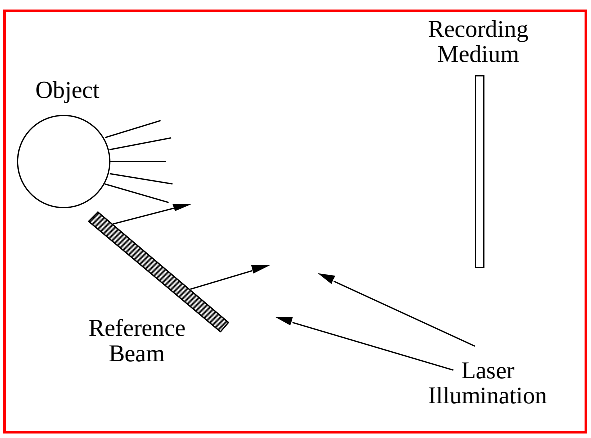
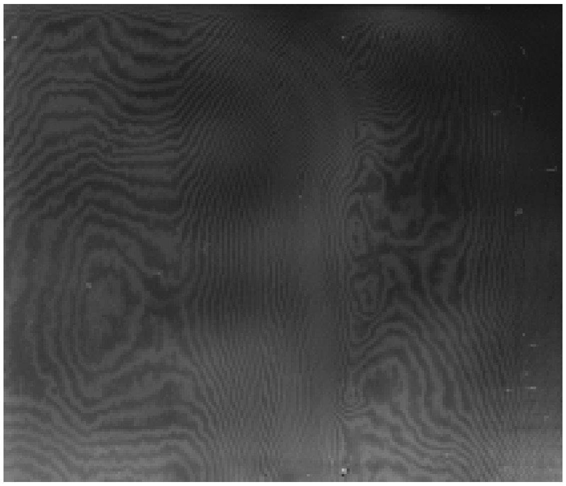
Part 7
Holography

- Basic Holographic Technique
- Light Sources
- Recording Materials
- Holographic Non-Destructive Testing
  - –Real-Time
  - –Double-Exposure
  - –Time-Average

Basic Hologram Setup



Hologram



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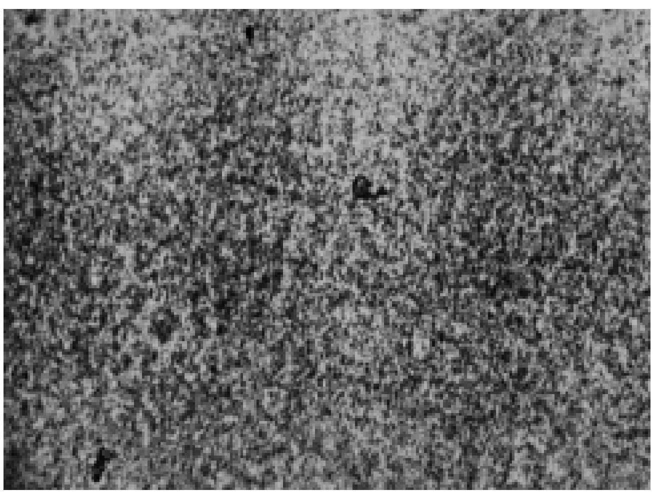
Hologram Seen Through Microscope



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Reconstructed Image

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Two Reconstructed Images

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Basic Theory

Object

$$O(x,y) = |O(x,y)| e^{i\alpha_o(x,y)}$$

Reference

$$R(x,y) = |R(x,y)| e^{i\alpha_R(x,y)}$$

Exposing Intensity

$$I = (O+R)(O+R)^*$$
$$= I_o + I_R + OR^* + O^*R$$

Amplitude Transmission

$$T_A = T_o - \beta I$$

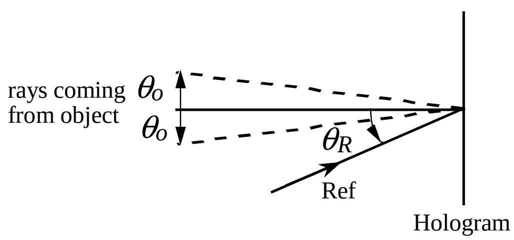
Primary Image

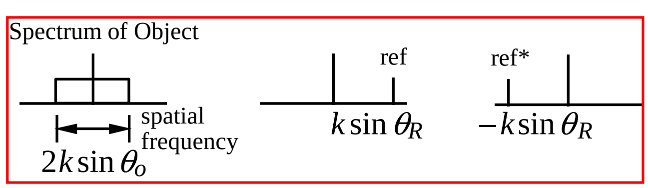
$$T_A R = RT_o - \beta\left[R(I_o + I_R) + I_R O + O^* R^2\right]$$

