2017-09-11 - Introductory Lecture

Lab computer creds

- Basic student:modernphysicslab

2017-09-18

EM Boundary Conditions - Lab Journal

Links

- Lab Manual (https://raw.githubusercontent.com/JonNRb/physics506/master/fresnel.pdf)
- Supplementary Material (https://raw.githubusercontent.com/JonNRb/physics506/master/fresnel.supp.pdf)

Agenda

- Get prelab questions checked.
  - Done
- Set up equipment / get familiar with equipment.
  - Nope
- Take initial measurements.
  - Nope

2017-09-20

EM Boundary Conditions - Lab Journal

Agenda

- Set up equipment / get familiar with equipment.
- Take initial measurements.

Diagram

Setting up the PASCO initially

- Looks like components are in the right order (on the line).
- Checked magnetic stage so the white lines line up.
- Aligned the laser using the screws.
- Moved things on the rails focused the laser better.
    - Positions on rails LTR `[36.5cm, 14cm, 1m]`
    - Semicircle was in the way
    - Also, position of polarizer doesn't seem to matter much.
    - New positions of lens: `37.5cm`
- OK, so there are dispersion losses: this doesn't really matter since the sample will always be present in all measurements **CHECK THIS LATER**

Procedure Part 1: ***Initial Observation***

Eyeballed not-that-special angles

- Reflection at `°`
- Sample tilted so incident is `50°`
- Transmitted at `Δ`

2017-09-25

EM Boundary Conditions - Lab Journal

Agenda

- Set up equipment / get familiar with equipment.
- Take rest of measurements.

General

- All angles measured are ±0.5°

Procedure Part 1: ***Initial Observation***

Brewster's angle estimation

- Laser polarization: 160°
    - We eyeballed the maximum laser intensity when changing the polarization. This should be the polarization of the incident beam.
    - When set up with the polarizer, we can set the absolute polarization of the beam incident with the sample. We shouldn't be losing too much power using the polarizer.
- Plastic sample

Polarization Angle	Incident Angle	Reflected Angle	Reflected Power	Transmitted Angle	Transmitted Power
90°	36°	76°	400 nW	16°	32 µW
0°	36°	76°	31.8 µW	16°	465 µW

- Plastic sample

Polarization Angle	Incident Angle	Reflected Angle	Reflected Power	Transmitted Angle	Transmitted Power
0°	39°	77°	22.4 µW	16°	215 µW

Polarization Angle	Incident Angle	Reflected Angle	Reflected Power	Transmitted Angle	Transmitted Power
90°	39°	77°	464 nW	16°	15.5 μW

Critical angle estimation

- Plastic sample
  - 256 nW energy of transmitted beam (at 28°), 1.89 μW of reflected beam (86°)
  - (Polarization shouldn't change the ratio between reflected and transmitted energies)

Procedure Part 2: ***Snell's Law***

- We're collecting:
  - For each (sample, interface) pair,
    - Transmitted angle
    - Incident angle
    - Transmitted energy
    - Incident energy
- Glass to air interface (has measurement errors DO NOT USE)
  - 40° incident angle, 13.4 μW, 29° transmitted angle
  - 35° incident angle, 15.6 μW, 21° transmitted angle
  - 30° incident angle, 18.5 μW, 15° transmitted angle
  - 25° incident angle, 16.4 μW, 12° transmitted angle
  - 15° incident angle, 15.6 μW, 5° transmitted angle
- Air to glass interface

Incident Angle	Transmitted Power	Transmitted Angle
15°	22.5 μW	6°
25°	---- μW	10°
35°	---- μW	14°
40°	---- μW	16°
45°	21.5 μW	9°

2017-09-25

EM Boundary Conditions - Lab Journal

Agenda

- Take rest of measurements.

General

- Had to replace batteries for FieldMaster power measuring device.
- Took new measurements for Snell's Law part. Our original measurements seemed to give bad predictions of `n_1 / n_2`; the ratios for each measurement were quite varied.
- Recalibrated the laser:
  - Laser at `1.0 cm` (did not move)
  - Lens at `27.2 cm`
  - Polarizer at `14.4 cm`
  - Polarizer set to `162°` (measured at little bottom nub thing)

Procedure Part 2: ***Snell's Law***

Glass to air interface

Incident Angle	Transmitted Angle
28°	43°
22°	32°
20°	30°
25°	36°
15°	22°

Plastic to air interface

Incident Angle	Transmitted Angle
15°	23°
20°	29°
21°	31°
30°	48°
25°	40°

<(~.~<) 10/10 PHIL

2017-10-03

EM Boundary Conditions - Lab Journal

Agenda

- Take rest of measurements.

