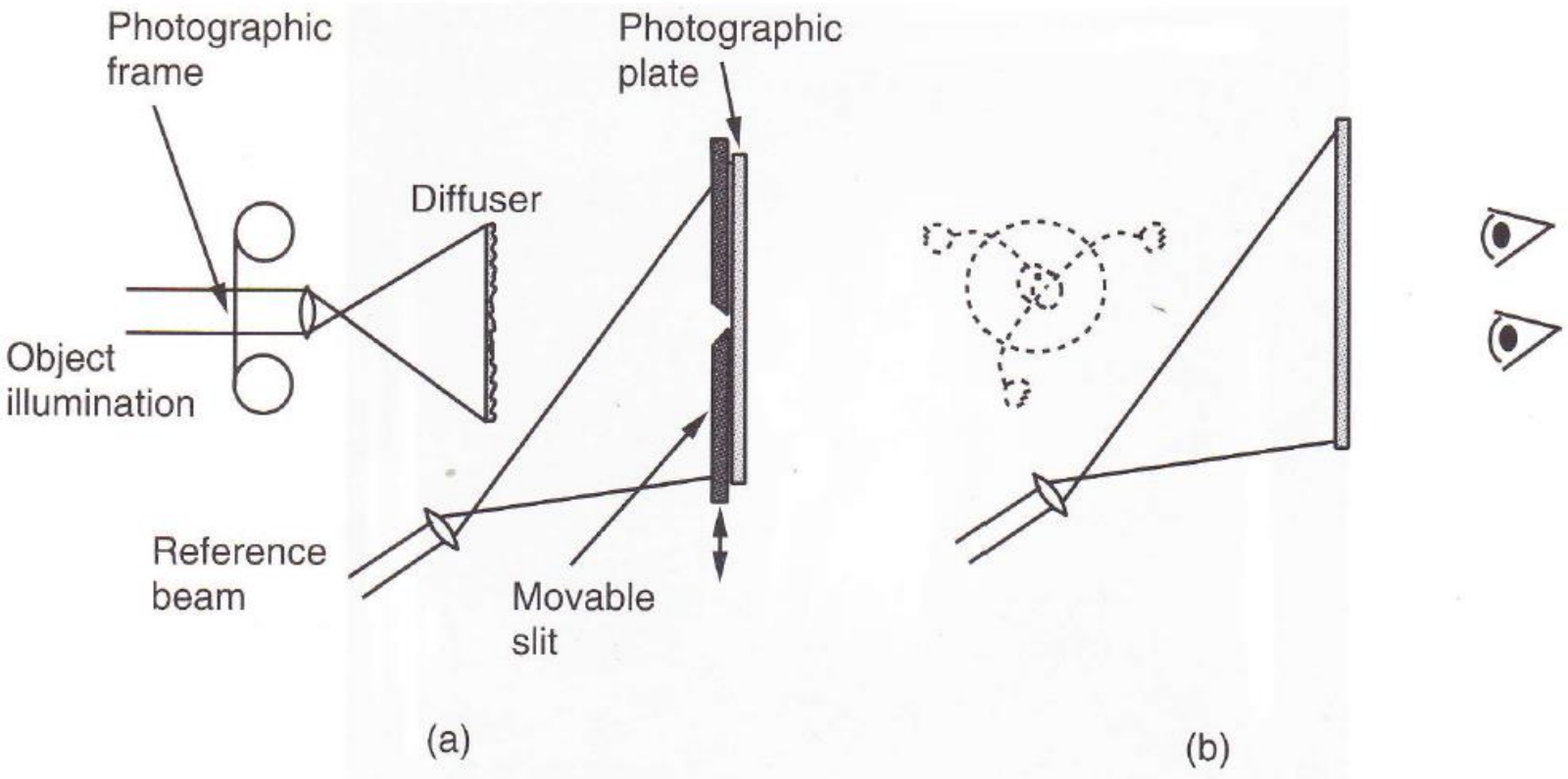
PH 201

OPTICS & LASERS

Lecture_Holography_2

Holographic Stereograms

- To create the illusion of 3D through stereo effect.
- It allows observer to see different images, taken from different perspectives, in each eye, thereby creating stereo effect.



Recording a holographic stereogram (top view). (a) Recording the holograms, & (b) viewing the image.

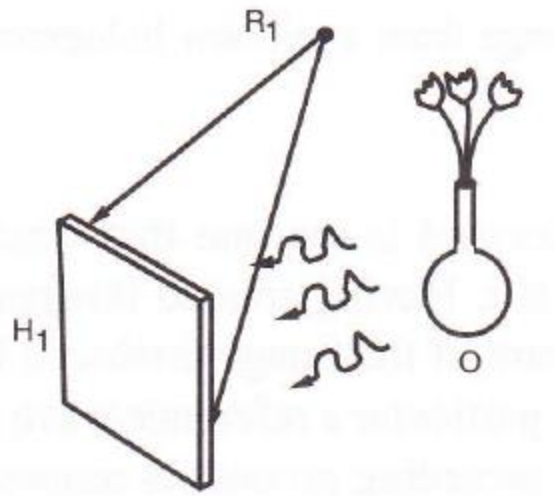
Holographic Stereograms

- A series of black & white photographs are taken of the subject from a sequence of horizontal positions, each with its own unique perspective.
- Each frame of sequence is then projected with light from a laser onto a translucent screen.
- A reference beam is introduced & a hologram is recorded through a movable slit.
- As photographic frame is advanced, slit is moved, with the result that a multitude of holograms are recorded side-by-side, each hologram capable of reconstructing an image of original object taken from a different horizontal perspective.
- If resulting hologram is illuminated in its entirety by a duplicate of reference wave, the observer will look through a different holographic stripe with each eye, & therefore each eye will see the subject from a different perspective, creating a 3D image through stereo effect.

Rainbow Holograms

[S. Benton, 1969]

- **Ability to view holographic images in white light. [Display applications]**
- **It is a two-step process. An initial hologram is made, & then a 2nd hologram is made using 1st hologram as part of process.**
- **1st step is recording a hologram (H_1) of 3D scene in usual way.**



- **1st hologram H_1 is illuminated with anti-reference wave (duplicate reference wave with direction of travel reversed).**