Conjugate Image

$$T_A R^* = R^* T_o - \beta\left[R^*(I_o + I_R) + (OR^*)^2 + I_R O^*\right]$$

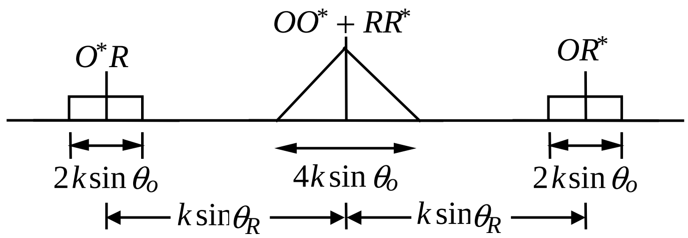
Separation of Orders





Spatial Frequency Spectrum of Hologram Transmission Function

$$T_A = T_o - \beta[(OO^* + RR^*) + OR^* + O^*R]$$



For separation of orders $\sin\theta_{R_{min}} = 3\sin\theta_o$

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Light Sources

Need coherence length of laser

- **Pulsed Lasers**
  - **Ruby 699.3 nm**
  - **Frequency Doubled Yag 530 nm**
- **CW Lasers**
  - **HeNe 633 nm**
  - **Argon 477, 488, 496, 502, 515 nm**
  - **Krypton 476, 521, 568, 647 nm**
  - **R6G Dye 570-650 nm**

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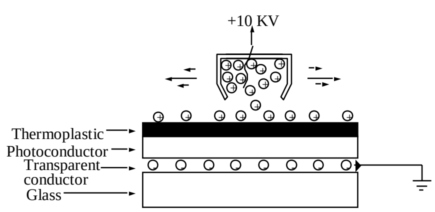
Recording Materials

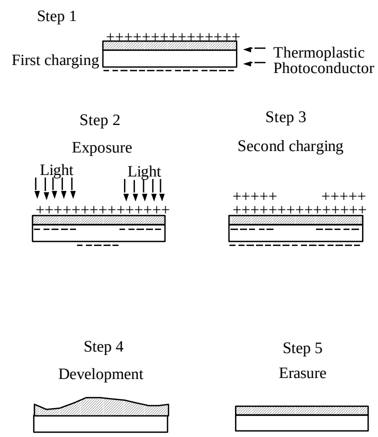
- **Photographic Film**
  - Most common
- **Photoresist**
  - Thin phase hologram
- **Dichromated Gelatin**
  - High efficiency volume hologram
- **Thermoplastic Device**
  - Convenient for holographic interferometry

Thermoplastic Recording Device



Film structure of a photoconductor-thermoplastic layer system. Corona charging device is shown.

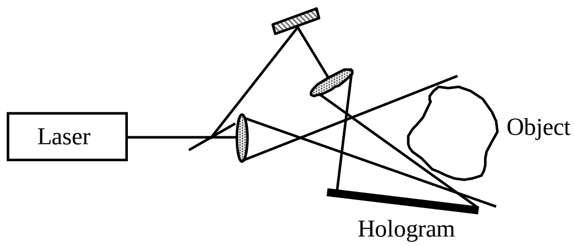
Recording-Erasure Cycle of Thermoplastic Hologram



Holographic Non-Destructive Testing

- **Real-Time**
- **Double-Exposure**
- **Time-Average**

Hologram Formation



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Real-Time Holographic Interferometry

- Make hologram of arbitrarily shaped rough scattering surface
- Process hologram
- Replace hologram in original position and illuminate with reference and object wavefronts
- If object is deformed interference fringes will be produced telling how surface is deformed
- Between adjacent fringes optical path between source and viewer changed by one wavelength
- While we are not obtaining surface shape, we are measuring shape change even though object surface rough compared to wavelength of light

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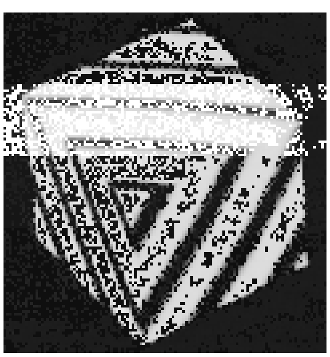
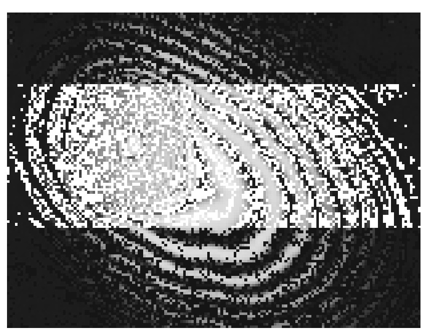
Double-Exposure Holographic Interferometry

- Same as real-time holography except two exposures are made before processing
- Advantage - no critical replacement of hologram after processing
- Disadvantage - continuous comparison of surface displacement relative to initial state cannot be made

Typical Holographic Non-Destructive Interferograms

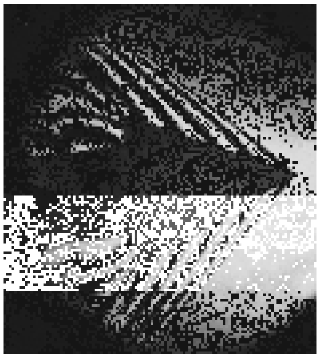


Fringes on aluminum cube due to uniform thermal expansion.

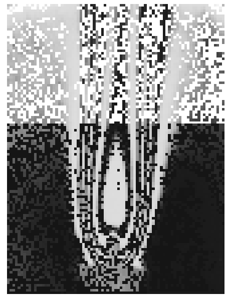


Debonded region of honeycomb construction panel.

