

OPTICS AND LASER PHYSICS LABORATORY #8
INVESTIGATION OF GAUSSIAN BEAMS -- PARAXIA
COMPUTER SIMULATIONS OF OPTICAL SYSTEMS
with David Lockwood



Introduction

You are about to embark on a series of 2 optics labs which center around the Mac software package, PARAXIA. In this lab, you will simulate three optical systems with PARAXIA- ABCD and determine the focal plane of a single lens set a known distance from the output plane of the I-70 laser. In the next lab, you will be using the single lens setup you analyzed here, setting it up in the laboratory, and comparing your experimental results to theoretical results.

Getting Started

Bring up PARAXIA on your Mac. From the PARAXIA menu choose ABCD (named ABCD because it uses matrices to calculate the output of the system). From the FILE menu choose NEW. You are looking at the project window. The twelve small squares on the left of the main window represent the different elements you may use to build an optical system. Some of these elements include: free space, neutral medium, thin and thick lenses, and flat and curved mirrors. Clicking a box will place it in the optical system. (The delete key may be used to eliminate a previously chosen element.) For all of the elements, except the flat mirror, the user must then choose the specific parameters for that element. (All lengths are in centimeters.) Single clicking on a box in the main window will allow you to see its individual ABCD matrix on the far right sub box, and double clicking on the same box will allow you to change the parameters for that element.

You're now ready to prepare for the computer simulation.

You will do simulations of several optical systems on PARAXIA. You will be able to compare the results given by PARAXIA with your own calculations using matrices. You will look at the results of two systems provided to you, and then make up one of your own.

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Procedure

Lets try a simple example to get you acquainted with ABCD. Follow the below-listed directions.

* We will use 100 cm of free space to look at the functions of ABCD.

-choose the icon for free space from the element palette which is located in the upper left corner of the project window. A dialog box for this element will appear on the screen. Highlight the box labeled length and enter your value of 100 cm.

* We now want to define the input beam for our system.

- choose WAVELENGTH from the DEFINE menu. The dialog box shows a default value of $6.328e-5$. This is the wavelength of a He-Ne laser expressed in cm. You can use any wavelength you like. The only requirement is that you are consistent. If you are using a He-Ne laser click onto OK. Should you be using a different type of laser highlight the default value using the mouse and enter the appropriate value.

* To further define the input beam you need to select INPUT from the DEFINE menu. You will find a dialog box in which you are able define the radius of curvature R and the beam radius (or spotsize) W. The default value for radius of curvature is "INF" the value we wish to use. For spotsize, we'll use a value of 0.01 cm (corresponding to 100 micrometers).

* Now we would like to look at how the input beam behaves as it travels through the 100 cm of free space.

- From the GRAPHS menu, choose BEAM PROPAGATION and observe the resultant graph of the beam as it propagates through free space, diverging as it travels.

* Let's complicate things a little bit. Suppose we would like to have a variable input beam width. We'll vary the width from our original value of 0.01 cm to a new value of 0.1 cm.

- Just like you did when you chose the original beam width you need to select INPUT from the DEFINE menu. To vary our value from one width to another, highlight the "variable" box.

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Our original value of 0.01 will be located in the "from" box and our second value of 0.1 must be placed in the "to" box. For the time being keep the other values constant.

* Let's look at the relationship between the varying beam width and the radius of curvature.

- ABCD has a very useful option which allows us to plot beam parameters as a function of the variable parameters of a system. Select BEAM PARAMETERS from the GRAPHS menu. Since we'd like to look at the relation between the variable beam width and the radius of curvature you should highlight this option in the dialog box. Then select 1 for the interface number and the number of points to plot. In this case since we're going from 0.01 to 0.1. The default should be 101. Once you've completed this, click onto OK and ABCD will plot width versus distance and radius of curvature versus distance in the parameters window.

- Once the plot is complete, you can choose the selection tool from the information region of the parameters window. The selection tool can be dragged across the plot using the mouse or the arrow keys. The corresponding radius and width can be read off of the information region. You will notice, as would be expected, that as we increase the waist size, R after propagation increases while the beam width first increases then decreases. While you work with the selection tool make a note as to the maximum width. When you make changes in the parameters the program makes automatic updates in the windows. In some cases this becomes bothersome or time consuming. To avoid this delay check the DELAY UPDATE box at the top of the project window. This will be more useful when working with ANIMATION.

* The last important function of ABCD we'd like to look at is ANIMATION. With BEAM PROPAGATION we looked at a beam of a particular width as it traveled through a medium. With ANIMATION we can look at how the beam behaves with variable parameters. In this case we'll look at the varying beam width.

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- Choose ANIMATE from the GRAPHS menu. Select 20 as the number of frames and CONTINUOUS animation. Click OK. The system begins a series of calculations and shows the animation frame by frame as it calculates. Once the calculations are complete the animation begins. You may notice that the animation does not produce any noticeable change as it moves through the parameters. To correct this we need to change the scaling of the plot. Select MODIFY AXIS from the GRAPHS menu. You'll notice that the automatic scaling has set the vertical axis to 0.1 cm. But you'll recall that when you looked at the beam width using the BEAM PARAMETERS function the maximum width was around 0.2 cm. For the vertical axis select " to +/- " and enter 0.2 cm. Then click OK. If you'd like to temporarily freeze the display, hold down the button on the mouse. In order to stop the animation you must use the hold command key (apple) and then push the period button "." .