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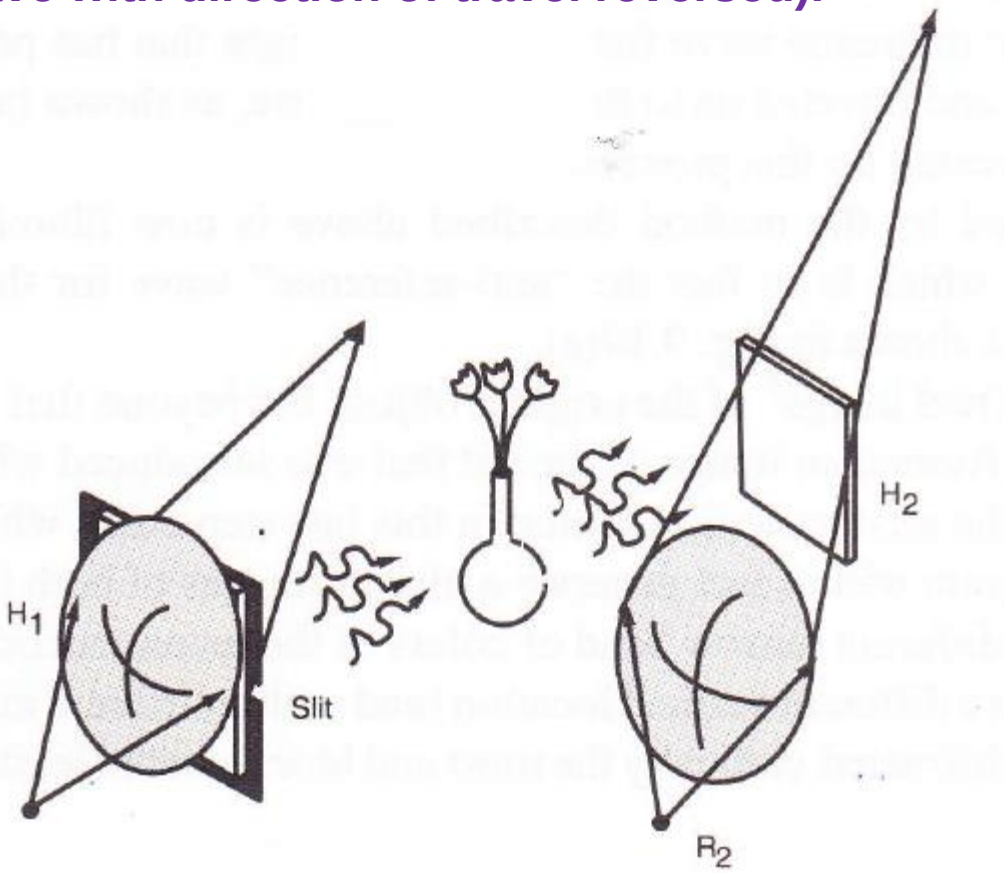
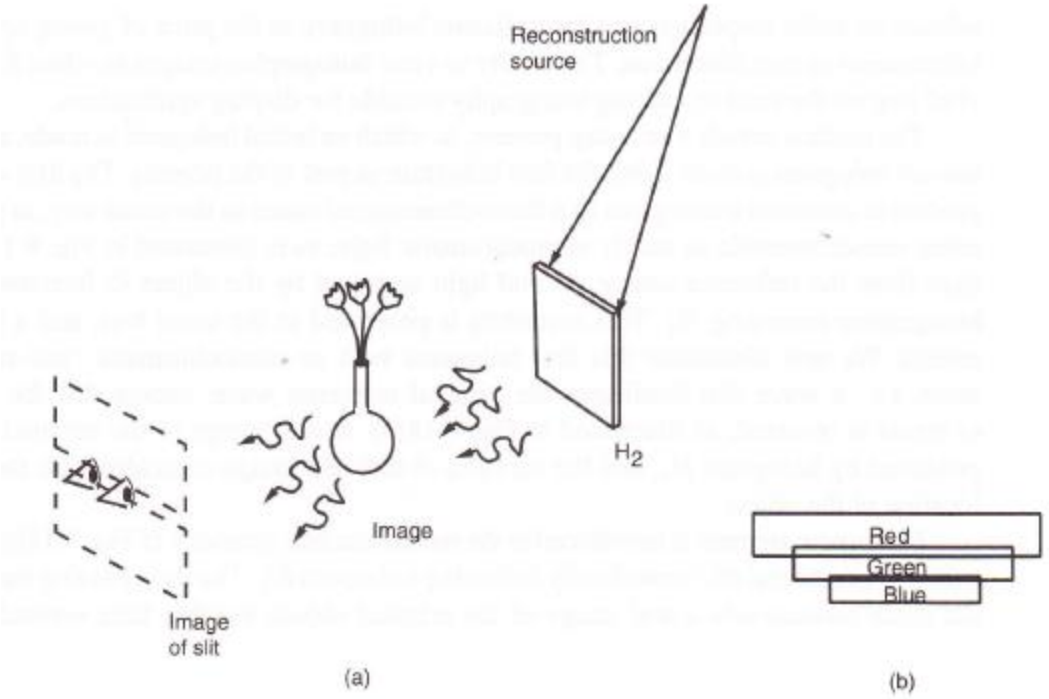


- A real image of original object is produced by hologram H_1 & location of real image coincides with original location of object.
- Now a new element is introduced in reconstruction geometry, a narrow horizontal slit immediately following hologram H_1.

- **Light passing through this slit again reconstructs a real image of original object, but this time vertical parallax is eliminated; the image that is formed is one that would have been seen from particular vertical location of slit.**
- **Having created this real image, a 2nd hologram H_2 is recorded, this time a hologram of the image produced by 1st hologram, with a new reference wave (converging spherical wave) being used.**



Reconstruction geometry **Slit sizes at different wavelengths**

Embossed Holograms

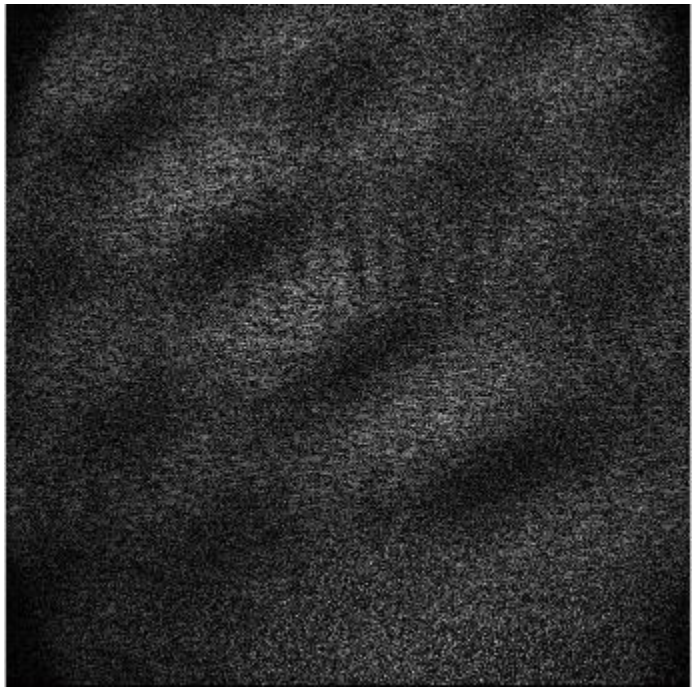
- Embossing is a highly refined & advanced technique for replicating CDs & DVDs, which have structures of same order of size as an optical wavelength.
- Embossing is applied for replication of holograms with substantial cost savings as compared with optical methods of duplication.
- Security cards, credit cards, magazines, books, monetary bills,…….
- 1st step is to record (powerful argon-ion laser is used) a hologram of subject of interest on photoresist.
- Photoresist is then developed, leading to a relief pattern that constitutes photoresist master hologram.
- A metal master hologram is now made from photoresist hologram by means of electroforming process.

Embossed Holograms

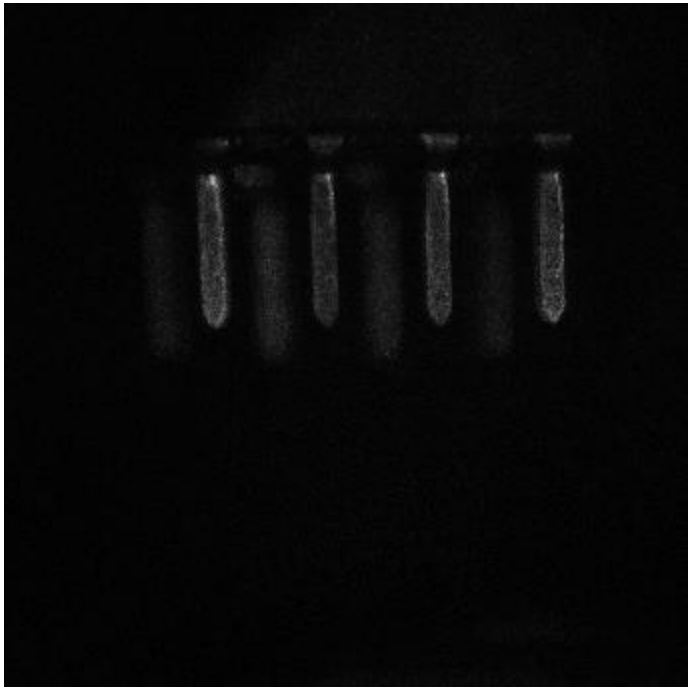
- A silver spray is applied to photoresist surface, making it conducting.
- Master is then immersed in a plating tank, together with a bar of pure nickel, & current is passed through tank with the result that a thin layer of nickel is plated on top of photoresist master.
- The layer of nickel, which forms metal master, is then separated from photoresist. This makes possible to use metal master in a 2^{nd} electroforming process, in which a 2^{nd} generation metal submaster can be made from original.
- The process can be repeated to make many metal submasters, which will serve as stampers in reproduction process.
- With submasters, embossing process (flat-bed embossing, roll embossing, & hot embossing) is initiated.
- In all cases, metal submaster is heated to an elevated temp, & used to stamp hologram patter, usually into a polyester material. Often embossed pattern is metallized to create a reflection hologram.

