Tutorial Solutions

9 Holographic Interferometry

9.1 Types of Interferometry

State the three types of Holographic Interferometry discussed in lectures and suggest a practical applications of each type.

Solution

There were **three** types of holographic interferometry discussed in lectures, these being:

Frozen Fringe: which is a two exposure hologram with the displacement fringes permanently recorder in the hologram. This type of interferometry is use where precise displacement information in needed, and if the exposures are taken with a very short pulse laser can be used to "freeze" very fast motion, for example flexing of turbine blades in a jet engine under test.

Live Fringe: which is very similar to *frozen fringe*, except that the first hologram is recorder and replaced in the optical system to give a master object with which the live object is interferometrically compared. This method is used to monitor very precise displacement is real time, but due to the optical difficulties it is usually limited to very slow movement. Typical uses are for measurement of thermal expansion or calibration of accurate displacement system. It is also the basic of holographic lens testing where the master hologram is computationally calculated and plotted.

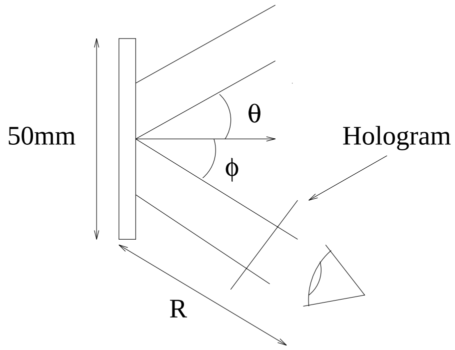
Time Averaged: is a single long exposure of a vibrating object which is used to determine amplitude and vibration structure. It is applicable to system that have regular small displacement vibrations, but no displacements since long exposures are required. Typical applications and in the analysis of sound systems, such a loudspeaker cabinets and musical instruments.

9.2 Linear Position

A linear translation stage is reported to have a positional accuracy of 1μm over a 1 mm range. You have a 50×50mm plate of aluminum with a 0.5 mm grid engraved on it which may be attatched to the translation stage either parallel or perpendicular to its motion. Suggest a suitable holographic scheme to test the accuracy of this stage.

Solution

Set up a *live fringe* holographic system with of geomerty



The fringe separation seen on the 50 mm plate is given by

$$D = \frac{R\lambda}{a\cos\phi\sin(\phi-\delta)}$$

where a is the distance and δ is the angle.

Select *in-plane* displacement, with the place parallel to the direction of the translation stage, so that $\delta = \pi/2$, so

$$D = \frac{R\lambda}{a\cos^2\phi}$$

We need to be able to see a movement if 1μm, so for $a = 0.5\mu$m we must have *two* visible fringes, so $D = 25$mm. If we have $\lambda = 633$nm (He-Ne laser), then,

$$\cos^2\phi = \frac{\lambda}{aD}R \approx 0.025R$$

But $\cos^2\phi < 1$, so that $R < 40$mm. So this sets a limit for the viewing distance.

Take $R = 35$mm as a sensible viewing distance. This is small but reasonable practical. Then we have that

$$\cos^2\phi = 0.8855 \quad \Rightarrow \quad \phi = 20^\circ$$

which is a reasonable practical system.

Note: to view a system at 35 mm you will have to use a magnifier, or small viewing microscope.

There is a 0.5mm grid on the plate, so if fringes are smaller than 0.5mm they will be difficult to see. So if $D = 0.5$mm then

$$a = \frac{R\lambda}{D\cos^2\phi} \approx 50\mu\text{m}$$

so we are only able to check 50μm section of the stage at once, so we would need 20 holograms to test the whole range.

In practice it is not very useful to test the whole range, but several test couble be carried out at different parts of the 1 mm travel.