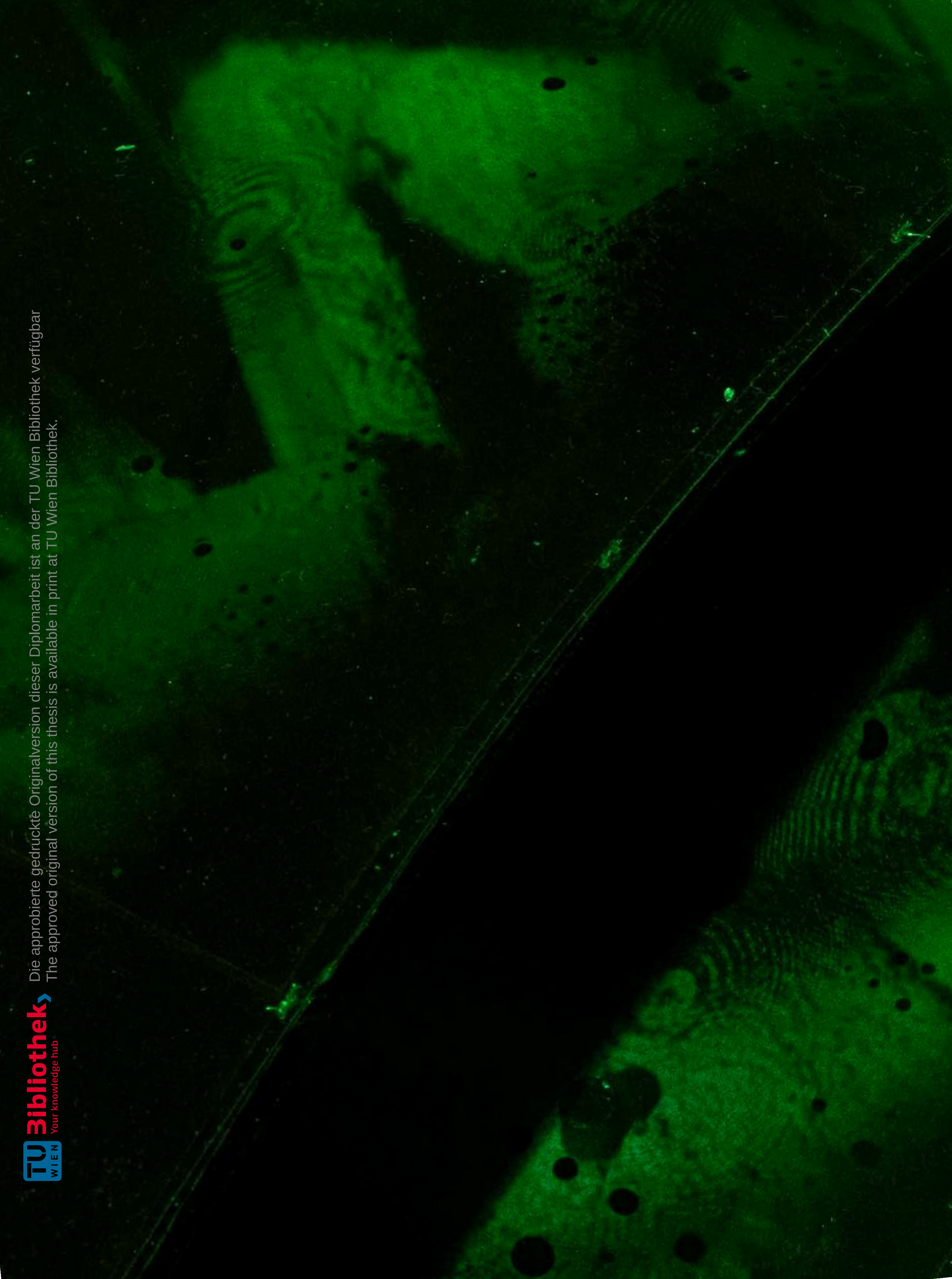

architektur + raumplanung

Diploma Thesis *Concrete Interference*

Submitted in satisfaction of the requirements for the degree of Diplom-Ingenieur / Diplom- Ingenieurin at the TU Wien, Faculty of Architecture and Planning

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The widely misinterpreted term 'holography' refers to a physical process and concept whose repeatedly predicted future as an influential medium stands in marked contrast to its actual development. Through alternative production methods and the expansion into new application fields, particularly in the technological and commercial sectors, holography has historically evolved from a promising imaging technique for art and culture into a simplified mass product that largely goes unnoticed in public perception.
This ambivalent situation is the subject of this thesis and has been examined and photographed within the framework of both a theoretical and practical engagement. In the context of an artistic project, the holographic recording process was tested, with a focus on exploring overlooked potentials. Subsequently, the practical experiences gained were critically reflected upon in conjunction with the historical and theoretical insights.

Der vielfach fehlinterpretierte Begriff 'Holografie' bezeichnet ein physikalisches Verfahren und Konzept, dessen in frühen und wiederkehrenden Phasen prophezeite Zukunft als einflussreiches Medium in deutlicher Diskrepanz zu seiner tatsächlichen Entwicklung steht. Durch alternative Herstellungsmethoden und die Ausweitung auf neue Anwendungsfelder, insbesondere in den technologischen und kommerziellen Sektoren, hat sich die Holografie historisch von einem vielversprechenden Abbildungsverfahren für Kunst und Kultur hin zu einem vereinfachten Massenprodukt gewandelt, das in der öffentlichen Wahrnehmung weitgehend unbemerkt bleibt.
Diese ambivalente Situation ist Gegenstand dieser Arbeit und wurde im Rahmen einer theoretischen sowie praktischen Auseinandersetzung untersucht und fotografisch dokumentiert. Im Kontext eines künstlerischen Projekts wurde das holografische Aufnahmeverfahren erprobt und dabei nach verkannten Potentialen gesucht. Im Anschluss wurden die dabei gewonnenen praktischen Erfahrungen gemeinsam mit den historischen und theoretischen Erkenntnissen kritisch reflektiert.

Fig. 1

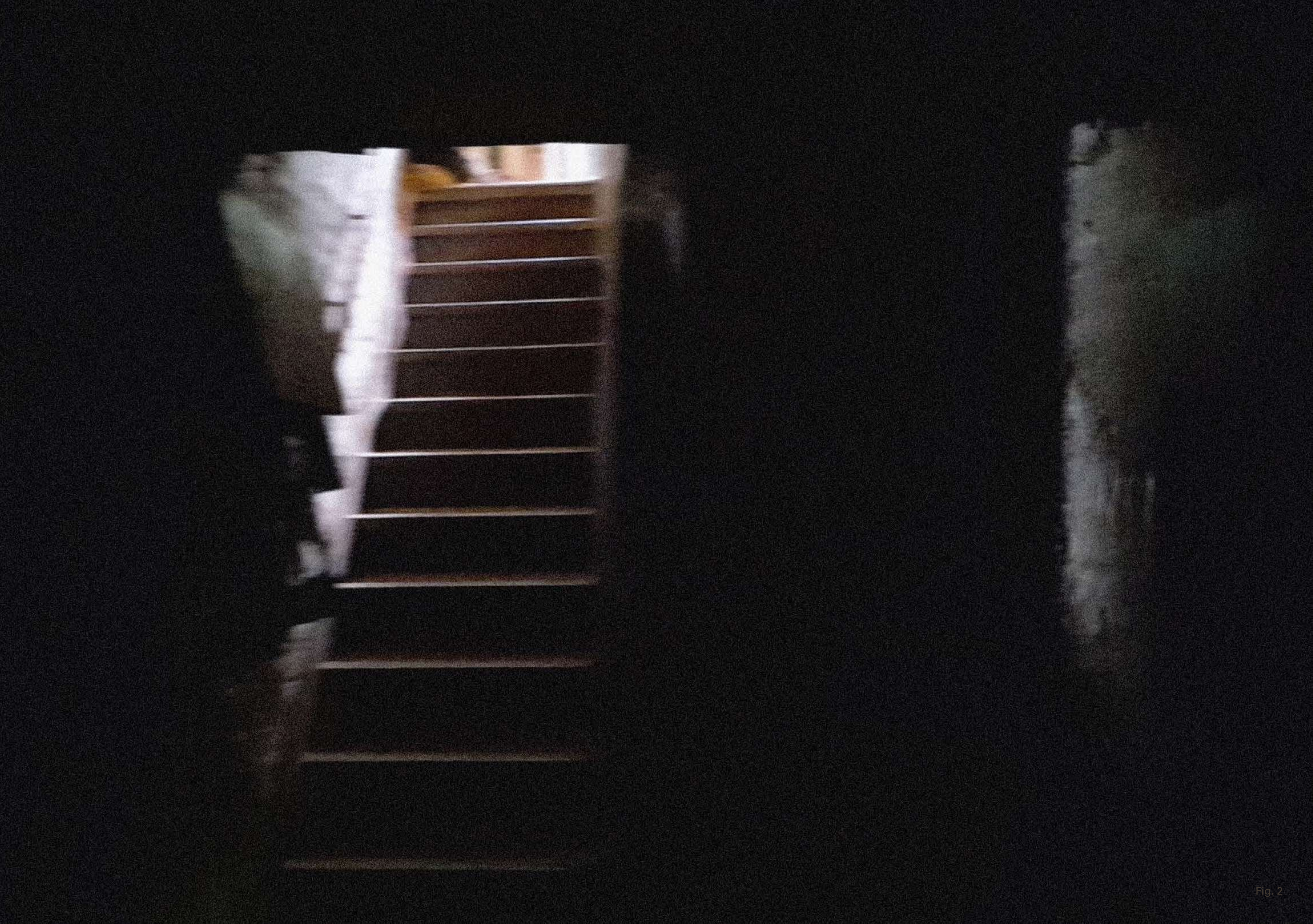
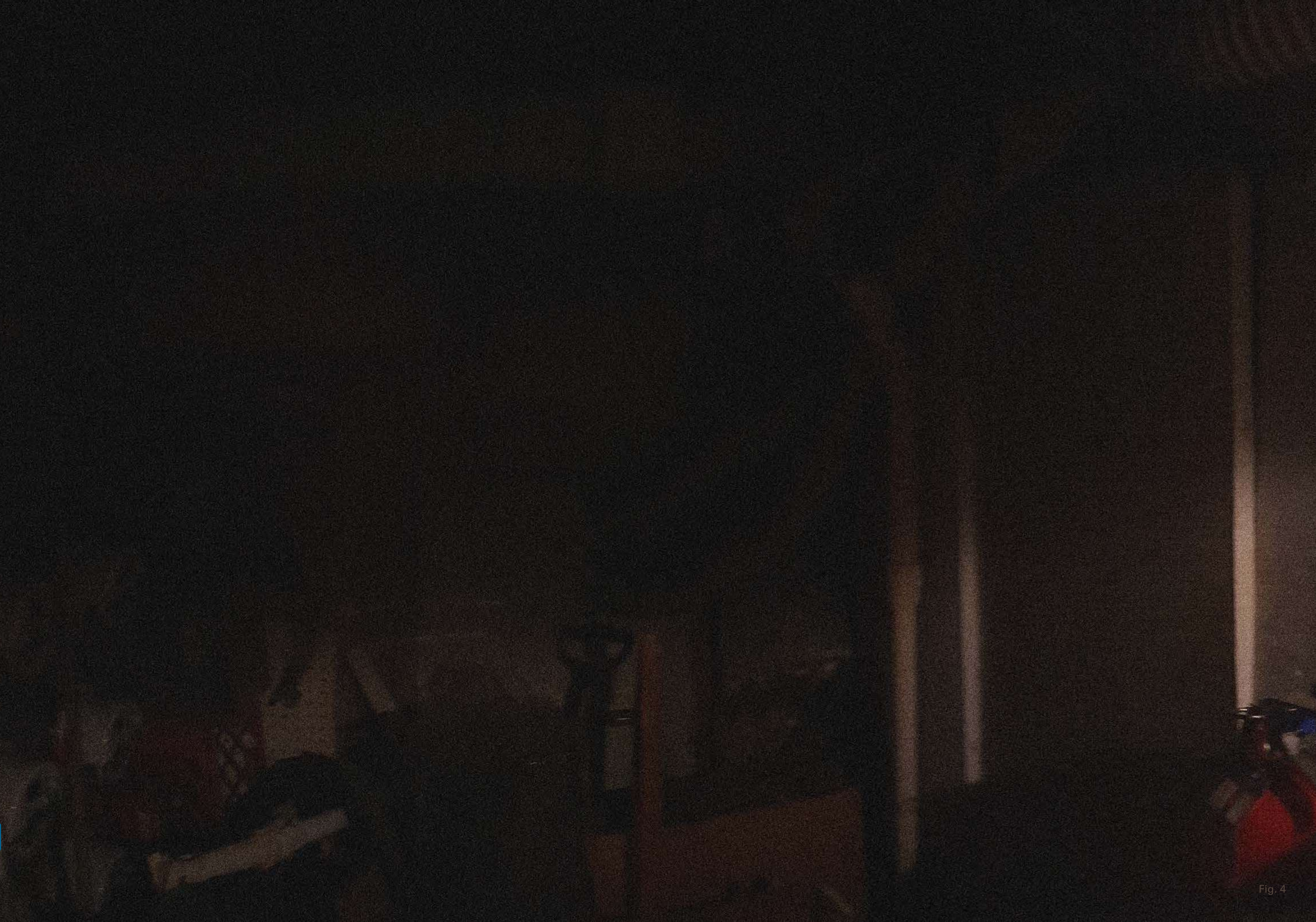