Recording Materials

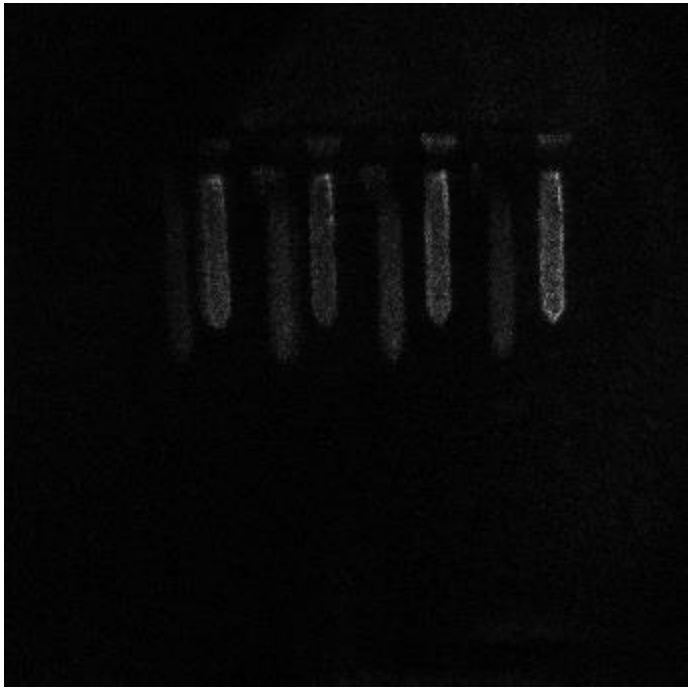
- **Photographic emulsions** (Reusable: NO, Processing: Wet)
- **Dichromated gelatin** (Reusable: NO, Processing: Wet)
- **Photoresists** (Reusable: NO, Processing: Wet)
- **Photothermoplastics** (Reusable: **YES,** Processing: Charge & Heat)
- **Photopolymers** (Reusable: NO, Processing: Post exposure)
- **Photorefractives** (Reusable: **YES,** Processing: None)



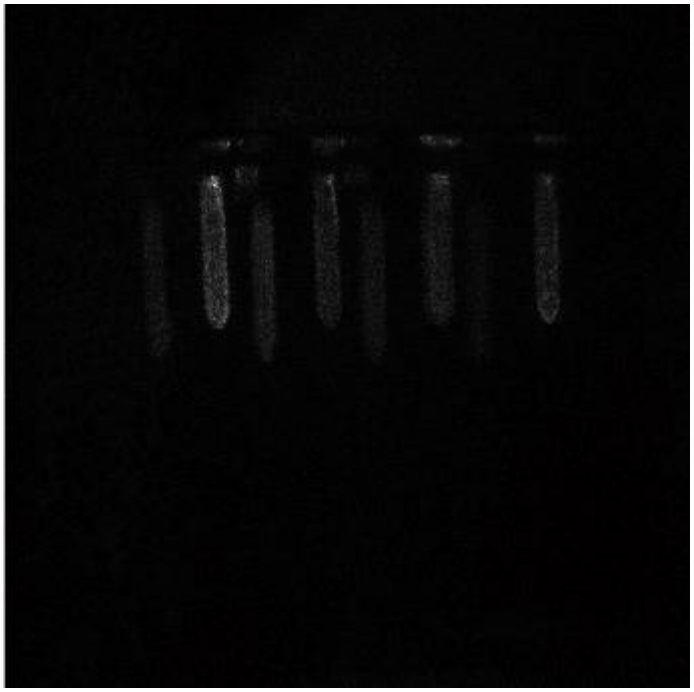
Phase-shift Fresnel hologram recorded at *d* = 179 mm



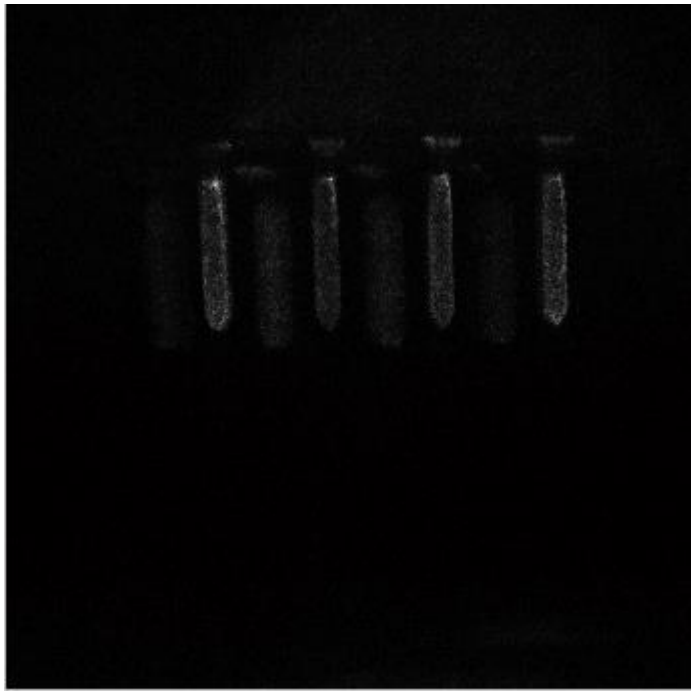
Reconstruction with Fresnel parameters



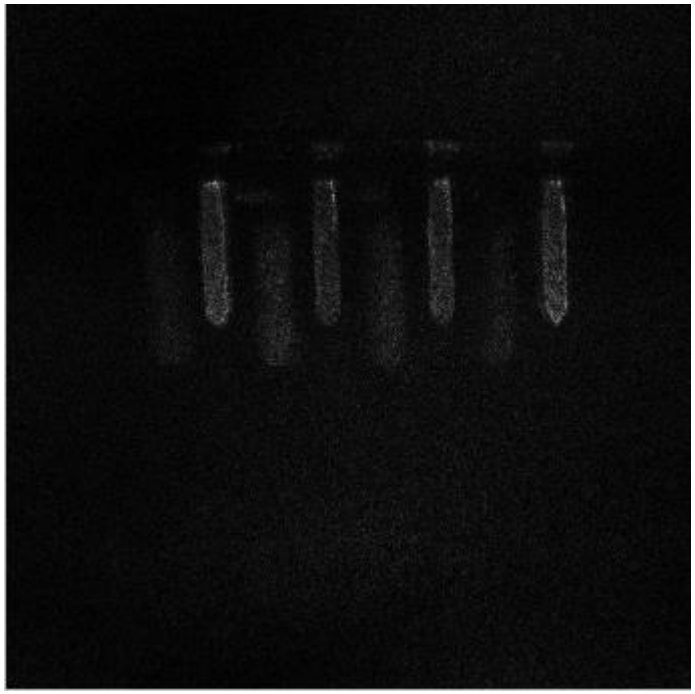
Reconstruction with cropped 25% (from right) watermarked hologram



