Properties of a He Ne Laser

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We explore the basic properties of a Helium Neon laser beam and confirm the general properties of laser light. Light emitted by lasers or "Light Amplification through Stimulated Emission of Radiation" is characterized by several distinct properties. Most notable are it's narrow range of frequencies, it's thin beam parallel to the body of the laser and it's ability to maintain coherence or sinusoidal shape over large distances.

INTRODUCTION

In this experiment we measure these properties on a Helium Neon laser. The experiments performed on the laser are meant to observe the various physical properties of the laser. We measured the Polarization of the Laser Beam, the Beam Diameter at the laser aperture, the Beam Divergence of the Laser, and the Beam Waist. In order to measure these parameters certain methods where used to determine the relevant values. For the polarization we utilized an angle polarizer with the intensity output in order to find the Degree of Polarization defined by:

$$\mathrm{P} = \frac{Imax - Imin}{Imax + Imin}$$

For the Beam Diameter we used the knife method in order to determine the radius of the beam at $1/\mathrm{e}^2$ intensity measured by a power meter. Measuring the beam diameter at a point far away from the laser and then comparing to the diameter at the aperture using the Fraunhofer Diffraction equation:

$$\Delta\theta = 1.22(\lambda/\mathrm{D})$$

Finally, in order to determine the beam waist we utilize a lens in order to find the the point of convergence of the laser. We then pick that location to measure the beam diameter using the knife edge method.

EXPERIMENTAL

Experimental determination of laser properties were measured using a long track on which components were aligned. On one end was the He-Ne laser and along its propagating axis the track allowed us to setup different components in order to analyze certain parameters. A power meter (Fieldmate Laser Power Meter) used mainly to measure the power of the laser throughout the lab. The varying methodologies to measure different parameters of the laser ultimately determined the components placed along the track. Minimization of error came from the unique mathematical analysis of the observed values.

RESULTS AND DISCUSSION

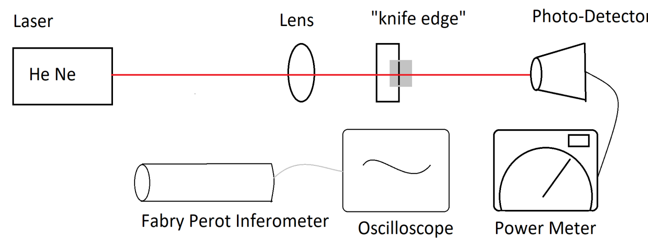

FIG. 1. Diagram showing the setup for various measurements. The adjustable knife edge used to cut off part of the laser beam is used to measure beam diameter. The lens is used in measuring beam waist and the photo-detector measured the intensity (through power) of the laser beam. The Fabry Perot Inferometer replaces the photo-detector in later trials to measure the coherence length and frequency spread of the beam.

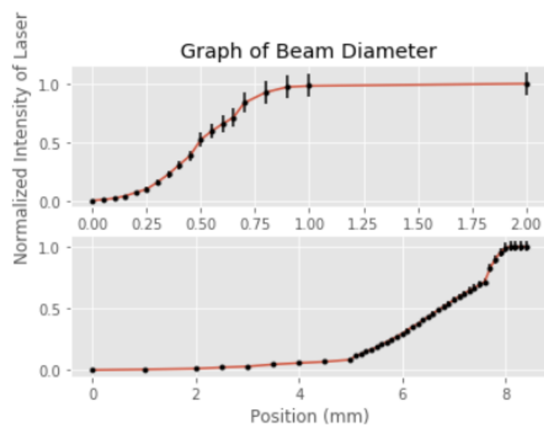

FIG. 2. The graph of the the beam diameter with fitted data curve. The y-axis has been normalized in order to fit the curve of f(z)

The graph of the θ vs $\mathrm{P}(\theta)$ was sinusoidal as would be expected from a rotation of the polarizer. After plotting the data finding the max/min intensities we were able to determine the polarization at .975 ± .005. From our lab manuals this concurs with the values given. For the determination of the the Beam Diameter we had the knife set up as in Fig 1 without the Interferometer, Oscilloscope, or Power Meter. Graphing the position of knife edge and intensity we utilized the intensity equation of a

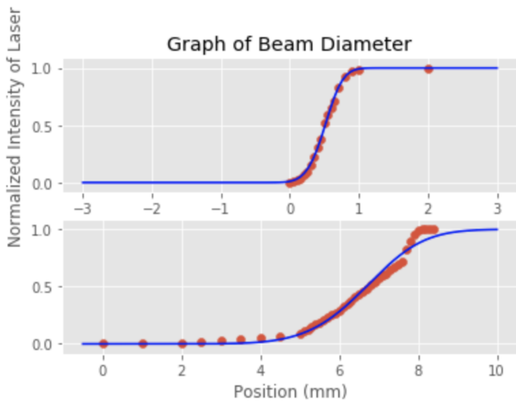

FIG. 3. The graph of the the beam diameter with error bars. Note the difference in the position of the x-axis. The y-axis has been normalized.

transverse Gaussian laser in the T_00 mode given by:

$$\mathrm{I(x)} = \mathrm{I}_0 \frac{\pi}{\beta^2} \int_{\infty}^{-\infty} e^{-\beta x^2} dx$$

Normalizing this equation provides the normalized intensity. For actual data analysis however we utilized an approximate equation modeled after the error function with a certainty within .9998 (given by the lab manual). In order to determine β which is defined as the radius of the laser at the point where intensity is at 1/e^2. The equation f(x) used is given as:

$$f(x) = \frac{1}{1+e^{f(z)}}$$

where f(z) is given as a polynomial equation and z is given as:

$$z = \beta \sqrt[1]{2}(x - x_0)$$

After fitting the curve we arrived at a value of .79±.05mm. For the beam divergence the beam diameter at 1.85m was 4.5 ± .06mm. Taking these two values and using the equation for the beam divergence we get a value of .27 ±.3 microRads. As wll as a coherence length of 5 cm. The error from beam diameter measurements propagated onto the error for the divergence. In order to reduce our error in Divergence we should perhaps hookup the intensity and position measurements of the knife method to a computer that can take data points at a higher sample rate. This would reduce the error.

For the calculation beam waist used the focal length value observed of 33.7± .05 cm and the distance derived from equation from beam waist is .3±.05 mm. For the coherence length observed from the Fabry-Perot Interferometer a value of 5cm was measured.

CONCLUSIONS

We conclude that the He Ne laser has a small frequency distribution and is therefore highly monochromatic. The beam divergence was larger than expected and well above the theoretical value expected from Fraunhofer diffraction, but still extremely small over a large distance. The measured coherence length was smaller than the expected value obtained through calculation. The limiting factor in our experiment was the short distance we had along the beam that restricted the number of distances we could measure coherence and divergence. This could be improved by using a longer track, at least several meters in length.