Fig. 2

Fig. 3



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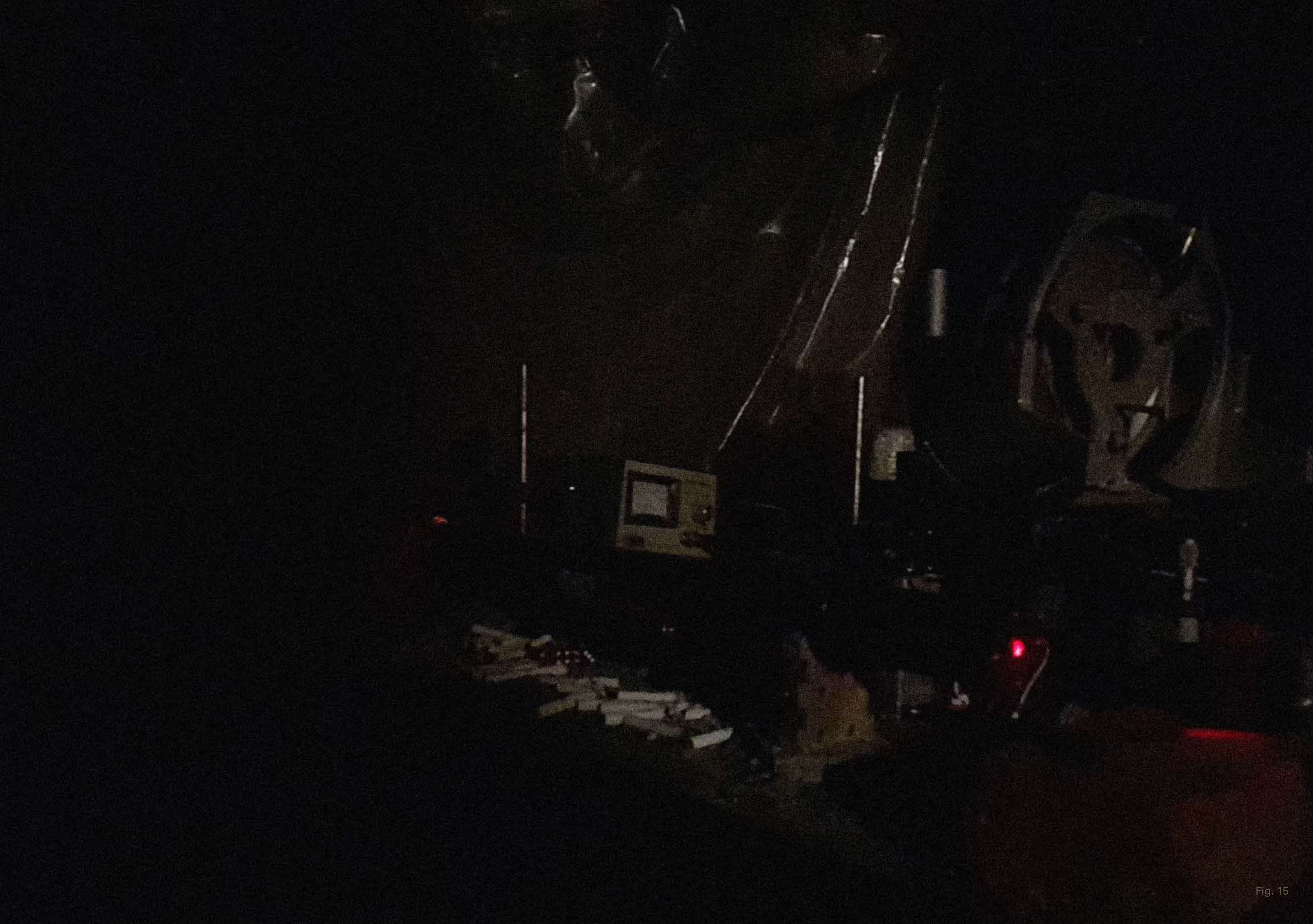


