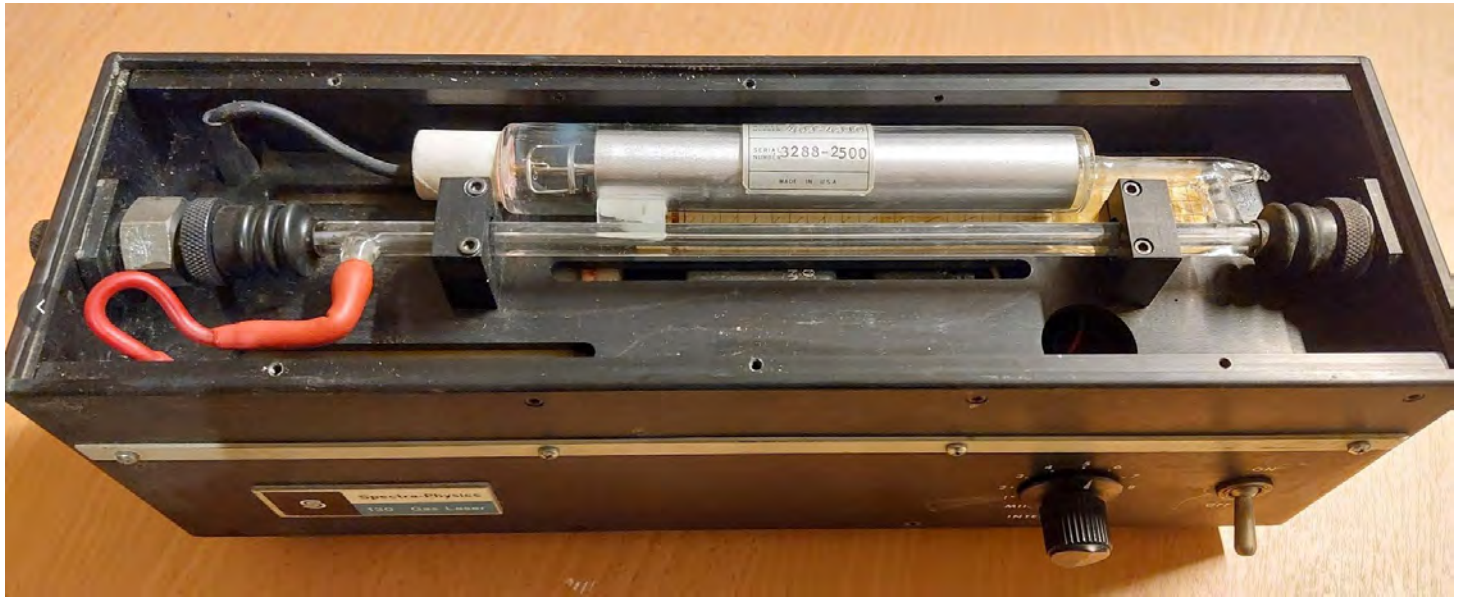
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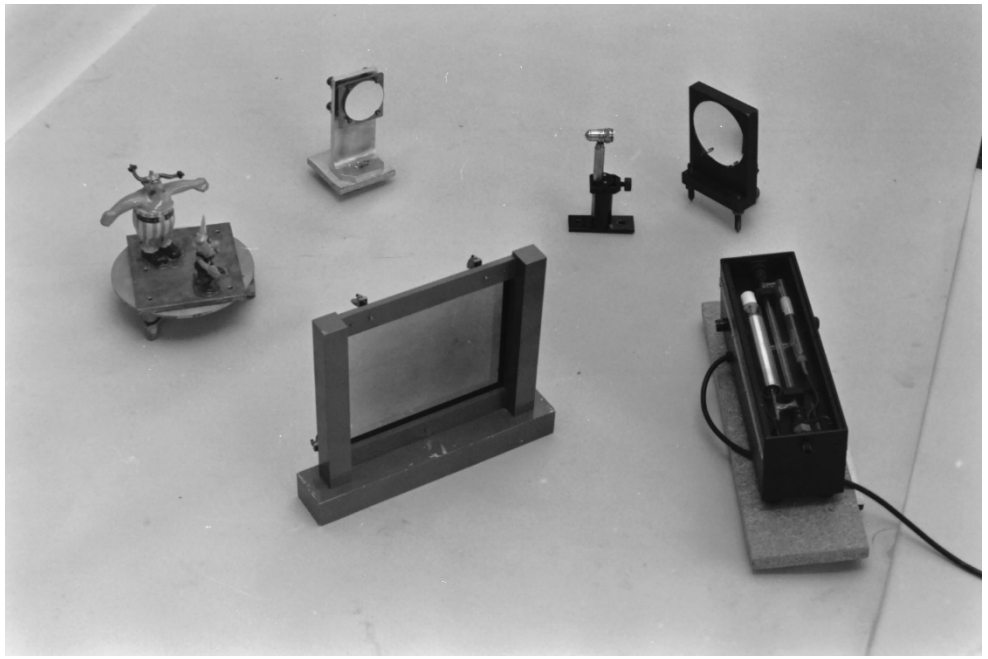




PRESERVE EQUIPMENT FROM ALL AGES!

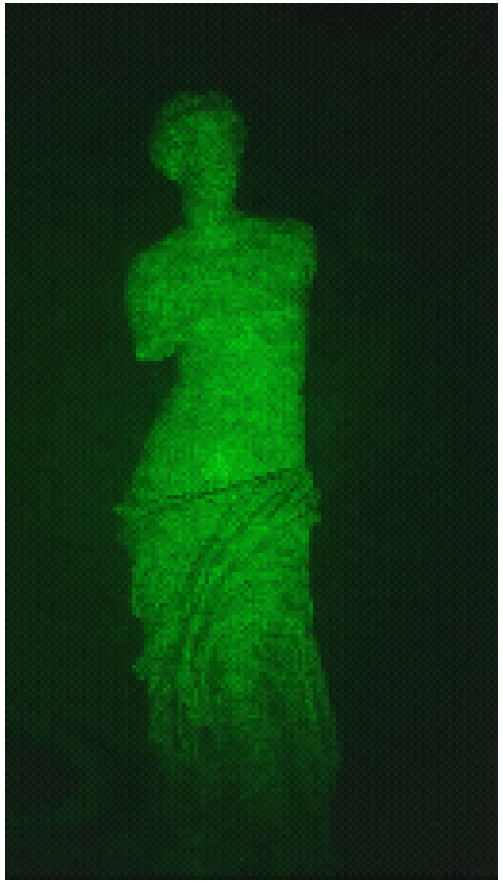
Old teaching instruments may be the most photogenic, but early 1960s lasers, early waveguides, oscilloscopes, and even hand-built mirror assemblies are just as important.



