Final: Practice II

P:

This problem deals with the Fabry-Perot interferometer. We have derived the following formula formula for its transmissivity

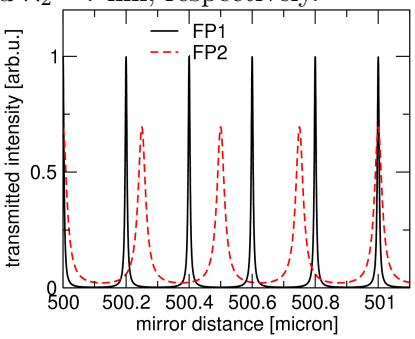
$$I/I_0 = \frac{T^2}{(1-R)^2}\frac{1}{1+F\sin^2(\Delta/2)}$$

where $\Delta = 2kd\cos\theta$ (the medium between mirrors is air, and we neglect additional phase change δ_r from the reflection on the mirrors).

A) Assume that the mirror distance is 0.5 mm, reflectance of each mirror is equal to 0.8, and transmittance is 0.2. Make a qualitative sketch of transmitted intensity versus wavelength (for, say, normal incidence) and:

1. Mark the points that correspond to transmission resonance
1. Identify the free spectral range, evaluate its value in units of frequency (i.e. 1/s)
2. Indicate in your sketch the quantities that determine the finesse
3. Calculate the minimal value of transmittance, and indicate in your sketch the corresponding points.

B) The following figure shows the transmittance of two different FPs, labeled FP1 and FP2, as functions of the mirror distance (which is the same in both FP1 and FP2), when illuminated by light with wavelengths of $\lambda_1 = 400$ nm and $\lambda_2 =?$ nm, respectively.

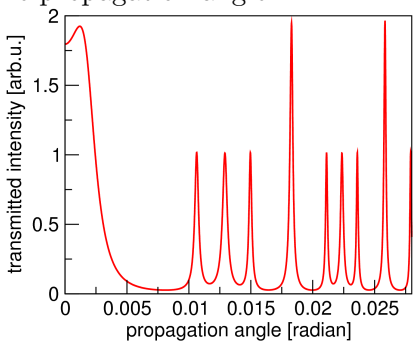


1. Which of the interferometers has mirrors with higher reflectance?

2. Which FP is ideal (has no losses) and which has mirrors with some absorption? Based on the graph, estimate the absorption A of the lossy mirror if you know that its reflectance is 0.7.

3. What is the other wavelength?

C) A FP is illuminated by a source with two discrete wavelengths λ_1 and λ_2. The transmitted intensity is shown here as a function of the propagation angle:



1. What is the fraction of the incident light power carried by each wavelength? Justify.

2. If the longer wavelength is 500 nm. What is the other wavelength?

3. Propose a method to estimate the FP mirror distance from the information in the above graph. Hint: Note the behavior of transmitted intensity in the vicinity of $\theta \approx 0$. Make an argument that we have a near resonance for zero angle. Choose an appropriate peak position to relate the mirror distance and wavelength to the corresponding angle. Use the fact that angles are small.

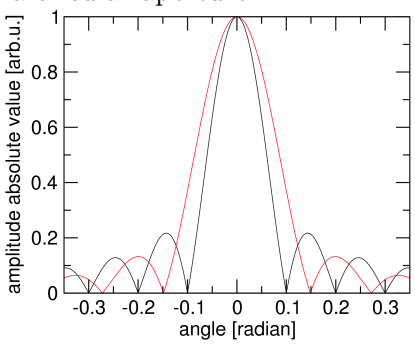
P: This problem concerns properties of optical coatings. A substrate of glass with the refractive index $n_s = 1.7$ is coated with a layer of transparent material with the index $n_c = 1.3$.

A) Is this layer designed as a high reflectivity or anti-reflective coating?

B) What should be the thickness h of the coating if it is supposed to work best at the wavelength of $\lambda = 520$ nm?

C) What should h be if it is designed for the incidence angle of 45 degrees?

P: This problem deals with Fraunhofer diffraction. The picture shows the absolute value of the field amplitude (to emphasize low-intensity features) versus diffraction angle. One of the curves represents diffraction on a slit, and the other diffraction on a circular aperture.

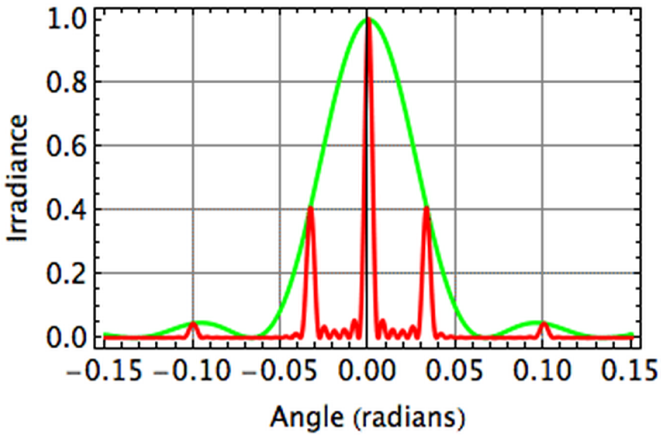


A) Identify which curve represents diffraction on a slit and which corresponds to a circular aperture. Justify your answer.

B) What is the width of the slit, expressed in units of wavelength of the incident light?

C) Based on the previous result (and the figure, of course), give an estimate of the circular aperture diameter.

P: N-slit as a diffraction grating. Consider Fraunhofer diffraction on an aperture consisting of N equivalent slits, characterized by their widths a and their center-to-center distance d.
The following figure shows the intensity pattern in the far field.



A) What is the meaning of the green-curve "envelope" in this figure?

B) There are three characteristic angle scales in this figure. Identify them in the graph and say to which parameter of the N-slit are they related.

C) Extract the necessary information from this picture and determine as much as you can about the parameters (N, a, d) of this N-slit.

D) Imagine that this N-slit is irradiated by a light beam that contains two colors, say red and blue. Sketch the qualitative picture of the resulting intensity pattern.

E) Describe in simple qualitative terms what kind of pattern would you see (with a color-sensitive detector such as human eye) if the N-slit is illuminated by white light.

P: A high-power femtosecond laser pulse has a peak intensity (irradiance) of $I_0 = 10^{15}$ W/m^2, and a Gaussian beam waits of $w_0 = 1$ cm. The duration of the pulse is $\tau = 50$ fs, and the central wavelength is $\lambda = 780$ nm.

A) What is a single photon energy corresponding to this pulse wavelength?

B) What is a single photon momentum p corresponding to this pulse wavelength?

C) Calculate the peak pulse power P in Watts.

D) Estimate the pulse total energy E_p in Jules.

E) Estimate the number of photons in the pulse.

F) The pulse is completely absorbed on a non-reflecting target. Estimate the total momentum force Δp transferred on the target.

G) Use the previous result to estimate the peak force exerted on the target.