General

- Came in to the lab to finish collecting data.

Procedure Part 3: ***Brewster's Angle***

- Prediction: based on *Part 2*, our Brewster's angle should be at around `55.1°`
- Need to measure
    - Incident
    - Incident power
    - Reflected
    - Transmitted
    - Power reflected
    - Power transmitted
- Incident power (p polarization): `39.6 µW`
- Incident power (s polarization): `593 µW`
- Incident power (maximum): `615 µW`
- Air to glass (s polarization)

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
25°	24.5 µW	16°	254 µW
30°	27.2 µW	20°	259 µW
35°	31.1 µW	23°	250 µW

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
40°	38.0 µW	24°	246 µW
45°	44.7 µW	28°	245 µW
50°	57.1 µW	30°	246 µW
55°	72.0 µW	33°	232 µW
55°	72.0 µW	33°	232 µW
60°	93.5 µW	34°	221 µW
65°	127 µW	36°	212 µW
70°	168 µW	38°	159 µW

- Air to glass (p polarization)

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
25°	750 nW	15°	16.3 µW
30°	577 µW	19°	16.4 µW
35°	604 nW	23°	17.0 µW
40°	486 nW	24°	17.0 µW
45°	328 µW	28°	17.1 µW
50°	217 nW	30°	17.2 µW
55°	75 nW	33°	17.2 µW
60°	76 nW	33°	17.2 µW
53°	68 nW	34°	17.2 µW
58°	68 nW	36°	17.2 µW
57°	72 nW	38°	17.2 µW

- Air to Plastic (p polarization)

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
25°	1.00 µW	19°	35.3 µW

2017-10-04

Agenda

- Get familiar with equipment
- Finish measurements from last lab
- Turn in pre-lab

General

- Do not do Hysteresis Curve
    - Luke said it was a waste of time and the Hall Probe is easier to use

The Zeeman Effect - Lab Journal

Procedure Part 1: ***Hysteresis Curve***

- Nope

EM Boundary Conditions - Lab Journal

Procedure Part 3: ***Brewster's Angle***

- Air to Plastic (s polarization)

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
25°	24.5 μW	17°	480 μW
30°	27.7 μW	21°	468 μW
35°	31.9 μW	23°	467 μW
40°	39.2 μW	26°	464 μW
45°	47.5 μW	28°	451 μW

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
50°	60.0 µW	31°	430 µW
55°	75.2 µW	33°	418 µW
57°	83.3 µW	33°	410 µW
60°	97.1 µW	34°	390 µW
65°	127 µW	37°	355 µW

Procedure Part 4: ***Critical Angle and Total Internal Reflection***

- Glass to Air (s polarization)

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
25°	6.84 µW	40°	232 µW
29°	2.32 µW	45°	225 µW
30°	7.67 µW	48°	218 µW
32°	12.3 µW	54°	212 µW
34°	14.3 µW	57°	186 µW
35°	17.8 µW	61°	191 µW
37°	22.5 µW	67°	142 µW
40°	41.7 µW	80°	80.6 µW
41°	91.7 µW	77°	1.18 µW
45°	64.8 µW	gone	gone

- Glass to Air (p polarization)

Incident Angle	Reflected Power	Transmitted Angle	Transmitted Power
25°	63 nW	37°	16.3 µW
29°	63 nW	45°	16 µW
30°	63 nW	49°	16 µW
32°	63 nW	51°	15.9 µW

2017-10-09

The Zeeman Effect - Lab Journal

Agenda

- Try doing Hysteresis curve

General

What the hysteresis curve should look like:

Part 1: ***Establish a Hysteresis Curve***

We're taking a bunch of data points at 1 Ampere intervals to establish our Hysteresis curve. We are going to increase the current up to +8 Amperes then bring it down to 0 A, turn off the power, and repeat several times.