Fig. 15

Fig. 16

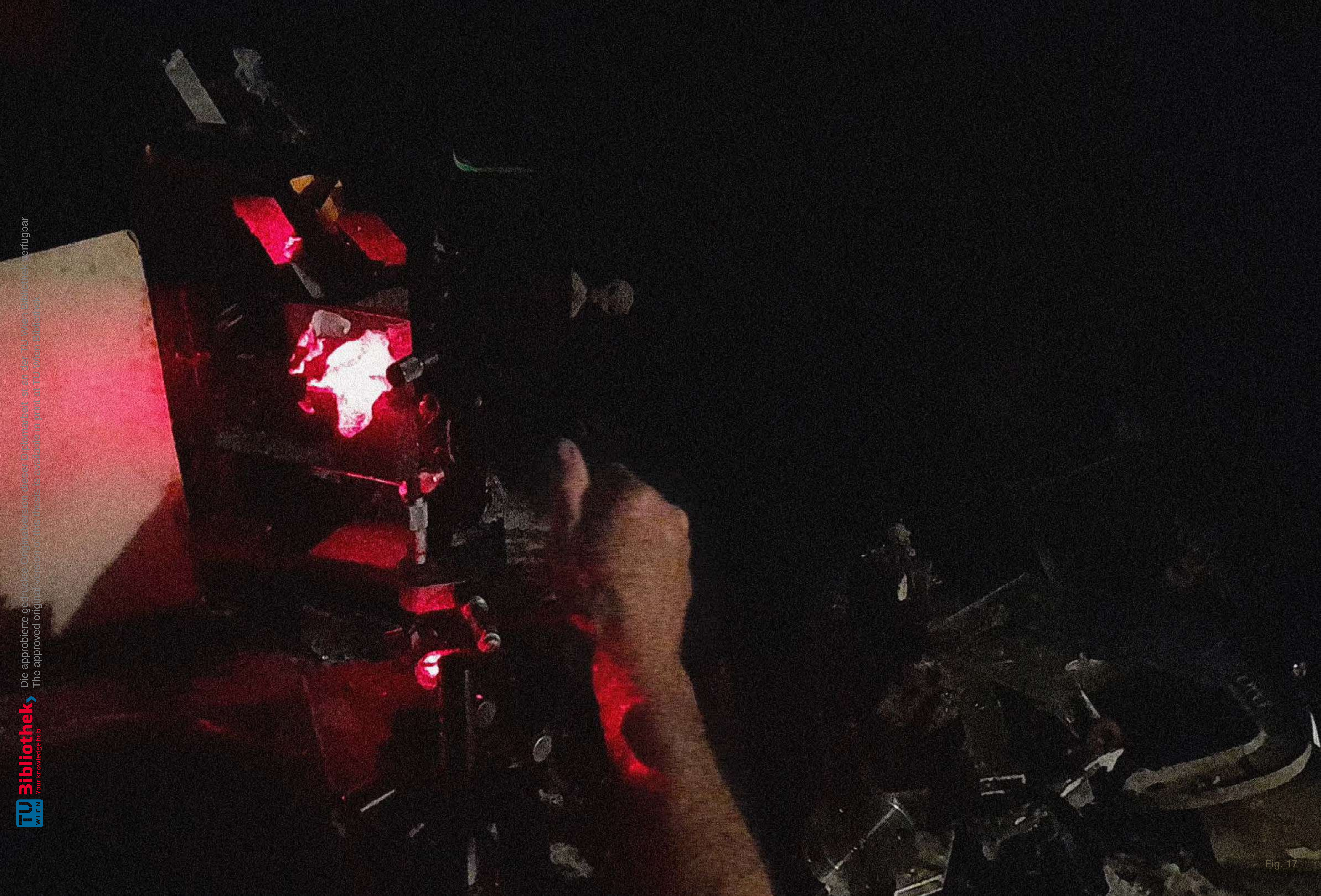


Fig. 17

Fig. 18

Fig. 19

Fig. 20

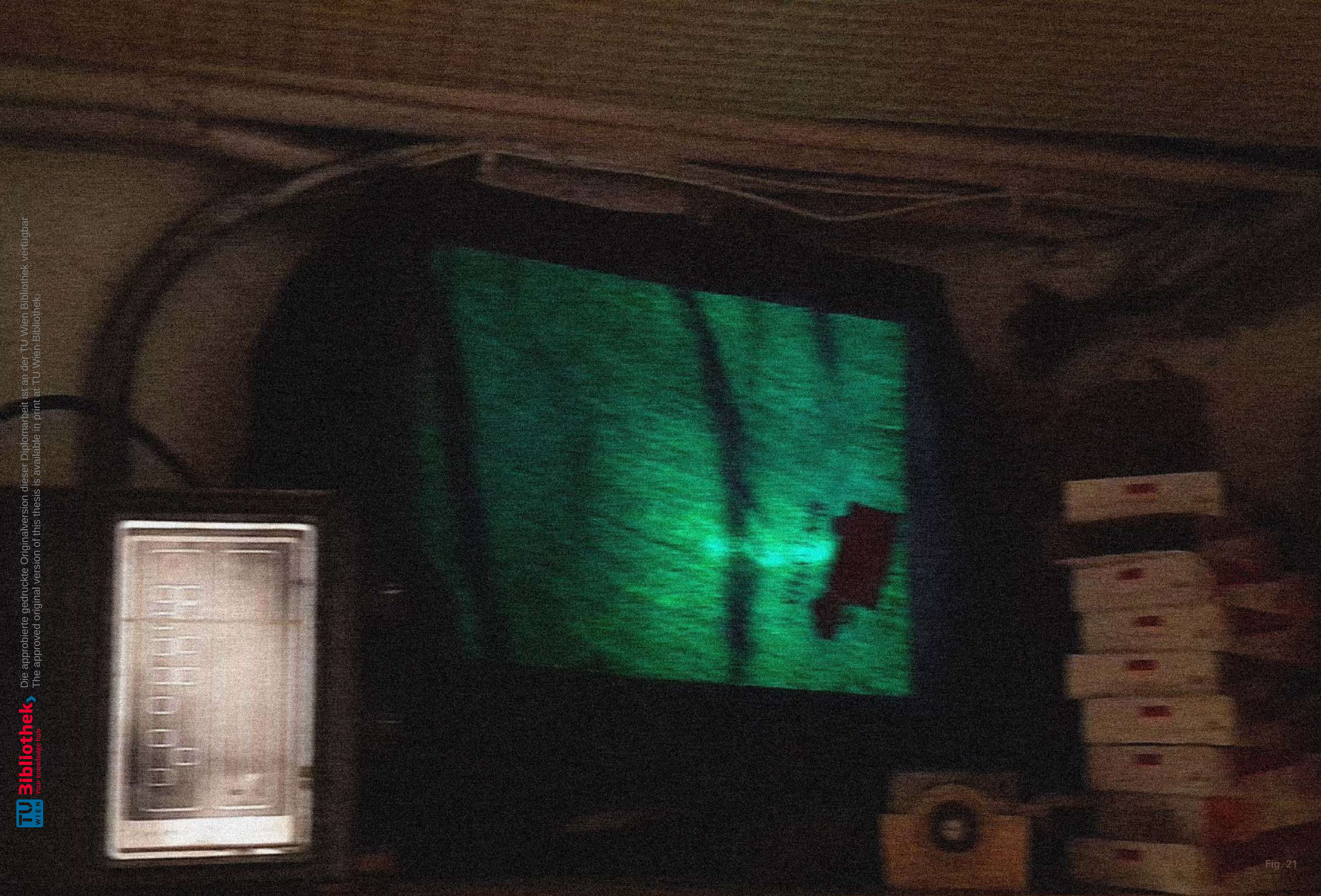


Fig. 21

Fig. 22

Fig. 23

Fig. 24

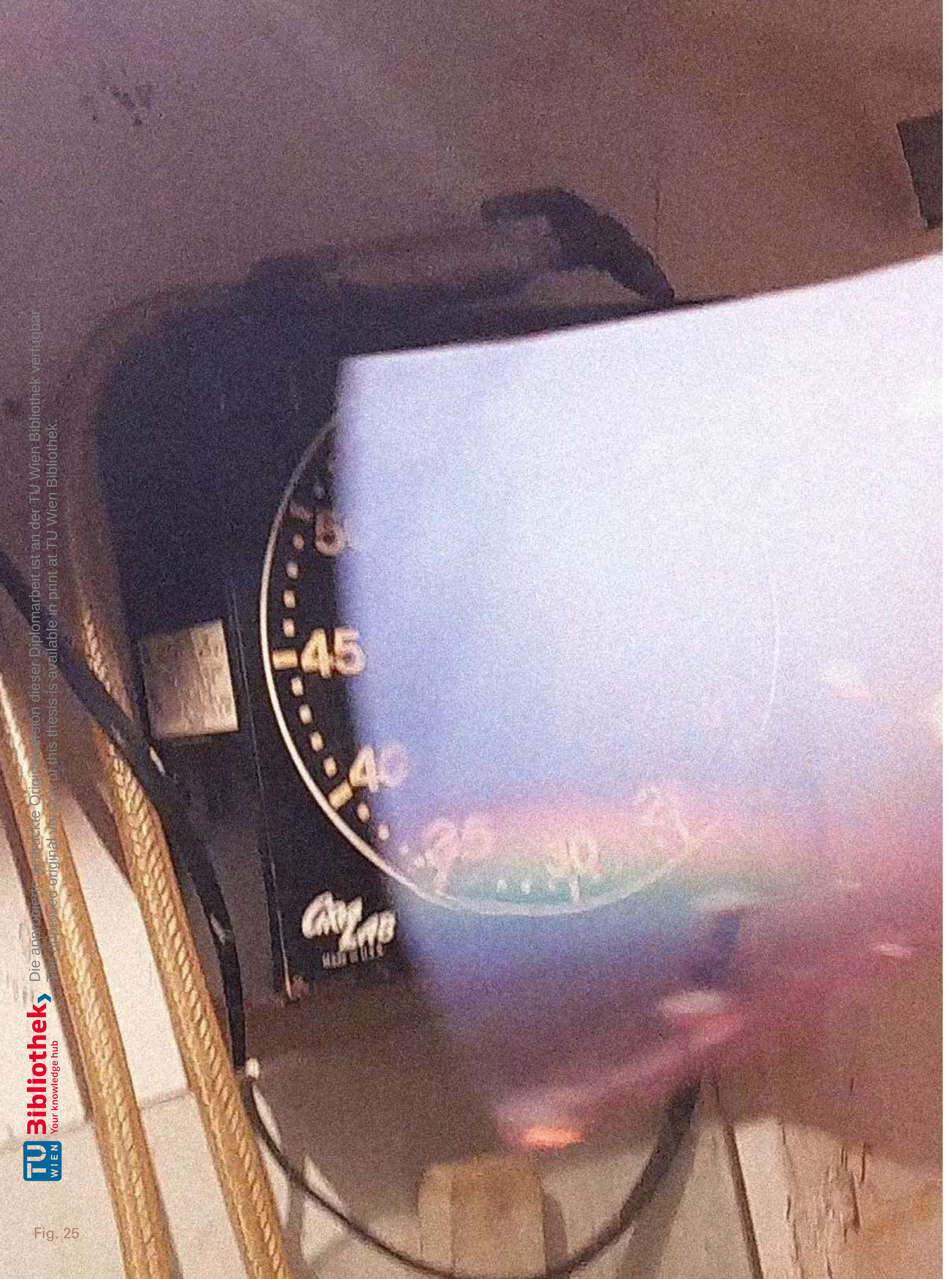


Fig. 25

1.1 Definition

The frequently blurred term 'holography'[1] is widely associated with different forms of three-dimensional images, whose technology is often considered to be fictional and futuristic. And yet, its initial scientific meaning is considerably more specific, although not entirely clear and describes a real physical method and concept on the principles of interference[2] (see 1.2). In its most original form, holography is the technique of recording light[3] waves that can later be reconstructed. An exact definition still proves to be difficult due to various types and applications. The name 'Hologram' can be referred to as the interference pattern, which can reproduce three-dimensional images. 'Holography' is a term used to describe the process itself.
Many associations have no relation to their fundamental physical processes and have found their way into the mainstream due to several reasons. 'Holography', as a synonym for various types of virtual (moving) images, has lost its actual meaning in general use. The frequency with which this term is applied unevenly exceeds the real prevalence of usage, even though not as much as one might expect, since holograms of reduced quality can be regularly found in daily applications. Holography, understood in its authentic physical sense and realized with high quality, can nonetheless transcend numerous false associations in its appeal.
Many misconceptions[4] obsolesce any physical matter and display free-floating, three-dimensional projections of light in empty space, even though it is only the interaction with materiality that enables 'seeing'[5].
In this sense, these types of 'holograms' are fictional, since it always requires a physical medium for images and projections, or light in general, to be seen.
So-called 'Holographic displays' are usually based on the 'Peppers Ghost Illusion'[6] found in the 19th century, which works by projecting on a transparent screen at a certain angle. This effect doesn´t work on the principle of interference and therefore shouldn´t be classified as real 'holography'. This also applies to many other imaging methods such as stereoscopy and lenticular printing. They all give the impression of three-dimensionality but rely on entirely different principles.

1. Old Greek holos ,whole', grafie 'writing'
2. 'Interference' is a physical phenomenon that applies to various types of waves, e.g., light, sound and matter. (see 1.2)
3. 'Light' refers to the visible frequency range of electromagnetic radiation [1, p. 9].
4. Fictional and futuristic associations have been widely disseminated in film and television shows that frequently assigned holography properties of real plastically, like the immersive 'holodeck' in Star Trek – The Next Generation. Another well-known example of deception is the 'holographic' projection of Princess Leia in Star Wars: Episode IV – A New Hope. Many cases show the desire of perfect illusion and movement [2, p. 153].
5. 'Seeing' refers to the impression received when light waves reach the eye, after being reflected and scattered by objects [1, p. 9].
6. A well-known example of a 'Peppers Ghost Illusion' being used was the 'hologram' of rapper Tupac Shakur during a concert at the Coachella Valley Music & Arts Festival, 2012.

Fig. 26
THE KISS II
Multiplex hologram by Lloyd Cross &
Pam Brazier, 1976
Copy exhibited at the Holographic Studios, NYC

1.2 Principle

The basic principle and recording method of holography can be explained in a variety of ways. For this reason, numerous analogies are employed in both scientific and amateur literature to communicate complex topics more effectively.
Holography is based on principles of quantum mechanics, particularly on the phenomena related to light interference[7 8]. The true hologram is the interference pattern formed on the nanometre scale and is therefore not visible to the naked eye. It can be imagined as an immensely complex arrangement of overlapping fringes. A very common analogy describes it as stones dropped on still water, resulting in ringlike waves interfering with each other.
When objects of matter get illuminated, they reflect and scatter incoming light waves into so-called object waves. Their amplitudes and phases contain the optically relevant information about the three-dimensional properties and position of the original object[9].
In photography, where only amplitudes are recorded, complete visual reconstruction is not possible due to the absence of phase information. Holograms contain both and are therefore capable of optically reproducing objects in full parallax.
The creation of holograms involves the recording of interference patterns on a recording medium. This process can be accomplished using a variety of methods and techniques that are based on the same fundamental principles.
The elementary components are usually one or more objects, a coherent light source (most commonly in the form of a laser[10]) and a recording medium. Additional constituents can vary according to the method applied.

There are numerous types of recording media (films), both digital[42] (see 2.3) and analogue[11], that can be used for holography. However, these media must possess sufficient resolution to record information at the nanometre scale. In the absence of pulsed lasers, it is crucial that optical setups are sufficiently mechanically stable throughout the holographic recording. Even minor vibrations[12] can reduce the brightness of the hologram or compromise the entire exposure.

7. Light waves need to be coherent (spatial and temporal) and of the same frequency to interfere with each other. This state is also referred to as 'in phase'. The synchronised waves form either peaks (constructive interference) or valleys (destructive interference). The amplitude of the new wave is the sum of the original waves [3, pp. 369-370].
8. In addition to 'traditional' optical there are alternative methods such as acoustic and acousto-optical holography, that are also likewise based on the principles of interference.
9. The amplitude describes the brightness of light. The phase of the wave contains information about the form of the illuminated object.
10. Lasers (Light Amplification by Stimulated Emission of Radiation) are the primary light source in holography, since they emit coherent light waves. Conventional white light sources produce only partly coherent light [4, p. 75]
11. Suitable analogue films can be based on silver halides, photopolymers, dichromated gelatin, thermoplastics or photoresists. The required resolution of around 1500 lp/mm is substantially higher compared to those of photographic film (~50-100 lp/mm) [4, pp. 126-141].
12. Any vibrations in the magnitude of the light wavelength should be avoided. Already amplitudes of ~30nm can decrease the contrast of interference fringes and therefore affect the appearance of the hologram [4, p. 96].

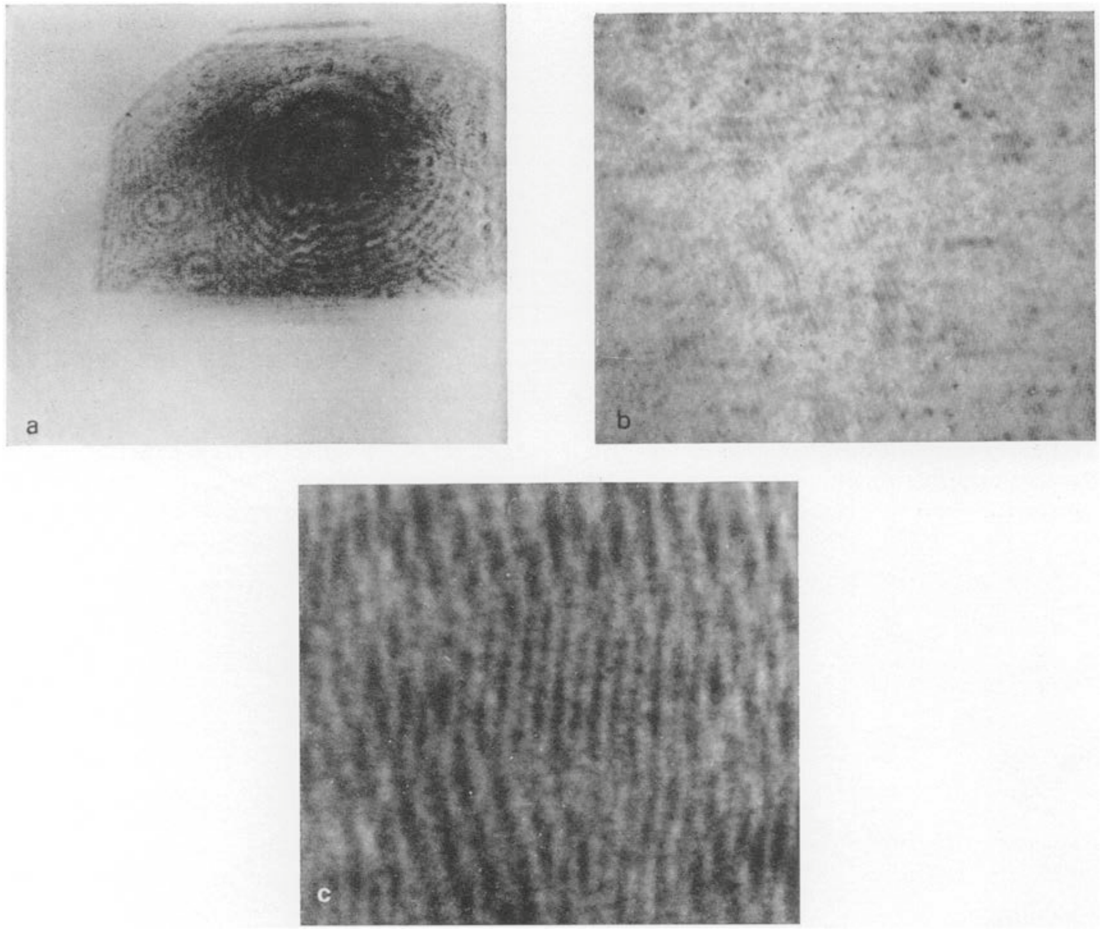


Fig. 27
Different magnifications of a hologram: (a) natural size; (b) 250×, with the interference pattern becoming slightly visible; (c) 1250×, where the complexity of the interference pattern is clearly apparent [6].

The basic recording principle can be explained with a Single-Beam Reflection Hologram:

The Laser emits a coherent beam that gets widened by an optical lens (optionally a spatial filter[13]) to become the ‘reference wave’ that hits and transfers through the holographic film plane to reach the object behind. The light wave will be reflected and scattered to become the ‘object wave’ which interferes on the film plane with the ‘reference wave’, forming the interference pattern.
After development, the initial object wave, that contains phase, amplitude and therefore spatial information of the original object, can be reconstructed by simulating the ‘reference wave’ used during recording. Depending on the type[14] of hologram, the interference pattern either reflects or diffracts the incoming wave, enabling the reproduction of three-dimensional images of the object.

13. Spatial filters are optical components that clean the light beam from irregular interference structures that can be caused by factors such as dust in the optical system [3, p. 89].

14. Holograms are essentially distinguished into Reflection- and Transmission holograms. Reflection holograms filter length-specific waves similar to the original reference wave during reconstruction (according to Bragg’s law). Therefore, these types can be illuminated by white light sources. Transmission holograms generally don´t filter light and diffract waves of different length, resulting in blurred multicoloured images in white light. For that reason, they are usually illuminated by lasers or other strongly filtered light sources [4].

