ENSC 470/894 Lab 3
Version 6.0 (Nov. 19, 2015)

Purpose
The purpose of the lab is
(i) To measure the spot size and profile of the He-Ne laser beam and a laser pointer laser beam.
(ii) To create a beam expander for the He-Ne laser and to measure the spot size and profile of the He-Ne laser beam before and after expansion.
You need to bring a USB drive for the data collection. Warning: please scan you drives for virus both before and after using here as students in the past have infected the computers.

Before starting create a sub directory for your group under the My Documents\e470-2015\Lab3 directory for your groups images. Please put these in the e470 directory with a directory name of your group (ie Group X). Save it to the hard drive so you do not lose the data. We cannot have you save to a USB drive as we have been infected with those before. We will be posting your images on the web so choose file names that make sense or record the file names in your notes.

Description
In this lab you will gain experience on building a simple beam expander for an He-Ne laser. You will be using the He-Ne |1 mW laser which is mounted on a post. The laser will be needed to be aligned on an optical peg board to an optical rail along which slides two "lens mounts" with adjustable posts and holder. Include error measurements where needed. Please contact the TA by email to setup a time for doing the lab. Also have the TA help you with the initial setup to make certain everything is working. Lab is done in the laser lab (ASB 10878) (the TA may also be in the lab so check there). Figure 1 shows the overall lab setup. Also before running the lab read the Appendix 1 tips section and refer to it if there are problems.

(1) First make certain the He-Ne laser (Figure 2) has been left on. The laser needs to be on for at least one hr prior to use to stabilize. Please note do not turn off the laser at the end of your work unless the TA says that is OK (end of labs for the week). The laser has a switch at it back end. At the front of the laser near the output is a sliding shutter. Make certain that the shutter is open and the beam is coming out of the laser. This laser power is at eye safe levels.

(2) For the xyz axis directions in this lab look at Figure 1. The laser is pointing in what we will call the x axis. The rail and lens holders run in that axis. The direction towards the screen is the y axis, and the vertical is the z axis. If the rail is not installed (last group has moved it) you may need to bolt it in place. Use the peg board holes that are in line with the silicon detector.

(3) In preparation for the lab, or during the lab, design a beam expander (Galilean type) to increase the beam size by a factor of 2.0 – 2.5 within the 35 cm length of the rail. You have the following lenses (all Plano Convex or Concave) focal lengths in mm:

Plano Convex f (mm): 50, 75, 100, 125, 150
Plano Concave f (mm): -25, -50, -75

The lens kit will be either on the table or on the larger vibration isolation table behind the main setup (plastic box or wooden box). Please keep the fieldmaster laser power meter at the back (see Fig 1 and Fig 5) as its power supply is delicate.