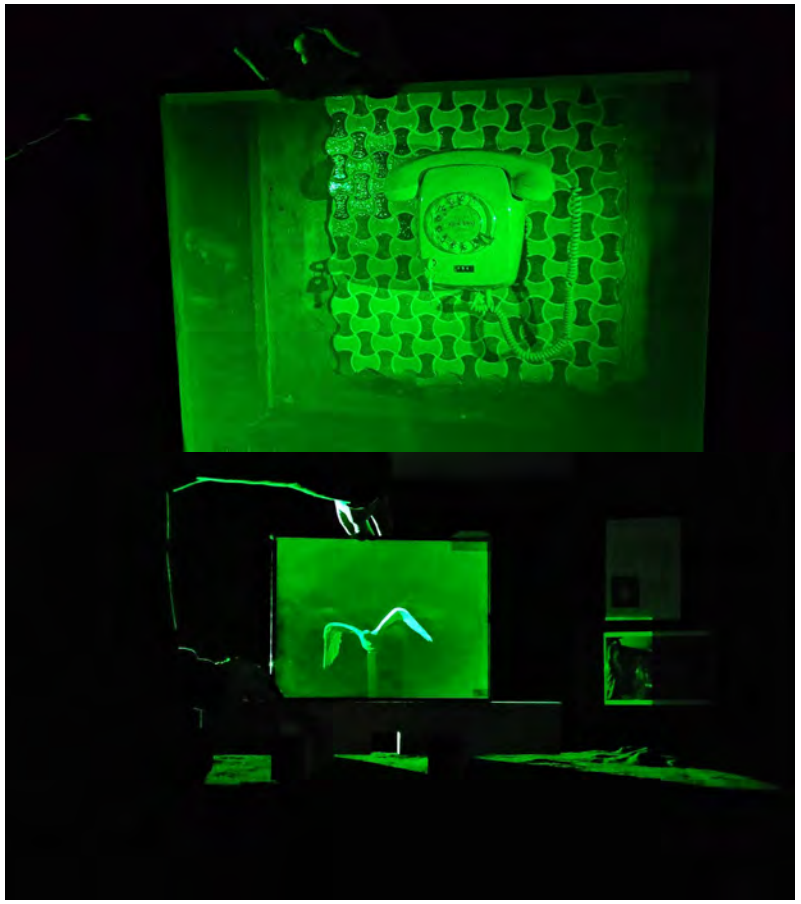


SOME VIDEOS OF HOLOGRAMS

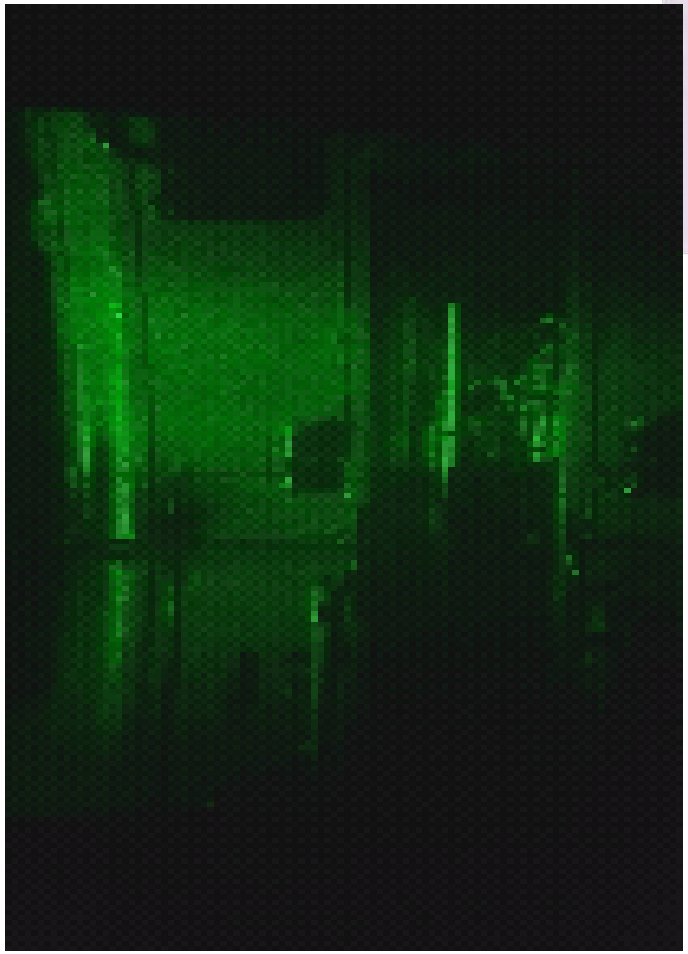
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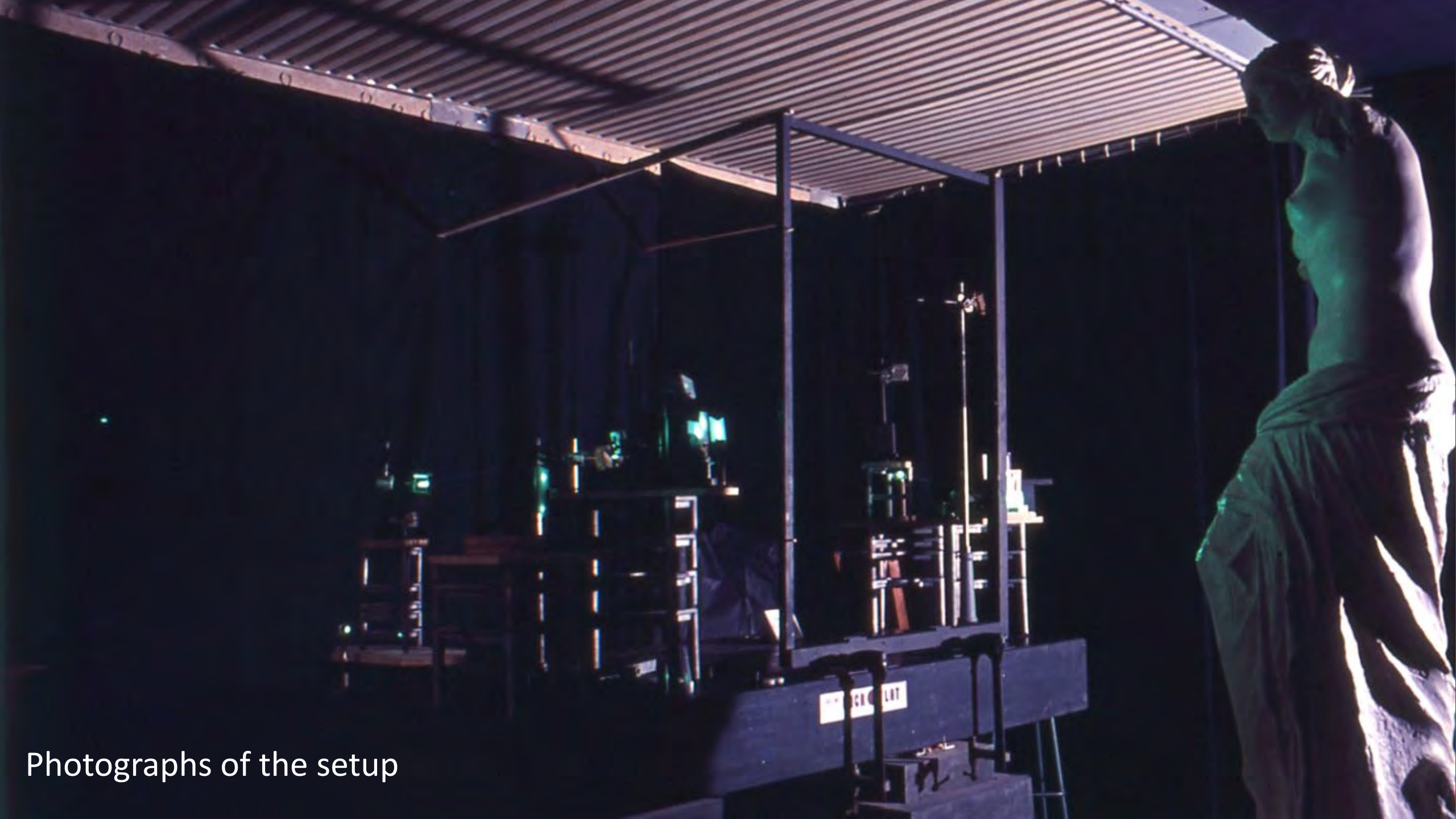
Hologram of the Venus de Milo, Besançon, LOBE, J. M. Fournier, G. Tribillon, 1976



