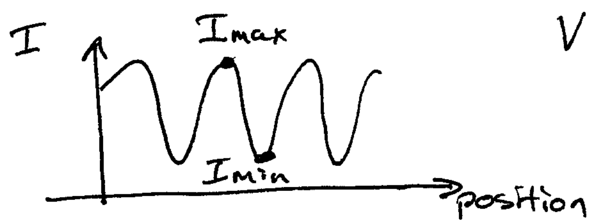
1.) A fringe field is formed by two interfering plane waves of the same wavelength, but different directions.

a.) (2 pts) What is the geometrical shape of each fringe (plane, hyperbolic, sphere, conic, etc.)?

b.) (2 pts) In what direction does the power flow, relative to the fringes?

Along the fringes

c.) (2 pts) Define fringe visibility.



$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$ (local measurement)

d.) (2 pts) What is the influence of polarization on the fringe visibility?

Visibility will be reduced by the dot product of the polarization states, where

$$V \propto |\hat{a}_1 \cdot \hat{a}_2^*|$$ $\hat{a}_1$ and $\hat{a}_2$ describe pol state of each beam

e.) (2 pts) A plane observation screen is used to view the interference fringes. How does the fringe visibility change versus orientation of the observation screen?

V is not affected by a change in observation screen orientation.

2.)

a.) (5 pts) Design the thickness of a quarter-wave plate that is made from MgF_2 at λ = 248 nm, where n_o = 1.40329 and n_e = 1.41615.

$$\Delta n = 1.41615 - 1.40329 = 0.0129$$

$$t = \frac{\lambda}{4\Delta n} = \frac{248\times10^{-9}}{4(0.0129)} = 4.82\times10^{-6}\,m$$

(could be multiples of 19.285 μm added here)

b.) (5 pts) With your design in part (a), what is the retardance at λ = 365 nm, where n_o = 1.38614 and n_e = 1.39834? (Please give your answer in units of λ at 365nm)

$$OPD = \frac{t\cdot\Delta n}{\lambda} = \frac{4.82\times10^{-6}(1.39834-1.38614)}{365\times10^{-9}}$$

$$= 0.161 \text{ waves}$$

3.) A Young's double pinhole interferometer is used with a g-line Hg source, where $\bar{\lambda}$ = 436 nm and $\Delta\lambda$ = 3.9nm with a Gaussian power spectrum. The pinhole separation d = 1mm, and the pinholes have equal transmission. State any assumptions that you make.

a.) (5 pts) What is the coherence length (in OPD_0)?

$$l_c = \frac{\bar{\lambda}^2}{\Delta\lambda} = 48.7\times10^{-6}\,m$$

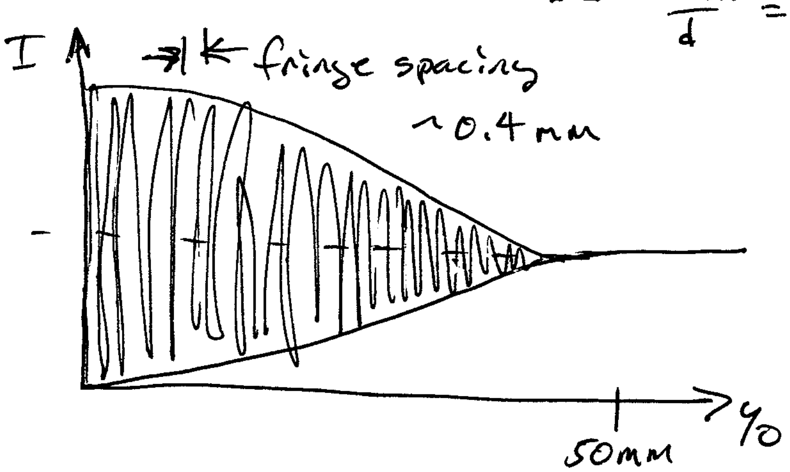
b.) (10 pts) Sketch a profile of the irradiance pattern for z_0 = 1 m separation between the pinhole plane and the observation plane. Limit your sketch over a range of y_0 = 0 to y_0 = 50 mm.

