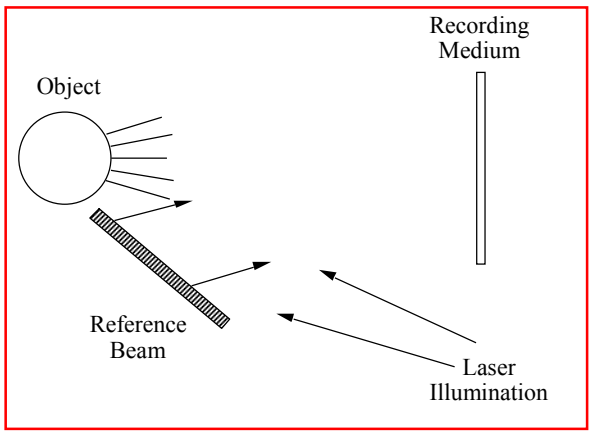
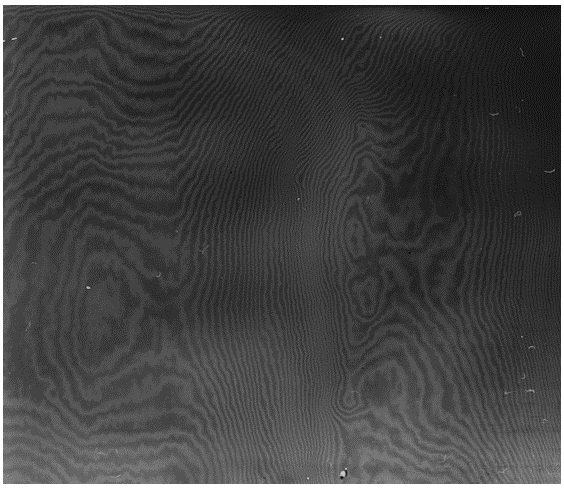
Chapter 17
Holography

