Wavemeter

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1 General Setup

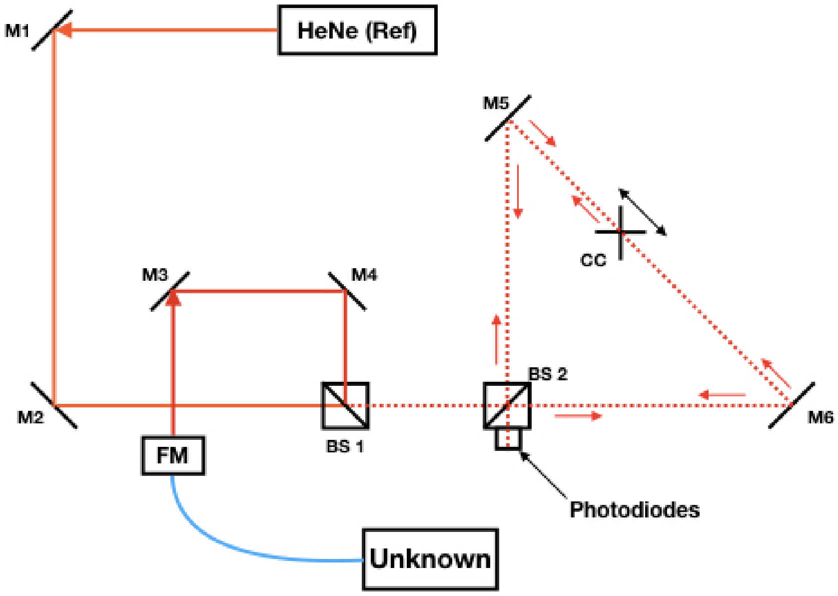

Figure 1:

Mirrors M1 and M2 are to set the height of the HeNe beam while mirrors M3 and M4 are to set the height of the unknown laser beam coming from the fiber mount. The HeNe should be set to a height of 85.5 mm and the unknown beam should be set to 76.5 mm. These heights are just the positions of the photodiodes from the surface of the breadboard. After the first beamsplitter, BS1, the HeNe and unknown beams should be horizontally aligned over one another and just displaced by their height separation.

The beams then go through a second beamsplitter, BS2. One leg reflects from mirror M5 to the cornercube and the other leg reflects from M6 to the cornercube. After reflecting from the cornercube, the HeNe and unknown beam on both legs flip height positions but are not displaced horizontally, i.e. the beams should ideally hit the cornercube on a vertical line that goes through center corner of the cornercube so that the return beam is only displaced vertically from the incoming beam. In both legs of the interferometer, the return beam for the HeNe should be at 76.5mm and overlapping the unknown beam en route to the cornercube, while the return beam for the unknown laser should be at 85.5mm and overlapping the HeNe beam en route to the cornercube.

The return beams from both legs meet up at the photodiodes so that the unknown beam interferes at the top photodiode and the HeNe beam interferes at the bottom photodiode. When properly aligned, the light at the photodiodes should oscillate between light and dark as the cart is moved. The interference fringes are counted by amplifying the oscillating signals at the photodiodes and counting these fringes. Having counted the fringes over one pass of the cart, the unknown wavelength can be determined by

$$\lambda_U = \frac{N_U}{N_{HN}} \lambda_{HN}$$

where N_U and N_{HN} are the number of fringes counted for the unknown and HeNe beams respectively.

1.1 Beam Alignment

At beam splitter 1, the HeNe beam should be set to a height of 85.5 mm and the unknown beam should be set to a height of 76.5 mm. The beams should be horizontally aligned and propagating as parallel as possible after the beam splitter. Then the beams need to be aligned with the corner cube and mirrors M5 and M6 to get interference fringes at the phototdiodes. Start by removing the corner cube cart so that the beams can propagate from M6 to M5 and vice versa. Use M5 and M6 to align the counter propagating HeNe beams so that they overlap across the entire loop formed by not having the corner cube cart in place. If I remember right, it's easiest to do this by just using M5 to align the beams on the right side of BS 2 (using the figure above) and using M6 to align the beams on the top side of BS 2 and doing this iteratively. If the HeNe and unknown beams were aligned parallel after BS 1, then this procedure should also lead to the unknown beams perfectly overlapping in the loop.