In observation space, $y_c = \frac{z_0 l_c}{d} = \frac{1\cdot 48.7\times10^{-6}}{10^{-3}}$

$OPD_0 \sim \frac{y_0 d}{z_0}$

$$= 48.7\times10^{-3}$$

$$\Lambda = \frac{z_0\lambda}{d} = \frac{1\cdot 436\times10^{-9}}{10^{-3}} = 436\times10^{-6}$$



4.) (15 pts) An interferometer is used in space outside the Earth's atmosphere. It is desired to use a distant star as the light source. The star can be considered as an extended incoherent source. A filter is used to limit the wavelengths to a narrow band around λ = 1 μm. The diameter of the star is 10^9 m. What is the distance of the closest star that will meet the requirement of obtaining a 1 m diameter coherent area illuminating the interferometer? State any assumptions being made. (Hint: You may assume a one dimensional source and describe it with a rect function.)

$$M_R(x_s, y_s) \sim rect\left(\frac{x_s}{10^9}, \frac{y_s}{10^9}\right)$$

$$\int_{-\infty}^{\infty} M_R(x_s, y_s)\, dx_s \sim \frac{1}{10^9} rect\left(\frac{y_s}{10^9}\right)$$

$$V\left(\frac{\theta_{ph}}{\bar{\lambda}}\right) \propto \left|sinc\left(10^9 \cdot \frac{\theta_{ph}}{\bar{\lambda}}\right)\right|$$

Assume $V=0$ is limit for coherent area.

$$\theta_{ph} = \frac{d}{z_o} \qquad d = 1m \quad \bar{\lambda} = 10^{-6} m$$

$$V=0 \Rightarrow 10^9 \frac{d}{z_o\bar{\lambda}} = 1 \Rightarrow z_o = \frac{10^9 \cdot d}{\bar{\lambda}}$$

$$= \frac{10^9 \cdot 1}{10^{-6}}$$

$$\boxed{= 10^{15} m}$$

5.) Newton's fringes are observed in reflection at near-normal incidence with a quasi-monochromatic light of wavelength 500 nm. The radius of curvature of the lens forming one part of the interfering system is 4 meters. The surface forming the second part of the interferometer is perfectly flat. The wedge is air with $n=1$.

a.) (5 pts) If the lens is in contact with the flat surface, is the center fringe bright or dark?

dark

b.) (10 pts) What is the radius of the 20th bright fringe? assuming (a) is true?

$$t \approx \frac{x^2}{2R}$$

$$OPD_0 = 2t(x)$$
$$= m\lambda + \lambda/2 \text{ for bright fringe.}$$

$$\frac{2x^2}{2R} = \lambda\left(m+\frac{1}{2}\right) \qquad x = \sqrt{R\lambda\left(20+\tfrac{1}{2}\right)} = 6.4\text{mm}$$

c.) (10 pts) Approximately how many dark rings can be observed in white light ($\lambda = 400$ nm to $\lambda = 700$ nm uniform power spectrum)?

$$\Delta\lambda = 300\text{nm}$$
$$\bar{\lambda} \approx 550\text{nm}$$

$$l_c \approx \frac{\bar{\lambda}^2}{\Delta\lambda} = \frac{(550\times10^{-9})^2}{300\times10^{-9}} = 0.86\times10^{-6}$$

$$\#\text{ rings (dark)} \approx \frac{l_c}{\bar{\lambda}} = \frac{0.86\times10^{-6}}{0.55\times10^{-6}} = 1.6$$

$\therefore$ ONLY ONE OR TWO DARK RINGS CAN BE OBSERVED.

6.) Give an example interferometer configuration illustrating each of the following fringe localization conditions:

a.) (5pts) Unlocalized

Laser illumination of any interferometer, where the laser exhibits a single mode with $l_c >>$ max OPD in measurement.

b.) (5 pts) Fringes of equal thickness

Fizeau illuminated with an extended Hg source.

c.) (5 pts) White-light fringes

Michelson with mirrors at equal displacement, but slightly tilted. Extended, white-light illumination.

d.) (5 pts) Fringes of equal inclination (Haidinger's fringes)

Michelson with parallel and displaced mirrors. Extended quasi-monochromatic illumination

e.) (5 pts) Localized fringes

Fizeau with extended, quasimonochromatic illumination.