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

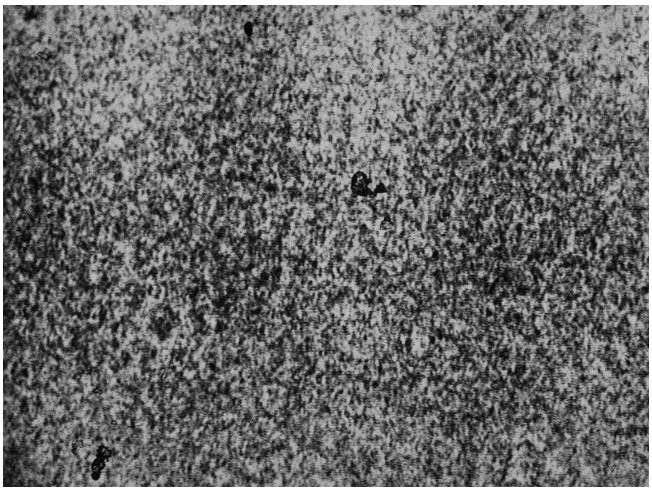
Basic Hologram Setup



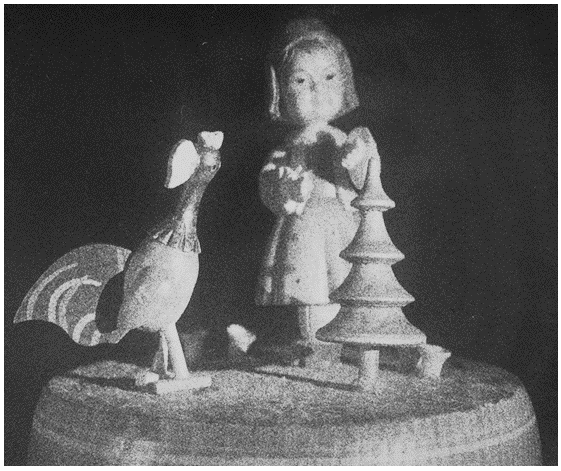
Hologram



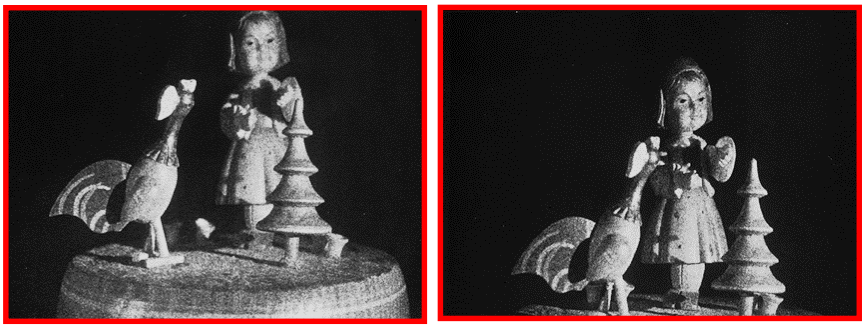
Hologram Seen Through Microscope



Reconstructed Image



Two Reconstructed Images



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

$$T_A = T_o - \beta I$$

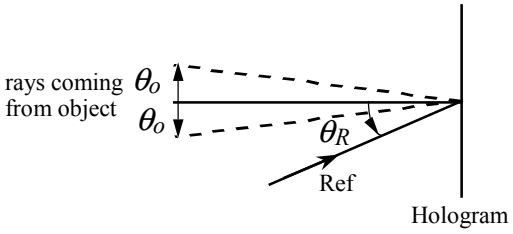
Primary Image

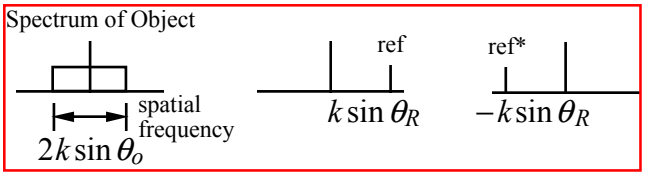
$$T_A R = RT_o - \beta\left[R(I_o + I_R) + I_R O + O^* R^2\right]$$

Conjugate Image

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

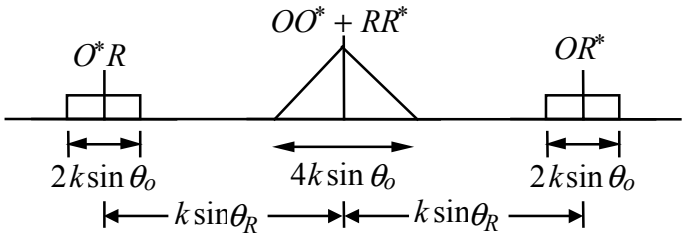
Separation of Orders





Spatial Frequency Spectrum of Hologram Transmission Function

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



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

Light Sources

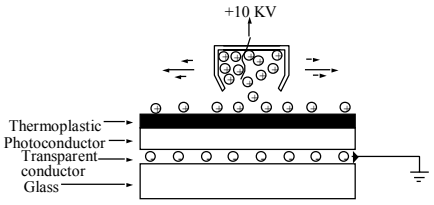
Need coherence length of laser

- **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**

Recording Materials

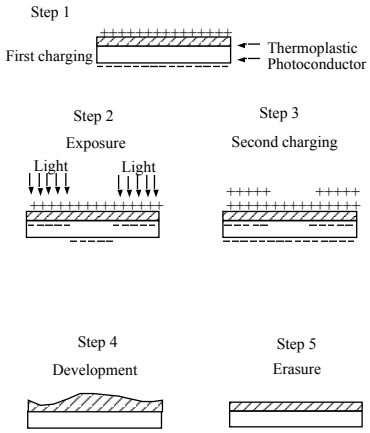
- **Photographic Film**
  - **Most common**
- **Photoresist**
  - **Thin phase hologram**
- **Dichromated Gelatin**
  - **High efficiency volume hologram**
- **Thermoplastic Device**
  - **Convenient for holographic interferometry**

Thermoplastic Recording Device



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

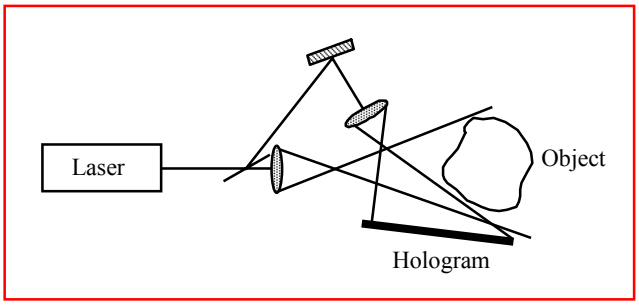
Recording-Erasure Cycle of Thermoplastic Hologram



Holographic Non-Destructive Testing

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

Hologram Formation



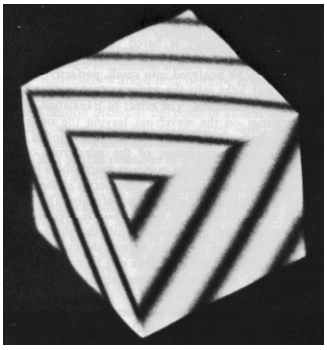
Real-Time Holographic Interferometry

- **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**

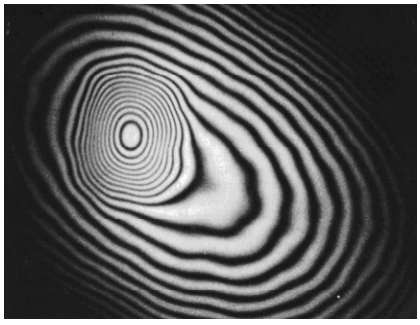
Double-Exposure Holographic Interferometry

- 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

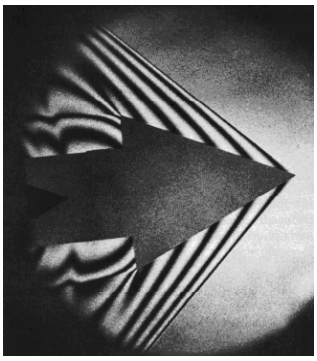


Fringes on aluminum cube due to uniform thermal expansion.

