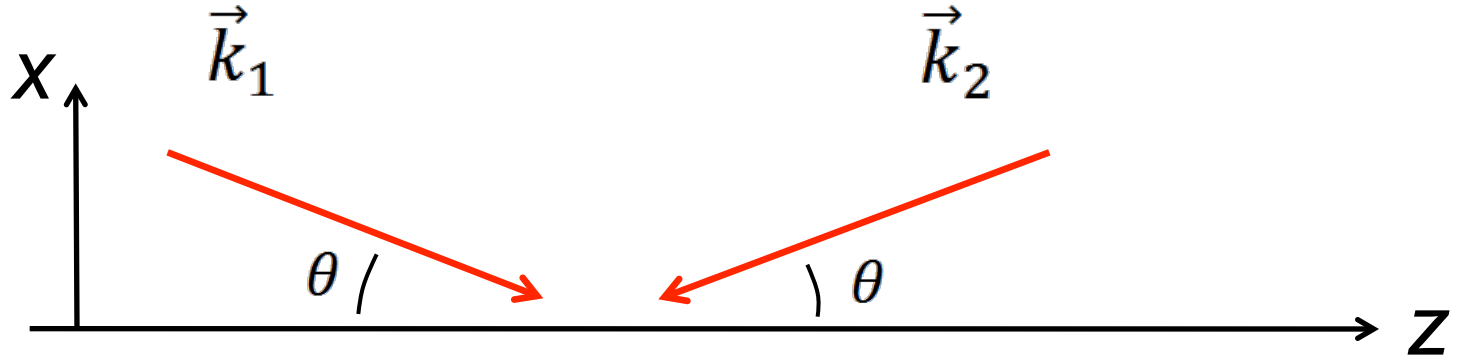
PHYS 408 Group Activities for Feb 24 2011

Please complete these exercises without opening the textbook. If you have questions talk with your group mates or raise your hand and Ellen or David will come to help

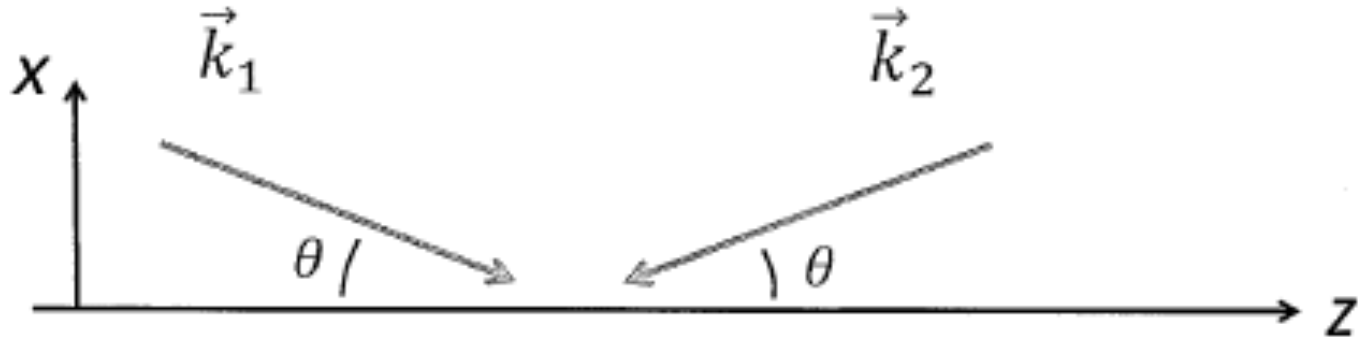
Two monochromatic plane waves $U_1(\vec{r}) = E_0 e^{i\vec{k}_1 \cdot \vec{r}}$ and $U_2(\vec{r}) = E_0 e^{i\vec{k}_2 \cdot \vec{r}}$ with same wavelength $|\vec{k}_1| = |\vec{k}_2| = |\vec{k}|$ are propagating thru space as shown below.

What is the intensity along the z-axis?



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What is the intensity along the z-axis?



Hint: the first step is to determine an expression for the fields along the z-axis

$\vec{k}_1 = k_0(\cos\theta\,\hat{z} - \sin\theta\,\hat{x})$; $\vec{k}_2 = k_0(-\cos\theta\,\hat{z} - \sin\theta\,\hat{x})$

$U_1 = E_0 e^{ik_0(\cos\theta z - \sin\theta x)}$; $U_2 = E_0 e^{-ik_0(\cos\theta z + \sin\theta x)}$

