Michelson Interferometer Lab Exercises

Patricia McMillin
Phys 465 Dr. Choudhary
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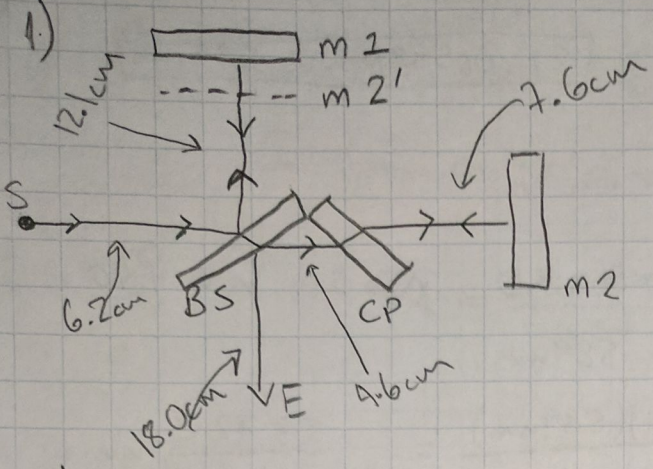
1)



2) The path difference for the light is $2d$, however, looking through the eyepiece 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:

$$\lambda/2 + 2d\cos\theta = (m + 1/2)\lambda \quad : \text{destructive}$$
$$\lambda/2 + 2d\cos\theta = m\lambda \quad : \text{constructive}$$

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 coherent light (meaning a very short range of wavelengths). Lasers also incorporate optial amplification, which is obtained through stimulated emission.

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

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

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

2)

$$n(2n_0 d(1-\cos\theta) - N\lambda) = n_0^2 d\sin^2\theta$$

$$2nn_0 d(1-\cos\theta) - n_0^2 d\sin^2\theta = Nn\lambda$$

$$d = \frac{Nn\lambda}{2nn_0(1-\cos\theta) - n_0^2\sin^2\theta}$$

$\theta = 90°$, $N = 7.0$, $n_0 = 1$, $n = 1.40$

$\lambda = 589nm$

$$d = \frac{7(1.40)(589nm)}{2(1)(1.4)(1-0) - n_0^2(1)} = \frac{7(1.4)(589nm)}{2(1.4) - 1} = \frac{5772.2}{1.8}\,nm$$

$$= 3206.7\,nm$$

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

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

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

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

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

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

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

4)

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

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

b) $2.29\pi - 2\pi = 0.29\pi = \frac{0.29(180)\pi}{\pi} = \boxed{52.2°}$

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

$A = E\cos(\omega t - kx)$

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

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

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

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 wavelength proposed.
Δd (mirror displacement)
is estimated to be able to detect a change in 10^{-20} m.