Reconstruction with cropped 25% (from left) watermarked hologram



Reconstruction with cropped 25% (from top) watermarked hologram

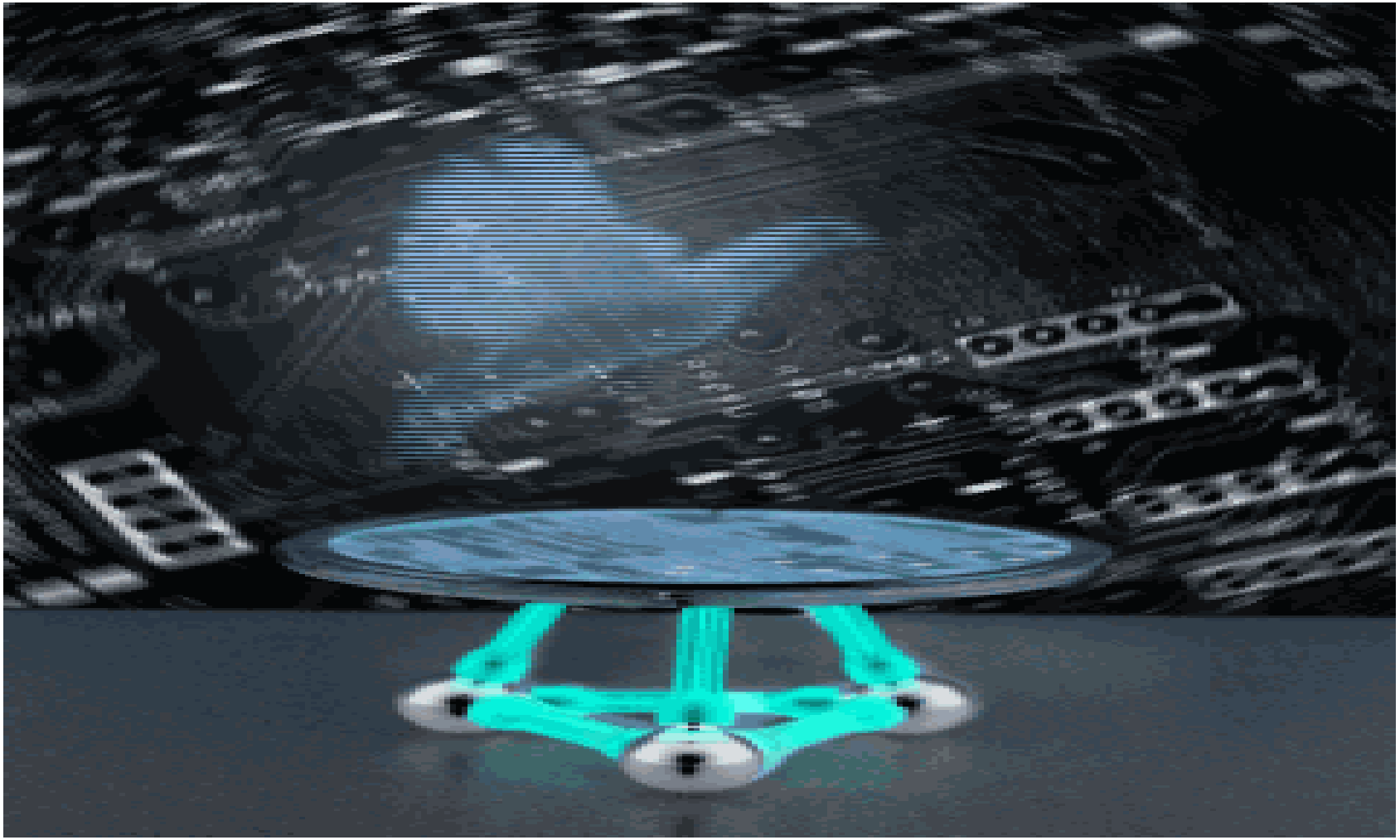


Reconstruction with cropped 25% (from bottom) watermarked hologram

Applications of Holography

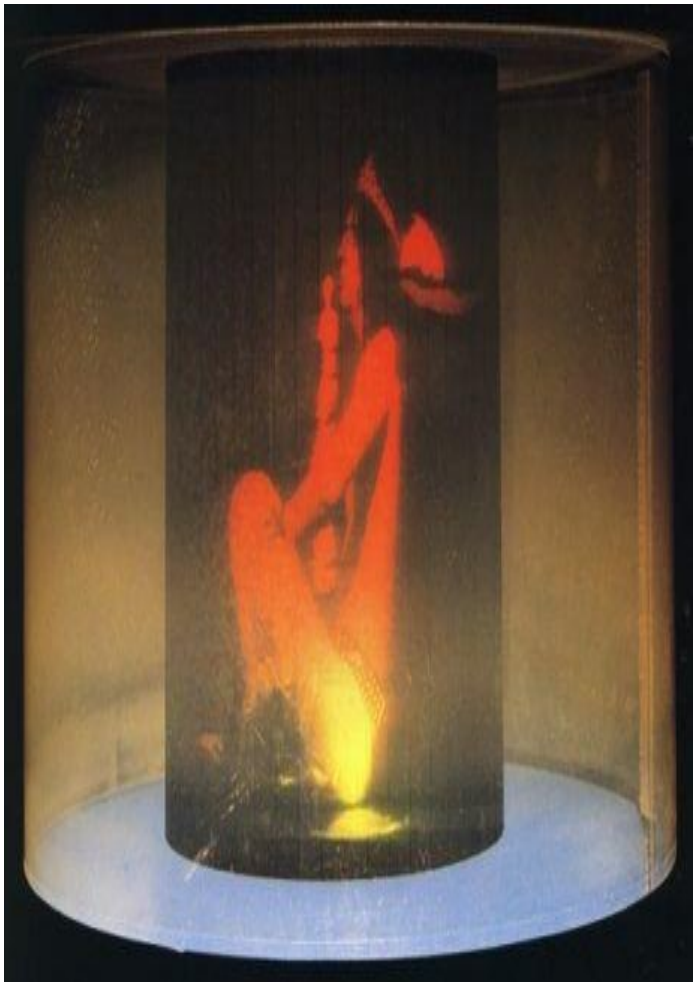
- **Entertainment** (Science fiction movies, trade show booths, museum display)
- **Teaching & Training**
- **Virtual Communication**
- **Security** (Identity card, Passport, Sticker or tag, etc.)
- **Simulation & Planning**
- **Military & Space Application**
- **Signal Processing**

Science fiction movies



Trade-show booths

Museum Display

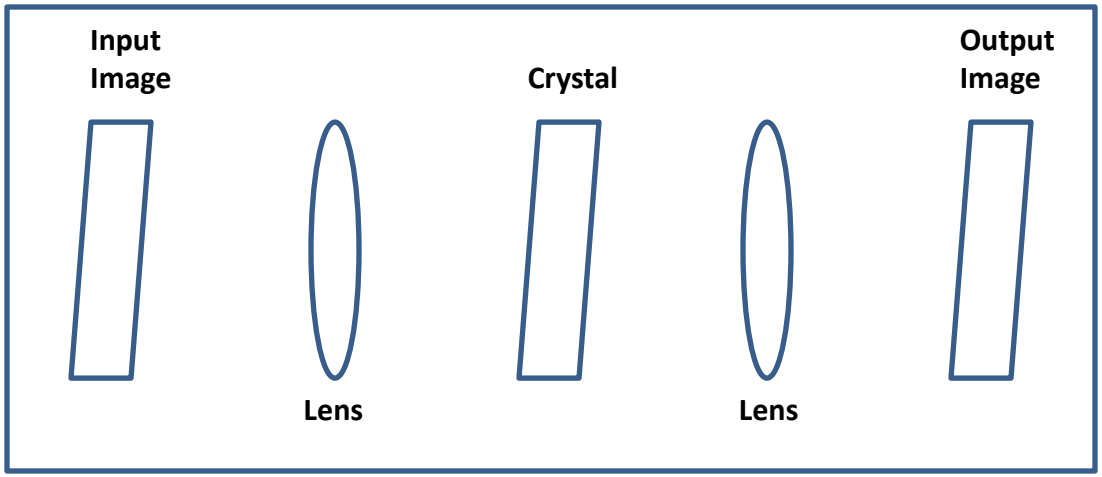


Optical Signal Processing

- Optical techniques are in many cases well suited to parallel processing of information.
- 1-D & 2-D arrays of data may be easily constructed by spatially modulating the intensity, phase, or polarization of a light beam.
- Complex interconnections between many sources & detectors can be readily set up in three-dimensions. Light beams are able to pass unaffected through each other.
- In order for beams of light to interact, they must meet in a medium with a non-linear response.

Image Amplification

- Non-local nature of the photorefractive response leads to optical amplification.
- Image of a test chart has been amplified 10 times by passage through a crystal of $LiNbO_3$.
- Image amplification is carried out in either the image or the Fourier transform domains.



Beam Fanning: In addition to amplifying a signal beam, PR effect also amplifies any light scattered within the crystal resulting poor SNR.