Data Point	Current	Field Strength
1	1 A	0.239 T
2	2 A	0.417 T
3	3 A	0.566 T
4	4 A	0.755 T
5	5 A	0.902 T
6	6 A	1.015 T
7	7 A	1.211 T
8	8 A	1.256 T

2017-10-11

The Zeeman Effect - Lab Journal

General

- Was late. I missed:
    - Putting in the mercury tube
    - Other setup
- Set up polarizing filter to 114°
    - Phil says this may not be necessarily right
    - "All relative to the fiber optic feed going into the SPEX" Phil says
    - "You may have to adjust the angle if your data is lumpy" Phil says

Part 2: ***Equipment Setup***

Followed the instructions.

Part 3: ***No Magnetic Field***

Centered the Polaroid to 114°. Recorded the 404.7 nm line using a narrow sweep range. Data was garbage.

Opened the aperture. Ahh now we're cookin!

2017-10-17

The Zeeman Effect - Lab Journal

General

- Zero fields, set polarizer to 114°
- Lab is incorrectly labeled: sigma splits, pi does not. This just affects our labeling thankfully.
- Increment 0.0005 nm
- Integration Time 0.5 s

Hg spectrum

Measurement	Current	Field Strength
1	10A	1.295 T

2A data utterly pointless (<-- pun)

- Range for 435.8 line: (436.15, 436.4)
- Range for 546.1 line: (546.48, 546.58)

Ne spectrum

- Range for 585.3 line (585.6, 585.8)

5 A, 4 A, 3 A

2017-10-18 ***X-Ray Prelab***

Jon Betti

1

X-Rays are photons on the order of `0.01 nm` – `10 nm`. This is small enough to probe crystalline structures of materials. The X-rays are produced by a beam of electrons accelerated over 30 kV into a water-cooled copper target (inside the Rigaku Miniflex).

2

Bremsstrahlung is used because there is a continuous distribution of wavelengths, which allows probing a distribution of wavelengths, unlike *K-shell* emission, which is good for specific wavelengths.

3

Bragg's Law describes how incident photons reflect constructively at certain frequencies as they interact with the electron clouds of atoms on the surface of a crystal and the lower layers. Bragg's Law gives the condition of this scattering: twice the interplanar distance times the sine of the incident angle must be an integer multiple of the wavelength (`2d sin(a) = n lambda`).

Because our sample is powdered such that there are many differently oriented crystallites, the beam will be incident at many angles. This ensures there are some crystallites for which there will be Bragg scattering.

4

The Miller indices essentially give coordinates of diffraction plane relative to the standard orientation of crystalline structure. The inverse of the distance multiplied by the crystal size gives the correct spacing of the planes for Bragg scattering.

5

`s = h^2 + k^2 + l^2`	Simple Cubic	BCC	FCC	FCC-diamond

`s = h^2 + k^2 + l^2`	Simple Cubic	BCC	FCC	FCC-diamond
1	100			
2	110	110		
3	111		111	111
4	200	200		200
5	210			
6	211	211		
7				
8	220	220	220	220
9	300, 221			
10	310	310		310
11	311		311	311
12	222	222	222	

source (appendix 6) (https://www.physics.rutgers.edu/grad/506/xrays/appendix-x-rays.pdf)

6

X-Rays interact with one another and interfere destructively.

7

As the sample is warmed, the crystal will expand (causing `a` to increase), causing the spectrum to contract.

2017-10-23

X-Ray Diffraction Lab

- Got rings
- Set up machine
- Recorded diffraction pattern for Si over full range at 2°/min

2017-10-25

X-Ray Diffraction Lab

Tried diffraction pattern of full range for copper. Data was noisy.

Took out copper sample. We thought the sample may be too low in the holder so we readjusted the positioning with some tape. Tried again. Still noisy?

2017-10-25

X-Ray Diffraction Lab

Took diffraction pattern for nickel from 160° to 0°. We have peaks in the expected places. Took data at specific different parts of the spectrum and saved data.

2017-11-06 ***Speed of Light Prelab***

1

- The ***Half-Wave Plate*** lets the incident beam pass through, but shifts its polarization vector by an angle. The angle can be adjusted by rotating the plate. We use this to adjust the beam incident to the ***Beamsplitter*** to adjust the amplitude ratio of the signal and reference beams (the signal attenuates on its path).
- The ***AOM*** is a device that has a medium whose index of refraction can be varied using an electrical signal. We use this to modulate the amplitude of the light beam.
- The ***Cube Beamsplitter*** is made of two triangular prisms the splits an incident beam into two beams with orthogonal polarizations.
- The ***Time Interval Counter*** measures signals on time intervals with 25ps accuracy. We need this to analyze our signals which will differ on a very small time scale.