Double Exposure Interferograms



Air Flow Past Cone



Candle

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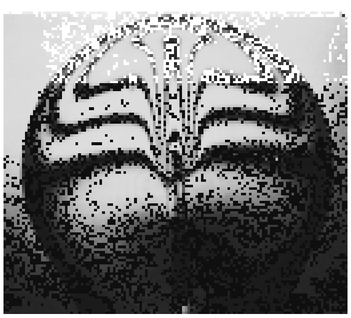
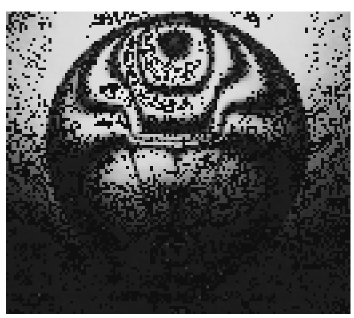
Interferograms of Temperature Field of Light Bulb





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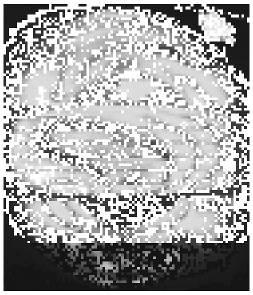
Holographic Tire Testing

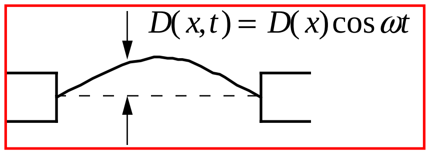


Arrows show weak areas

Time-Average Holographic Interferometry

- **Make hologram of vibrating object**
- **Maximum vibration amplitude should be limited to tens of wavelengths**
- **Illumination of hologram yields image on which is superimposed interference fringes**
- **Fringes are contour lines of equal vibration amplitude**

Vibrating Membrane



Phase of scattered light

$\delta(x,t) = -2(2\pi / \lambda)D(x)\cos\omega t$

Object

$O(x,t) = O(x)e^{i\delta(x,t)}$

Holographic Exposure proportional to

$$\langle I \rangle = \frac{1}{T}\int_0^T \left(|O|^2 + |R|^2 + OR^* + O^*R\right)dt$$

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Fringe Intensity Function

Transmission function term of interest

$$\frac{1}{2\pi}\int_0^{2\pi} e^{i\delta(x,t)}d(\omega t) = J_o\left[\frac{2\pi}{\lambda}2D(x)\right]$$

Intensity of observation point proportional to

$$\left\{J_o\left[\frac{2\pi}{\lambda}2D(x)\right]\right\}^2$$

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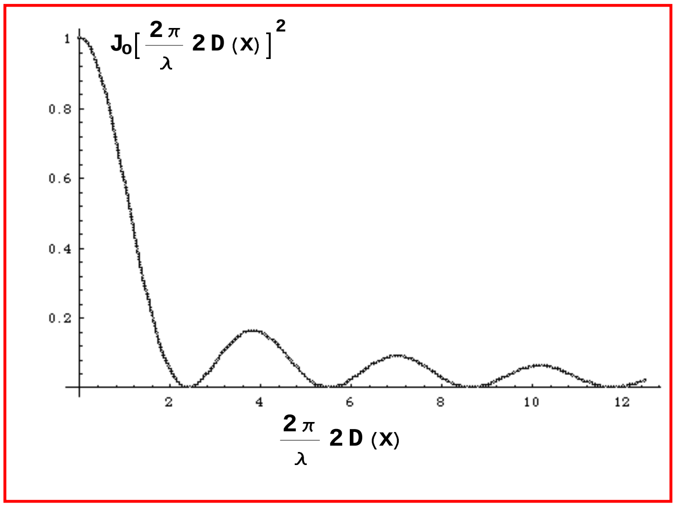
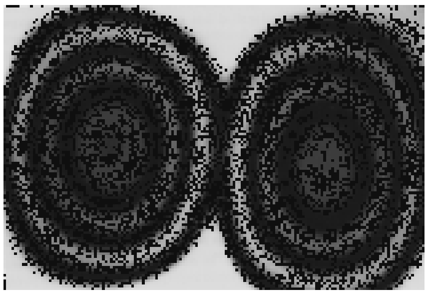
Plot of Zero Order Bessel Function



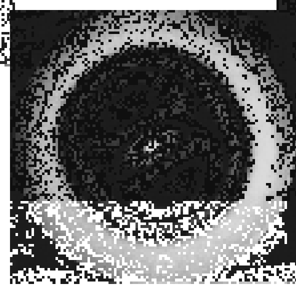
Time-Average Holographic Interferograms



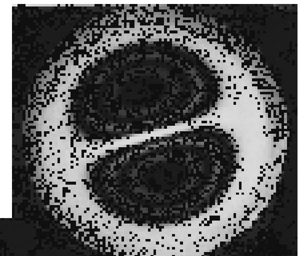
Vibrating Plate

Interference Patterns for Different Vibration Modes

Mode 1



Mode 1 and Mode 2



Mode 2

Vibrating Guitar