

OPTICS AND LASER PHYSICS LABORATORY #9
INVESTIGATION OF GAUSSIAN BEAMS --
EXPERIMENTAL CONFIRMATION
with David Lockwood



Introduction

Your task in this lab is to measure the beam radius w of an argon ion laser set-up on the optical table just like you used in the computer simulation with PARAXIA in the last lab (System 3, Lab 8). Measurements will be made in both x and y planes via pinholes and CCD cameras and determinations will be made to see if the beam is Gaussian.

* First you must determine the focal length of your biconvex lens. A good estimate can be made using the infinite object method. A good place to do this is on the second floor at the top of the stairs leading up from Spring Street. Here you can focus the image of the wing of Culler from across the courtyard onto the stairway wall. Using a meter stick, hold the lens above the stick and move it forward and backward from the wall until a clear inverted image is formed. Upon focusing your image you will have a good estimate of the focal length of your lens. Once you have an estimate of your focal length you can set up the system described in Figure 1. The actual value of the focal lens is found in the lens case.

Setup

Place pinhole at your chosen distance from the lens. Position pinhole so that the laser beam strikes the pinhole in its center when the apparatus is positioned for maximum adjustability in both x and y planes. You will be able to determine the appropriate positioning of the pinhole by watching its back surface. When the pinhole is appropriately positioned the laser beam will be visible on the back surface of the pinhole. Then remove pinhole and position the detector so that the beam strikes the detector in its center. Replace the pinhole.

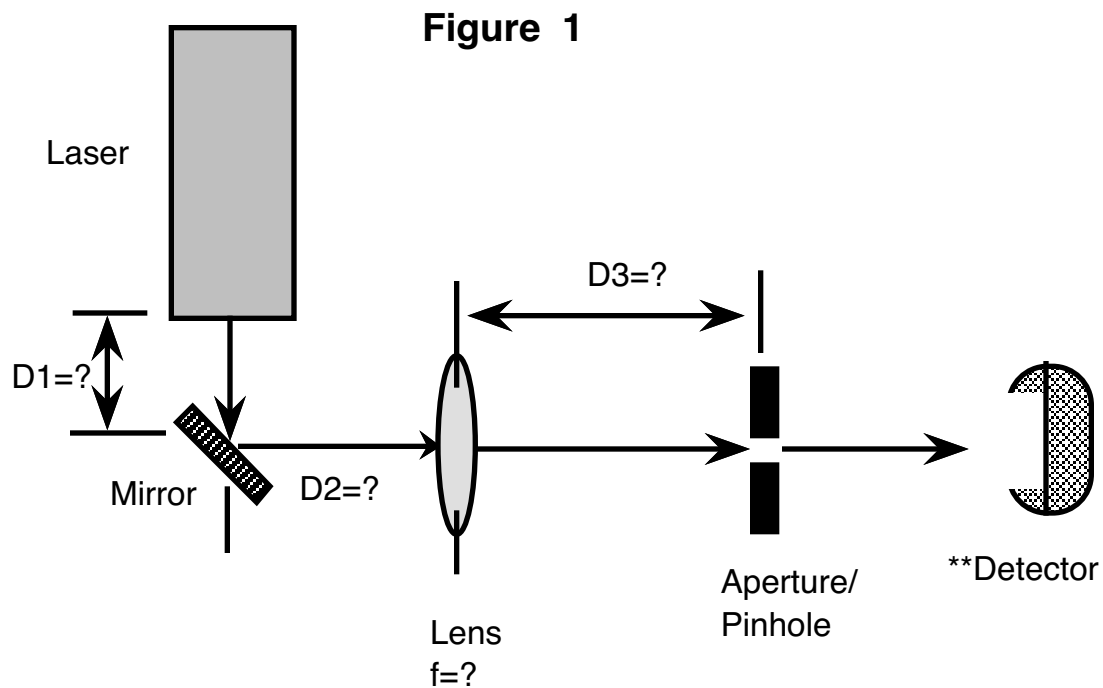
Turn on the multimeter and adjust the pinhole in first the X , then the Y direction to obtain a maximum value for the power (P). The maximum power in the X - Y plane is associated with the center of a Gaussian beam. Record the position of the lens with respect to the output of the laser and the pinhole.

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Data

The setup is now complete. You are ready to start taking data. Let's work along the X-axis first, while maintaining the Y-axis at its central position. Slowly sweep the pinhole along the X-axis.

As you do, so locate and record the positions of minimum intensity on both sides of the central maximum. Plan to take approximately 30 data points between these two minimums, recording both position and the corresponding intensity at each point. Repeat the procedure for the Y-axis with the X-axis centered.



** A lens may be needed so entire beam fits on active area.

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Data Analysis

For the data taken along the X-axis plot P vs. X. Find the equation of the line by fitting the following equation to your data.

$$P = A e^{\pm 2\left\{\frac{x^2 + y^2}{w^2}\right\}}$$

Eq. 1

You will find that P_{\max} is the appropriate value for A. You will also notice that the equation is centered at zero, and in order for Eq. 1 to fit the data the positions of maximum measured power at the central X position must be readjusted to "zero". To accomplish this subtract your X_{\max} value (the position of P_{\max}) from each X value. You can vary X_{\max} slightly to better center your theoretical plot. Varying your "A" value slightly will improve your fit height-wise. Varying your value for "w" will improve the fit width-wise. It is easiest to place these three values in a separate column on your spreadsheet so that you can easily improve your fit. The beam width is defined as the full width of the beam at the $1/e * P_{\max}$ values. The theoretical value w corresponds to the radius of the beam. Record this value for later use. Print out a copy of your spreadsheet, both data and curve fit tables should be clearly labeled. The graphs of your data and curve fits should have axes clearly labeled, the expression for the fit with the numerical value of "A" and "w", data points, and smooth curve fit line.

Repeat the process for the Y-axis data.

- 1) Did you have consistency in your results for beam radius in both X and Y planes? If not, what do you infer from your results?

- 2) How might you improve your results? What seems to have the greatest influence on accuracy?

- 3) Compare the resulting measured beam radius to the PARAXIA predicted outcome.

- 4) From your exposure to PARAXIA, what parameters of the optics system would be most likely to account for any deviation in your results? What parameters seem to have the least effect? How could you best correct for the deviation in your laboratory results?

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The CCD Camera as Image Capturer

Next we will utilize the CCD camera to measure the same beam's spot size. You must use sufficient neutral density filters to protect the camera when operational. Before capturing the spot on camera, adjust the camera's position to intercept the whole beam and move the camera along the optica axis until the minimum spot size is found on the monitor. Remember that the CCD camera has an active area of around 1 cm x 1 cm. With the CCD camera attached to the computer, a program called Image 1.59 is opened. By selecting **start capture** from the SPECIAL menu, the "full-sized" screen (456 x 556 pixels) opens to display the image sent from the camera. To grab a frame from the live image, click the mouse button when the cursor is over the image. This image can be saved for later manipulation of the image or to print it out by selecting **save as** from the FILE menu. The pixel size on "full screen" setting is $6.94 \mu\text{m}$.

Use the Image program to analyze the data and determine the radius of the beam. import the data to a spreadsheet and graph the beam profile found with the CCD camera and compare it to the graph of the pinhole data. Apply the Gaussian line-fit to the data and determine the radius from that.

- 1) How do the two methods of radius determination you used with the CCD camera compare?
- 2) How does the CCD camera compare to the pinhole? Discuss advantages/disadvantages of each.
- 3) How did you estimate error in each case?
- 4) Which method gave you the least error?