Physics 210 Lab 5B: A Thrifty Determination of the Wavelength of a Laser

Andrew Rippy,* Caleb Powell, Will Lillis, Joey Forchetti, and Dr. J. Brown
Department of Physics, Wabash College, Crawfordsville, IN 47933
(Dated: May 2nd, 2020)

In this report, we describe the measurement of the "wavelength of a laser on the cheap." We found that our laser had a wavelength of 634.6 nm, which falls reasonable close to the 632.8 nm wavelength typical of helium-neon lasers.

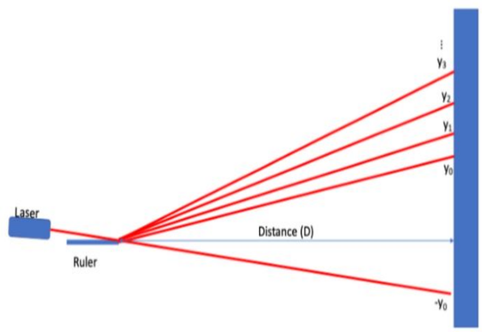

FIG. 1. A Laser refracting off the machinist's ruler

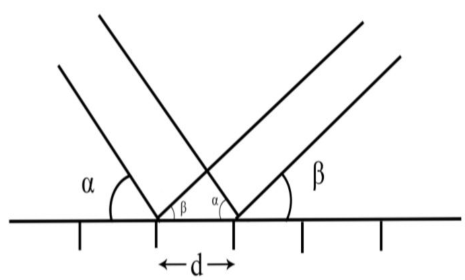

FIG. 2. A diagram of the refracting laser, where α is the angle of indicence, and β is the angler of a refracted beam.

I. INTRODUCTION

The measurement was carried out by directing a laser at a mcahinist's ruler at a small grazing angle, α. The beam refracts at several angles, β_n, which we can use to determine the wavelength of the laser.

II. THEORETICAL MODEL

Using the figures below, we can construct a model to determine the laser's wavelength.

The first order refracted beam has the same angle as the angle of incidence, α of the laser. Thus, we have:

$$\alpha = \beta_0 \tag{1}$$

Moreover, since the incident angle is kept very small, we can use the small angle approximation $\sin(\alpha) \approx \alpha$. This gives us now:

$$\alpha \approx \sin(\beta_0) = \frac{y_0}{l} \tag{2}$$

Using Fig. 1, we see the triangle formed between the wall from the distance to the ruler, k, the height of the beam, y_0, and the β_0 laser length, l, we can write:

$$\cos(\beta_0) = \frac{k}{l} \tag{3}$$

which can be further rewritten to be:

$$l = \frac{k}{\cos(\beta_0)} \tag{4}$$

Thus, we now have that:

$$\alpha = \frac{y_0 \cos(\beta_0)}{k} \tag{5}$$

Since we know β_0 is sufficiently small due to α being sufficiently small, using the small angle approximation, we have that $\cos(\beta_0) \approx 1$, thus we now have:

$$\alpha = \frac{y_0}{k} \tag{6}$$

From Fig. 1, we also note that:

$$\beta_n = \tan^{-1}(\frac{y_i}{k}) \tag{7}$$

Using Fig. 2, we find the difference in the width of the wave-fronts to be:

$$S_0 - S_n = n\lambda = d(\cos(\alpha) - \cos(\beta_i)) \tag{8}$$

for the n refracted beams, where $d = 0.5$ mm is the length between the ruler lines.

III. EXPERIMENT

A. Procedure

1. Place the ruler on a flat surface, such that it is far ($> 5m$) from a wall, and perpendicular to that wall.
2. Measure said far distance from the ruler to the wall (k)

3. Direct the laser beam at a sufficiently small angle α at the ruler.

4. Measure the "height" of the various refracted maxima on the wall, using the height of the ruler as $y = 0$.

5. Calculate the angle α according to Eq. 6, each β_n according to Eq. 7, and the corresponding calculated wavelength λ according to Eq. 8.

