COMPUTER GENERATED HOLOGRAMS
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PART IV: CHAPTER ONE
REPLICATION, FANOUTS AND INTERCONNECTS

Introduction

The original motivation for replication gratings was for optical production of integrated circuits. The idea was to create the photolithographic mask for one circuit and then, using the replication grating, created an array of images to simultaneously expose the photoresist. This application was taken over by the step-and repeat camera. However, the replication gratings have found other uses.

Image Replication

The original application is summarized by the following two equations. The first equation expresses the point spread function (psf) of the replication grating as a collection of points.

$$psf(x,y)=\sum_{n}\delta\left(x-x_n\right)\delta\left(y-y_n\right)$$

The second equation expresses the fact that the imaging system's output is the convolution of the input with the psf of the system.

$$u(x,y)*psf(x,y)=\sum_{m}u\left(x-x_m,n,y-y_m,n\right)$$

The Dammann grating is one of the first to target the replication task. The properties of that grating are:

- Uniform diffraction (on axis) orders up to a particular order
- 2-D from 2 x 1 – D, i.e., 1 – D gratings are crossed to give the, separable, 2-D grating
- π step binary phase gratings
- Set up equations for 0, ± 1, ± 2, ± 3
- 3 nonlinear equations in 3 columns
- Solve
- K phase jumps $\rightarrow$ 2k + 1 diffraction orders
- Generalization – binary $\rightarrow$ trinary $\rightarrow$ quaternary

Let's look at the simplest example. We take a 1-D transmittance which has the following values as a function of x:

- 0 for $x < -1$ or $x > 1$ or $x = x_0$ or $x = x_1$
- -1 for $-1 < x < x_1$
- +1 for $x_1 < x < x_1$
- +1 for $x_1 < x < x_1$
- -1 for $x_1 < x < 1$

In other words three phase-rectangles located between x=0 and x=1. Explicitly we have

$$u(x) = -rect\left(\frac{x - \frac{x_0}{2}}{x_0} + rect\frac{x - \frac{x_0 + x_1}{2}}{x_0 - x_1} \right) - rect\frac{x - \frac{1 + x_1}{2}}{1 - x_1}$$

The Fourier transform can be done easily (it consists of a sum of rect functions multiplied by linear phase factors). The transform depends on x_0 and on x_1. It also has hermetian symmetry because the direct-space function is real. We can now pick a point and reflection about the origin. We have two equations, one for the transform at the point and one for the transform at the origin. Setting the absolute values to one, we now have two equations in two unknowns. We can solve for the edge locations in the original image. If we have made an intelligent choice for the location of the point in the transform, then periodically repeating the object will reinforce the value at out desired points, while destroying the values in the interstitial spaces.

Fanouts and Interconnects

Two additional, very closely related, applications, for the replication elements are fanouts and interconnects. Communications applications come immediately to mind, but other applications such as connection maps in neural networks are also appropriate. The distinguishing feature differentiating fanouts and interconnects is the selection of the input. For a fanout a fixed input id distributed to multiple outputs. The interconnect, on the other hand is used where various inputs will be selected and those inputs directed to multiple outputs, the actual implementation can be done in several ways. Consider the following categories of devices.

Free Space- 3D

The free space implementation is most easily visualized as out usual 4-f system lenses and CGH's. There are of course endless variations on this theme.

advantages:

- greater flexibility since beams can cross without degradation
- mechanical point-to-point contacts are eliminated

limitations:

- performance is sensitive to alignment
- affected by small wavelength changes
- image spreading effect of off=axis elements (limits to ~ aperture diameter)

Substrate mode hologram (SSMH) - 2D

The substrate mode hologram provides a much different design for fanout-interconnect. In this design, the wave propagates in a substrate and the input, output and distribution are handled by holograms. The substrate thickness turns out to be approximately equal to the beam diameter divided by two. This relation means that, for example, a 5mm beam diameter requires a 2.5 mm substrate thickness.

advantage:

- high-stability

disadvantage:

- more stages, more thickness

Utilizing Polarization Effects (Kostuk, et al, 1990)

The technique

- object and reference beam 90% in the emulsion, p – diffraction efficiency is 0
- used 649-F emulsion
- formed at 499nm reconstructed at 633nm
- used planar gratings
- optical bus
- ferro-electric half-wave plate

Volume holograms

The problem, multiple diffraction orders on injection. The solution, volume holograms,

advantages:

- single diffraction order
- color selection

materials:

- film _ bleach
- dichromated gelatin

compromise:

Hybrid 2D-3D CGH. The emulsion is first exposed to generate a Bragg hologram. Next a binary hologram is printed into the emulsion, result the Bragg hologram is overwritten in the bright areas. The dark areas then contribute to the reconstruction.

approach:

use coupled wave equations

definations:

s- perpendicular (senkrecht), p- parallel

S(x) = diffracted

R(z) = reconstruction (incident)

C = component along the z-axis

the equation:

$$C_R R' = jK_{s,p} S \qquad C_S S' - jK_{s,p} R$$

Diffractive – Reflective Optical Interconnects, K.-H. Brenner- F. Sauer

- use a thin hologram and a mirror
- also multiple reflections

- focused, collimated