$U_T = U_1 + U_2 = E_0(e^{ik_0\cos\theta z} + e^{-ik_0\cos\theta z})$

along $\hat{z}$ axis → $x=0$

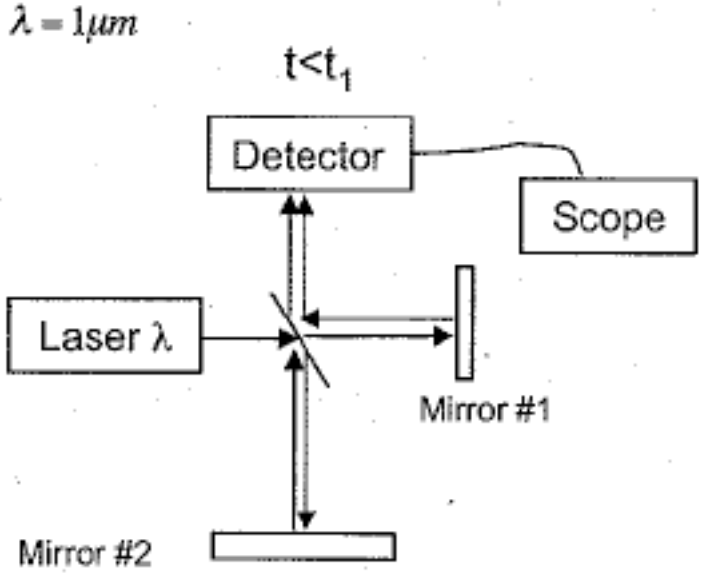
$|e^{i\phi} + e^{-i\phi}|^2 = |1 + e^{i2\phi} e^{-i2\phi}|$ $I_T = \frac{1}{2}\frac{1}{\eta}|U_T|^2 = \frac{1}{2}\frac{1}{\eta}|E_0|^2\,2\left[\cos(2k_0\cos\theta z) + 1\right] = 4I_0\cos^2(kz\cos\theta)$

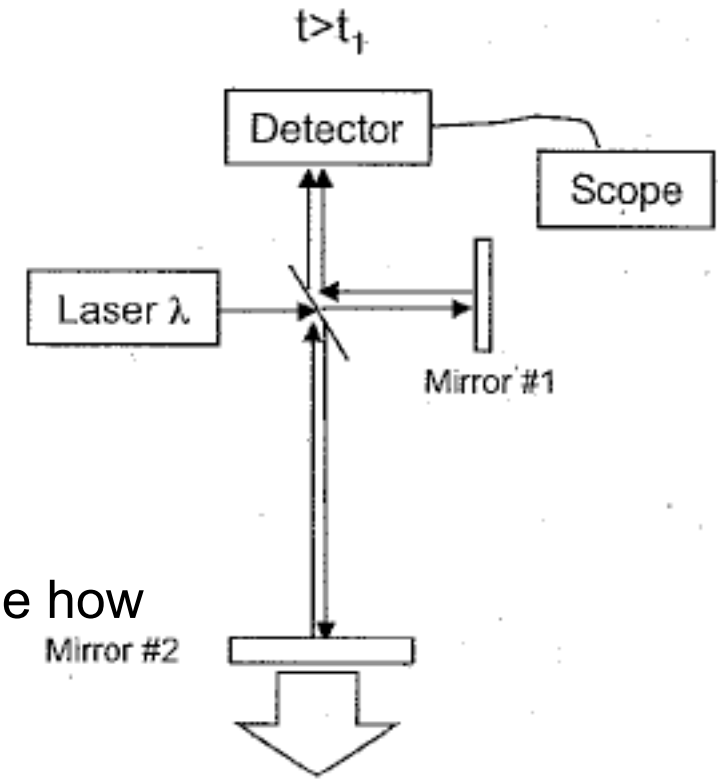
w/ $I_0 = \frac{1}{2\eta}|E_0|^2$

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You and your lab partner Billy-Bob are using the interferometer below to measure the acceleration of gravity (g). Mirror #1 is held fixed and mirror #2 is dropped at $t=t_1$ and the scope records the output of detector. The entire interferometer is located in a vacuum chamber to minimize any effects of air.

$\lambda = 1\mu m$





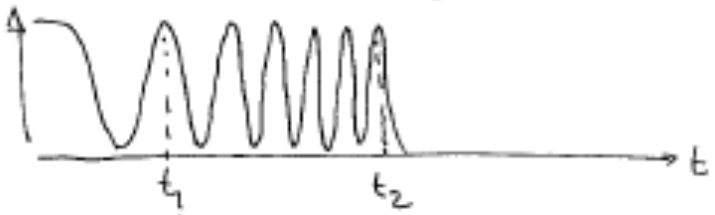
1-Qualitatively in your own words describe how this setup can measure g

2-Find an expression for g based on measurements from the scope

Bonus- An interferometer can be used as a gyroscope to measure rotation. Describe how it could work and estimate if a hand sized device could measure the rotation of the earth

1) As the mirror moves the relative phase b/w the two arms of the interferometer changes causing the intensity to oscillate as measured by detector. By figuring out how far mirror has moved as a function of time the mirror's acceleration can be determined.