2

The speed of light is about 300,000 km/s. If the Earth moved through the aether at 30 km/s, we would need to detect differences in the speed of light by 0.0001 c to demonstrate the existence of the aether.

3

Our electronic measurement tools are extremely accurate. The ***Time Interval Counter*** measures on the picosecond scale, which is sufficiently accurate to measure the amplitude shift in light bouncing off a ΔL of 1m. The largest source of error will be our distance measurements. Assuming we can measure Δt with perfect accuracy, if there was 4mm of total ΔL error we would be within 0.0001 c for a 40 m run. This is sufficiently accurate to detect the aether.

4

We're analyzing AM waves, so the finite wavelength of light is important in that respect. Also, some of our equipment is specialized for the red light our laser uses since it relies on optical principles that depend on the wavelength. Visible light is on the order of THz frequency and the AM waves we are producing are on the MHz order, so we shouldn't have any issue with poor sampling of the AM waves like we would if the wave frequency was closer to the AM frequency.

2017-11-06

The Speed of Light Lab

- Did prelab and talked with group about lab
- Tried to measure delta L with a measuring tape, but encountered difficulty
- Measured delta L with Bosch laser
    - Eva and Phil brought up circular logic but I think a black-box argument is consistent

2017-11-08

The Speed of Light Lab

Goal for today: get signal and reference beams on the oscilloscope

- Turned on laser system (AOM, laser, detectors) and focused beam
- Turned on function generator and set a 1Hz sine wave
- Filtered out 1st order beam with an index card at the half-wave plate
- Got parallel beam from beam splitter into the reference detector
- Got perpendicular beam from beam splitter to first mirror
- Moved mirrors to get the signal beam into its detector
- We're not seeing anything on the oscilloscope
- Moved frquency to MHz scale and now we see the reference beam
- Recalibrated half-wave plate and now we get two signals. They're really noisy.

2017-11-10

Collecting X-Ray spectroscopy data from Unknown #1

- Sweept from 105° to 35° at 2°/min

2017-11-08

The Speed of Light Lab

Goal: remove noise and measure `c` with the oscilloscope

- Our mirrors must have been moved. We had to readjust them all over again and filter the AOM output again
- The detectors weren't ON. Turning them on removed the noise.
- Recalibrated half-wave plate to get equal amplitudes on the oscilloscope ~400 mV
- Measured out of phase frequency: 4.13 MHz
- Measured in phase frequency: 8.82 MHz

2017-11-15

The Speed of Light Lab

- Set up SRS and took measurements

Phase (degrees)	Frequency (MHz)	Jitter
−1.105	8.505	5.11
−1.756	8.503	4.71
−1.411	8.509	4.87
0.552	8.513	5.23
−14.091	8.2	5.94
−25.231	7.9	8.14
15.67	8.8	4.74
−42.676	7.6	3.74
−57.774	7.3	4.03
−77.319	6.9	3.56

Phase (degrees)	Frequency (MHz)	Jitter
60.293	1.5	2.00
73.318	1.8	0.878
86.090	2.1	3.06
101.420	2.4	1.25
116.294	2.7	1.62
132.649	3.0	1.4
149.336	3.3	17.7

Phase (degrees)	Frequency (MHz)	Jitter
47.664	1.2	2.91
34.593	0.9	0.748
21.651	0.6	0.75

Phase (degrees)	Frequency (MHz)	Jitter
−161.204	4	3.43
−150.177	4.3	4.51
−146.632	4.6	4.24
−151.694	4.9	3.91
−135.101	5.2	3.5
−126.326	5.5	3.25
−113.784	5.8	2.62
−102.991	6.1	2.59
−91.871	6.4	2.48
−78.844	6.7	2.55

Phase (degrees)	Frequency (MHz)	Jitter
−146.144	4.9	10.3
−137.922	5.2	8.94
−140.186	5.5	11.6
−129.850	5.8	6.45
−115.058	6.1	5.65
−103.23	6.4	5.34
−93.905	6.7	7.05