# MSE 2069 – MATERIALS SCIENCE OF NANOSTRUCTURES

Problem Set 1 – Due Jan. 24, 2007

These problems are designed to be challenging and somewhat open-ended. It may be helpful to search for other textbooks to assist your derivations. Web searches and consultation with colleagues are permitted, but be sure that the work you turn in is original and your own.

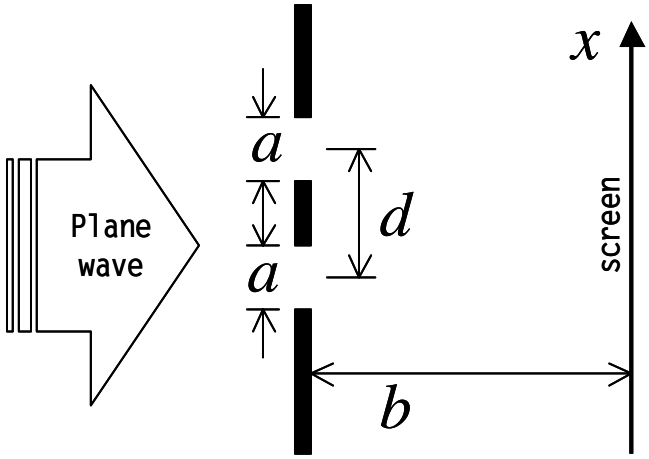
## 1) OPTICAL IMAGING

Consider diffraction of an incident plane wave passing through two infinite slits as shown in the figure below:

a) Using the Fresnel approximations, derive the functional form for I(x) the intensity of light observed on the screen.

b) Plot your expression for reasonable dimensions of the system (corresponding to what is used in standard DUV lithography). Under what conditions (if any) do the two slits appear as one on the screen ?

c) Modify your expression to consider incoherent light. (Assume you can still use the Huygens principle, however).

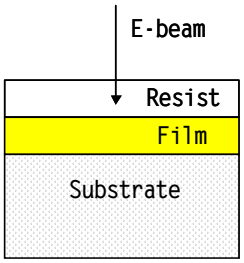



EXTRA CREDIT:

Add a cylindrical lens of focal length f between the mask and the screen, so that the screen is at the focal plane of the lens. Using the derivation of the Airy circle as a guide, find the function I(x) in this case.

## 2) ELECTRON BEAM LITHOGRAPHY

Electron beam lithography involves the use of a tightly focused electron beam to chemically modify a resist such as PMMA in selected regions. The standard models consider a volume where interactions between electrons and a uniform material occur via energy loss and scattering.




Consider electron beam writing on a multilayer consisting of 50 nm of resist, a 50 nm film of $SrTiO_3$, and a Si (001) substrate.

a) Modify the standard models to account for interactions in this multilayer system. You should be able to estimate the range and lateral scattering in each of these layers as a function of incident beam energy.

b) If the resist is PMMA, what would be the e-beam parameters that will give the best resolution ? Be sure to consider effects other than the interaction volume. Is it realistic to use PMMA resist this thin ? Why or why not ?

c) Propose a new resist material to improve resolution. The only limitation here is that it cannot be a carcinogenic, toxic, or radioactive compound. Show by numerical estimate and sketches why this would be better than PMMA at a 50 nm thickness.