Image Amplification by Two-Wave Mixing

[J. H. Hong, A. E. Choiu, and P. Yeh, Appl. Opt. 29 (1990) 3026-3029]

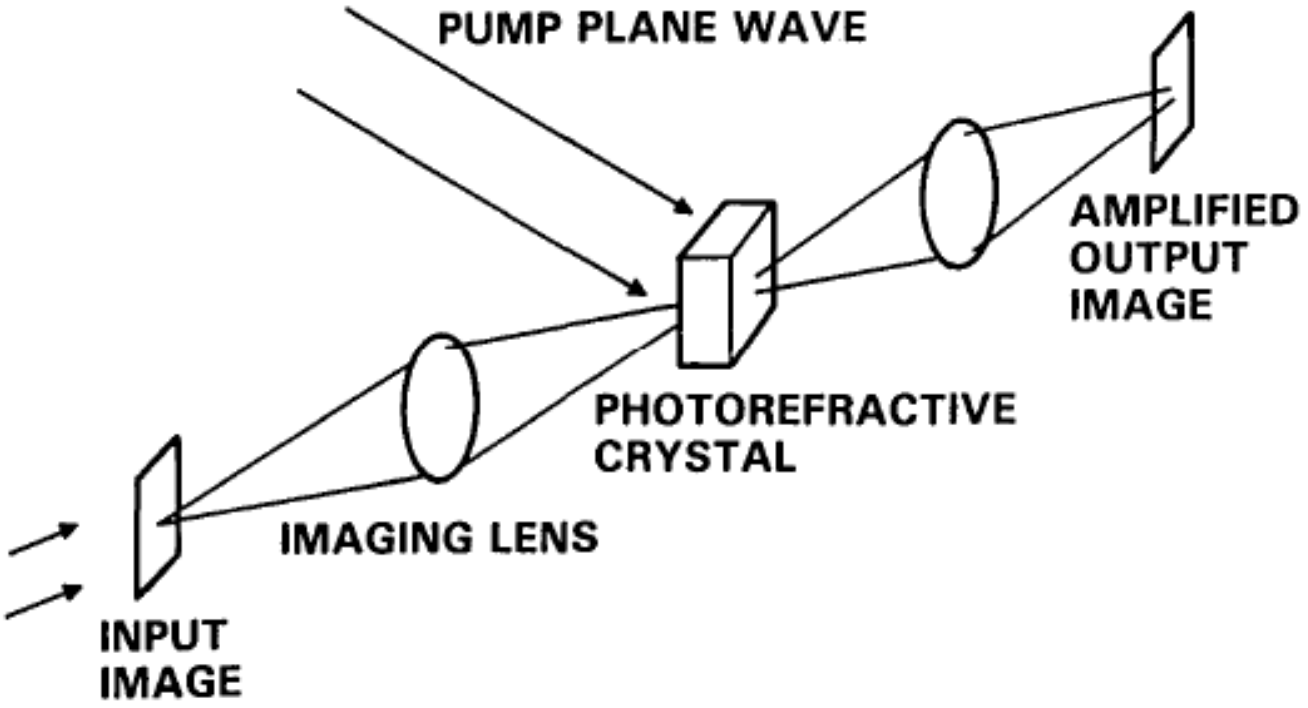


Fig. 1. Typical image amplification experiment using two-wave mixing in photorefractive crystals.

Phenomenon of energy transfer in two-wave mixing in non-linear optical media for coherent amplification of images.

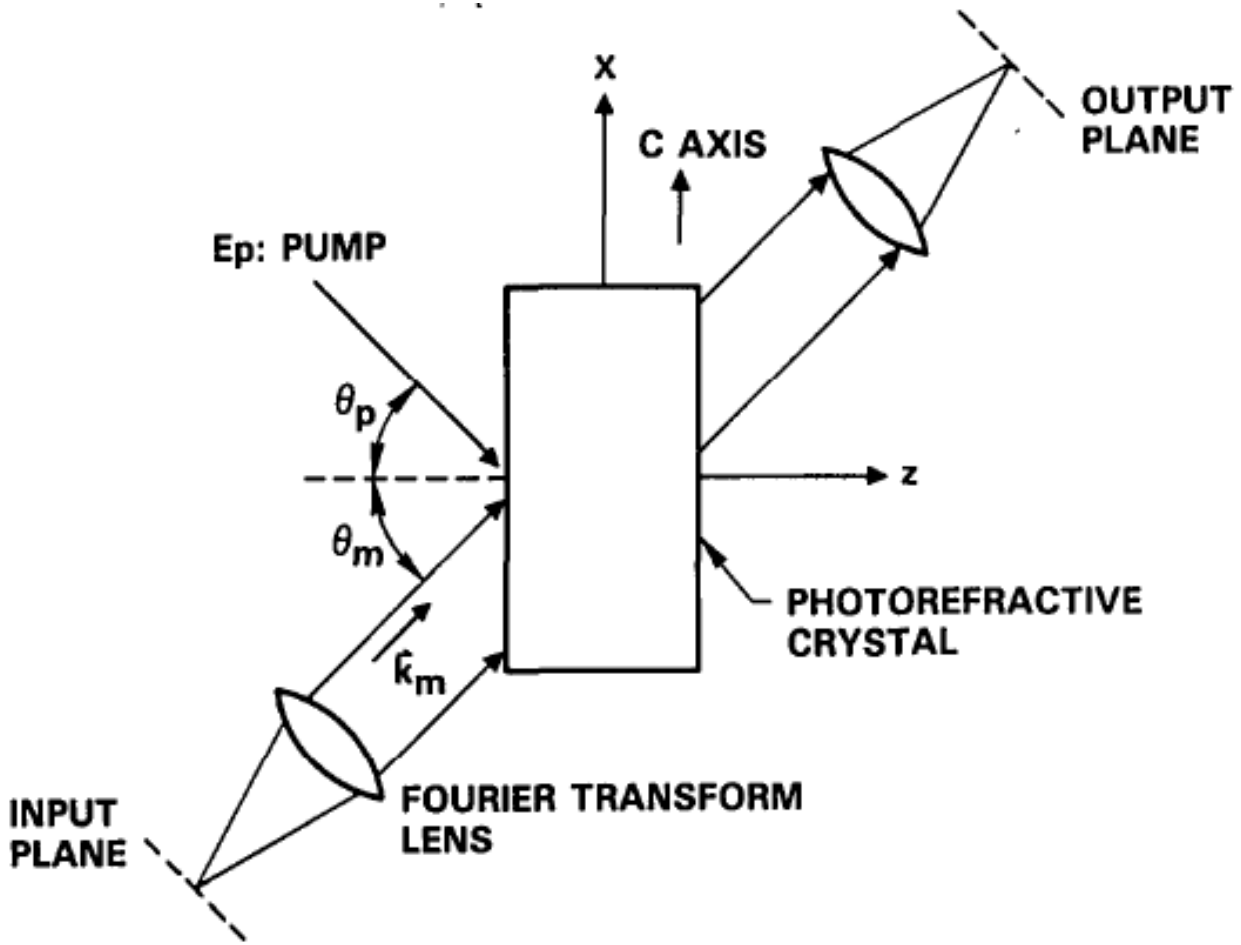
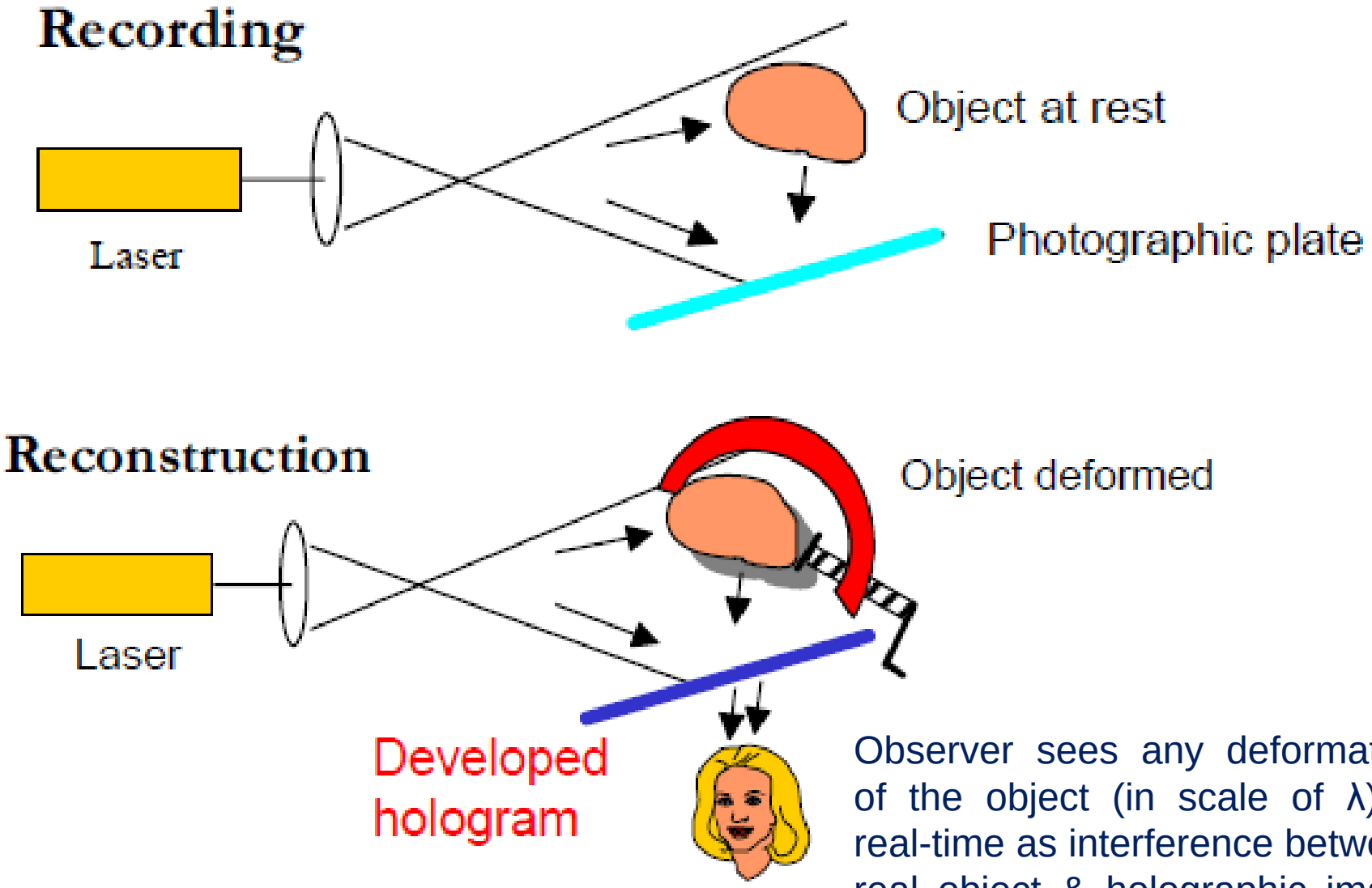


