Topic 8: Holography

Aim

These two lecture covers the basis of holographic recording and reconstruction of off-axis holograms. The types of holograms and various reconstruction materials are also reviewed.

References

- Goodman **Chapter 9** (more than is needed).
- Guenther Chapter 12.
- Hariharan *Optical Holography*, Cambridge 1986 (Detailed reference book)
- Hecht *Optics* Chapter 14.3 (good overview)
- Caulfield, *Handbook on Optical Holography*, Academic Press, 1986 (All you ever need to know about practical holography).
- Solymar & Cook, *Volume Holography and Volume Gratings*, Academic Press 1981. (Mathemetical details of volume, or white light, holography.)

8 Holography

8.1 Efficiency of Amplitude Hologram

Show that if the fringe intensity pattern of a hologram is

$$g(x,y) = g_0 + \delta g(x,y)$$

then the Amplitude transmission of a thin hologram formed from this distribution is

$$T_a(x,y) = T_0 - a\delta\hat{g}(x,y) + b(\delta\hat{g}(x,y))^2$$

where a and b are constants dependent of the film type. and

$$\delta\hat{g}(x,y) = \frac{\delta g(x,y)}{g_0}$$

When reconstructed this amplitude transmission will result in first and second order reconstructions. Calculate the ratio of power between the first and second order reconstructions, and hence estimate the required ratio of *intensities* between the *object* and *reference* beams used to form the hologram so that the first order reconstruction has 5 times the power of the second. (assume the film has $\gamma = 1.3$).

Hint: You will have to assume that $r^2 \gg o^2$ where r^2 is the reference beam intensity and o^2 the object beam intensity to get to the expression quoted in lectures.

Estimate total efficiency of such a hologram, assuming that the plate is exposed to an OD≈ 0.5. The total efficiency is defined at the intensity in the First Order reconstruction over the total input power.

Hint: Make the same assumption regarding r^2 and o^2. This part is rather difficult, *almost italic!*.

8.2 Bleached Holograms

If an amplitude hologram is bleached to form a phase distribution of

$$T_a = \exp\left(\imath\Phi(x,y)\right)$$

where

$$\Phi(x,y) = 2\pi\frac{g(x,y)}{g_0}$$

where $g(x,y)$ and g_0 are as defined in the previous question. Show that this hologram will reconstruct in a similar manner to the amplitude hologram.

Calculate the ratio of power between the first and second order reconstructions, and hence estimate the required ratio of *intensities* between the *object* and *reference* beams used to form the hologram so that the first order reconstruction has 5 times the power of the second. Compare with with the result for the question above, and comment.

8.3 A Real System

Consider the system for recording a hologram shown in lectures. Assume the *intensity* efficiency of the components are:

Component	Efficiency
Mirror	90%
Microscope Objective	80%
Beam Splitter	90%
Object (onto hologram)	5%

If you want the ratio of Reference Beam to Object Beam *intensity* 5:1, calculate the ratio of the beam splitter required.

If the laser has an output power of 5 mW and the holographic material requires and exposure of $20\,\mu\mathrm{J}/\mathrm{cm}^2$ *estimate* the exposures time needed to record the hologram when a) using a 35 mm film, b) using a 10×10 cm glass plate.

Hint: Ignore the fact that the laser beam is a Gaussian, and assume the recorded hologram is a circular patch the width of the film. Remember that 35 mm film has an active area of 24×36 mm.

8.4 Trying to be too Clever

*A "clever" student is using the holographic system from the previous question and decides to increase the object reflectivity by painting it white correction fluid (*TIPP-EX*). They now spend many hours totally failing to make a hologram, why?*

What should they have painted it with?

8.5 Beam splitter for Holography

In a holographic system you have to vary the beam splitter ratio depending on the object. Several optic companies make a "variable beamsplitter" which allows you to alter the beam ratios by simply rotating a knob. Suggest an explanation for this optical system.

Hint: It contains two half-wave plates and a polarising beamsplitter.

8.6 Multi-Image Holograms

You will notice that several of the holograms in the display on JCMB Level 4 appear to contain more than one image. Explain how this can be done.

8.7 Is it Holography?

Over the last few years there has been a range of apparent 3-dimensional images, (auto-stereograms), appearing on drink cans, in newspapers, as adverts, and in poster shops. Explain how these work, and how they are related to holograms.

Hint: You have to focus your eyes “behind” the printer sheet to see the image. This, combined with a good physics training, should be enough for you to work out how they are produced and work.