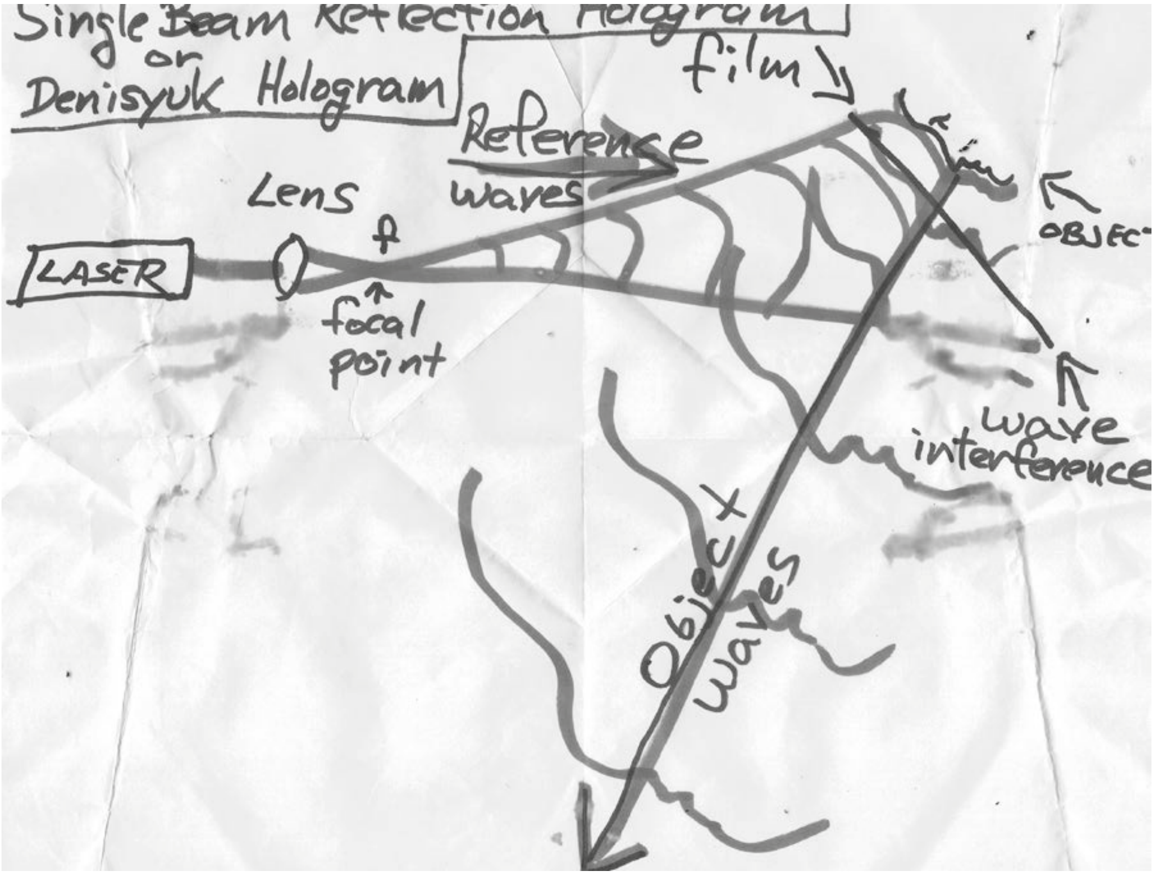


Fig. 28
Single Beam Reflection Hologram.
(Illustration by Jason Sapan)

„...looked at it from different angles. I could be making all this crap up. We´re a block from Belvue Hospital, some guy running around in a white lab coat... Just saying, not even a dad joke. But, if it´s true, you notice this object right here? Can you identify what it is?

Is it a microscope[15]?

Yes, good job. What do you do with a microscope?

You magnify things?

You can see things magnified.

You looked into it?

Wow! That´s nuts!

You can get closer

That´s nuuuuts!

Thank you. I live for that. And it´s going to get better. ... Yeah, I got some really awesome shit for you guys, seriously.
Remember when I said, it´s like an impression of a mold a hologram? I think the most common mold that everyone has in their house and not the bad type of molds... is a muffin pan. You´re making cupcakes, you put the batter in, cook it, take it out. You gotta wash the pan, you flip it over and there are no longer cups in the (bumps?) right?
So you guys see the pyramid here?
Yeah.
You notice it is popping out in front? If anything is valid here. Look, if I block the light, we tilt the image. If I flip it over, it´s inside out[16] and everything down to the size of light waves has been stored.
You see the lady inside here? Watch her!
Now I´m going to show you a little bit of a technical thing. I hope you appreciate this. HELP ME! That´s important and look it´s just a piece of film which brings up the notion that everything here is black and white film (holographic film). We don´t use colour. Colour is the size of a light wave. Think of a heart: BUMBUMBUM BumBumBum bum bum bum. Red, orange, yellow, green, blue, violet... ultraviolet...INFRAREDThe size of the light wave I am photographing is the colour you see. And speaking of colour: This is a full-colour hologram[17]. You see every hair on his head, his eye colour and everything. So it´s three different exposures with three different lasers. Red, green and blue.
I forgot to ask, what do you guys do?...“

‚Laser Tour‘
Holographic Studios NYC, 18 August 2023

15. The microscope mentioned in the conversation is a holographic recording which, when examined closely through the eyepiece, displayed an enlarged image of a mosquito (Fig.29).
16. Depending on type, view and angle of illumination, the appearance of a hologram can either be ‘orthoscopic’ or ‘pseudoscopic’. The latter means that the perspective of the conjugated images are manipulated in a way that they appear inverted (convex forms would be perceived as concave) [3, p. 19].
17. In the recording process for colour holograms, exposures with differently coloured lasers will be taken on a single holographic film. Challenges may arise in the form of unbalanced colour intensities or unwanted overlaps, commonly referred to as ‚cross-talks.‘ An alternative method to avoid the latter is the so-called ‘Rainbow’ Transmission hologram [3] [5].

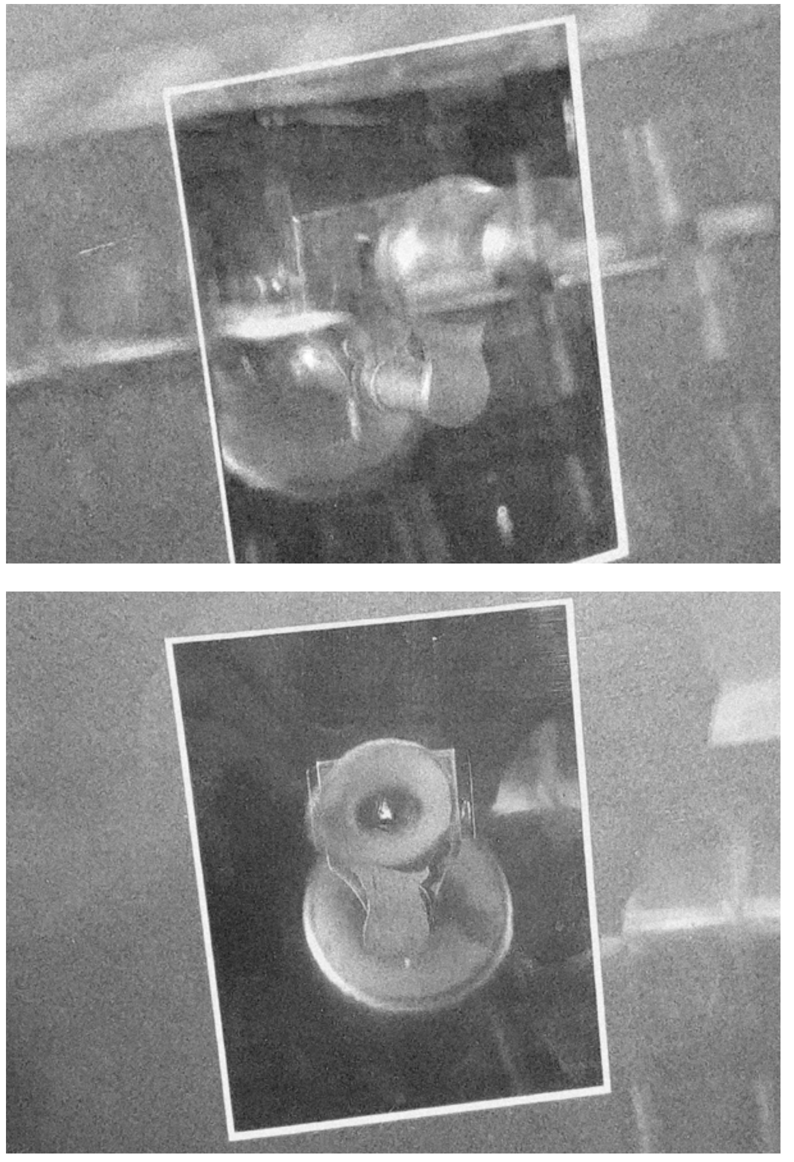


Fig. 29
Hologram of a microscope

Fig. 30

The historical development of holography is characterised by ambitions and expectations that contrasted with its actual progress. It appears as if the medium is rarely present in visual perception, despite its usage in daily applications. To better understand the causes of this ambivalent situation, it is necessary to distinguish between the various actors involved in its historical evolution.

2.1 Precursors

Foundational work that has led to the development of holography reaches back to the 17th century[18]. In particular, the wave theory of light and the discovery of interference and diffraction have been fundamentally important for subsequent advancements in the field. Numerous scientists[19] can be mentioned in the context of essential holographic developments, especially the work of Dennis Gabor[20], which is widely considered to be a foundational contribution. In his 1948 published journal 'A new microscopic principle', he describes an alternative solution for improved microscopic resolution and incidentally illustrates the holographic recording principle.
„It is a striking property of these diagrams that they constitute records of three-dimensional as well as of plane objects.
One plane after another of extended objects can be observed in the microscope, just as if the object were really in position.“ [7, p. 778]
His experiments were realised prior to the discovery of laser technology with mercury arc lamps positioned in an 'In-Line'[21] setup, which requires transparent objects and can cause image breakups [1] [3].
Most theoretical ideas in holography could only be realised after the invention of the laser in the early 1960s, which provided the coherent light necessary for light interference. Early developments in holography which happened during the era of the Cold War had been strongly influenced by military funding and secrecy. Research in the field occurred in the USA and the UDSSR simultaneously, without mutual knowledge. Groundbreaking progress took place at the 'Willow Run Laboratories'[22] (USA) by E. Leith (1927-2005) and J. Upatniek (1936), as well as at the Wawilow Institute (former. UDSSR) by Y. Denisyuk [8] [9]. The latter succeeded in recording reflection holograms with a dim, but coherent Mercury Arc lamp [10].
Leith and Upatniek conducted their research to solve the 'Twin Image' problem that occurred in Gabors 'In-Line' Holograms.
In 1963, they successfully recorded holograms that showed high depth and parallax in an 'Off-Axis' setup [11]. In the same year, they successfully recorded holograms which showed high depth and parallax in an 'Off-Axis' setup, and in 1964, holograms were publicly exhibited for the first time during the 'Spring Optical Society of America Meeting' [8].

18. Notable figures include C. Huygens (1629-1694), T. Young (1733-1829), A. J. Fresnel (1788-1827), and J. von Fraunhofer (1787-1826) [1].
19. For their work from the second half of the 19th century, notable figures include: G. Kirchhoff (1824-1887), Lord Rayleigh (1842-1919), E. Abbe (1840-1905), G. Lippmann (1845-1921), W. L. Bragg (1890-1971), M. Wolfke (1883-1947), and H. Boersch (1909-1986) [1].
20. Dennis Gabor (1900-1979) worked at the Imperial College in London and received the Nobel Prize in 1971 for his research contributions regarding the interference of light [3].
21. 'In-Line' refers to a setup in which object and light source stand perpendicular to the film plane. 'Off-Axis' describes the opposite.
22. The 'Willow Run Laboratories' were affiliated with the University of Michigan and were located in Ann Arbor. Their research included funding from the United States Department of Defense [12].

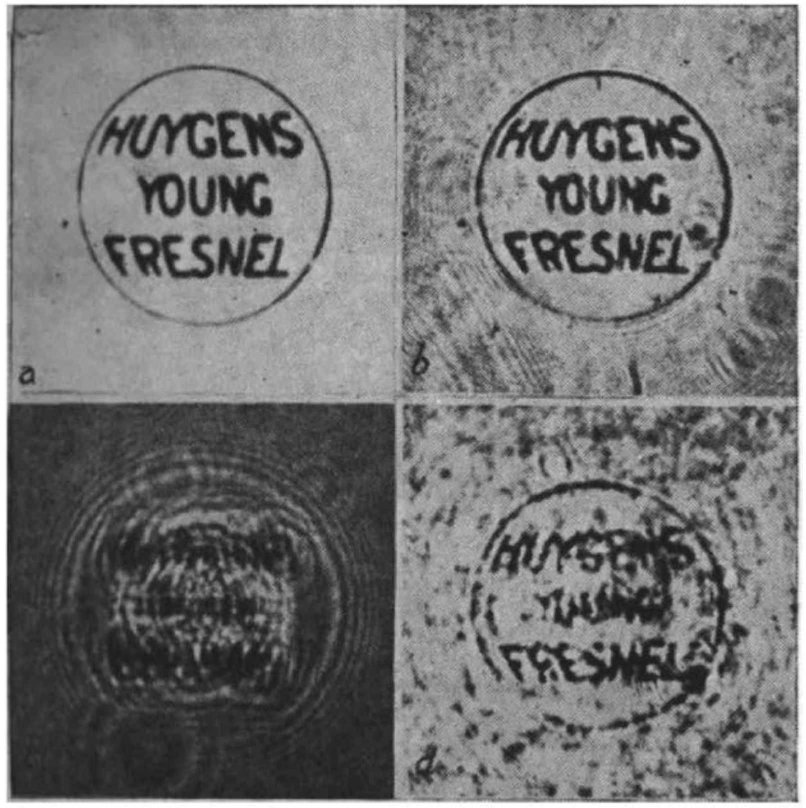


Fig. 2. (a) ORIGINAL MICROGRAPH, 1·4 MM. DIAMETER. (b) MICROGRAPH, DIRECTLY PHOTOGRAPHED THROUGH THE SAME OPTICAL SYSTEM WHICH IS USED FOR THE RECONSTRUCTION (d). AP. 0·04. (c) INTERFERENCE DIAGRAM, OBTAINED BY PROJECTING THE MICROGRAPH ON A PHOTOGRAPHIC PLATE WITH A BEAM DIVERGING FROM A POINT FOCUS. THE LETTERS HAVE BECOME ILLEGIBLE BY DIFFRACTION. (d) RECONSTRUCTION OF THE ORIGINAL BY OPTICAL SYNTHESIS FROM THE DIAGRAM AT THE LEFT. TO BE COMPARED WITH (b). THE LETTERS HAVE AGAIN BECOME LEGIBLE

Fig. 31
Excerpt from ‚A New Microscopic Principle'; D. Gabor (1948). The section in the lower right (d) is a ‚reconstruction' (hologram) of a photograph (section in the upper left; a) [7].