Other holograms and cine-holograms in the collection UMLP / Optique@FEMTO-ST



Hologram of a railway carriage, Besançon, G. Tribillon, 1984



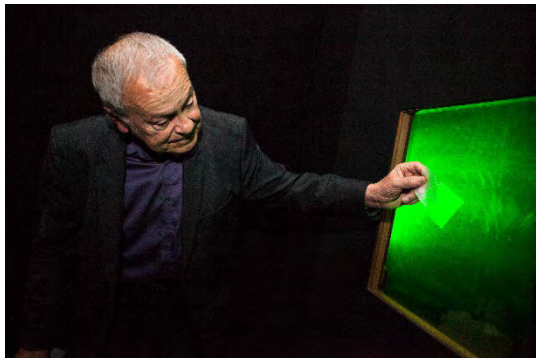
Photographs of the setup

HOLOGRAMS IN BESANCON

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G. Tribillon, C. Bainier & J.M. Fournier, Besançon 2015



J.M. Fournier, Besançon, 2015

OPTICA ACTA, 1977, VOL. 24, NO. 8, 893–896

Large-sized holographic interferometry in real image

G. TRIBILLON and J. M. FOURNIER
Laboratoire de Physique Générale et Optique, Associé au C.N.R.S., No. 214, 'Holographie et Traitment Optique des Signaux', Université de Franche-Comté 25030 Besançon Cédex, France

(*Received* 14 *December* 1976)

Abstract. The recording of large holograms has been performed on photographic plates up to 1·5 m². Applied to holographic interferometry, this achievement permits the analysis of holographic real images of large models and the recording of the topography of interference fringes.

Mémoire original — *J. Optics (Paris)*, 1978, vol. 9, n° 3, pp. 157-162

LABORATOIRE DE PHYSIQUE GÉNÉRALE ET OPTIQUE
(L.A., C.N.R.S., n° 214)
« HOLOGRAPHIE ET TRAITEMENT OPTIQUE DES SIGNAUX »
UNIVERSITÉ DE FRANCHE-COMTÉ
F 25030 Besançon Cedex (France)

ENREGISTREMENT ET RESTITUTION HOLOGRAPHIQUES EN LUMIÈRE BLANCHE SPATIALEMENT INCOHÉRENTE

D. COURJON. J. BULABOIS

3698 APPLIED OPTICS / Vol. 17, No. 23 / 1 December 1978

White light holographic portraits (still or animated)

Nicole Aebischer and Bernard Carquille
Université de Franche-Comté, Faculté des Sciences et des Techniques, Laboratoire de Physique Générale et Optique, associé au CNRS, 25030 Besançon cedex, France.
Received 29 August 1978.
0003-6935/78/1201-3698$0.50/0.
© 1978 Optical Society of America.

THREE-DIMENSIONAL IMAGING, SPIE PROCEEDINGS VOLUME 0402 1983
INTERNATIONAL TECHNICAL CONFERENCE/EUROPE | 18-22 APRIL 1983, GENEVA

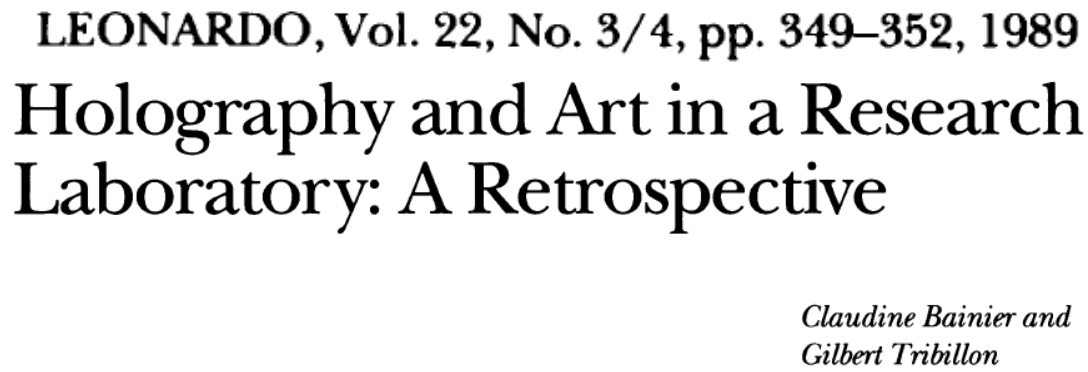
Multicolor holography of animated scenes by motion synthesis using a multiplexing technique

N. Aebischer and C. Bainier

Laboratoire d'Optique, LA 214 - Faculté des Sciences et des Techniques
Université de Franche-Comté - 25030 Besançon Cedex, France

HOLOGRAMS

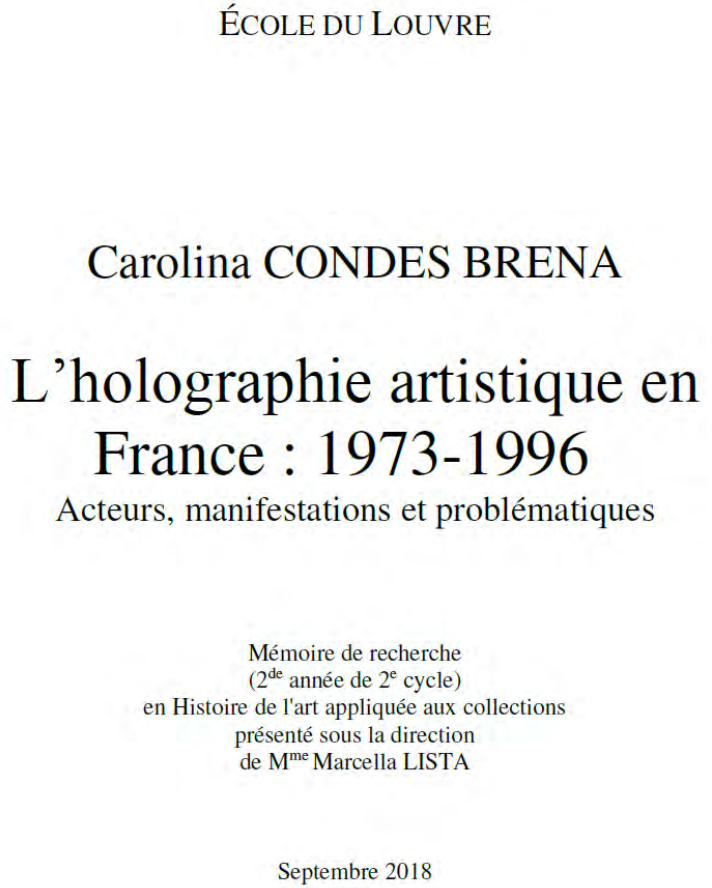
Our collection of holograms is of both scientific and artistic importance.



