Michelson Interferometer
Lab Exercises

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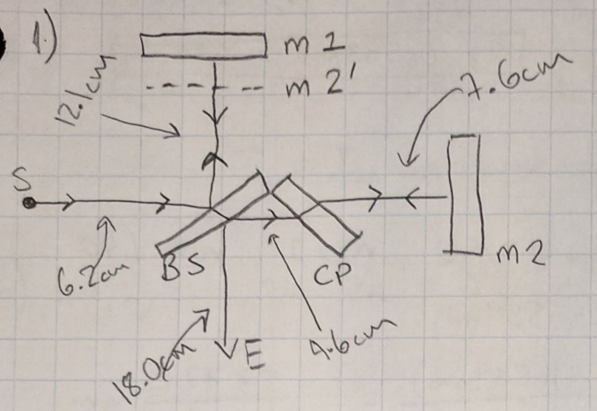
1)



2) The path difference for the light is 2d, however, looking through the eye piece the path difference is $2d\cos\theta$, if the observer looks into a system at θ. Reflections change the phase of light by $\lambda/2$, so the total path difference between the two beams is

$$\delta = \lambda/2 + 2d\cos\theta$$

So the beams will constructively interfere at:

$$m\lambda = \lambda/2 + 2d\cos\theta \qquad m = 0, 1, 2, 3 \ldots$$

And for destructive interference will occur at $\lambda/2$ away from these points:

$$\boxed{\begin{array}{lcl} \lambda/2 + 2d\cos\theta = (m + 1/2)\lambda & : & \text{destructive} \\ \lambda/2 + 2d\cos\theta = m\lambda & : & \text{constructive} \end{array}}$$

3) Light will appear constructively if the light is completely in phase, meaning the amplitude of the waves add.

Light which is out of phase (by $\lambda/2$) will interfere destructively, meaning when the amplitudes add, no light appears.

A laser emits cohered light (meaning a very short range of wavelengths). Lasers also incorporate optical amplification, which is obtained through stimulated emission.

1) shift mirror 2 by 0.233mm   shift of fringes = 792

$$\lambda = \frac{2\Delta d}{\Delta N} = \frac{2(0.233\text{ mm})}{792} = \frac{0.466\text{mm}}{792} = 0.000588\text{ mm}$$

$$\boxed{\lambda = 0.588\,\mu m = 588\,nm}$$

2)

$$n(2n_od(1-\cos\theta) - N\lambda) = n_o^2 d\sin^2\theta$$

$$2nn_od(1-\cos\theta) - n_o^2 d\sin^2\theta = Nn\lambda$$

$$d = \frac{Nn\lambda}{2nn_o(1-\cos\theta) - n_o^2\sin^2\theta}$$

$\theta = 90^\circ$, $N = 7.0$, $n_o = 1$, $n = 1.40$

$\lambda = 589\text{nm}$

$$d = \frac{7(1.40)(589\text{nm})}{2(1)(1.4)(1-0) - n_o^2(1)} = \frac{7(1.4)(589\text{nm})}{2(1.4) - 1} = \frac{5772.2}{1.8}\text{ nm}$$

$$= 3206.7\text{ nm}$$

$$\boxed{d = 3.2\,\mu m}$$

3) $\lambda = \frac{2\Delta d}{\Delta N}$ $\Delta d = \frac{\lambda\Delta N}{2}$

$$\Delta d = \frac{\lambda_1(\Delta N)}{2} \qquad \Delta d = \frac{\lambda_2(\Delta N + 1)}{2}$$

$$\frac{\lambda_1(\Delta N)}{2} = \frac{\lambda_2(\Delta N + 1)}{2}$$

$$\lambda_1\Delta N = \lambda_2 + \lambda_2\Delta N$$

$$(\lambda_1 - \lambda_2)\Delta N = \lambda_2 \qquad \Delta N = \frac{\lambda_2}{\lambda_1 - \lambda_2}$$

$$\Delta d = \frac{\lambda_1\left(\frac{\lambda_2}{\lambda_1 - \lambda_2}\right)}{2} = \frac{(589.1)(589.59)\text{nm}^2}{2(589.1 - 589.59)\text{nm}} = 354{,}415.8\text{ nm}$$

$$\boxed{\Delta d = 354\,\mu m}$$

4)

a) $$\delta = \frac{2\pi(n_2 - n_1)\cdot d}{\lambda}$$

$$\delta = \frac{2\pi(1.4-1)\cdot 2000\text{nm}}{700\text{ nm}} = \frac{2\pi(0.4)(20)}{7} = \frac{40(0.4)\pi}{7} = 2.29\pi = \boxed{412.2^\circ}$$

b) $$2.29\pi - 2\pi = 0.29 = \boxed{16^\circ}$$

5) λ $\quad x$ = movable mirror $\quad$ arms = $d_2 = d_1$ @ $x = 0$

$$A = E\cos(wt - kx)$$

$$A_1 = \frac{E}{\sqrt{2}}\cos(wt - 2kd_1 - kd_2) \qquad A_2 = \frac{E}{\sqrt{2}}\cos(wt - 2kd_2 - kd_1)$$

$$I_{.} = I_m\cos^2(k(d_1 - d_2)) = \boxed{I_m\cos^2\left(\frac{2\pi x}{\lambda}\right) = I}$$

6) $n = \frac{c}{v}$ $\qquad v = c/n = \frac{3.0\times10^8 \text{ m/s}}{1.54} = \boxed{1.9\times10^8 \text{ m/s}}$

8) Parameters of LIGO:

Arms are 4 km.
LASER emits 1064nm light
Δd (mirror displacement)
can be found within 10^{-18} m.

Parameters of LISA:

Currently, the arm lenght is proposed to be 2.5 million km.
Currently there is no definite laser wavelenghth proposed.
Δd (mirror displacement)
is estimated to be able to detect a change in 10^{-20} m.