2.2 Forecasting

The history of holography is shaped by illusionary ambitions and expectations that emerged from the 1960s onward in repetitive phases. Particularly in the early stages after the first publication of holograms, developments in the field can be observed that predicted the medium a far-reaching future across various sectors.
Early commercially motivated stakeholders[23] emerged in the 60s, particularly around the Willow Run Laboratories[22]. Apart from commissioned works, new applications of holography were explored, most notably in the fields of film and television[24]. However, most ambitions were set aside due to technical requirements that were unlikely to be met in the foreseeable future [11].
In the context of 'Counterculture', communities and educational institutions[25] emerged in the early 1970s that developed methods to create holograms independently and aimed to disseminate this knowledge. Components from optical laboratories were replicated in cost-efficient and easily available resources. Holography was forecasted to be the medium of the future, that will take an important role in the democratisation of information. Magazines such as 'Whole Earth'[26] or 'Radical Software'[27] reflect these movements and their discourses about the environment, technology and sociology. At that time, the principle of interference also inspired concepts of holism and systems theory[28].

23. The first commercial stakeholder was the 'Conductron Corporation', founded in 1960 by Keeve M (Kip) Siegel in Ann Arbor. The firm that later evolved into 'KMS Industries'. Conductron Corp. produced e.g. holograms for artists Bruce Nauman (1968) and Salvador Dalí (1970). They also recorded 500000 transmission holograms for the 1976 Science Yearbook. In 1968, they succeeded in creating the historically first holographic portrait with a pulsed laser [12].

24. Conductron Corporation succeeded in creating simple holographic animations; however, ambitions such as broadcasting the Olympic Games with holographic television remained in the realm of fiction [11].

25. A notable mention is the 'San Francisco School of Holography', that was founded in 1971 by the likes of Lloyd Cross. The school had significant influence in developing holography artistically, as well as disseminating, expanding and developing the medium in new areas. Various new methods and interventions, such as automatic printers for stereo ‚multiplex' holograms, have been realized using cost-effective and readily available tools. In 1973, the 'SOH' became the 'Multiplex Company' with the intention of developing holographic devices, e.g., cameras, storage devices and solar holography. In ‚The Story of Multiplex,' L. Cross describes his idea of an ‚ultimate' hologram depicting the ‚world' captured by a satellite [14].

26. 'Whole earth catalogues' were published between 1968 and 2002 by Stewart Brand and 'Point Foundation'. It self-describes its intention to be an 'evaluation and access device' [15].

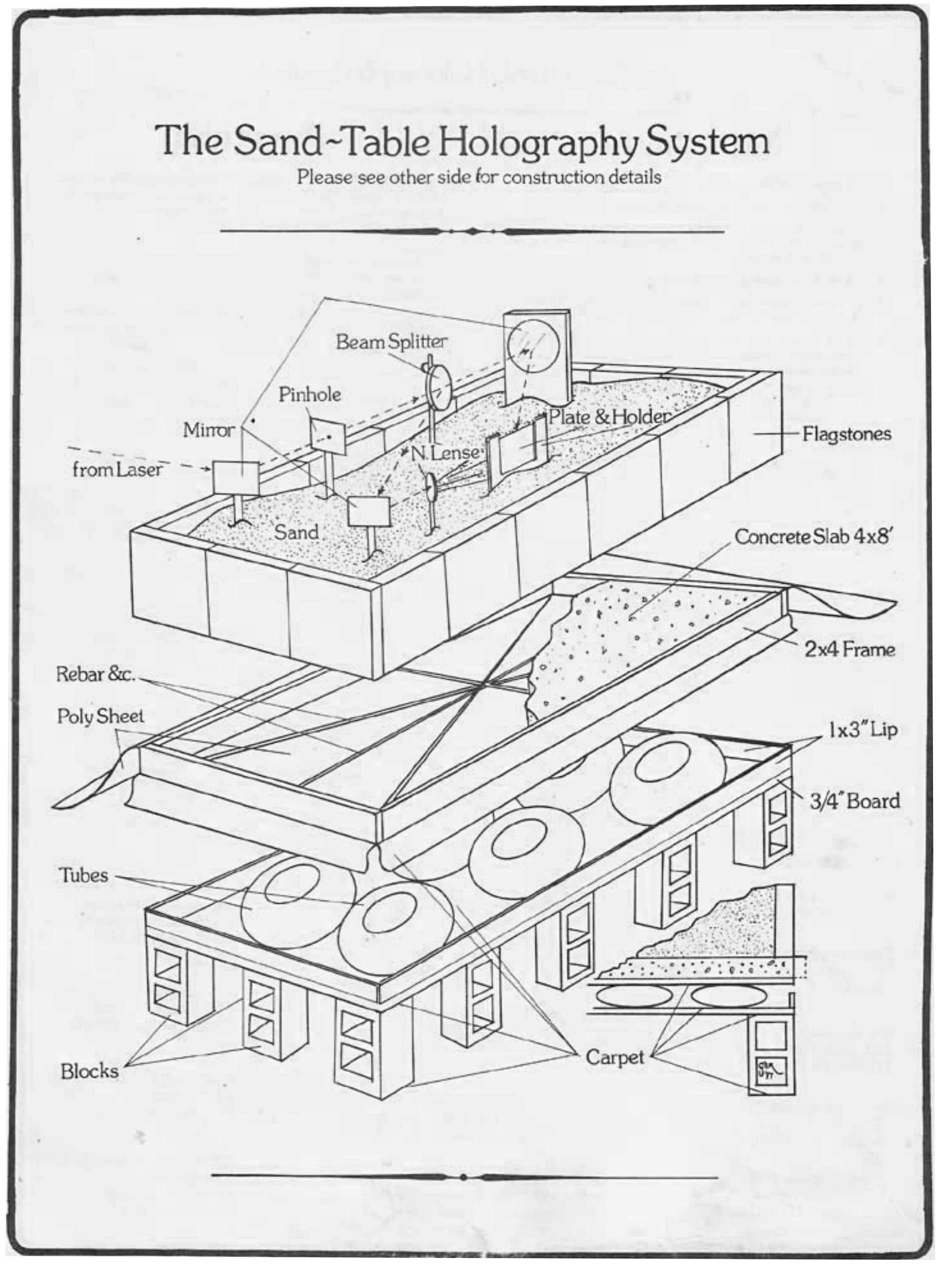


Fig. 32
Pamphlet describing the ‚Sand-Table Holographiy System'; published by the SOH, 1978 (Sharon McCormack Collection & Archives) [19]

27. ‘Radical Software’ was first published in 1969 by the Raindance Corporation in New York. Its founder’s intention was to provide a ‘theoretical basis for implementing communication tools in the project of social change’ [16]. Holography was frequently mentioned in the context of 3D television, data storage and immersive spaces. *“It begins to seem as if experience, not surgery, is the design avenue for deliberate human evolution. All this before the mass availability of mini-laser communications technology, holographic environments instead of rooms/ walls of plaster, liquid crystal read out systems, etc . etc .”* [17, p. 7]

28. Wide acceptance has been gained by the likes of physicist David Bohm (theory of a holographic universe) and neuropsychologist Karl Pribram (‚holonomic brain model‘).

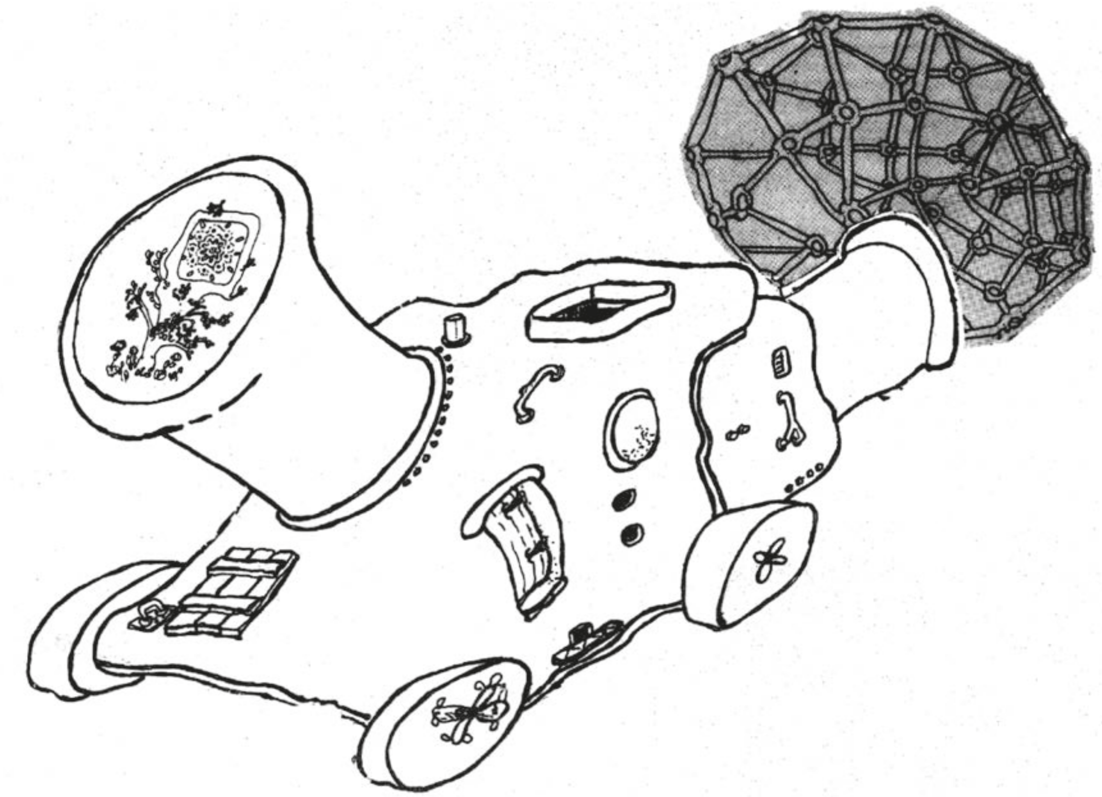


Fig. 33
Illustration from ‚Radical Software‘ Volume 1, No. 4 (1971) [20]

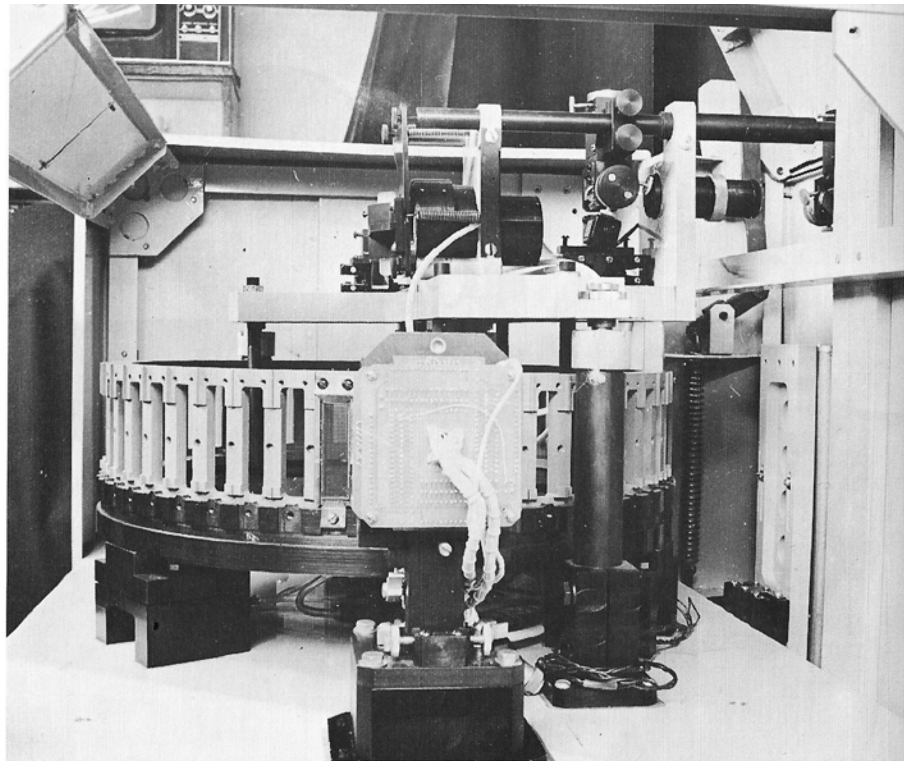


Fig. 34
Associative holographic memory developed in the former UDSSR [13].

As mentioned in section 2.1, in the 1950s and 60s research occurred in the former UDSSR under strict secrecy, leading to significant contributions in the field. However, early publications received only modest attention, not least because of the lack of application prospects [9]. Unlike the development in the USA, the medium progressed mainly in scientific and technological fields and found little relevance in social and artistic contexts.
One early application of holography was in the recording of historical artifacts that required special security measures, enabling their replication for exhibitions as a means of promoting soviet culture. In science, efforts have been made to develop holography further in fields such as data storage[29] or holographic optical elements[30] [13].
Many ambitions and efforts have been made by various stakeholders, particularly in the early phases, to further develop and establish holography into more common and widespread applications, such as movies[31] and television[32]. Although many ideas could have been theoretically realised, they were largely set aside for various reasons, including technical and commercial factors. The same applies to concepts in other fields, such as architecture[33] and immersive applications[34].