Once the beams are overlapping as best as possible, then the cornercube needs to be aligned into place. Reminder, the vertical positions of the return beams after the cornercube will be flipped with respect to the beams before reflecting from the cornercube. Then without adjusting M5 and M6, try to position the cornercube by hand so that it (1) runs parallel to the beam paths and (2) so that the beams hit the cornercube at positions that are displaced only vertically from the center of the cornercube. The first point is important so that the positions of the beams at the photodiodes do not oscillate as the cart is driven. The second point is important because the return HeNe beams should overlap the incoming unknown beams (and vice versa) as best as possible. If the cornercube is not centered on the beam paths, then the return beams will be displaced horizontally and the overlap will not happen. This is also why you should try not to use mirrors M5 and M6 to align the beams parallel and center with the cart.

After this, you should be able to see interference (a kind of flickering) at the photodiodes where the beams meet up as the cart is moved slowly (the fringes will probably be too fast to see as the cart is moving, but there should be some flickering immediatly after the cart is moved due to small vibrations). To check this, just take out the gray metal thing that holds the photodiodes into the beamsplitter so you can see the interference of the beams.

If you're able to see interference by eye but can't see fringes at the output of the square wave circuit, it could be that the beams aren't hitting the photodiodes very well. For this you could check two things. (1) At the photodiodes, the HeNe and unknown beams should still be horizontally aligned. If they are not, then this probably means that they weren't horizontally aligned well enough at BS 1. You can try to correct for this by adjusting M3 and M4 or M1 and M2, but you shouldn't need to change both pairs. (2) At the photodiodes, the beams should also not oscillate as the cart is moved (or the oscillation should be at most barely visible). If this is not the case you could try adjusting mirrors M5 or M6 (whichever one looks like it is oscillating more) just a little bit. But remember, this will change the return beams after reflecting from the CC from that of the beams before hitting the CC (essentially undoing what you did when you overlapped the beams with the cart removed) so don't change these very much, or just start the alignment process over.

2 Main Circuit Box

On the main circuit box, there should be three "ports" for input and output from the box. One port (call it port 1) is the input from the photodiodes which should be connected to 2 green and 2 red wires inside the box. Another port (port 2) is the output of the start/stop signal and square wave signals to be sent to the microcontroller. This port should be connect to 1 orange wire (output for unknown square wave signal), 1 yellow wire (output for HeNe square wave), 1 red wire (start stop signal), and 1 green wire (I think its green) connected to microcontroller ground.

The last port (port 3) is input to process the start/stop signal which should connect to 1 yellow, 1 purple, 1 green, and 1 orange wire

2.1 Square Wave Circuit

The photodiodes for the reference HeNe and the unknown laser connect to port 1 on the circuit box. Each photodiode has one connection connected to ground in the circuit box and one connection that sends the photodiode signals to separate op amps. Both photodiodes should have a black wire and a green wire. For the top (unknown beam) photodiode, the green wire should be connected to another green wire at port 1 (inside the circuit box) connecting it to ground. The black wire for the top photodiode should be connected to a red wire at port 1, sending the signal to an opamp. For the bottom (HeNe beam) photodiode, the black wire should be connected to a green wire at port 1 connecting it to ground. The green wire for the bottom photodiode should be connected to a red wire at port 1 sending the signal to a separate op amp.

The layout of the square wave circuits for the HeNe and unknown beams are nearly identical. Each op amp chip has an A op amp and a B op amp. The photodiode signal is first amplified by the A op amp. The output of the first op amp is then sent through an RC high pass filter to zero DC offset on the signal. The signal is then sent through an RC low pass filter to eliminate as much noise as possible while still maintaining the oscillating signal from the fringes. The signal is then sent through the inverting input (-) on the B op amp with the non-inverting input (+) connected to ground with no feedback. This essentially forms a comparator and produces a square wave signal from -3V to +3V. This output is then sent through a resistor and a Zener diode connected to ground (not sure what this circuit combo is called) to eliminate the negative voltage. The final output is a 0-3V square wave between the resistor and the diode. Inside the circuit box (at port 2), the wire for the HeNe output signal is yellow and the wire for the unknown laser signal is orange. The supply voltages for the op amps in the square wave circuit is $V^+ = 3.6$V and $V^- = -3.3$V.