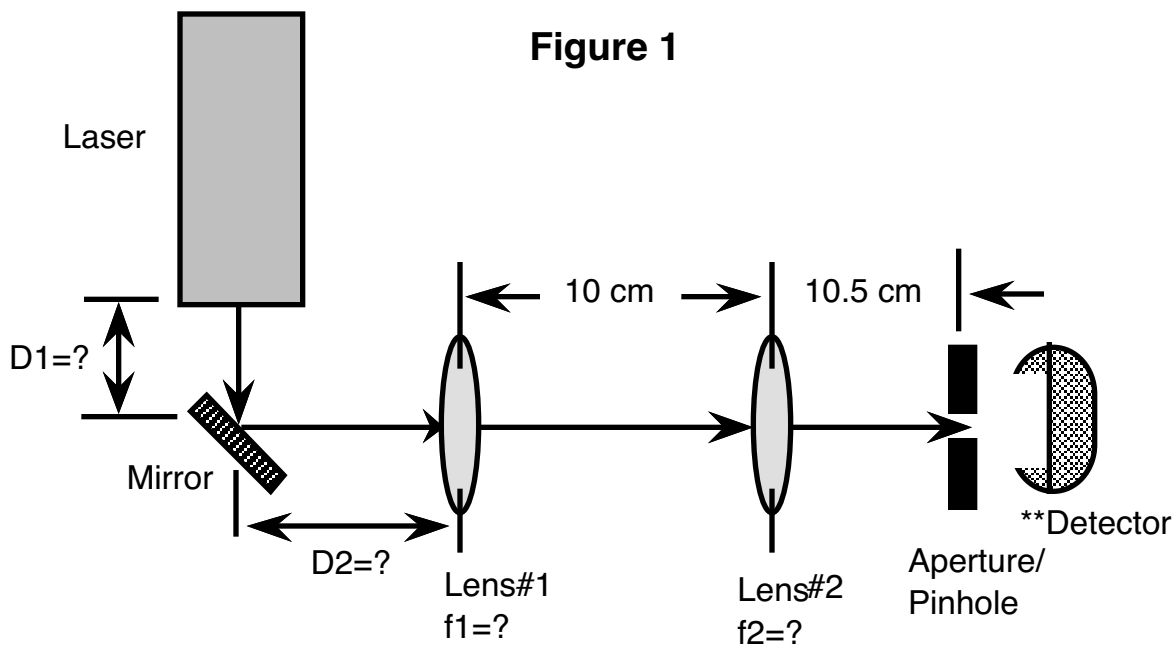
* Take some time with ABCD and make sure you have a good understanding of its functions. Once you feel comfortable with what we've covered, you should go on to the following parts.

By this point in the course you should be familiar with the ability of matrices to determine the output of an optical system. The input beam for the three systems with which you are working should be that beam radius and wavelength from the actual laser. The Innova 70 argon ion laser has a beam diameter of 1.5 mm and radius of curvature of 10 m at the output plane. The wavelength we use is either 514.5 nm or 488 nm (green or turquoise respectively) and you need to see where the laser is operating for input into PARAXIA. Next lab period, you will be setting up System #3 (as seen in Figure 1 of **Lab #9**). Careful simulation this week will enable you to compare to your experimental results next week.

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System 1

System 1 (Figure 1) consists of an input beam which travels through some chosen distance of free space before it strikes a lens of focal length f_1 then travels through 10 cm of free space before striking lens #2, f_2 , and through 10.5 cm to a pinhole and the detector. Use input parameters as mentioned above, and then vary a parameter of your choice for animation of the optical system.



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

- 1) Draw out your optical system in your notebook, and record the parameter you varied for animation along with its range.
- 2) Write out the matrices for each of these optical elements by hand, substitute the necessary numbers, and then multiply them for comparison.
- 3) Save the system in PARAXIA in a FILE (list in notebook) and then place in a FOLDER with you and your partner's name on it.

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System 2 (Design Your Own)

By now you should have a good feel for what you can accomplish using ABCD. Be wild and crazy!! Create your own system to investigate with PARAXIA. See what happens if you allow input spotsize to vary or wavelength.

- 1) Draw out your systems, list input parameters, and write down the final matrix in the lab notebook.
- 2) Animate the system for a range of input parameters.
- 3) Save the system in your folder and note the name under which it is filed in your notebook.

- 4) What happens if one of your elements is a cylindrical lens?

- 5) Which of the input parameters (or optical components) had the greatest effect upon output?

System 3

In preparation for Lab 9, look at the physical set-up of apparatus in the Lab 9 Figure 1. You will need to select distances and lenses so that the resulting beam diameter is actually measurable with our detectors and pinholes. This means that you need to choose f and propagation distances so that the spotsize is between 0.1 mm and 1.5 mm. Write out the ABCD matrices for the beam's propagation from exit face of the laser through the lens system and multiply them. Find the final ABCD matrix analytically then substitute values for various distances to determine a numerical value for each element. Compare this result with PARAXIA program. Next week you will compare this result with your actual laboratory measurements.

- 1) Sketch your system, list input parameters, save the system in your folder and note its name.

- 2) Why would the final spotsize need to be within the range mentioned above? i.e. what factors would influence your ability to measure the spotsize in the laboratory?

- 3) Discuss any additional uses for PARAXIA you discovered when working with the system you created.