Fig. 2. Two-wave mixing with the crystal at the Fourier plane of the input image. The pump E_p is a plane wave and the image effectively consists of a set of point sources.

Holographic Interferometry

- Movement in the face has been contoured using HI.
- Fringe spacing represents a movement of 30 μm & was created by two pulses from a ruby laser.

Real-Time Holographic Interferometry



Observer sees any deformation of the object (in scale of λ) in real-time as interference between real object & holographic image of object at rest.

Observer sees any deformation of the object (in scale of λ) in real-time as interference between real object & holographic image of object at rest.

Observations:

- Film has to be replaced exactly at the original location.
- Film developed at site (not moved).
- Emulsion pre-swelled before exposure.

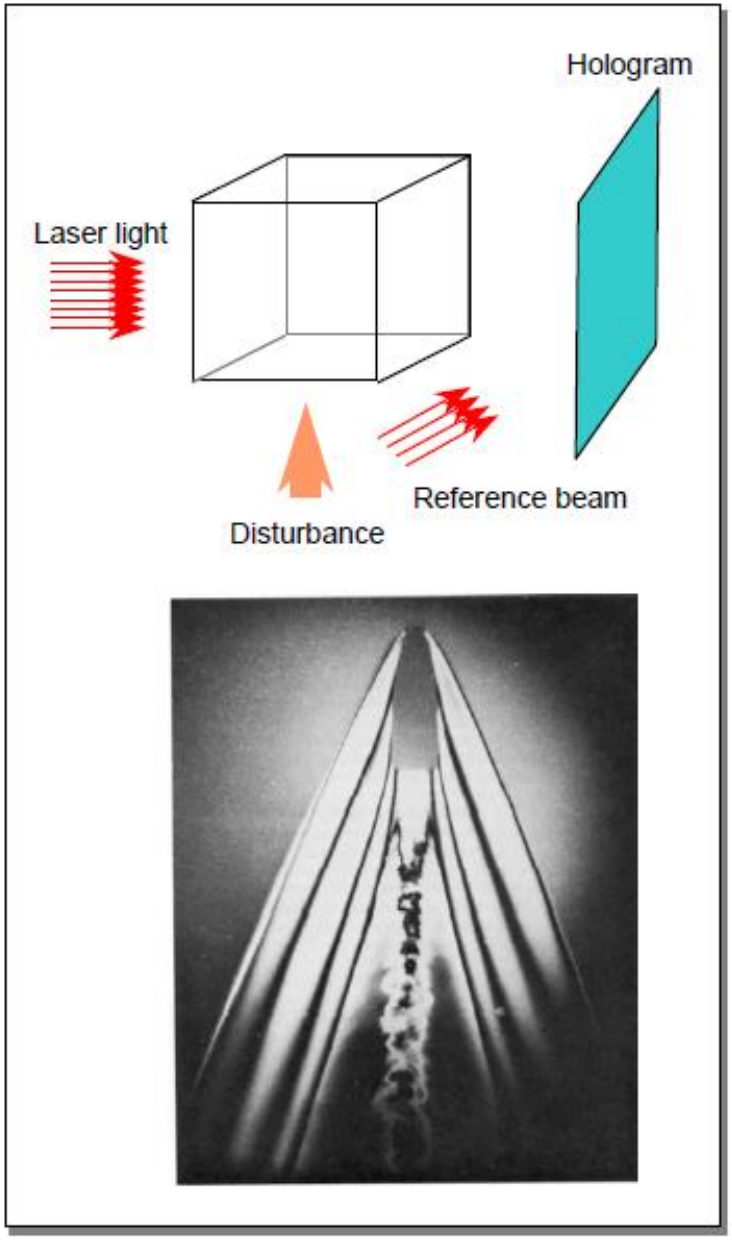
Double-Exposure Holographic Interferometry

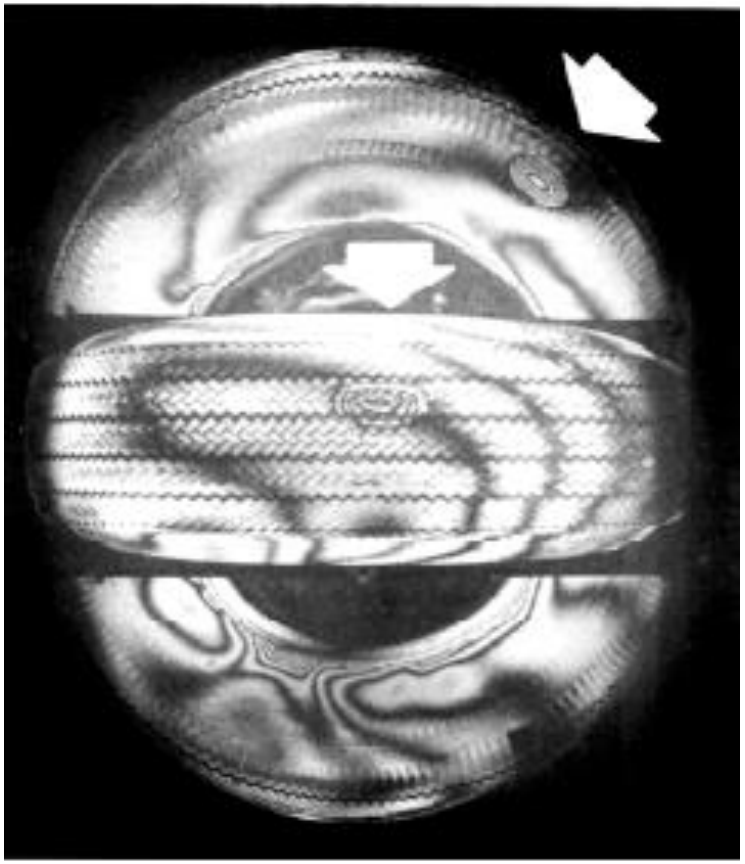
- Two successive holograms of the object recorded in the same medium at different instants of time.
  - 1st exposure: object is in some reference state.
  - 2nd exposure: object is moved or deformed.

