3.1 Recording and Reconstructing Holograms

Objective:

Understand the principle of holography; learn how to record and reconstruct holograms.

Experimental Setup

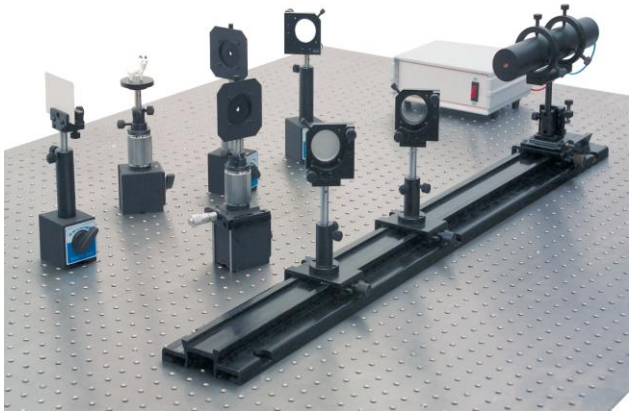

Figure 1-1 Photo of experimental setup

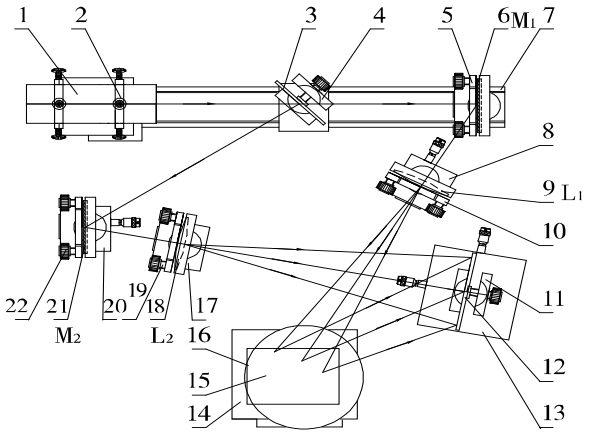

Figure 1-2 Schematic of system setup

1: He-Ne Laser (LLL-2)
2: Laser holder (SZ-42)
3: Beam Splitter (7:3)
4: Lens Holder (SZ-08)
5: Two-axis Tilt Holder (SZ-07)
6: Flat Mirror M_1
7: Optical Rail (LEPO-54)
8: Magnetic Base (SZ-04)
9: Beam Expander Lens L_1 (f'=15 mm)
10: Lens Holder (SZ-08)
11: Plate Holder A (SZ-12)
12: Holographic Plate
13: Magnetic Base (SZ-04)
14: Object
15: Loading Table (SZ-20)
16: Magnetic Base (SZ-04)
17: Beam Expander Lens L_2 (f' = 4.5 mm)
18: Two-axis Tilt Holder (SZ-07)
19: Magnetic Base (SZ-04)
20: Flat Mirror M_2
21: Two-axis Tilt Holder (SZ-07)
22: Magnetic Base (SZ-04)

Note: Photos may vary from actual parts

Principle

Light is a transverse electromagnetic wave, so the propagation of a monochromatic light wave can be written as

$$x = A\cos(\omega t + \varphi - \frac{2\pi}{\lambda} r) \tag{1-1}$$

where A is the amplitude, ω is the circular frequency, λ is the wavelength and φ is the initial phase.

Conventional photographic films can only record the amplitudes of light reflected from an object. As a result, the photo is a planar picture. By contrast, holography can record not only the

amplitude but also the phase of the light, so that the holographic image is three-dimensional. If a hologram is broken or cut, each small portion still contains the information about the whole object. There are two steps in holography, as shown in Figure 1-3. The first step is to record all the information of the light reflected from the object on a holographic plate, and the second step is to illuminate the hologram and reconstruct the electromagnetic wave of the object.

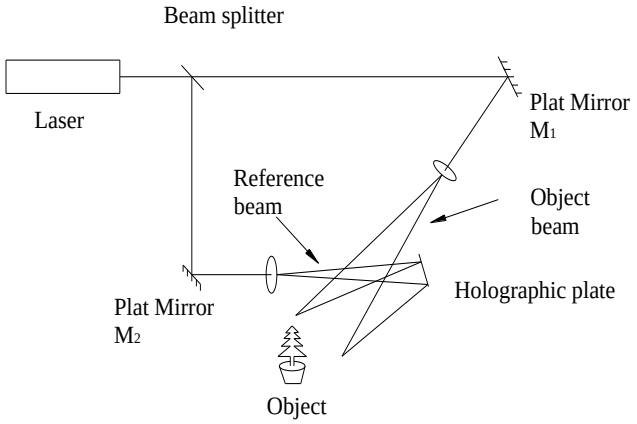

Figure 1-3 Schematic of holographic recording and reconstructing

The interference pattern contains both amplitude and phase information of the object. When it is recorded, a hologram of the object is obtained. In this process, a laser beam is split into two beams: one beam, called the reference beam, is directed toward a holographic plate; another beam, called the object beam, is reflected off an object. The object beam contains the information of the object such as location, size, shape and texture of the object. Then the two beams are recombined to produce an interference pattern on the holographic plate, which is recorded in the light sensitive emulsion.

To reconstruct a hologram, a laser beam is used to illuminate on the holographic plate at the same direction as the reference beam. Then a three-dimensional image of the object can be observed.

Experimental Procedures:

1. Refer to Figure 1-2, align all components in same height on the rail, let the primary plane of the system parallel to the table, remove lenses L_1 and L_2 from optical path first;
2. Set approximately equal optical path length for object beam and reference beam, and let their intersection angle at about 30° to 40°;
3. Adjust M_1, let object beam illuminate on the central portion of the object;
4. Adjust M_2, let reference beam illuminate on the central portion of the holographic plate (use a paper plate of a similar size for setup);
5. Insert L_1 and L_2 back, adjust them so that the object beam and reference beam are still at their original centers.
6. Move L_2 back and forth to change the illuminating intensity of the reference beam; let the intensity ratio of reference beam to object beam about 5:1 to 10:1;

7. Fix all components, turn off indoors light, replace the paper plate with a holographic plate, and expose the holographic plate with the He-Ne laser for 10 to 15 seconds;
8. Develop and fix the hologram;
9. Put back the hologram at its original location, remove object and block object beam, observe the reconstructed image of object.

Note: The hologram recording experiment is recommended to be carried out on a vibration isolated optical table.