2.2 Start/stop detector and circuit

The start/stop detector (SSD) (product number EE-SV3) is located along the edge of the disk that pushes the retroreflector cart. The SSD signals to start counting fringes when the notches in the side of the disk change from open to blocking the detector. When the detector is blocked by the disk, the output of the SSD (pin E) is 0 volts. When the detector is unblocked, the output is a positive voltage that is amplified to +3 volts by an op-amp in the circuit box. This amplified signal is sent through a red wire to port 2. This signal is then sent to the microcontroller. The transition from 0 volts to +3 volts triggers an interrupt on the microcontroller to start counting fringes. The SSD pin connections and op-amp circuit are shown in the circuit diagram titled start_stop. The color of the wires connected to the SSD are not the same as the colors of the connections inside the circuit box at port 3. For example, the A pin on the SSD is connected to a red wire. The red wire is then connected to a yellow wire inside the main circuit box at port 3. These color changes are indicated in the circuit diagram.

3 TI Launchpad Microcontroller

The connections from the main circuit box to the microcontroller are:

$$\begin{aligned} \text{Unkown square wave} &\rightarrow \text{P1.3} \\ \text{HeNe square wave} &\rightarrow \text{P1.5} \\ \text{Start/stop signal} &\rightarrow \text{P1.6} \end{aligned}$$

The code for the microcontroller is run from the Code Composer Studio IDE. Currently, the program only works by starting the program in debug mode and then stopping the program to view the variables. The project is called 2counters which contains the main.c file for running the program.

4 Cart Motor

The motor that moves the corner cubes was recycled from the EXFO wavemeter. The connections are shown below:

brown	$-V_s \approx 6.5$V
blue	$+V_s \approx 11$V
green	ground
all other connections	unknown/unneeded

There is a small circuit box dedicated to changing the cart supply voltages by two separate potentiometers. The cart seems to change the voltages quite a bit once it is connected, therefore, the voltages listed above are for before the wires are connected to the cart. The voltage levels listed here are just approximate levels at which the cart moves smoothly. Once the cart is connected and moving, the levels can be adjusted so that the cart moves at the slowest possible speed without jitter or stopping. This is important because it seemed like the op amps in the square wave circuit did not work properly when the cart moved too fast. It is difficult to find the sweet spot so that the cart moves smoothly yet slow enough that the square waves are generated properly. But it can be done.

5 Other Details

5.1 Things that need to be done yet

The program I wrote for the microcontroller currently only works in debug mode in the Code Composer Studio IDE. So in order to make a measurement, you have to start the program in debug mode while it keeps track of the variable, then stop the program in order to view the values of the variables. So one big thing that needs to be done yet is to find a way to get the program to display the wavelength each time it runs through the while loop.

Another thing to do would be getting the program to work on a laptop. Or find some other way so that everything is contained on the cart so that the wavemeter can be moved around the lab.

Another small thing to do is to find a better way of connecting the outputs from the circuit box to the inputs pins on the microcontroller. When I left, I was using alligator clips for the connections.

5.2 Weird things

The optical breadboard needs to be grounded, otherwise the square wave outputs acquire some weird oscillations. I never figured out exactly why, but if I remember correctly, I think it has something to do with the power supply to the HeNe laser.

Another weird thing has to do with the wires connecting the outputs from the circuit box to the microcontroller pins. I initially had a very long cord (15ft) which connected to the wires inside the circuit box through a hex panel connector. The square wave signals straight from the circuit box were good when the long cord wasn't connected. Then when I connected the long cord, the signal was lost in some large oscillations. I first thought it had something to do with the hex connector so I soldered the wires in the cord to the respective wires inside the circuit box. This didn't help at all. I then cut the long cord down to about 3-4 feet and the signal looked perfect. Having to deal with a short cord shouldn't be a problem if the setup can be arranged to be completely contained on the cart.

6 Manuals

In the microcontroller code I reference a few manuals for where to find information relevant to specific lines of code. Manual A Seems good for info on how to set timer registers. Manual B is good for how to configure the pins for the particular settings. Manual C is more device specific and doesn't seem quite as helpful but might have something of use that I overlooked