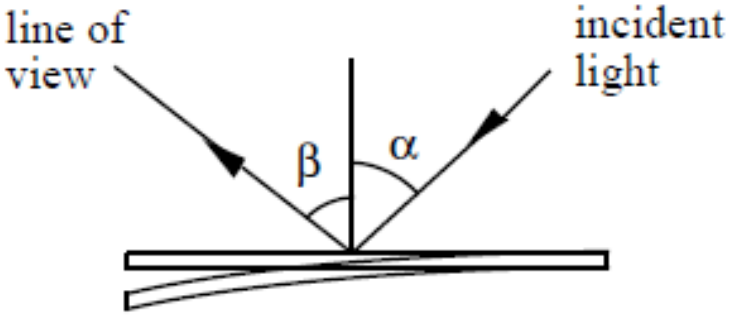
  During reconstruction, the two images interfere as though there were two copies of the object present.

- If conditions at the recordings are different ⟶ interference between the reconstructed holographic images reveals the deformations.

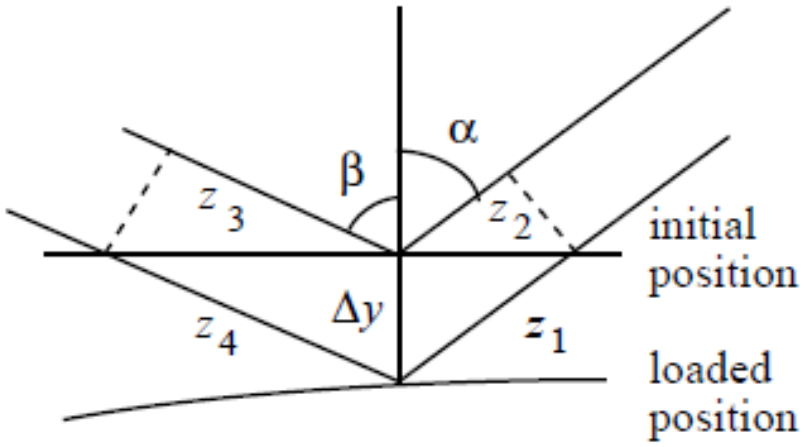
- simple to carry out
- avoids problem of realignment of the hologram
- distortion due to emulsion shrinkage minimized
- double-pulse laser (e.g., ruby laser)
- compares only two time instances


Hologram
Laser light
Reference beam
Disturbance



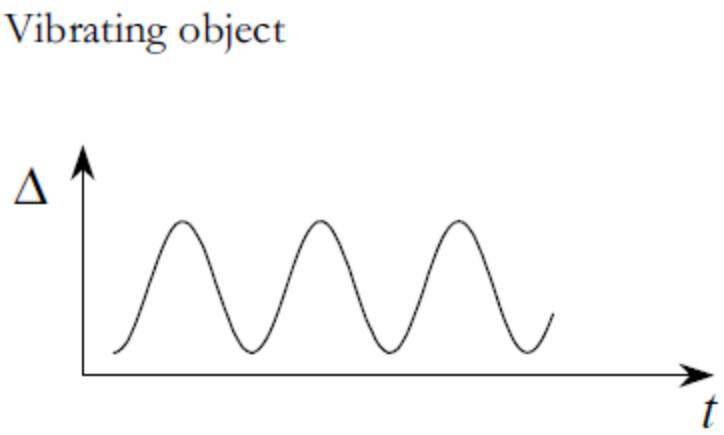


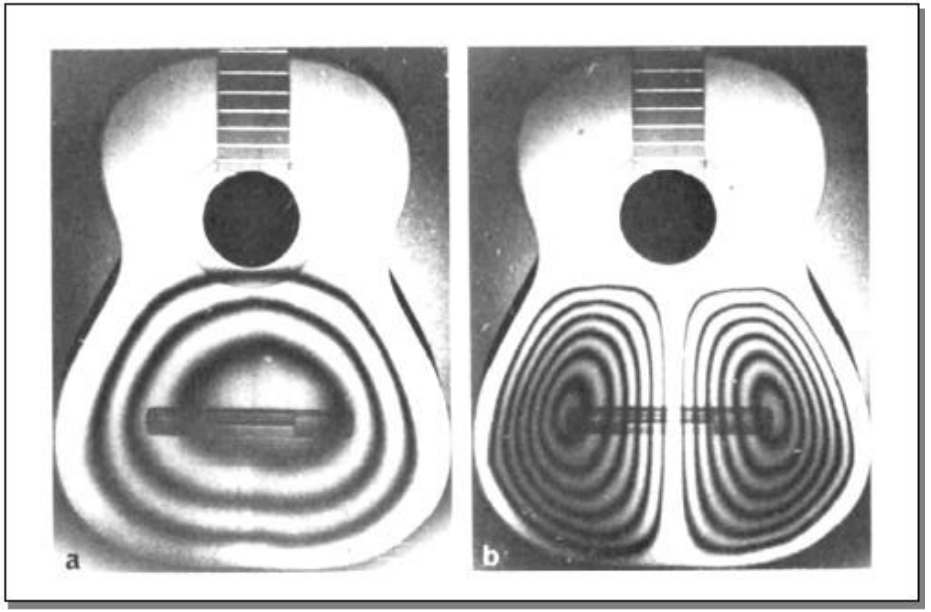
Geometry used during reconstruction of the double-exposure hologram.



Enlarged view of a portion of the bar, showing the displacement in more detail.

Time-Average Holographic Interferometry





- **Hologram is recorded of the vibrating surface with an exposure time which is long compared to the period of vibration.**
- **Exposure over several time periods**
- **Reconstruction: interference of the extremum positions**
- **Simple to carry out.**

Associative Memories

Illuminating the hologram with one of the stored images reconstructs the reference beam used to store it.

The angle reveals the identity of the input image (pattern recognition)

Other Applications

Microscopy

- Electron & X-ray holography
- High-resolution volume imagery

Holographic Optical Elements

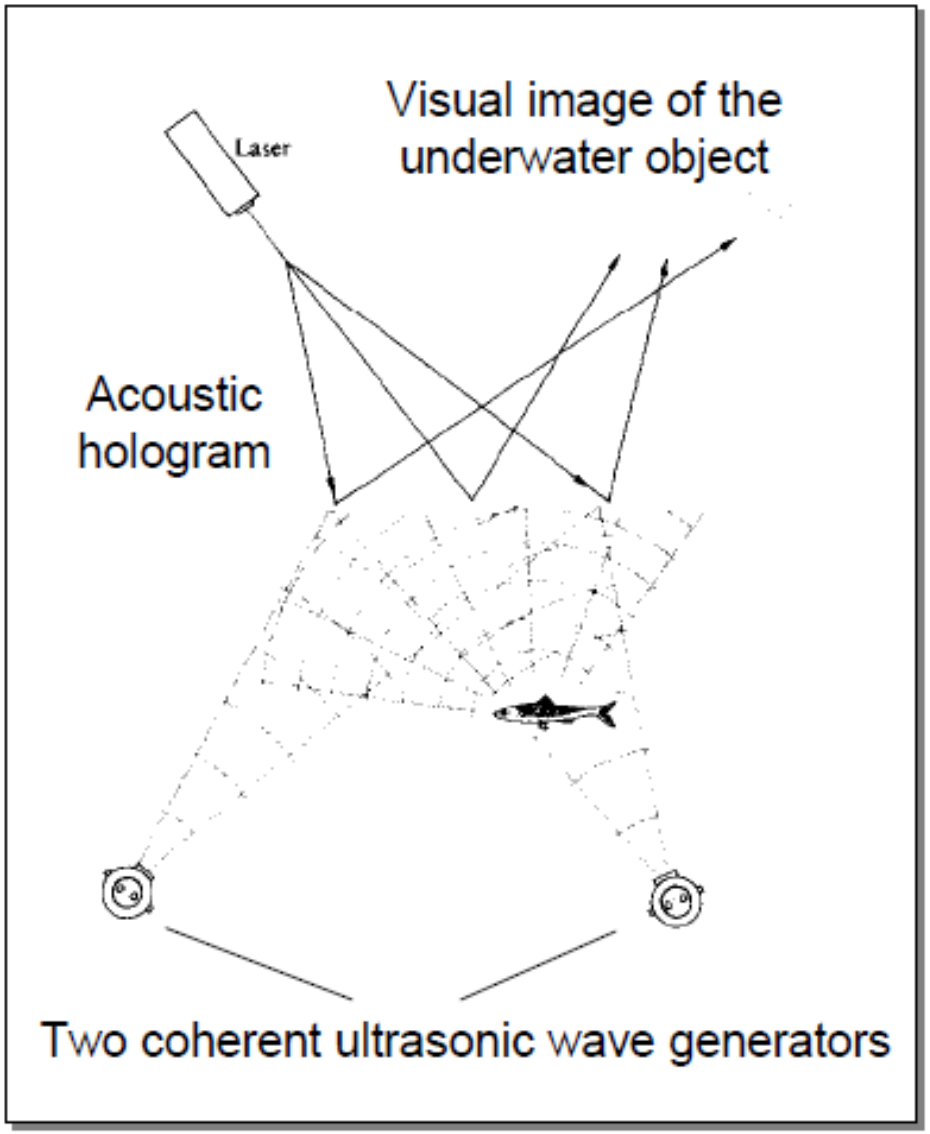
- Optical scanning, head-up displays, helmet-mounted displays, …..

