Assignment 8

1. Michelson Morley Experiment

a)

Ether hypothesis gives;

Speed of light from $B \rightarrow M_1$ $\quad c + u$

" " $M_1 \rightarrow B$ $\quad c - u$

" " $B \rightarrow M_2 \rightarrow B$ $\quad \sqrt{c^2 - u^2}$

∴ Time for light to travel $B \rightarrow M1 \rightarrow B$

$$t_1 = \frac{d}{c+u} + \frac{d}{c-u} = \frac{2d}{c} \frac{1}{1 - u^2/c^2}$$

Time for light to travel $B \rightarrow M2 \rightarrow B$

$$t_2 = \frac{2d}{\sqrt{c^2 - u^2}} = \frac{2d}{c} \frac{1}{\sqrt{1 - u^2/c^2}}$$

b) $2\Delta t = 2(t_2 - t_1)$

$= \frac{d u^2}{c^3}$ for $u \ll c$

Change in phase $\Delta\phi = 2\Delta t\, \omega$

Shift of one fringe corresponds to $\Delta\phi = 2\pi$

$\therefore$ # fringes shifted $\Delta N = \frac{\Delta\phi}{2\pi}$

$= \frac{2d}{\lambda}\left(\frac{u}{c}\right)^2$

c) Speed of Earth $u = \frac{1.4 \times 10^8 \text{ km} \times 2\pi}{1 \text{ yr.}} \simeq 3 \times 10^4 \frac{\text{m}}{\text{sec}}$

$\therefore \Delta N = \frac{2 \times 11}{5.9 \times 10^{-7}} \times 10^{-8} = 0.4$

d) $(\Delta N)_{obs} = 0 \Rightarrow$ Ether does not exist!

This led to Einstein's postulate that c is constant $\Rightarrow$ Special Relativity.

2. Fabry Perot Etalon

a) $\lambda = \frac{c}{\nu} = \frac{3 \times 10^{8}}{5 \times 10^{14}} = 6 \times 10^{-7}\ m$

b) $\nu_{FSR} = \frac{c}{2d} = 125\ MHz.$

$\Rightarrow d = 1.2\ m$

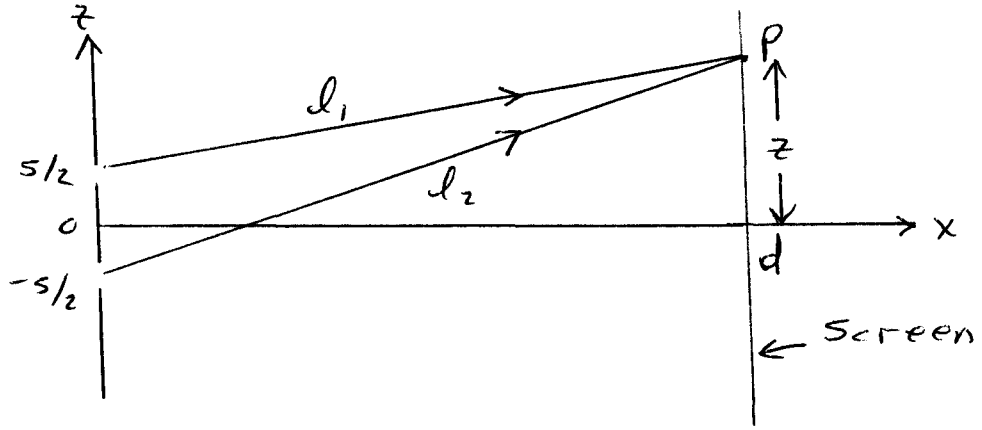
c) Finesse $F = \frac{\nu_{FSR}}{\Delta\nu_{1/2}} = \frac{125\ MHz}{2.5\ MHz} = 50$

d) $Q = \frac{\nu}{\Delta\nu_{1/2}} = \frac{5 \times 10^{14}}{2.5 \times 10^{6}} = 2 \times 10^{8}$

e) Finesse $F = \frac{\pi \sqrt{R}}{1 - R}$

$F = 50 \Rightarrow R = 0.94$

3. Light is incident on a pair of slits separated by 0.5 mm. The diffraction signal is observed on a screen 2 meters from the slits. Find the wavelength of light if adjacent maxima of the diffraction signal are 2.5 mm apart.



Distance from upper slit to P is

$$l_1 = \sqrt{d^2 + (z - s/2)^2} \simeq d + \frac{1}{2d}(z - s/2)^2 \quad \text{for } d \gg z - s$$

Distance from lower slit to P is

$$l_2 \simeq d + \frac{1}{2d}(z + s/2)^2$$

Path Difference $\Delta l = l_2 - l_1 = \frac{zs}{d}$

Constructive Interference occurs when $\frac{zs}{d} = m\lambda$

m = integer

Neighbouring maxima occur at

$$z_{m+1} = (m+1)\frac{\lambda d}{s} \quad \& \quad z_m = m\frac{\lambda d}{s}$$

$$\therefore \Delta z = z_{m+1} - z_m = \frac{\lambda d}{s}$$

$$\therefore \lambda = \frac{s\Delta z}{d} = \frac{0.5 \times 10^{-3} \times 2.5 \times 10^{-3}}{2} = 6.25 \times 10^{-7}\ m$$

4. What are the wavelengths of light generated when infrared light generated by a YAG laser when its frequency is a) doubled and b) tripled in a nonlinear crystal?

$\lambda_{YAG} = 1.06\ \mu m$ (infrared)

Frequency doubled is at $\frac{1.06}{2}\ \mu m = 532\ nm$ (gree

Frequency tripled is at $\frac{1.06}{3}\ \mu m = 355\ nm$ (UV)

5. See laser textbooks etc.