2) On scope, the trace will look like



between t_2 & t_1 relative phase has change $5 \cdot 2\pi$

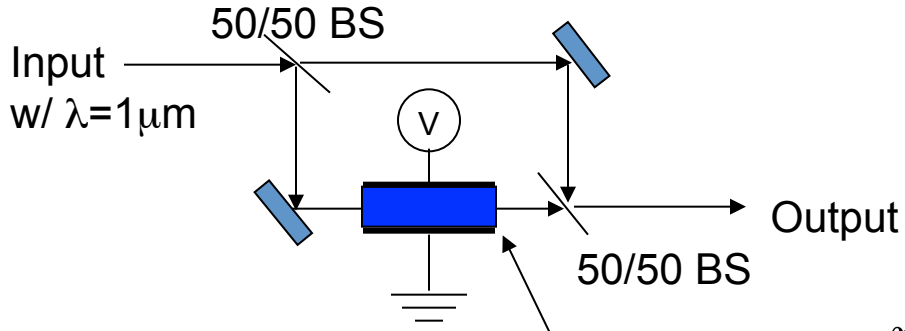
$\Rightarrow k\Delta x = 5 \cdot 2\pi$ w/ $\Delta x = \frac{1}{2} g(t_2 - t_1)^2 \cdot 2$ ← factor of 2 b/c change in distance is ~~twice~~ for Michelson

$\Rightarrow \frac{2\pi}{\lambda} g(t_2 - t_1)^2 = 5 \cdot 2\pi$

$$g = 5 \cdot \lambda \frac{1}{(t_2 - t_1)^2}$$

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Consider the interferometer below. A piece of glass whose index depends on an externally voltage applied is placed in one arm of the interferometer. In other words consider this as a simple piece of glass whose index of refraction varies with an applied voltage. Also model the input as a plane wave.



3- Such an interferometer can be used as a voltage controlled optical switch for the output light. In a few sentences and/or a few lines of math, explain the physical principles on how this device works as an optical switch.

4- How much voltage would be required to switch the output light from completely off to completely on? *(Hint: feel free to specify any missing parameters)*

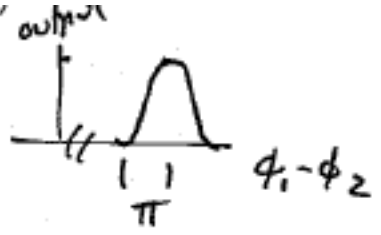
Bonus-Such interferometers are used in optical networking applications to encode electrical data on to optical waves to be transmitted along optical fibers. State of the art switches can work at speed upwards of 50 Gbit/s. What are some of the practical limits that would limit these speeds?

3-

By controling the relative phase difference b/w the two arms of the interferometer you can switch the light off (complete destructive interference) or on (complete constructive interference)

4-

we need to shift the phase by π



length of glass

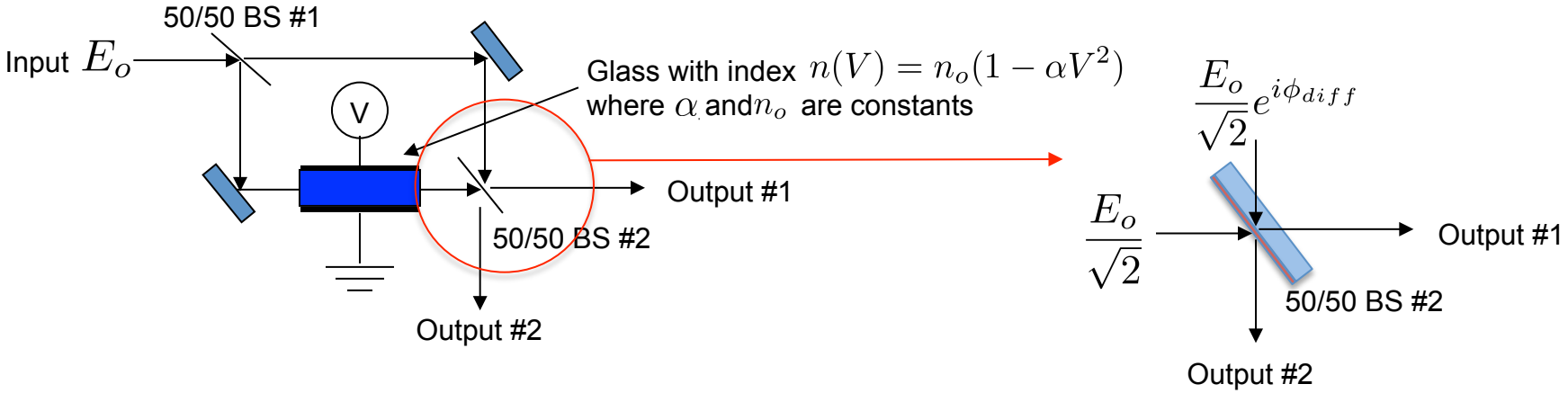
$$\Delta\phi = \pi = k_0 L \Delta n$$

$$\pi = \frac{2\pi}{10^{-6}} L \left[n_0(1 - \alpha V_1^2) - n_0(1 - \alpha V_2^2) \right]$$

$$\frac{1}{2} \cdot 10^{-6} \frac{1}{L \alpha n_0} = V_2^2 - V_1^2$$

where V_1 is the voltage when light is off & V_2 is voltage when light is on

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5-Find the total field (E_1 & E_2) and total intensity (I_1 & I_2) at Outputs #1 and #2.

6-Does total input intensity = output intensity? (it better!)…if not figure out what you did wrong…