Security Applications

- Credit cards, bank notes, …..

Advertising, art

Accoustic Holography



Holographic Lithography

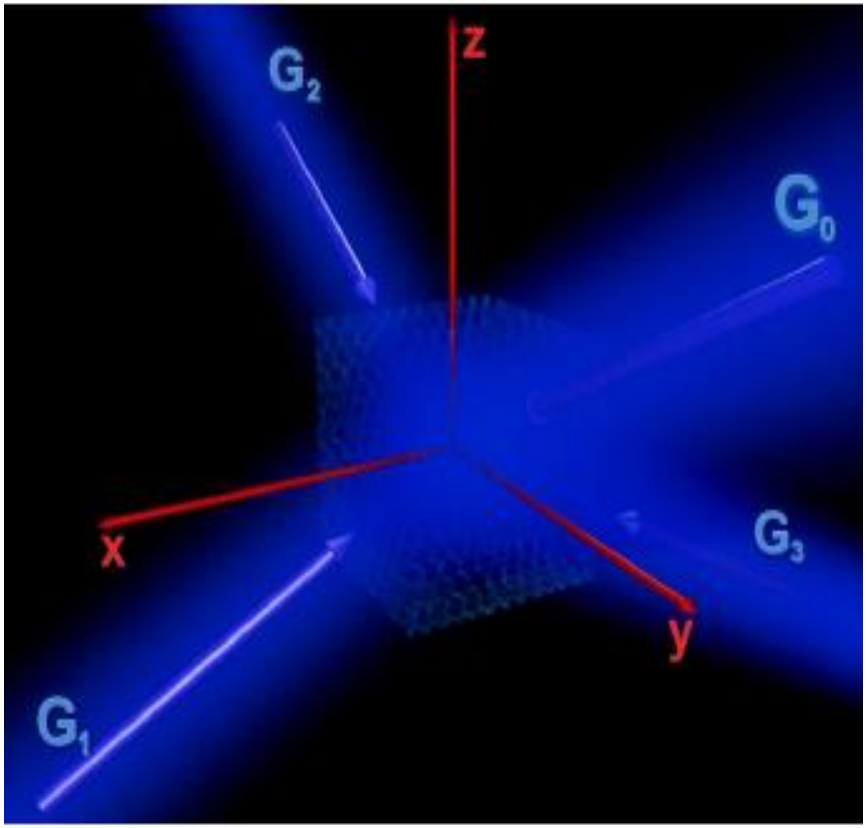
Fabrication of Photonic Crystals by Holographic Lithography (HL)

HL is the transformation of interference of two or more laser beams on the photoresist (or photopolymer)

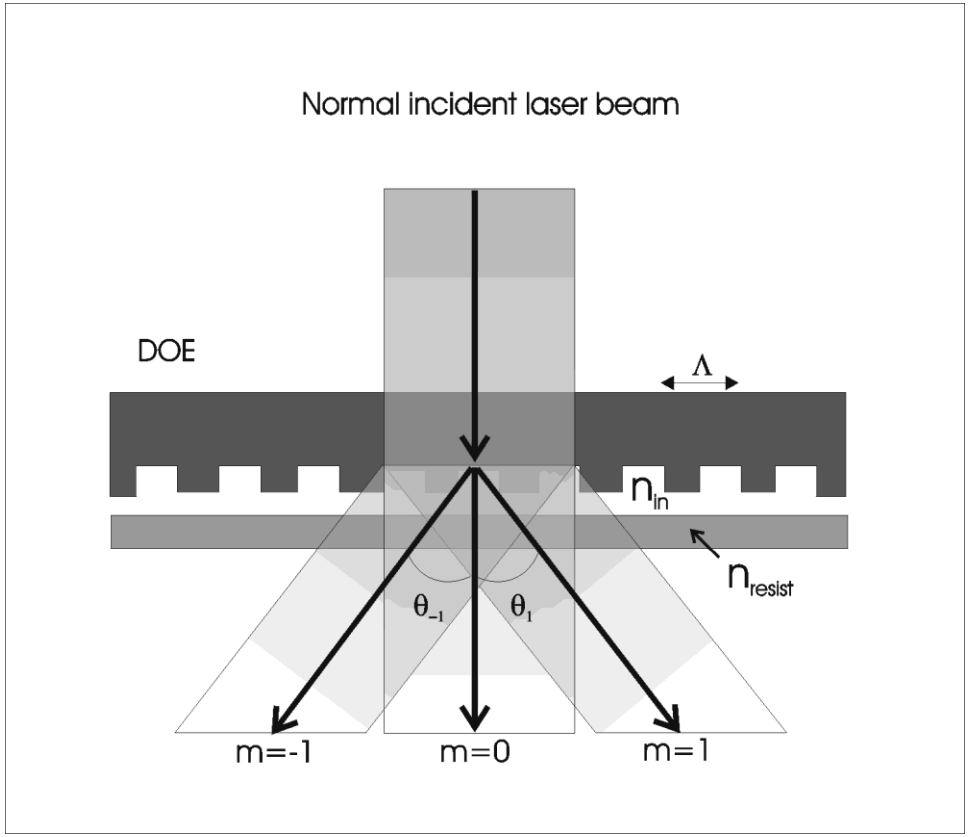
Different approaches are

- **Single Exposure**
  - DOE or HOE geometry
  - Multiple beam geometry
- **Multiple Exposure**

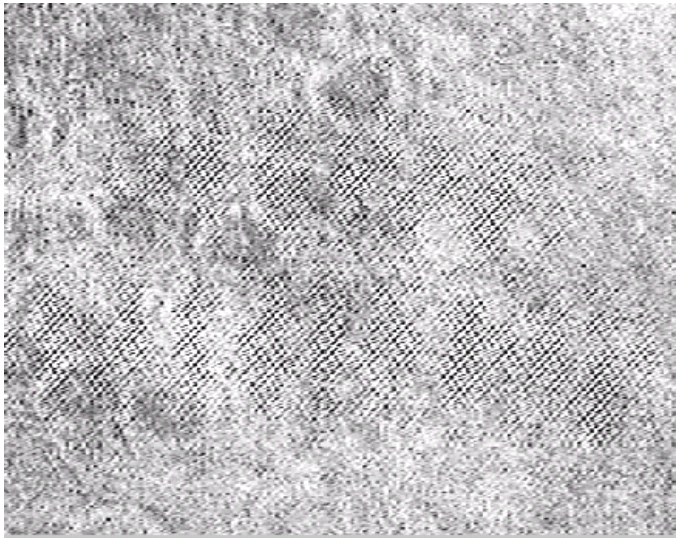
Multi-Beam HL



DOE based HL



Ref.: Campbel, Nature 404 (2000) 53.



THANK
YOU