LEONARDO, Vol. 22, No. 3/4, pp. 349–352, 1989

Holography and Art in a Research Laboratory: A Retrospective

Claudine Bainier and Gilbert Tribillon



ÉCOLE DU LOUVRE

Carolina CONDES BRENA

L'holographie artistique en France : 1973-1996

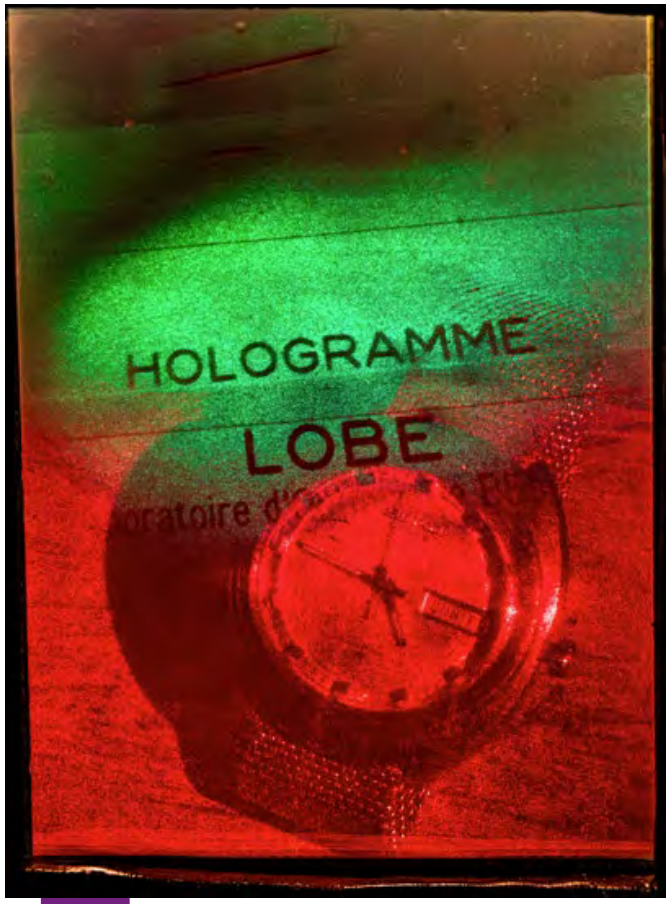
Acteurs, manifestations et problématiques

Mémoire de recherche
(2de année de 2e cycle)
en Histoire de l'art appliquée aux collections
présenté sous la direction
de Mme Marcella LISTA

Septembre 2018

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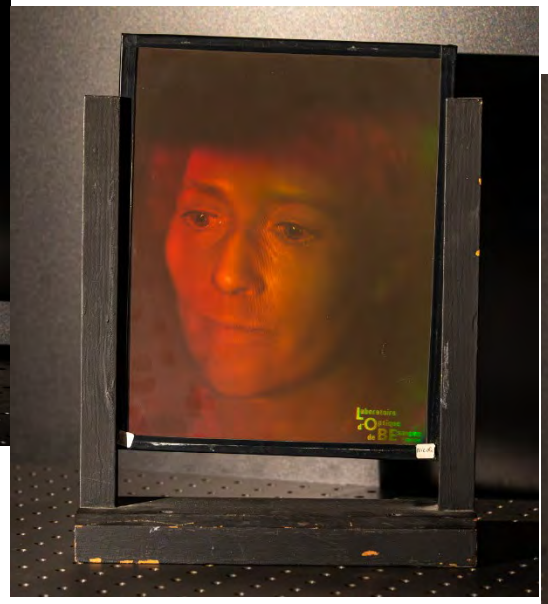




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N. Aebischer and B. Carquille, "White-Light Holographic Portraits (Still or Animated)", *Applied Optics* **17**, No. 23 (December 1978).

N. Aebischer and C. Bainier, "Multicolor Holography of Animated Scenes by Motion Synthesis Using a Multiplexing Technique", in Proceedings of the SPIE, *Three-Dimensional Imaging* **402** (April 1983).



