Chap. XX: In-Line Reflection "Denisyuk" Holograms (in progress)

Introduction

We have talked so far about the creation of image points in three dimensions by the diffraction analogs of negative and positive lenses. Similar images can be produced by the diffractive equivalents of mirrors, with some interesting side effects. Just as there are in-line and off-axis transmission holograms, so are there in-line and off-axis reflection holograms, and we will proceed through each type in turn. Our style of analysis will be quite different looking, but near the end we will see that the same equations used for transmission holograms also apply to these holograms—recasting them into mirror terms makes certain mathematical questions easier to answer. We will start by looking at the fundamental image formation properties involved.

Image formation by convex mirror

There are many ways to produce a three-dimensional image with mirrors. We will begin by looking at the formation of a 3-D image one point at a time. Imagine illumination of a plane mirror by a white-light point source. If the mirror is a plane or flat mirror, the reflected virtual image is formed on the opposite side of the mirror at a distance equal to the distance to the illumination source.

Imagine now that the mirror is a convex mirror, like the wide-angle side-view mirrors for automobiles. Illumination of this kind of mirror with a distant point source produces an image behind but fairly close to the mirror. The more deeply the mirror is curved, the nearer to the mirror the image is formed. In fact, the image of an infinitely-distant point source (such as the sun) is formed at a distance equal to half the radius of curvature, which is usually called the "focal length" or F (to give them the same mathematics as lenses). The shorter the radius of curvature, the closer to the mirror surface will the image be formed. The ideal shape for the mirror is parabolic for an infinitely-distant source, and hyperbolic for nearer source (the source and image must be at the vertices of the hyperboloid).

To form an image that consists of many points, we need many mirrors. Unfortunately, there can be only one real, reflecting, glass mirror at any one place, unless we imagine that each is only very weakly reflecting (and that their surfaces can interpenetrate). But the conceptual picture of many mirrors, one for each image point, is very useful.

wide variety of candidate mirrors

The next step is to realize that there are an infinite number of mirrors that will form a point image in the smae place. That is, an infinite number of hyperboloids that have the same vertices. We can imagine that these could exist simultaneously, and could be nested with some separation. If each is only partially reflecting, each could produce an image literally superimposed on the others. Multiple sets of these multiple nested mirrors could then produce the multiple-point image mentioned before.

The question then becomes: how to produce such a nested array of images, even for an image of a single point? Luckily, interference offers an answer!

Creation of mirrors by interference patterns

standing waves, and beyond

Sampling by holographic layer (slices)

domains of (thick) hologram recording

2-source “interference” moiré diagram

measurement of “thickness”

$Q = 2 \cdot pi \cdot lambda \cdot T / n0 (spacing)**2$

Mirror model of thick holograms

nested hyperbolic mirrors

sliced by emulsion surfaces

created by interference

Reflection hologram recording geometries

Peak wavelength

pancake stack

pre-swelling effects

shift with angle

Spectrum width

thickness effect

delta-n effects

chirp effects

Diffraction efficiency

single scatter model

Kogelnik analysis

mirror focus model

distances

magnifications