29. Amongst others, holographic mass storage systems, spatial-temporal light modulators (‚PRIS'), associative holographic storage systems, and synthetic holograms were developed [13].
30. Holographic optical elements (HOE) are understood as optical elements that are based on principles of interference. In the USSR, devices for precision measurement, telescopes, holographic cameras (used in the Interkosmos program, Salut-6), and „compact holographic systems" were developed in this regard [13].
31. There are some theoretical considerations regarding the creation of holographic (cinema) movies, including those involving multiple recordings (frames) on a film, whose reconstruction would occur through altered incident angles of the reference beams. D. Gabor20 proposed a holographic stereoscopic screen to enhance stereoscopic cinematography, and an apparatus for short-time 'kineholography' was developed at the Physical-Technical Institute of the Academy of Sciences of the (former) USSR [1].
32. One of the central challenges for holographic television would be the enormous data volumes that would require significantly higher transmission capacities [1]. There have been experiments to transmit holograms on liquid crystal displays (LCD) or digital micromirror devices (DMD). However, the necessary resolution size poses a problem [4].
33. Ideas for establishing holography in architectural concepts have been made by e.g. Anton Furst at the Light Fantastic Exhibition at the Royal Academy of Art, London, in 1977. The drawing depicts a holographic auditorium where visitors could be guided by a hydraulic platform. Architect Julian Marsh, in collaboration with Jo Fairfax, developed a design for the National Holography Centre in East Midlands, which would have structurally integrated holography (e.g., in walls) [18].
34. *„When people are able to take a hologram home and use it, the impact will be tremendous - on the environment, on design, and even on architecture," Cross said. „Holography can create the future," said Pethick. „Using holography, the physical environment can be anything that man can conceive ." Holograms on a skyscraper's window glass - not obscuring the inside view - might create huge pictures for people outside. Or, since visual reality could be created without physical restraint, Cross thinks a building lobby could be converted into an illusion of a tropical paradise."* Article about the ‚School of Holography', Radical Software, 1973 [16, p. 57]

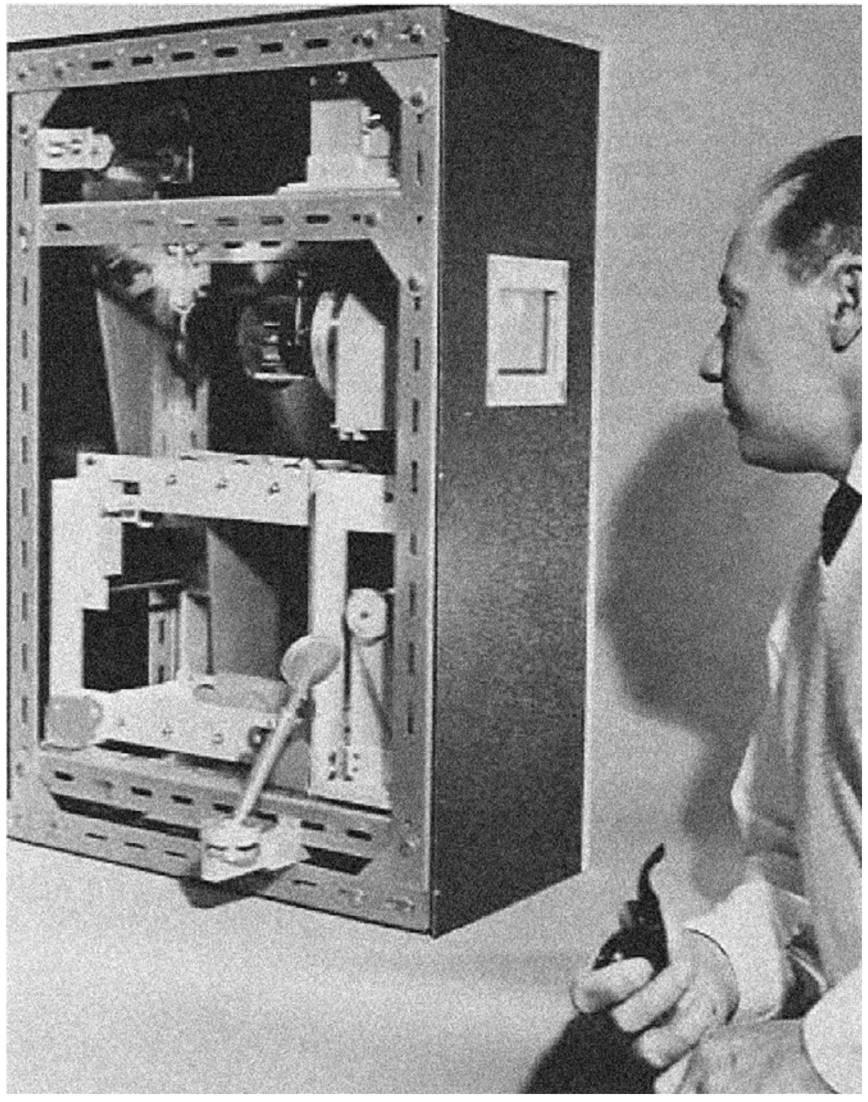


Fig. 35
Holographic movie viewing system by *North American Philips Corporation* [21].

Expectations in the field of holography have, ever since the first public appearance, been most frequent in regard to the establishment in various parts of society and the displacement of related technologies and communication tools. Thus, most stakeholders measured the 'success' of holography in terms of its expansion and continual progressive increase [11, p. 378]. Particularly during the 1970s and 80s numerous efforts have been made internationally, to enhance public awareness through both temporal and permanent exhibitions[35]. Particularly amongst permanent venues dedicated to holography, there were education initiatives in the form of 'schools' and courses. The period was characterised by numerous attempts to commercialise holography, during which the term 'holographer' was also coined [22].
Particularly in the artistic context, the medium was often deemed too technological[36], which led to its artistic integrity being questioned more frequently. Not least for this reason, artistic holography communities often formed their own presentation and discourse spaces separate from established institutions[37]. This isolation from external criticism, along with a resulting introspectiveness, are possible causes for the lack of critical self-reflection that could have been beneficial for the growth and development of the medium in the artistic context [23].

35. Amongst others, the Det Nya Mediet exhibition in Stockholm (1976), the Light Fantastic exhibition (1977-1978) in London, Through the Looking Glass (1978, travelling exhibition in the USA), and Light Dimensions (1983; Bath, UK) [22. In Austria, the exhibition Holographie in der UdSSR was shown at the Technical Museum in 1981, as well as Holographie in Wien, Faszination und Zukunft eines neuen Mediums during the Wiener Festwochen in 1986.

36. „It would appear that most technicians and scientists who attempted to become holographic artists did not understand art and failed to appreciate that artists are more likely to be turned of by science than to be impressed. Some holographers, especially those who were excited by the science, failed to understand why being a good holographer did not make one a good artist." [24, p. 19]

37. Overall, it seems that artists within the holographic art community have never felt adequately acknowledged by established galleries and museums. They have, in turn, criticised what they perceive as a preference for holographic works created by those whose main discipline is not holography [25]. If any connections existed, they were primarily with technological institutions and museums rather than with art institutions from other disciplines. The MOH (Museum of Holography, Chicago), which closed in 1992, sold its entire collection at a foreclosure auction for $180,000 to the MIT Museum (Massachusetts Institute of Technology) [26].

Fig. 36
Swiss physicist Gregor Antes during the construction of his holographic laboratory [27].

While holography has been little established sustainably in the fields of art, culture, and society, the method has been influential in the development of various scientific and technological applications. In this context, holographic interferometry[38] and embossing holography[39] have been particularly significant. The latter is the most cost-effective method for mass reproduction [4]. It is frequently used in the packaging and advertising industries, as well as being firmly established in security technology[40]. In the latter case, it often involves so-called 'kinegrams'[41], which are greatly simplified and often computer-generated holograms that are ubiquitous on banknotes, credit cards, and identity cards.
The development in research and technology increased gradually from the 1960s to the early 1990s, and consequently, so did the number of applications across various disciplines [22]. A significant change that affected other research areas, such as metrological holography and holographic interferometry, was the transition from analogue to digital[42] methods [24].
The fact that many ambitions, particularly those to establish holography as a novel means of communication on a mass scale, have not been fulfilled is likely a reason why the medium is often perceived as ‚failed' in general perception. In practice, this often manifested in the form of short-lived companies and initiatives. Particularly in holographic film production, only a limited number of companies remain active[43]. The number of active ‚holographers', public exhibitions and galleries specialised in holography, has also steadily declined since the 1990s [11].

38. Holographic interferometry is a method used, amongst other things, for non-destructive testing. The advantage over methods such as photoelasticity and the moiré effect is its ability to detect small deformations (<1 µm) [4].
39. Embossing holography is a method by which holograms can be ‚printed' in high quantities. A ‚master hologram' (transmission hologram) recorded on a photoresist layer is transferred to a thin metal film either by vacuum or chemically. The hologram can then be embossed onto aluminium foil using a stamp. Afterwards, the foil is typically coated with a protective layer and applied to a substrate material. The disadvantage of embossed holograms is a significantly reduced spatial depth (approximately 2-3 cm). For this reason, a staggered arrangement (kinegrams[41]) of 2D images is often chosen as the motif. [4]
40. Holograms are not entirely counterfeit proof. However, various security measures can be integrated that significantly complicate the effort or make it more costly.
41. 'Kinegrams' were developed in the 1980s by Swiss physicist Gregor Antes in a specially set-up laboratory in the basement of his parents' house in Zurich. Through the company Landis & Gyr, the first orders followed, e.g. from the Swiss National Bank. In 1988, kinegrams were printed for the first time on a currency (Austrian schilling) [27].
42. In digital or electronic holography, image sensors (e.g., CCD or CMOS chips) are used instead of traditional analogue recording films. This allows for the characteristics of the interference fringes to be interpreted more accurately and in real time [5].
43. Larger film manufacturers such as Kodak, Ilford, and Agfa-Gevaert have long ceased their production of holographic films. An exception is the company Slavic, based in Pereslavl-Zalessky (Russia), which has been producing high-resolution films, including for holography, since 1974. According to their website, there are still about 100 employees (out of a total of approximately 4,000) working in the production department [28].

Fig. 37
Holography Marketplace second edition, 1991
[30]

The causes of this ambivalent development are not clearly identifiable from a purely historical perspective. It is relatively evident that the ambitions for growth in the fields of art and communication have not been fulfilled as some stakeholders had aimed, and many technological forecasts[44] were never realised (see section 2.2). Some seek reasons for the complex situation and the preceding developments in the inherent properties of holography, such as its difficulty in being mass-reproduced[45]. Other critical voices refer to the practices of certain actors and institutions, as well as their role in the development of the medium itself.
In retrospect, it is particularly regrettable that amongst the many concepts developed, especially in the early phase, those with potential in other areas, such as architecture and spatially immersive applications, were never translated into practical implementation, with few exceptions.

44. *„ …we cannot judge straightforward technological failure here. There was, however, a failure of technological forecasting, owing to over-confidence in short-term achievements made in an over-inflated funding environment. “* [11, p. 385]

45. *„Können traditionelle Kunstformen – wie Gemälde, Skulpturen oder auch Fotografien – mittels fotografischer Reproduktionstechniken in kürzester Zeit einen hohen Verbreitungs- und Bekanntheitsgrad erreich, so bleibt das Künstlerhologramm in der Regel an den Ausstellungsraum gebunden. Nur hier ist es dem Betrachter möglich, sich einen angemessenen Eindruck davon zu verschaffen.“* [29, p. 12] (While traditional art forms—such as paintings, sculptures, or photographs—can achieve a high degree of distribution and recognition in a short time through photographic reproduction techniques, artist holograms typically remain tied to the exhibition space. It is only in this context that viewers can gain an appropriate impression of them.)

Fig. 38

This chapter documents a practical engagement with holography. It addresses the challenges involved in acquiring and preparing the necessary infrastructure, the learning process and personal experience during hands-on practice, as well as the results-driven search for theoretical and contextual alternatives in working with the medium. The insights gained were also intended to facilitate a more informed interpretation and understanding of both the historical developments described in Chapter 2 and the current situation.

3.1 prior testing
3.2 concrete interference
3.3 setup/process

3.1 Prior testing

The possibilities for representation in holography are highly dependent on technical and spatial conditions during recording. These inherent factors are not limited to the size and nature of the subject, but also include the type, duration, and playback options of the hologram. Furthermore, as the requirements increase, so does the complexity, and consequently, the need for expertise.
Prior to the actual work, there was a learning and trial process that was significantly limited by its technical framework conditions. The main challenge in acquiring the necessary technical prerequisites primarily lies in financing. Optical instruments, lasers, and vibration-isolating[46] devices can be highly expensive and difficult to finance independently, primarily because there is very little demand for them outside of research institutions. Not least for this reason, as early as the initial phase of holography's history (section 2.2), efforts were made to find alternatives to expensive equipment and to create the necessary technical conditions through 'DIY' solutions. The methods developed in this context were disseminated both in print and via the internet and are frequently used, especially amongst amateurs.
In the initial experimental phase, a setup commonly known as a „sandbox" arrangement in the context of holography was chosen. In this setup, the optical instruments, as well as the film[47] holder and laser[48], were embedded in a sand bed and aligned using a single-beam method[49]. This resulted in a series of small-format transmission and reflection holograms of test objects made of metal and concrete[50].
The second phase of this experimental process was carried out in a holography laboratory using professional optical components[51] and more powerful lasers on a vibration-isolating table[52]. These conditions allowed for improved result quality and significantly reduced the interval times between exposures. The latter is a crucial factor for continuous work, especially when performing multiple exposures.