"There's no place like home", Paula Dawson, LOBE/FEMTO-ST, 1980



Size 1 x 1.5 m²

"There's no place like home", Paula Dawson, LOBE/FEMTO-ST, 1980

Photographs of the setup



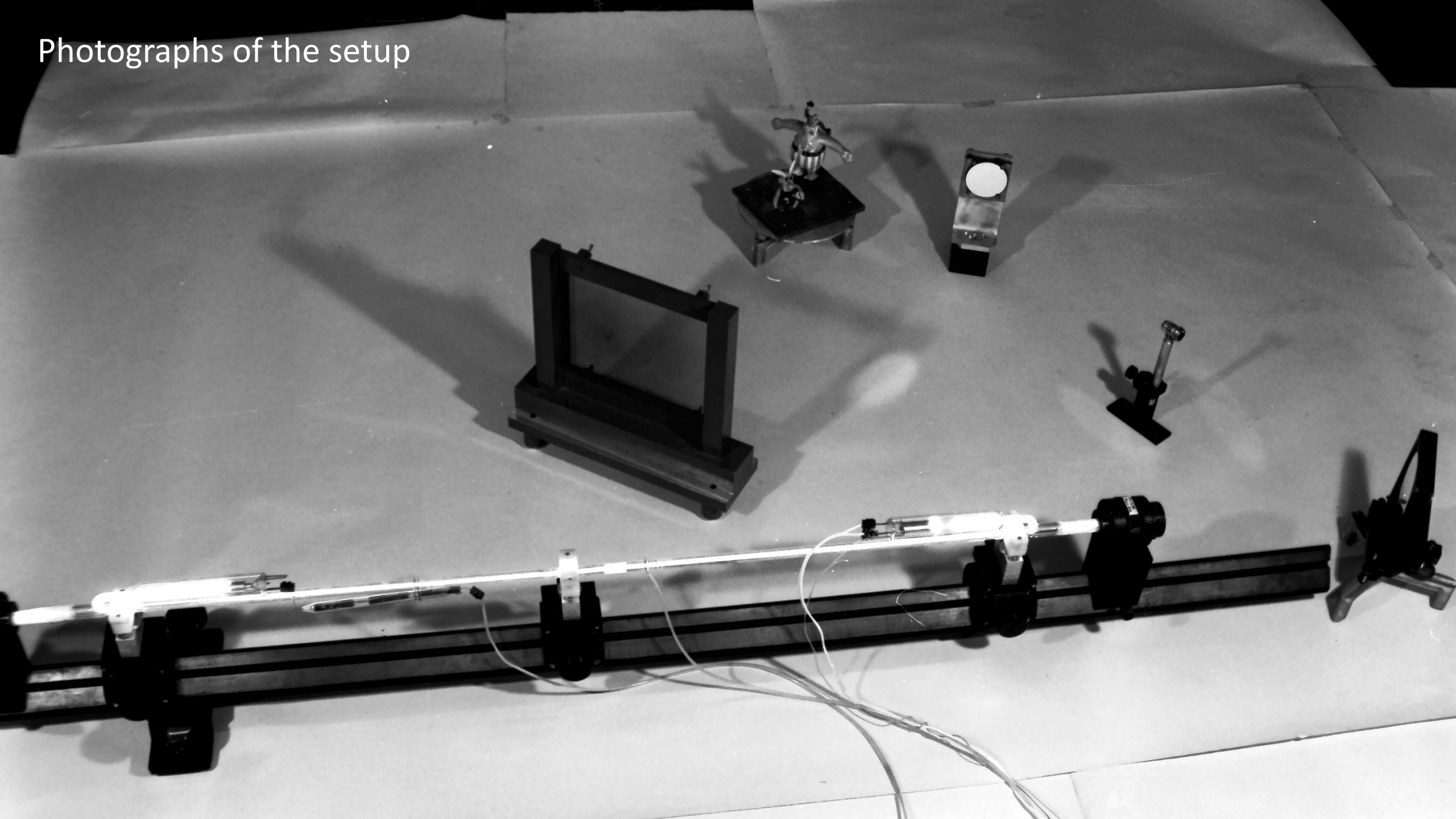


Photographs of the setup

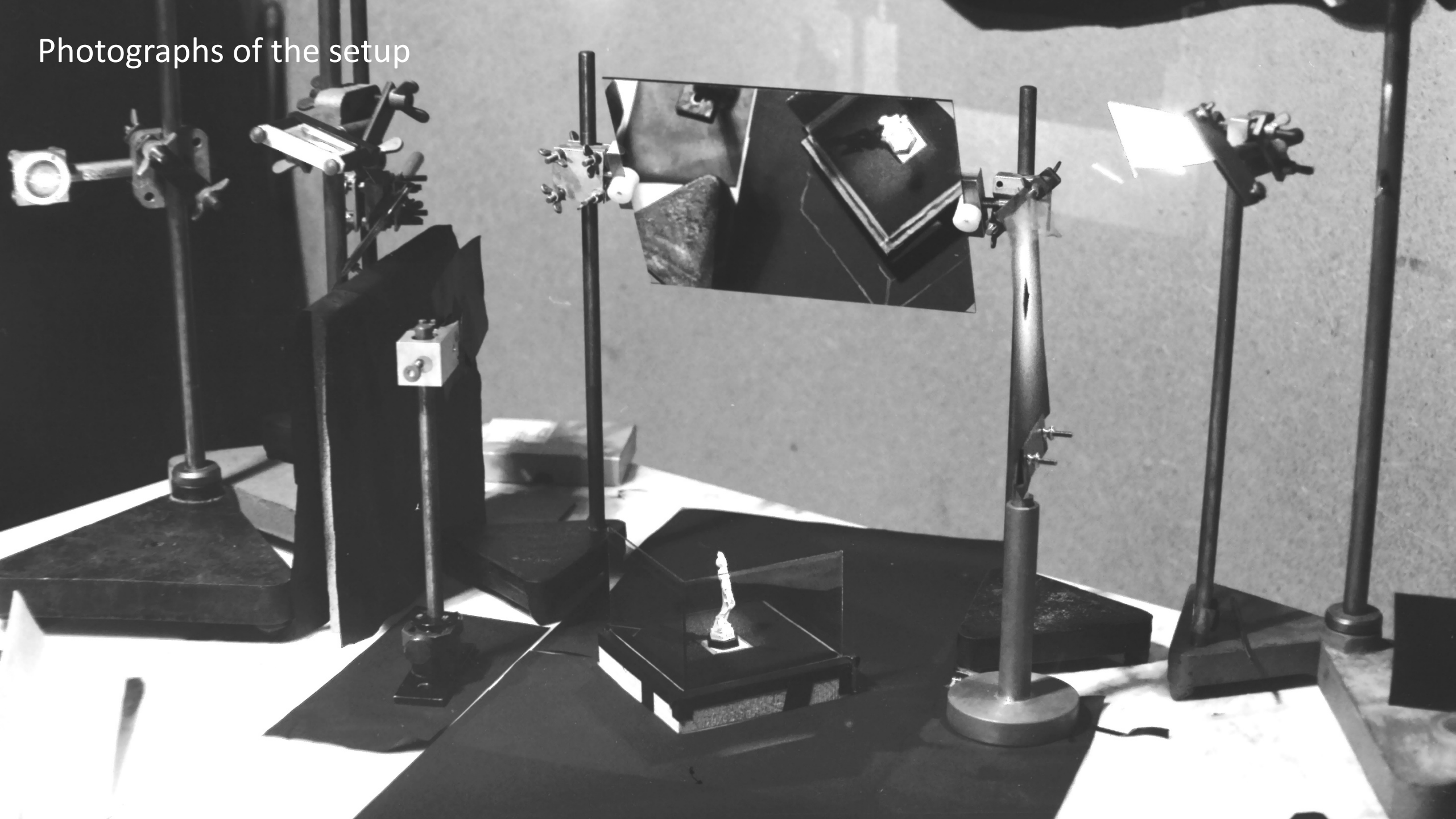
Photographies du montage



Photographs of the setup

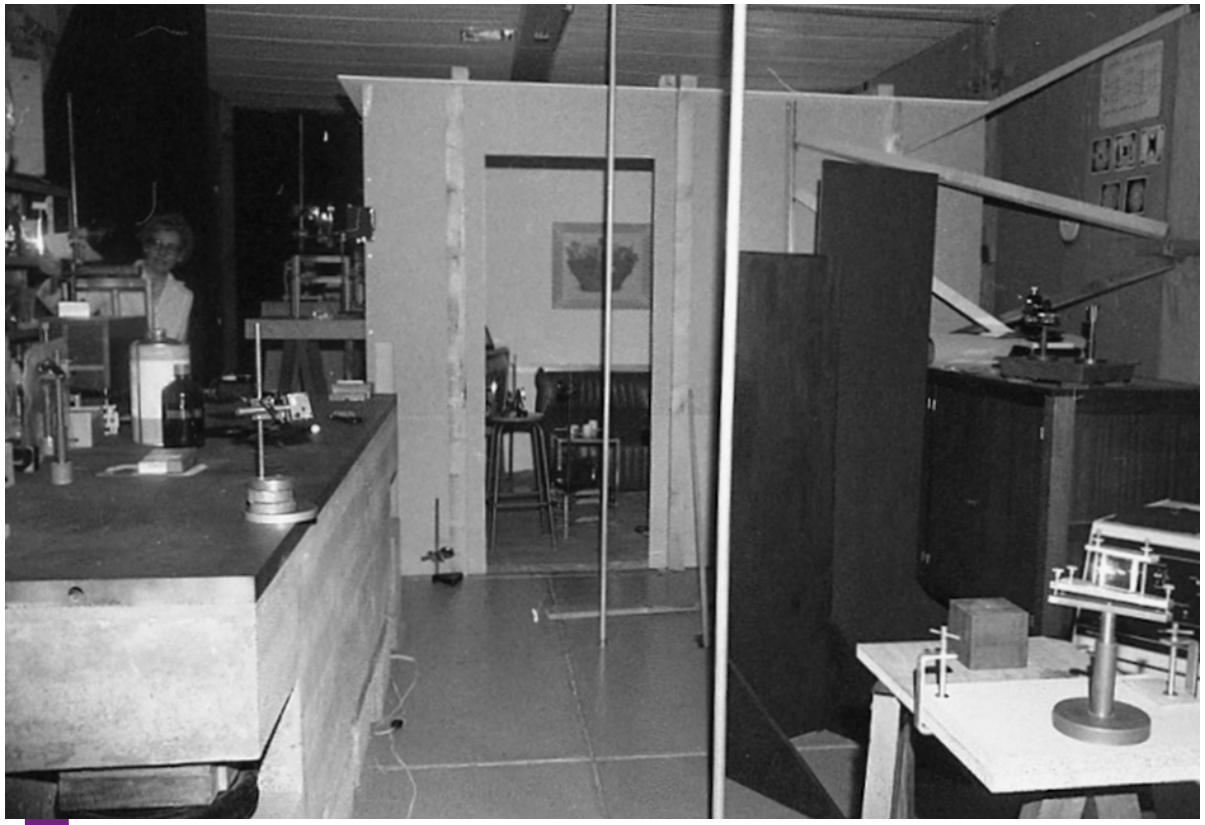


Photographs of the setup



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Art Journal 2022

Zsofi Valyi-Nagy

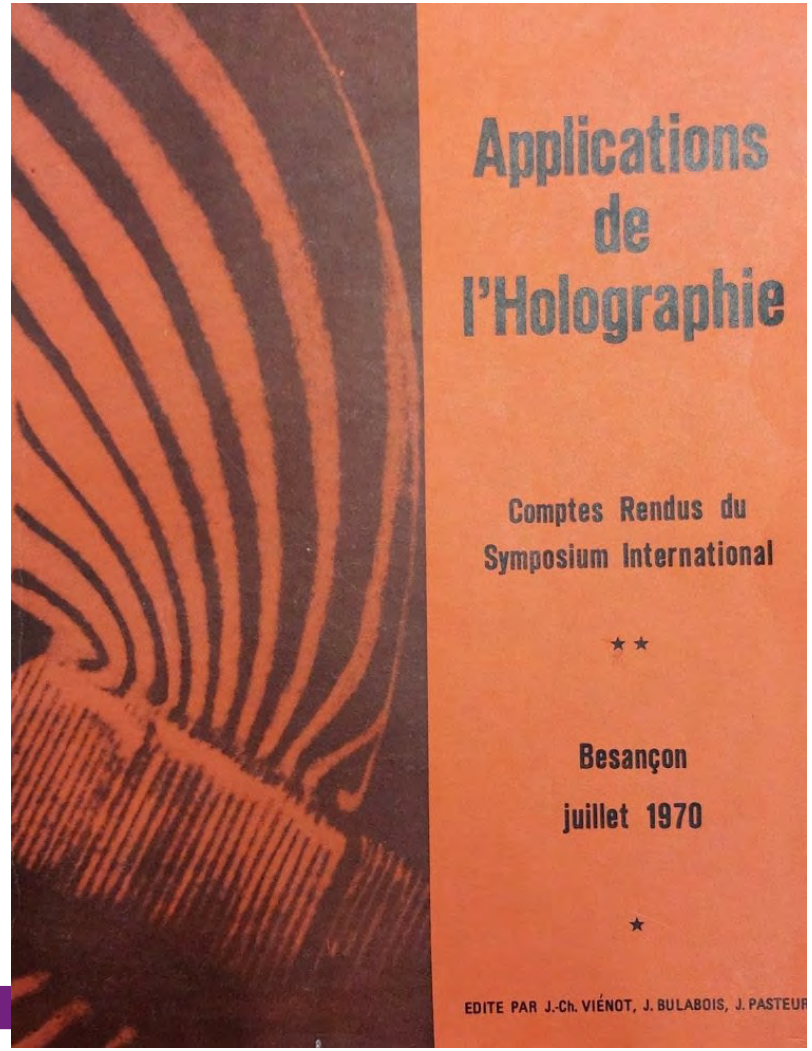
Feeling into Paula Dawson's Holograms

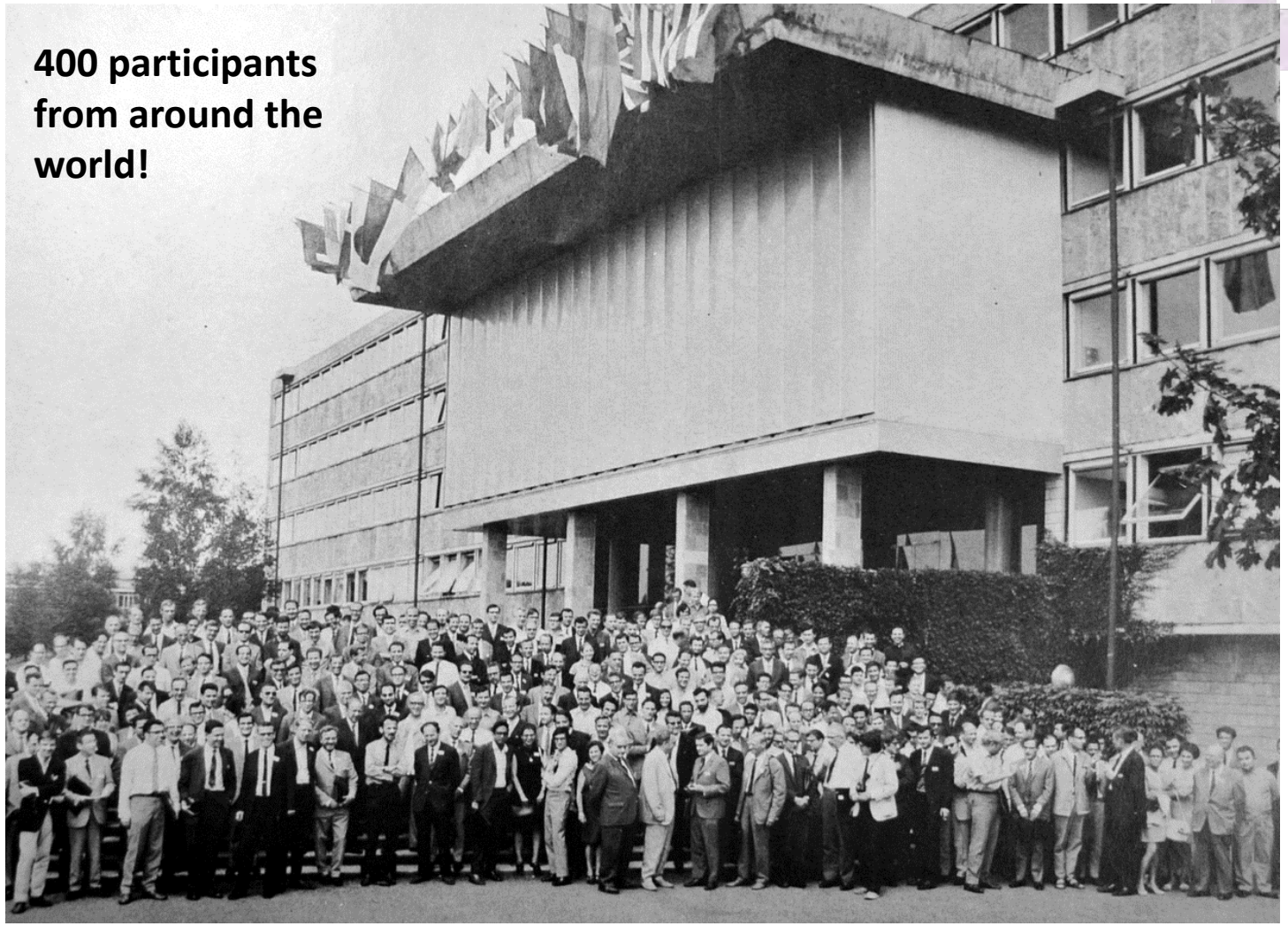
On New Year's Eve 1989, the Australian artist Paula Dawson (b. 1954) threw a party at a bar in Sydney.[1] Wearing a red dress that matched the wallpaper, carpet, and booths, Dawson served champagne to her friends as they played darts, shot pool, and danced around a jukebox. While this bar could have been, in Dawson's words, "every bar you've ever been into," it was no ordinary pub.[2] The bar was fabricated inside the National Acoustics Laboratory, inside a "shell" that protected it from natural light, noise, vibration, and air turbulence—conditions necessary to create laser transmission holograms of the interior space, the largest analog holograms ever made. The following year, the resulting triptych *To Absent Friends* won the Grand Prix at ARTEC, the first international high-tech art biennial in Nagoya, Japan, and was the subject of a documentary film of the same name.