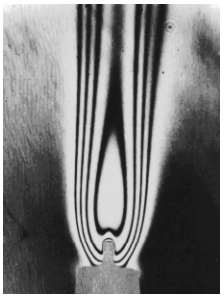


Debonded region of honeycomb construction panel.

Double Exposure Interferograms

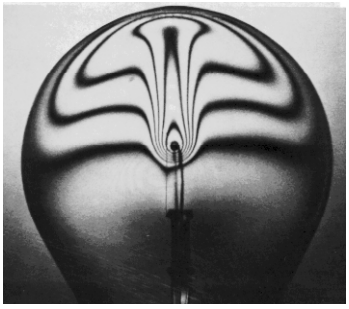


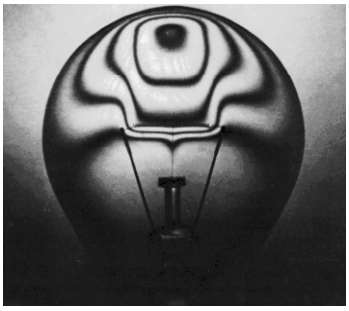
Air Flow Past Cone



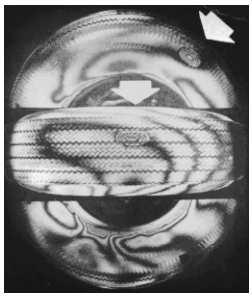
Candle

Interferograms of Temperature Field of Light Bulb





Holographic Tire Testing

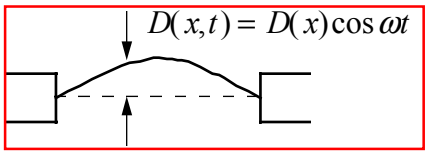


Arrows show weak areas

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

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

Object

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

Holographic Exposure proportional to

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

Fringe Intensity Function

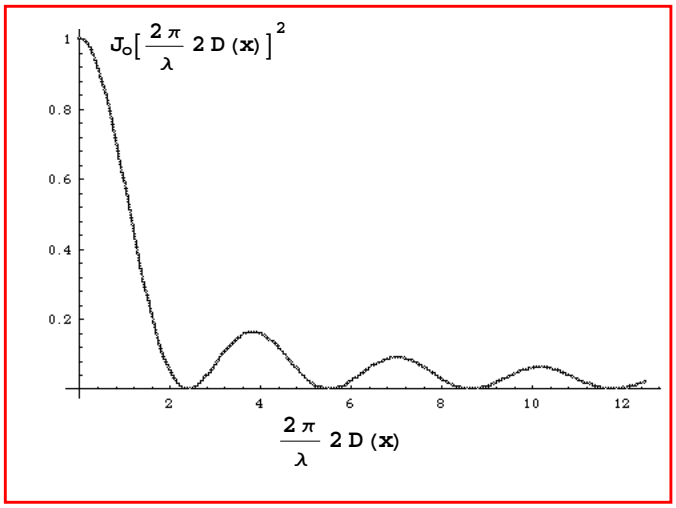
Transmission function term of interest

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

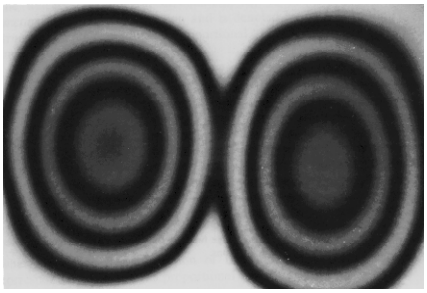
Intensity of observation point proportional to

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

Plot of Zero Order Bessel Function

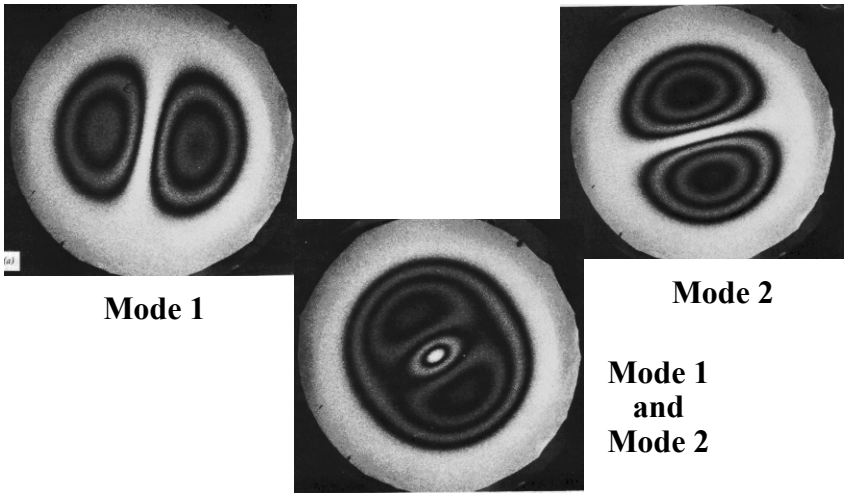


Time-Average Holographic Interferograms



Vibrating Plate

Interference Patterns for Different Vibration Modes



Mode 1

Mode 2

Mode 1
and
Mode 2

Vibrating Guitar