Lecture 21

Holograms

Amplitude, Phase and Intensity

- The primary characteristics of a wavefront are the spatial distributions of
  - amplitude
  - phase
- A photographic film records the intensity of the wave as a function of the spatial co-ordinates
  - No Phase information
  - Cannot reconstruct the wavefront
  - Cannot reproduce the “view” of the object
- However an interference pattern does contain some phase information
  - cycles represent π change in phase

Amplitude, Phase and Intensity

- Consider two *coherent* beams incident upon a film
  - first one is normal to film
  - second at angle Θ_i
    - phase is $kx_0\sin\Theta_i$
- Amplitude is $[1 + \exp(i\, kx_0\sin\Theta_i)]$
- Intensity is $2[1 + \cos(kx_0\sin\Theta_i)]$
- Assume this is same numerically as the developed film transmission
- This is a diffraction grating in two parts - 1 and $\cos(kx_0\sin\Theta_i)$
- Illuminate with a normal “reconstruction” beam and let $\Lambda \equiv \lambda/\sin\Theta_i$

Amplitude, Phase and Intensity

- Result is

$$\left(1 + \delta(\sin\Theta_i)\right) \frac{\sin\left(\frac{\pi N\Lambda}{\lambda}[\sin\theta]\right)}{\sin\left(\frac{\pi\Lambda}{\lambda}[\sin\theta]\right)}$$

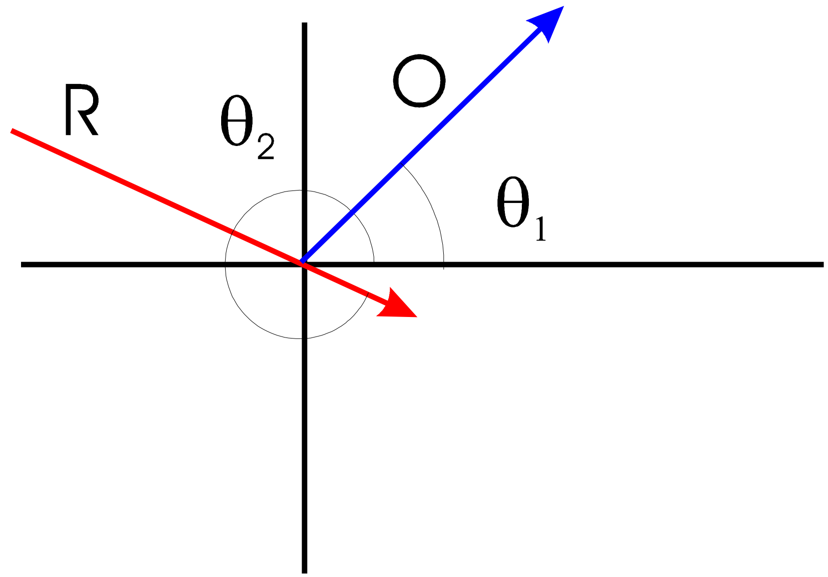
- First term is plane wave (diffracted and dull)
- Second term is the same as second incident wave
- (also a third wave at $-\sin\Theta_i$ - but we won't worry about that)

Basic Holograms

- Remember these are *coherent* waves
- General case of two waves O(bject) and R(eference) waves
- Pattern is - $|O|^2 + |R|^2 + O^*R + R^*O$
- Assume that this is the same as transmission pattern
- Illuminate with beam aR (a is a scaling amplitude)
- $aR(|O|^2 + |R|^2 + O^*R + R^*O)$

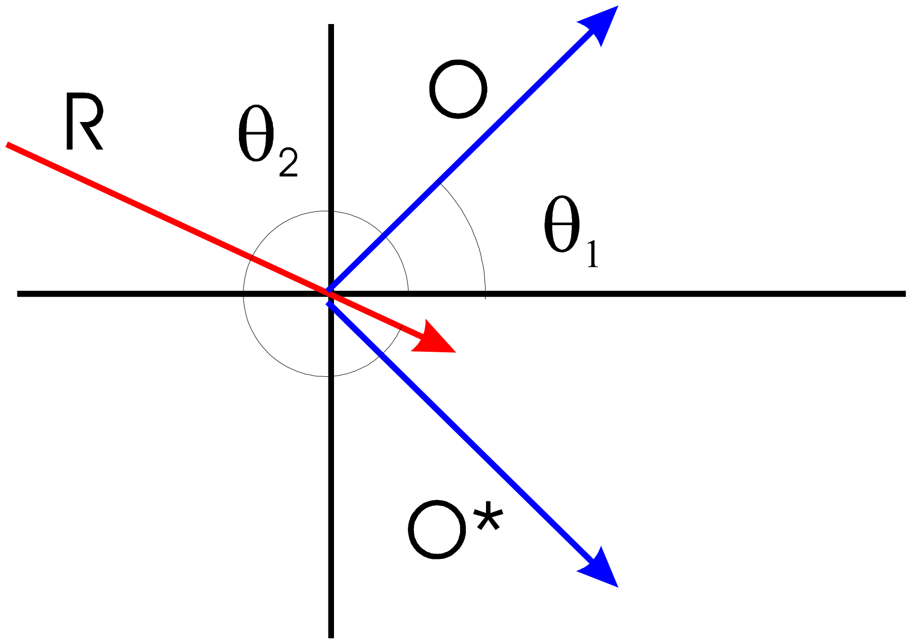
  $= aR|O|^2 + aR|R|^2 + aRO^*R + a|R|^2O$
- Last term is a reconstruction of O
- If the beams are spatially separate (different directions) and we can distinguish them

To Clarify...



- Object wave is $O\exp(ik\sin\theta_1)$
- Reference wave is $R\exp(ik\sin\theta_2)$
- Intensity is $O^2 + R^2 +$
  $OR\{\exp[ik(\sin\theta_1 - \sin\theta_2)]$
  $+ \exp[-ik(\sin\theta_1 - \sin\theta_2)]\}$
- Assume that this is transmssion of hologram
- Illuminate with $R'\exp(ik\sin\theta_3)$
- $\{O^2 + R^2\}R'\exp(ik\sin\theta_3)$ Direct
  $+ ORR'\exp[ik(\sin\theta_1 - \sin\theta_2 + \sin\theta_3)]$ Object
  $+ ORR'\exp[ik(\sin\theta_2 - \sin\theta_1 + \sin\theta_3)]$ Conjugate
- If $\theta_2 = \theta_3$ the object wave is reconstructed

To Clarify...



- Can get some interesting effects by changing wavelength and angle of illumination
- Different wavelength gives magnification / demagnification effect
- Variation in angle of reconstruction beam distorts image
- Illumination with white light produces rainbow like tinge to image
- Double exposure produces interference fringes highlighting image differences between exposures