PREWORK

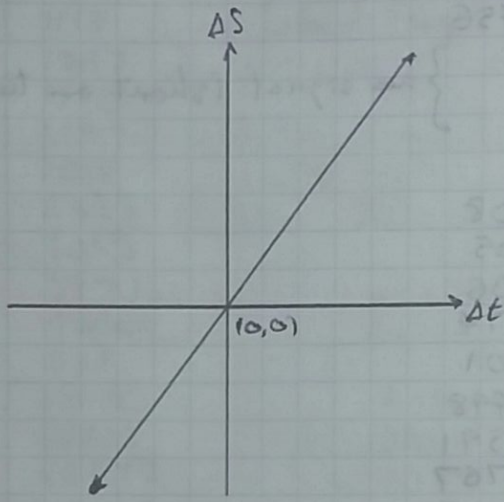
1. Given $t = S/c$ ~~and~~ and $t_k = S_k/c$,

$$S = S_k + \Delta S$$

and $$\frac{S}{c} = \frac{S_k}{c} + \Delta t \iff S = S_k + c\Delta t$$

so $\Delta S = c\Delta t$.

2.



3. If the time taken for light to travel through both configurations is equal, the optical path lengths must be equal, i.e.,

$$2(x_1 - l_m) + 2l_m n_m = 2(x_1 + \Delta x)$$

$$\iff l_m n_m - l_m = \Delta x$$

$$\iff n_m = \frac{c_a}{c_m} = \frac{\Delta x + l_m}{l_m}$$

$$\iff c_m = \frac{c_a l_m}{\Delta x + l_m}.$$

4. If the times taken are equal, then

$$\frac{2(x_1 - l_m)}{c_a} + \frac{2l_m}{c_m} = \frac{2(x_1 + \Delta x)}{c_a}$$

$$\iff 2(x_1 - l_m) + 2l_m \frac{c_a}{c_m} = 2(x_1 + \Delta x)$$

$$\iff 2(x_1 - l_m) + 2l_m n_m = 2(x_1 + \Delta x)$$

$$\Rightarrow OPL_1 = OPL_2.$$

5. It is necessary to modulate the laser so that the outgoing pulse signal can be compared to the incoming ~~e~~ pulse signal to determine the time taken for the pulses to travel through the setup.

6. Modulating the laser 1000 times slower would not change the time difference between the two signals, which is the quantity being measured. Reducing the frequency sent to the oscilloscope enlarges the time difference, making it easier to measure accurately.

7. A 1.9 m rod of titanium dioxide would cause a time difference of

$$\Delta t = \frac{2(x - l_m)}{c_a} + \frac{2l_m}{c_m} - \frac{2x}{c_a}$$

$$= \frac{2l_m}{c_m} - \frac{2l_m}{c_a}$$

$$= \frac{2l_m n}{c_a} - \frac{2l_m}{c_a}$$

$$= \frac{2l_m(n-1)}{c_a}$$

$$= \frac{2 \times 1.9\ \text{m} \times (2.6 - 1)}{3\times10^8\ \text{ms}^{-1}}$$

$$= 20.3\ \text{ns},$$

but this is longer than the period of the modulation, which is 20 ns, making it possible to mistakenly measure ~~the~~ $\Delta t = 0.3$ ns when reading off the oscilloscope screen.

It would be good to have a rough idea of the time difference beforehand to prevent such an error.

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EXPERIMENTAL PLAN

AIR

1. Put meter in $\Delta\phi$ mode and zero with mirror at zero on scale
2. Move mirror by 5cm and measure Δt using cursors on oscilloscope.
3. Repeat, moving down scale.

Errors:
- Distance: resolution of scale
- Time: resolution of oscilloscope scale
- Time: fluctuation of signal and difficulty in aligning cursor

Find c by plotting Δs on y-axis and Δt on x-axis - ~~gradient of best fit line~~ linear fit gives speed of light with uncertainty.

ACRYLIC / WATER

1. Fix initial reflector position, insert rod and zero meter.
2. Remove rod and move reflector until phase difference returns to zero. Note position.
3. Change initial position by 5cm and repeat.

Errors: same as for air, and also
- Uncertainty in length of rod
- Inhomogeneity of material in rod
- Path length changes due to refraction by ends that are not perfectly perpendicular to beam

Each repetition of step 2 gives a value of c: average these to get a representative value. Uncertainty is the standard deviation of the values or the average of the individual uncertainties, whichever is larger.

The refractive index of air is 1.000293, so unless the speed in the material is known to 5 or more significant figures, it is reasonable to approximate $n_{air} = 1$.

Idea: repeat experiment with apparatus at 90° to demonstrate independence of c on direction.