46. Vibration isolation is essential when recording holograms without pulsed laser (see section 1.2, 12).
47. The photopolymer film Bayfol HX200 was used as the recording material.
48. Both a diode laser and a HeNe laser (each with less than 10 mW output power) were used. The exposure times exceeded 10 minutes.
49. It should be noted that the experiments took place in an apartment on the fourth floor of a multi-story building. To minimise vibrations, exposures were carried out exclusively in the early morning hours, and additionally, household appliances such as the refrigerator were turned off before and during the recording process.
50. The concrete was pigmented red to match the colour of the laser (635 nm) to enhance the visibility of the holograms.
51. The setup included, amongst other things, spatial filters and various optical mirrors with magnetic or mechanical mounts.
52. The experimental table consisted of a honeycomb structure with a metric breadboard and featured active pneumatic vibration isolation.

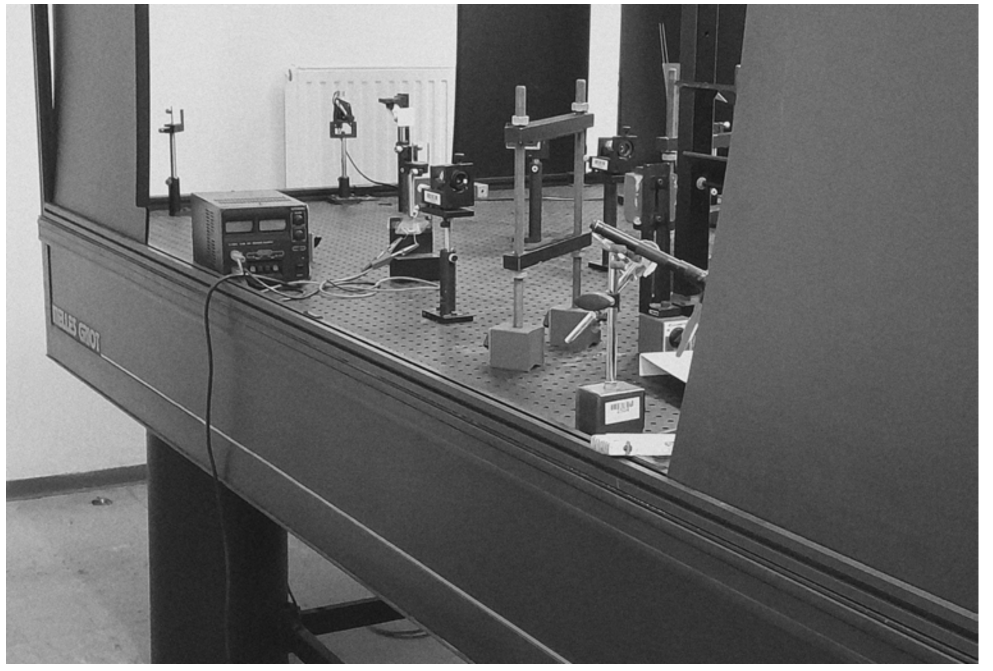


Fig. 39
Transmission hologram produced using a "sandbox" setup.

Fig. 40 (right)
Setup used in the second phase of testing and for the recording of *Concrete Interference* (see 3.2).

3.2 Concrete Interference

Holography is a highly sensitive process that demands careful handling of materials, equipment, and environmental factors, leaving little room for irrationality or spontaneity. This often results in an excessive level of caution and rationality, which can lead to sterile, trivial outcomes, primarily aimed at avoiding „faulty“ or blurred recordings. Yet, it is precisely these so-called „optical anomalies“ that reveal the unique characteristics of the medium and make its nature perceptible. In this way, the hologram itself becomes the subject.
The work process for Concrete Interference was characterised by a physical pre-production phase with concrete, followed by the actual recording procedure. In this process, the pigmented concrete objects were holographically reproduced, merged and assembled into a multi-layered texture.
Concrete, in its tactile quality, outward appearance, and physicality, stands in stark contrast to the material-specific properties of synthetic film materials. The associated heaviness and porosity, recorded on plastic-based film, create an ambivalent impression between visuality and physical reality.
Multiple exposures generated new structures and overlays, forming a somewhat blurred assemblage. The space between technical necessity and ‘flawless’ recording was consciously explored. Optical anomalies and imperfections were tolerated and understood as part and expression of the process.
The otherwise sensitive procedure of conventional recordings was replaced by repetitive work cycles and, not least, accelerated and quantified by the elimination of chemical development. Between technical ignorance and pure productivity, space emerged for chance and irrationality.
Concrete Interference is an attempt to accentuate the fundamental inherencies of a medium by deprioritizing subject-matter and iconographic questions, and to highlight its potential in terms of transformation and emergence beyond mere visual reproduction.
Additionally, through the apparent distortion of reality and the adoption of new perspectives, the work aims to break up perceptual automatisms amongst viewers and to stimulate a questioning of their own perception.

Fig. 41
Possible assemblage of the concrete bodies with the film layer positioned above.

Fig. 42 (right)
Holographic recording

3.3 Setup/Process

As mentioned in Section 3.1, the imaging possibilities in holography are always associated with specific technical requirements. For the work on concrete interference, the main goal was to ensure a continuous workflow. This meant minimising the intervals between exposures and shortening preparation times. Additionally, it was important to provide a certain level of confidence in achieving a 'successful'[57] recording, without striving for excessive perfection.

For the recording process, a single-beam reflection setup was chosen, with the film plane[53] positioned horizontally. This allowed the concrete objects to be freely moved on the table surface without additional fixation. The laser[54] beam was directed via mirrors into a spatial filter, then expanded and shaped before being projected onto the horizontal film plane. The film rested on a grid of spacers and was secured with magnets, ensuring stability after each realignment. After some exposures, the concrete objects were newly selected and rearranged within the irradiation area, establishing new spatial relationships between them.

A photopolymer film[55] was chosen as the recording material, which eliminated the need for chemical development and made the results visible immediately after exposure. This type of film is significantly more light-resistant than conventional silver halide emulsions or dichromated gelatin films, and therefore requires a higher exposure dose-meaning either a more powerful laser or a longer exposure time[56].

Over a period of a few weeks, more than 50 films (each measuring 20x30 cm) were exposed, with 6–9 individual holograms recorded on each. Of these, around 6 exposures were 'unsuccessful'[57], and almost all exhibited clearly visible diffraction fringes, especially in the centre of the holograms. During exposure, colour shifts could be observed on the film plane, which provided an early indication of whether an exposure would be successful or not.

53. The film plane consisted of a glass plate onto which the photopolymer film was laminated before the first exposure (the film adheres statically).

54. A green diode laser (Coherent Sapphire LP OPSL) with a wavelength of 532 nm and an output power of 300 mW was used as the light source.

55. As in Section 3.1, the photopolymer film Bayfol HX200 was used. Since this is a colour-sensitive film, lasers of different colours could be employed. In the yellow spectral range, the film is less sensitive to light, which allowes preparations to be carried out under a strongly dimmed ‚safelight' in this range.

56. The exposure time ranged between 10 and 12 seconds, during which an area of about 10x10 cm of the film could be covered. Each film (20x30 cm) was exposed at least six times and then illuminated with UV light for about 20 minutes to bleach it. This post-exposure UV treatment helped improve the quality and colour reproduction of the holograms [31].

57. In this context, "unsuccessful" exposures refer to recordings that produced either no hologram or a very faint one. "Successful" exposures are those in which the hologram, despite optical anomalies, was clearly visible.

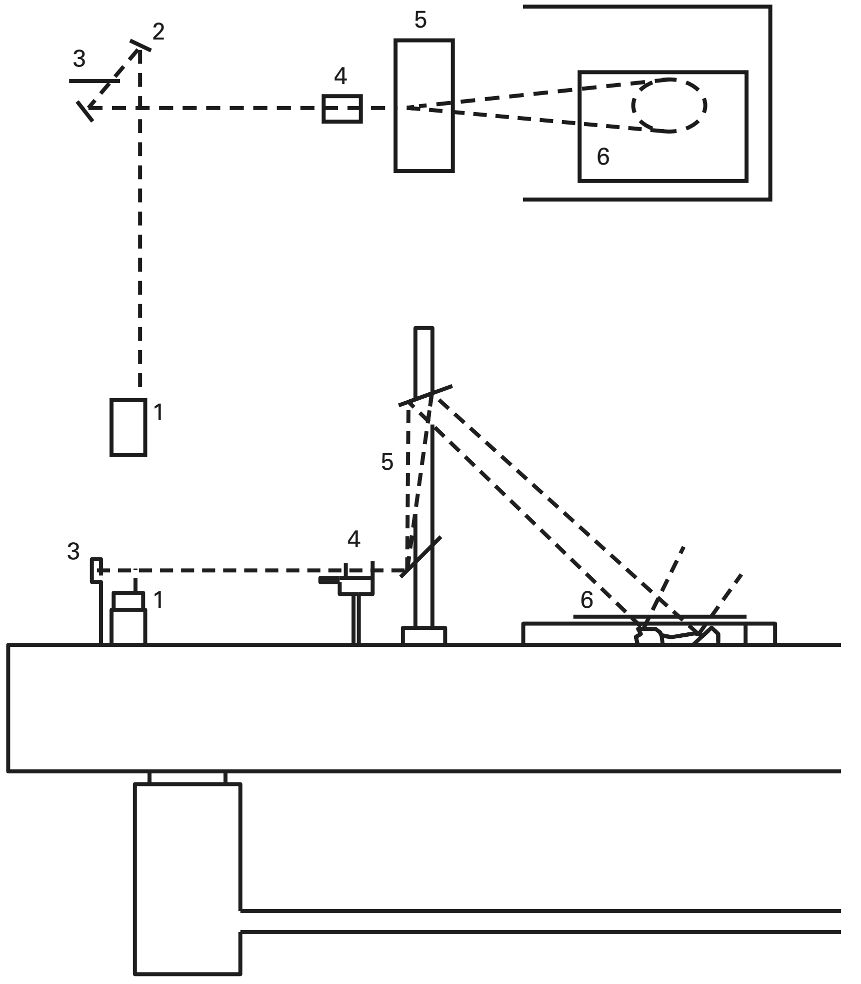


Fig. 43
Setup used for recording
Concrete Interference.

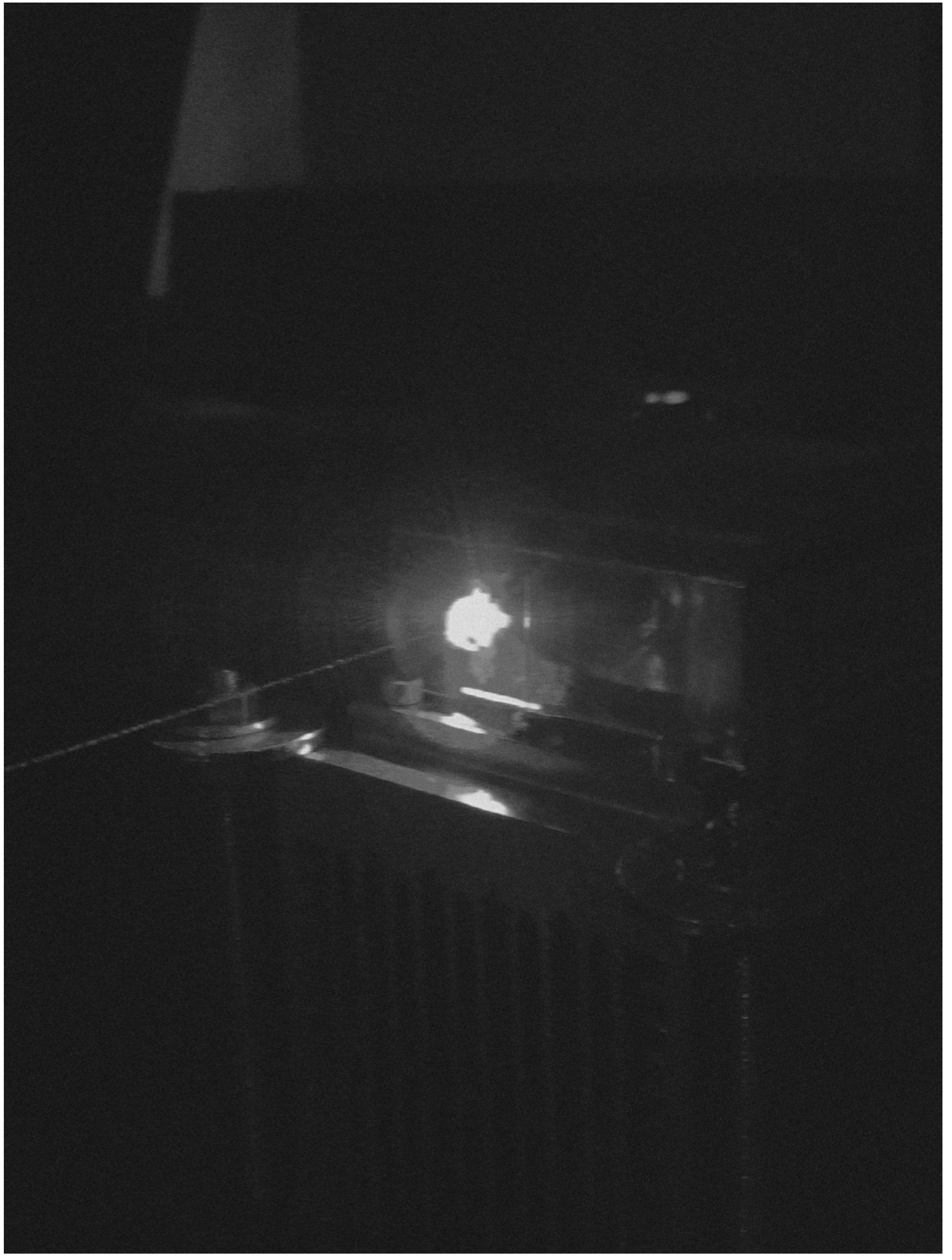
1 Laser
2 Mirror assembly for deflecting the laser beam
3 Optical shutter
4 Spatial filter (microscope objective, pinhole aperture)
5 Mirror assembly for directing the expanded laser beam onto the film plane
6 Film plane (glass plate with laminated holographic film), resting on point holders with interposed concrete objects

Fig. 44
Before each exposure, the beam path was checked, the holographic film was laminated onto the glass plate (in the dark), and the concrete objects were rearranged.