An accomplished holographer with a background in sculpture, dance, and performance, Dawson began specializing in large-scale holograms in the late 1970s, pushing the physical limits of the medium in both scale and subject matter. As large-scale holographic glass plates were rare, the artist shot *To Absent Friends* on custom three-by-five-foot (95 x 150 cm) Kodak plates, the last such plates to be manufactured. Ten years later, she described these holograms as "an endangered species of image."[3] Today, analog holograms remain endangered—difficult to preserve, rarely exhibited, and remembered as little more than an overhyped, fussy medium that flopped as an art form.

I am grateful to Paula Dawson and the Macquarie University Art Gallery for their generosity and enthusiasm for my research from afar, to my two anonymous reviewers, to Bridget Madden for her help with images, to Seth Estrin, Solveig Nelson, Christine Mehring, Patrick Crowley, Sophie Lynch, Maggie Borowitz, Zhenru Zhou, Melissa Horn, Lachlan McNamee, Alexandra Drexelius, Matthew Robinson, and to audiences at the Research in Art and Visual Evidence Workshop, the 2020 CAA Annual Conference, the Centre André Chastel in Paris, and Ed Wesly's annual holographers meetup

BACK TO 1970 - CONFERENCE ON HOLOGRAPHY

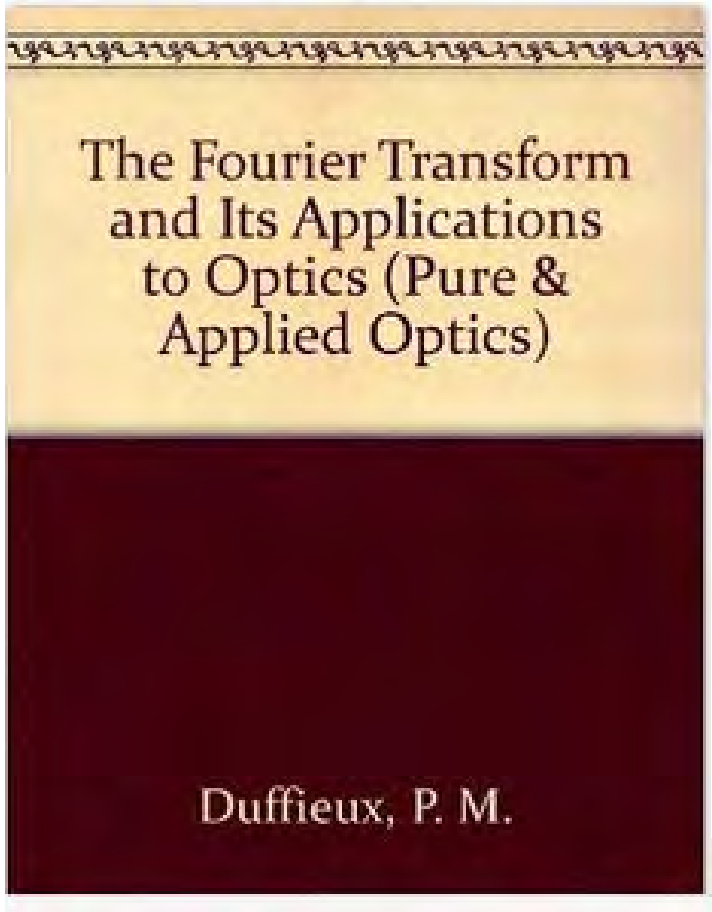




MODERN OPTICS BORN IN BESANÇON, FRANCE

Just before the invention of the laser, Pierre-Michel Duffieux (1891-1976) from Besançon had established the principles of optical imaging using techniques based on Fourier optics.

These methods underpin not only imaging using lasers and techniques such as holography, but also the design of all optical systems, from the camera on your mobile phone to the James Webb Space Telescope.



NATURE VOL 304 21 JULY 1983

BOOK REVIEWS

Fourier and Duffieux: a French connection

P.W. Hawkes

The Fourier Transform and its Applications to Optics, 2nd Edn.
By P.M. Duffieux. *Wiley: 1983. Pp.197. £32.25, $45.25.*

THE French edition was published in 1970 and was itself a revised version of the text of 1946: why should Wiley bring out an English translation of an old book by someone as obscure as P. M. Duffieux?

The answer is simple. Duffieux was one of the great original spirits of modern optics and it is entirely right that efforts should be made to rescue his name from obscurity. Virtually single-handed, he founded the subject that we now call Fourier optics and introduced the notion of spatial frequency. Moreover all this was achieved despite a woefully inadequate knowledge of the necessary mathematics.

The creation of Fourier optics revealed the intimate connection between image-forming devices and communication channels. It became apparent that optical instruments filter the information presented to them by the object under study and that this filter takes a very simple form if we study its effect on the Fourier transform or "spatial frequency spectrum" of the object. Moreover, Fourier methods have generated a new branch of coherence studies as well as providing a suitable vocabulary for discussing the information-carrying capacity of microscopes and the relation between this and their traditional Fourier (series) transform.

