MICROELECTRONIC ENGINEERING
MCEE 515/615 Nanolithography Systems

Franoisher Diffraction and the Fourier Series

The first goal of this laboratory is to produce, measure, and quantify the Fraunhofer diffraction patterns from a grating photomask through Fourier analysis. Two grating masks will be utilized at two laser wavelengths. Mask pitch, duty ratio, and source wavelength will be measured.

In the second week the goal is to collect the Fraunhofer diffraction patterns to create an image. This collection of limited orders is similar to using a stepper as related to imaging and manufacturing of IC semiconductors.


PROCEDURE (first week)

1. Obtain the following items:
   a) HeNe laser (wavelength = 632.8 nm)
   b) Green laser (wavelength to be determined)
   c) Two polarizers
   d) Screen to block beam at end of setup
   e) Two grating masks
   f) Ruler
   g) Intensity detector (Newport Research Model-818 Photosensor) and amplifier (Newport Research Model-815).
   h) Paper

2. Place one grating mask in the mask holder. With the laser illuminating the grating mask, project the diffracted pattern onto the screen. Align the laser so that the optical axis is perpendicular to the screen.

3. Make observations of the transmitted diffraction pattern on the screen by measuring distances:
   a) From the mask to the screen
   b) From the 0-order to the +/- 1st order
   c) From the 0-order to the +/- 2nd order
   d) From the 0-order to the +/- 3rd order
   e) From the 0-order to the +/- 4th order
4. Using the Newport Research Model-818 Photosensor and Newport Research Model-815 amplifier, measure the intensity of the undiffracted beam (this may need to be attenuated) and the 0, +/- 1st, +/-2nd, +/- 3rd and +/- 4th orders.

5. Use the collected data to plot and calculate the grating pitch, also calculate the line/space duty-ratio, and the “leakage” that exists in the line regions of the mask.

6. Repeat steps 2-5 with the second grating mask.

7. Repeat steps 2 and 3 with the green laser for both grating masks. Use this data to plot and calculate the wavelength of the green laser.

8. Measure the masks for line space and pitch on microscope in the SMFL.

**PROCEDURE** (second week)

1. Obtain the following items:
   a) HeNe laser (wavelength = 632 nm)
   b) Green laser (wavelength determined from previous week)
   c) Grating masks
   d) Aperture, lenses and stands
   e) Two polarizers
   f) One small focal length (~50mm) positive lens
   g) A CCD camera

2. Place one grating mask in the mask holder. With the HeNe laser passing through the two polarizers and illuminating the grating mask, align the laser so that the optical axis is perpendicular to the mask.

3. Place a lens with a small focal length immediately after the grating; this places the mask within the focal length, which causes the diffraction orders to expand.

4. Place an additional lens (or lenses) in succession to cause the diffraction orders to converge at a relatively large distance away, which should cause them to expand enough to cover the CCD.

5. Make sure the diffraction orders are centered in the lenses.

6. Place the aperture in a convenient location amongst the series of lenses in the Fraunhofer region. It is easiest to center the diffraction orders with the aperture in the closed position.

7. Place the CCD camera so that the diffraction orders converge upon it.
a) Open the image capture application and set the camera to collect images in grayscale.

b) Adjust the second polarizer’s angle relative to the first polarizer to adjust the maximum brightness level.

8. Capture images (in a lossless format) and make observations of:
   a) 0-order only
   b) 0-order and +/- 1st order
   c) 0-order, +/- 1st order and +/- 2nd order
   d) Add higher orders if possible
   e) +/- 1st order only
   f) Move the aperture off the optical axis so that only the 0th and +1st orders pass through the iris.

9. Repeat steps 2-8 with the other grating.

10. Repeat steps 2-8 with the green laser.

11. DATA ANALYSIS
   a) Quantify the image contrast with an image editing program; either assign numerical values to the line and space regions based on how “black” and “white” the pixels are, or make a cutline and plot the brightness versus location. How does contrast vary with the number of collected diffraction orders?
   b) How is the pitch affected by the inclusion/exclusion of the zero diffraction order?
   c) Is the object imaged with only the zero order? Explain.
   d) Relate all of your answers to the Fourier transform; as can be explained mathematically.