Fig. 45 (right)
Increase of laser power (300 mW).

Fig. 46
Buffer time of approximately three minutes to allow potential vibrations to subside.

Fig. 47
Opening of the shutter and exposure of the film for approximately 12 seconds.



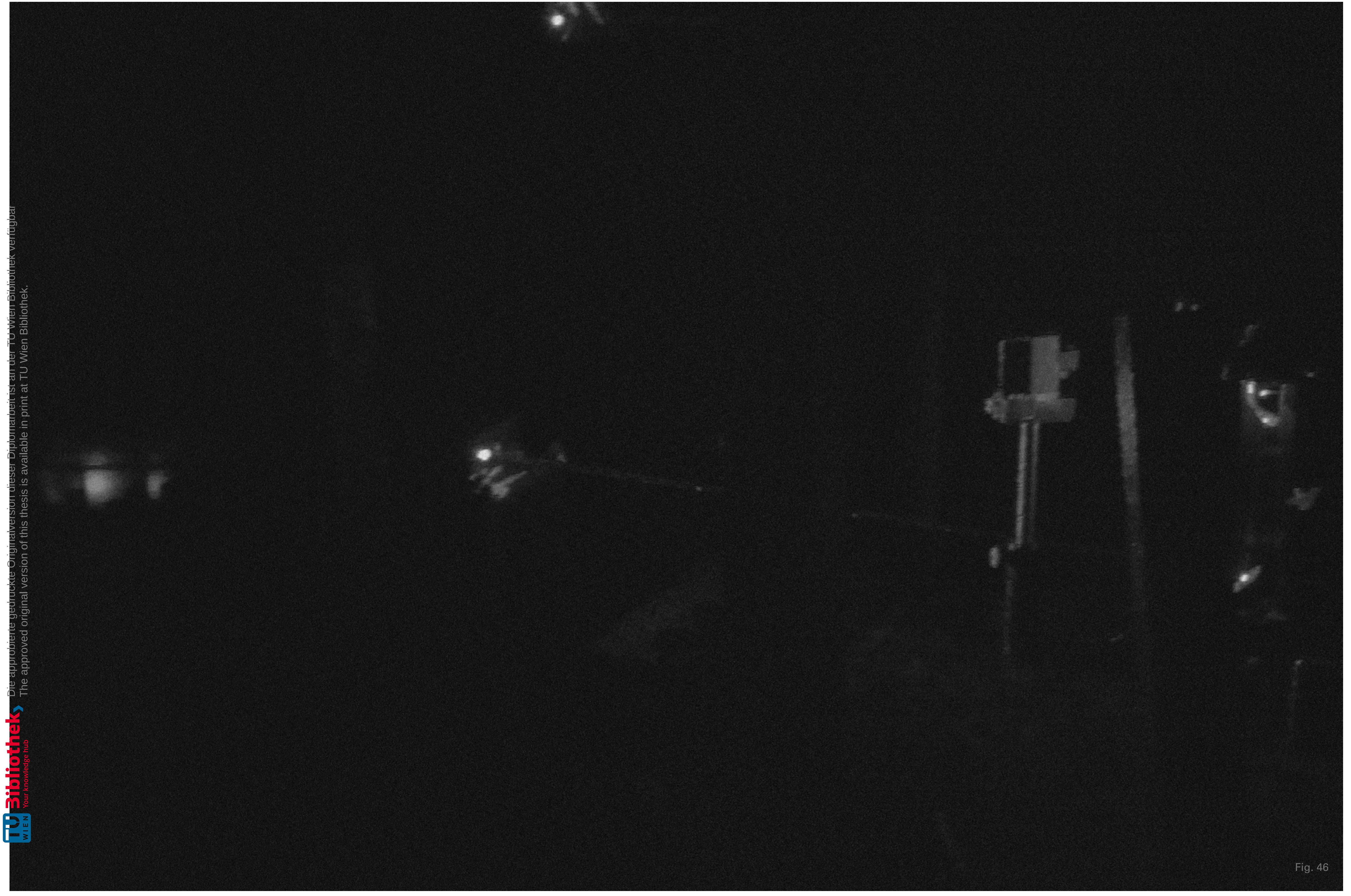


Fig. 46

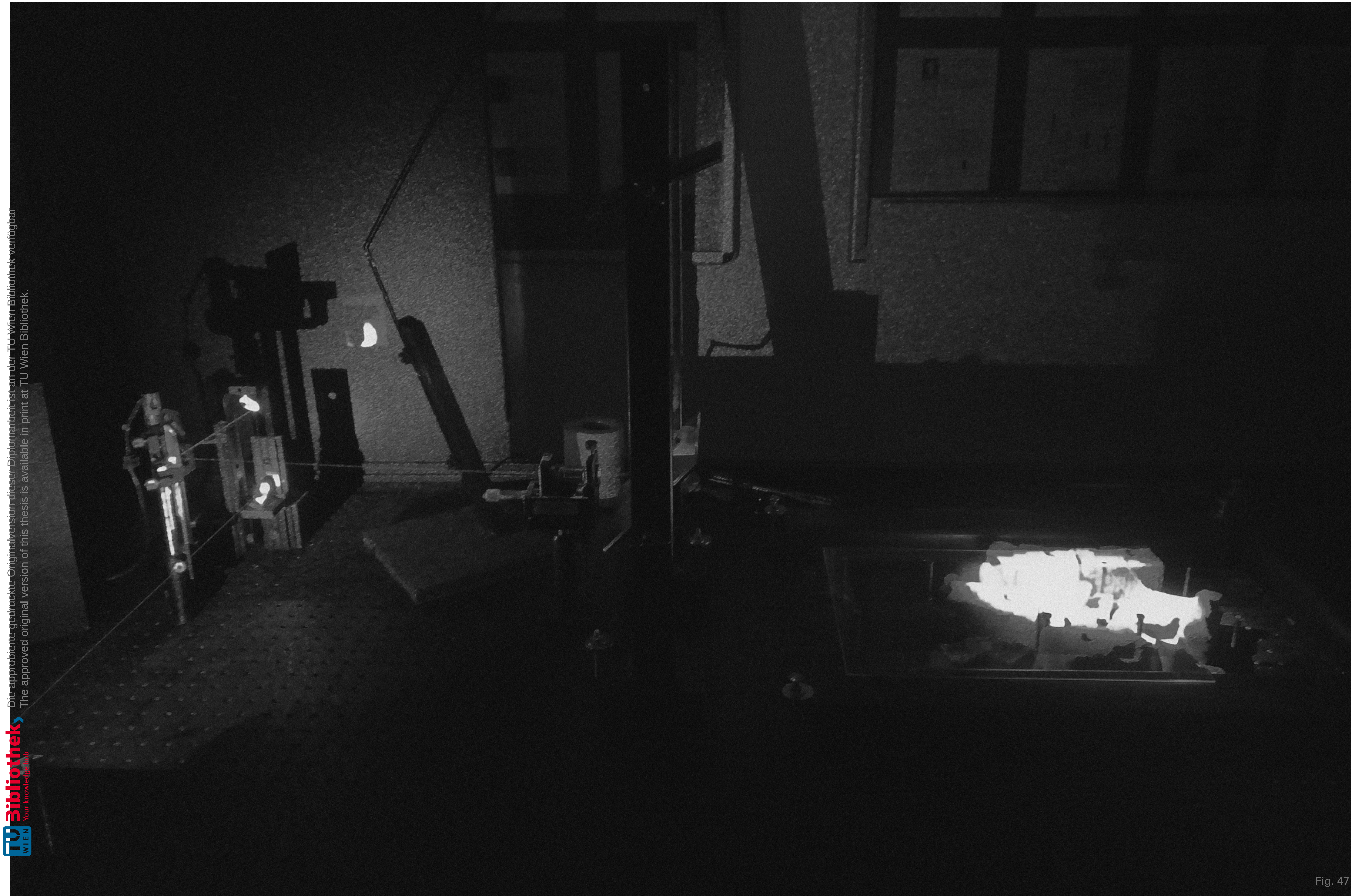


Fig. 47

Fig. 48
Hologram immediately after exposure.

4. Epilogue

This thesis began with a purely technical explanation of holography found in a specialist book on optics, as well as a holographic portrait of the artist Alfons Schilling (1934–2013), which is archived in a box within his artist's estate.
In the subsequent phase of research and experimentation, I was primarily driven by the question of how this medium could find itself in such an ambivalent situation-where, in the strictly confidential commercial sector of embossed holography and security technology, billions are generated, while the artistic and amateur segment appears almost desolate and abandoned, with only a manageable number of truly active participants remaining worldwide. A single answer to the question of how this contradictory situation came about seems difficult to formulate due to the complex interrelations involved. As mentioned in section 2.3, causes may be found either in the inherent properties of the medium per se or in the ways various stakeholders have dealt with it within its historical context. I would argue that many of the observable symptoms can fundamentally be traced back to the considerable barriers posed by the need to provide the technical infrastructure required for recording, as well as the associated financial costs (see 3.1). These factors have significantly impeded the dissemination of holography, particularly within the amateur and artistic sectors. Especially in individualistically oriented societies, collective efforts to overcome these primarily financial obstacles are rarely found. The fact that ‚classical' holography remains relatively rare preserves a certain fascination for the medium, especially in contrast to other media where a kind of perceptual habituation has set in and content tends to outweigh the medium's impact. The sight of ‚real' holograms often appears strange to many people, though not entirely new, since so-called ‚Kinegrams'[41] have become widespread in everyday life. It is almost ironic that, amid all the misconceptions, the form of ‚true' holography that has achieved the greatest public visibility has been assigned its own distinct name.
The title of section 2.3 refers to a quote from an interview that I had read but was unable to find again during the writing of this thesis. The interview was conducted with an early pioneer of holography, who warned against tending toward “too linear predictions” regarding future applications of holography. In his view, instead of drawing comparisons to photography and film, one should seek out applications that truly correspond to the unique potentials of holography.
The inherent property of holography to optically replicate objects in three dimensions is the reason why its capacity for ‚complete' recording and pure documentation of realities is so often emphasised. However, I believe it is above all the possibilities for spatial transformation, rather than mere replication, that lend the medium its true relevance. Holography enables the visual merging of objects and the formulation of new structures that could not exist under real, physical conditions. Additionally, holography creates space on a surface that, unlike virtual images such as those produced by a mirror, is permanent and not contextually dependent. In contrast to classical pictorial spaces, where the space coincides with the image itself, a hologram generates a space that exists outside the image, yet remains inextricably linked to it [32]. The act of capturing three-dimensionality on a two-dimensional surface can even be understood as an intensification of those fictional misassociations in which the ‚hologram' is situated within the same real (action) space as the observer and does not create its own inherent spatial extension.
This thesis was my attempt to avoid “too linear predictions” and to find a somewhat more unconventional approach

to holography. I believe it is only appropriate to focus primarily on a critical engagement with the medium itself, rather than on ambitions for its establishment and expansion. Holography may never fully achieve the latter, but will instead likely remain more or less relevant in different phases. For me, it was above all the sites of activity and the people involved-including completely outdated websites and other oddities-that held immense documentary value. In particular, the Holographic Studios in NYC represented a kind of spatial narrative in this context, with an almost relic-like yet highly authentic character. Attached is a recording from a "LaserTour."

„*...There is nothing like oh this like Albert Einstein. Noo noo, you know my pet dog could figure this out. Wuff Wuff! But it is not hard, and I mean like that´s the thing I try to impress on people. It´t astounding but it´s also beautiful because it´s so simple. There is no like "Well but (...?)" No! There´s no such thing and it´s making these words up. It´s simple. It´s beautiful because it´s elegant and it´s simple. So if you start to think something is complicated, just ask me and I guarantee you...really stupid simple. I can do this. Living proof! If I can do this, any idiot can do this. Trust me! And I teach this stuff.*"

Jason Sapan, alias ‚Dr. Laser',
14 August 2023
240 East 26th Street; New York City

The preceding photographs were taken in August 2023 at the Holographic Studios, primarily in the ‚Big Lab' and the Darkroom, during the recording of a reflection hologram and the duplication of a multiplex hologram. The latter is a recording of Andy Warhol, who, in 1977, had a hologram of himself made while reading a newspaper at the Holographic Studios [33].
Concrete Interference was produced in the holography laboratory of the Höhere Graphische Bundes-Lehr- und Versuchsanstalt (1140, Vienna) during the period of May to June 2024. In this context, I would like to thank those who provided the technical infrastructure, as well as all others who have helped make this work possible and indirectly shaped it—especially Christoph for providing excellent support.

Dedicated to my grandmother.

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List of figures

The cover and back cover photos, as well as all photographs on the following pages, were taken by the author in the course of the work *Concrete Interference* in 2025.

It should be noted that the content of this thesis was written independently by the author in German, without the use of any external aids. The subsequent translation into English and the proofreading were also carried out by the author, with AI-based editing tools only being used for orthographic, grammatical, and stylistic review.