B. Data

*See end of Report

Taking the average of all calculated laser wavelengths, we found:

$$\lambda = 634.7 \text{ nm}$$

Since uncertainties were not provided for several parameters, we did not calculate the uncertainty for λ

IV. CONCLUSION

We found the wavelength of the laser to be 634.7 nm. This matches closely with the expected wavelength of around 632.8 nm for helium neon lasers. This experiment could be improved further by including error propagation, running more trials, and further varying the distance k between the ruler and the wall.

ACKNOWLEDGEMENTS

I acknowledge the support of the Wabash College Physics Department and Professor Brown's benevolence in these crazy times.

* anrippy22@wabash.edu

TABLE I. Trial 1, $k_1 = 5.68$m, $\alpha_1 = 0.031$, $d = 0.0005$m

y (m)	n	β (deg)	λ (m)
0.18	0	0.031	-
0.23	1	0.06	6.34×10^{-7}
0.44	2	0.078	6.35×10^{-7}
0.53	3	0.093	6.36×10^{-7}
0.60	4	0.11	6.36×10^{-7}
0.67	5	0.12	6.37×10^{-7}
0.73	6	0.13	6.36×10^{-7}
0.78	7	0.14	6.36×10^{-7}
0.84	8	0.15	6.38×10^{-7}
0.89	9	0.16	6.40×10^{-7}
0.93	10	0.16	6.39×10^{-7}
0.98	11	0.17	6.38×10^{-7}
1.02	12	0.18	6.41×10^{-7}

TABLE II. Trial 2, $k_2 = 5.59$m, $\alpha_2 = 0.042$, $d = 0.0005$m

y (m)	n	β (deg)	λ (m)
0.23	0	0.042	-
0.37	1	0.066	6.35×10^{-7}
0.46	2	0.082	6.16×10^{-7}
0.54	3	0.097	6.34×10^{-7}
0.61	4	0.11	6.32×10^{-7}
0.68	5	0.12	6.54×10^{-7}
0.73	6	0.13	6.33×10^{-7}
0.79	7	0.14	6.34×10^{-7}
0.84	8	0.15	6.36×10^{-7}
0.88	9	0.16	6.34×10^{-7}
0.93	10	0.17	6.36×10^{-7}
0.97	11	0.17	6.35×10^{-7}
1.02	12	0.18	6.34×10^{-7}
1.06	13	0.19	6.45×10^{-7}

TABLE III. Trial 3, $k_3 = 5.68$m, $\alpha_3 = 0.036$, $d = 0.0005$m

y (m)	n	β (deg)	λ (m)
0.20	0	0.04	-
0.35	1	0.061	6.35×10^{-7}
0.45	2	0.080	6.32×10^{-7}
0.54	3	0.094	6.31×10^{-7}
0.60	4	0.11	6.32×10^{-7}
0.67	5	0.12	6.33×10^{-7}
0.74	6	0.13	6.44×10^{-7}
0.79	7	0.14	6.34×10^{-7}
0.84	8	0.15	6.36×10^{-7}
0.89	9	0.16	6.35×10^{-7}
0.93	10	0.17	6.35×10^{-7}
0.98	11	0.17	6.35×10^{-7}
1.02	12	0.18	6.35×10^{-7}

TABLE IV. Trial 4, $k_4 = 6.43$m, $\alpha_4 = 0.034$, $d = 0.0005$m

y (m)	n	β (deg)	λ (m)
0.22	0	0.034	-
0.39	1	0.060	6.26×10^{-7}
0.51	2	0.079	6.32×10^{-7}
0.60	3	0.094	6.35×10^{-7}
0.68	4	0.11	6.33×10^{-7}
0.75	5	0.12	6.25×10^{-7}
0.83	6	0.13	6.36×10^{-7}
0.89	7	0.14	6.37×10^{-7}
0.95	8	0.15	6.35×10^{-7}
1.006	9	0.16	6.36×10^{-7}
1.05	10	0.16	6.32×10^{-7}