In 1941, Duffieux presented his ideas to the Société de Physique but again no one understood. Write a book about it, urged Pierre Fleury, and in 1946 or 1947 the Rennes printing firm of Oberthur delivered *L'Intégrale de Fourier et ses Applications à l'Optique* to its author, by then a professor at the University of Besançon, who published it privately. To obtain a copy,



Duffieux: "J'eus une révélation hallucinante".

CONCLUSIONS

Preserving scientific history provides a better understanding of the development of a university and a particular field of teaching or research.

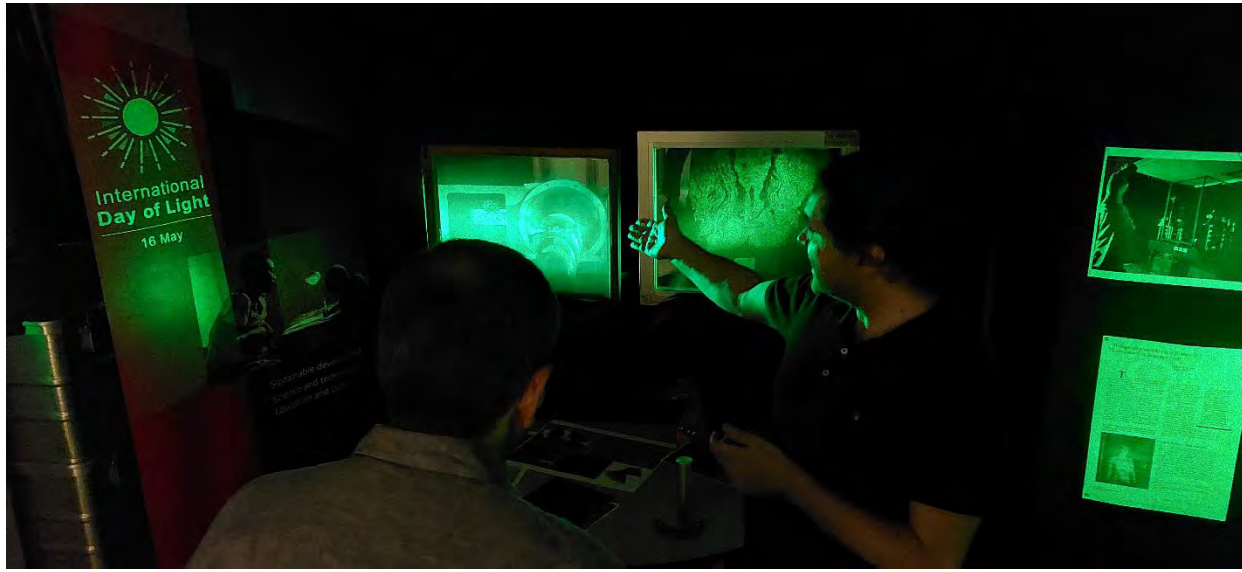
It is possible to construct a **rich picture of the past** that can stimulate and **inspire the current generation** of staff and students.

A series of **project-based courses** has been set up from bachelor's to master's level, using reverse engineering to understand certain unknown instruments.
The Optics Department's hologram collection is in the process of being listed as a **historic monument**.

Come and visit us and see for yourself!



Prof. Eric Mazur visiting our collection in 2024



FOR FURTHER INFORMATION

I learned it through the hologram

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Holography is an advanced coherent imaging technique that records and reproduces 3D images using the principles of interference and diffraction. It finds numerous applications in fields such as biomedicine, engineering, art, and microscopy. Teaching holography at university provides students with a unique opportunity to learn more about optical physics. Moreover, it fosters creativity and innovation, as students can explore the potential of Digital Holography for their own future research.

https://doi.org/10.1051/photon/202311931

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The generation of three-dimensional images remains one of the major challenges of advanced imaging techniques today, even though holography, invented by Denis Gabor in 1948 (Nobel Prize in Physics 1971), is one of the leading approaches in this field. Holography is a powerful coherent imaging technique that can record and reproduce 3D images with stunning detail and realism. Unlike traditional photography, which captures only a 2D representation of a scene, holography allows us to capture the full depth and complexity of the visual world. Holography is based on the principles of interference and diffraction, which describe how light waves interact with each other to create complex fringe patterns up to nanoscale. The Optics Department of the FEMTO-ST Institute at the University of Franche-Comté in Besançon, France, is one of the laboratories that pioneered laser manufacturing and holography techniques in the early 1960s [1]. These achievements were made possible in part by P.M. Duffieux, who founded the Optics laboratory in Besançon, and who is recognized as one of the pioneers of modern optics thanks to his book on Fourier optics which was published in 1946 [2]. Duffieux laid the foundations of an extensive series of activities within the French research community that have touched on nearly every aspect of contemporary optics and photonics, such as optical information processing, digital holography, and optical computing. Digital holography (DH) is a modern form of holography that uses solid-state cameras and/or 2D digital display to record or reconstruct images in phase and in amplitude. DH offers several advantages over classical holography to carry out laboratory experiments, including greater speed, sensitivity, and the added flexibility associated with digital processing. DH is therefore an extraordinary means of getting students to perform a wide variety of experiments related to advanced optical instrumentation and complex image formation.
Overall, holography and DH are powerful imaging techniques with wide-ranging applications in areas such as advanced microscopy and in high-performance display technologies for screens. As technology continues to evolve and improve, holography constitutes an extraordinary means to teach and •••

Optics and Photonics News Vol. 36, Issue 2, pp. 38-45 (2025)



Preserving Optics Heritage

at the University of Franche-Comté

John M. Dudley, Luc Froehly, Jerome Salvi,
Pierre Verschueren and Maxime Jacquot

An effort to safeguard the legacy of optics includes a museum of historical instruments, some dating to 1845.

The faculty of science at the University of Franche-Comté in Besançon, France, was established in 1845, with a mission to teach a broad range of theoretical and experimental topics across the natural and physical sciences. In the area of physics, the faculty was set up with an extensive collection of 332 instruments related to the fields of mechanics, electricity, thermodynamics, acoustics and, of course, optics. Many of these historical instruments have survived in good (sometimes even working) condition and are displayed in a science heritage collection hosted at the Centre national de la recherche scientifique (CNRS) Institute FEMTO-ST at the university. This collection is extremely popular with visitors, from science luminaries to the general public, and it forms an essential component of outreach and public engagement activities for the university.

Facing page: View of museum instruments. Above: Koenig's apparatus for the analysis of sound.
Photos by J.M. Dudley

https://doi.org/10.1364/OPN.36.2.000038

Research and teaching in physics at the University of Franche-Comté 1845-1970

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Abstract

Recently uncovered archives at the University of Franche-Comté in Besançon (France) reveal a rich history of research and teaching in physics since the Faculty of Science was first established in 1845. Here, we describe a selection of notable activities conducted by the named Chairs of Physics during the period 1845-1970. We uncover a long tradition of major contributions to physics education and research, including the production of highly regarded physics textbooks that were widely used in Europe, as well as pioneering contributions to electron diffraction and microscopy, Fourier optics, and holography. These discoveries yield valuable insights into the historical development of physics research in France, and show how even a small provincial university was able to stay up-to-date with international developments across several areas of physics.

Keywords: History of Physics, History of Optics, French Universities

arXiv:2403.09271 [physics.hist-ph] (2024)

Thank you for your attention

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