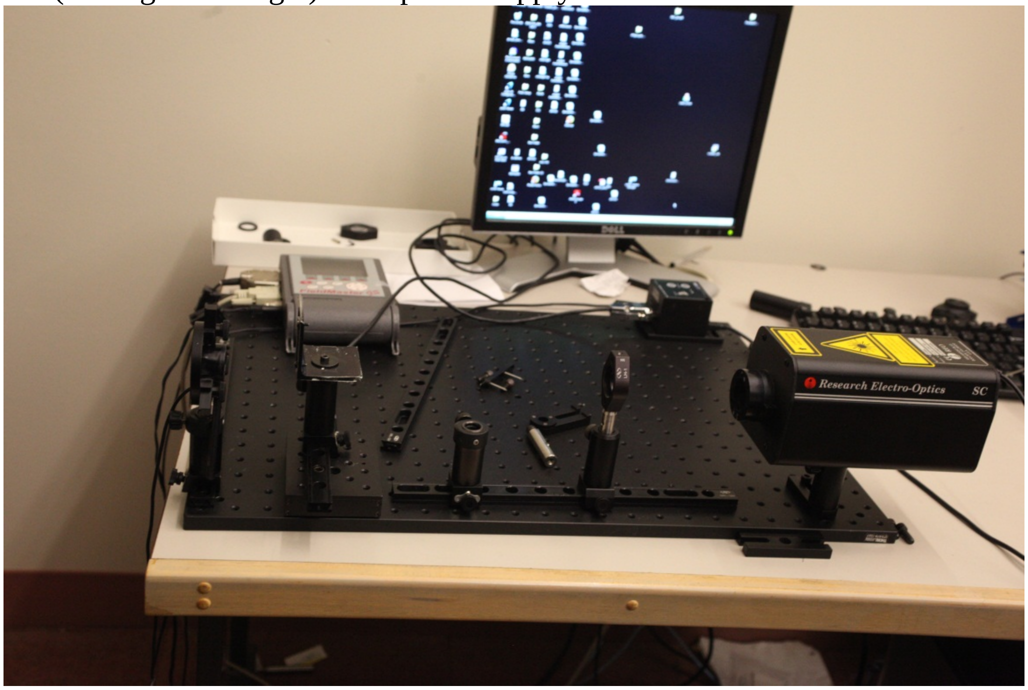


Figure 1: Overall lab setup

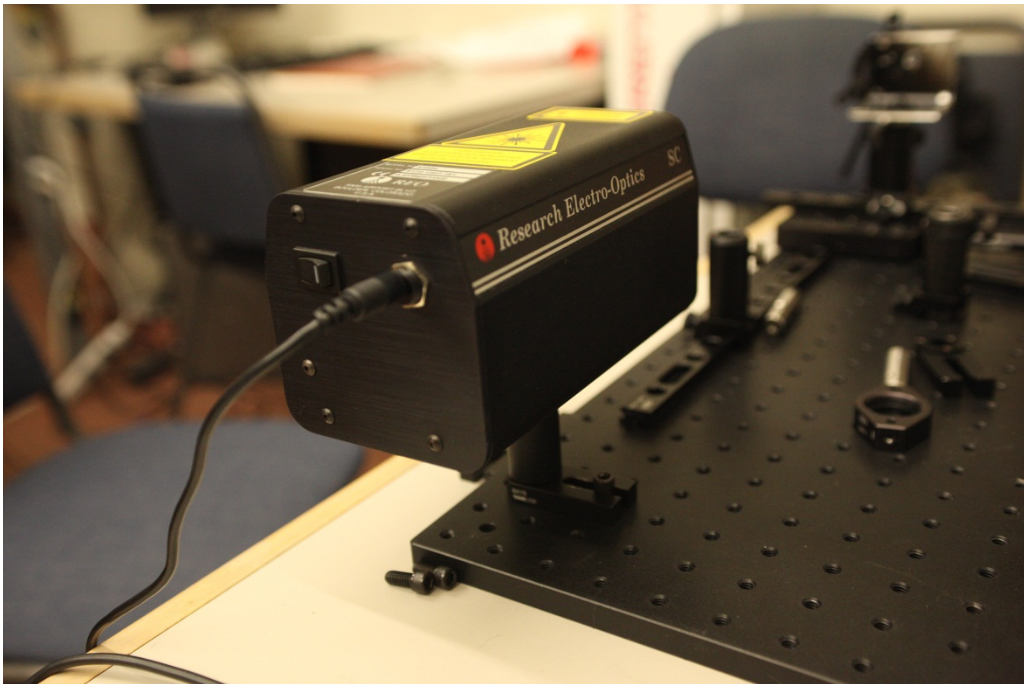


Figure 2: He-Ne laser (note switch at the back)

(3) You are to first align the laser to the centre of the rails. Observe the laser beam hitting the silicon detector (Figure 4) and the knife edge. We need to make certain the laser beam is aligned to near the centre of the detector. You should see the red laser beam as in Fig. 4 at the detector. The laser (Figure 2) is mounted on a post in a post holder that is in turn on a post holder positioner (Figure 3) that is bolted to the peg board. You may need back off the bolt of the post positioner (Figure 3) slightly slide the laser in the y direction (up or down in Figure 3) the lock the bolt with the hex driver Allen key set. To make certain the laser is positioned correctly put a post on one of the post holders on the rail and set it at the laser height. Move the post to near the laser and check the laser hits the centre of the post. If not move the laser (as before) until the beam it's the center of the post (use the stud holder at the top of the post as a marker). Now slide the post to near the end of the rail (near the knife edge). Rotate the laser until it is centered there also. Slide the post back to near the laser and check the beam is still centered on the post (in case the rotation moved the laser). Repeat until both are in line. Then make certain the beam hits both the top of the post and then hits the centre of the silicon detector. This may require you to change both the y position of the laser, and the z (height). Z is controlled by moving the laser up and down with the laser`s post holder.

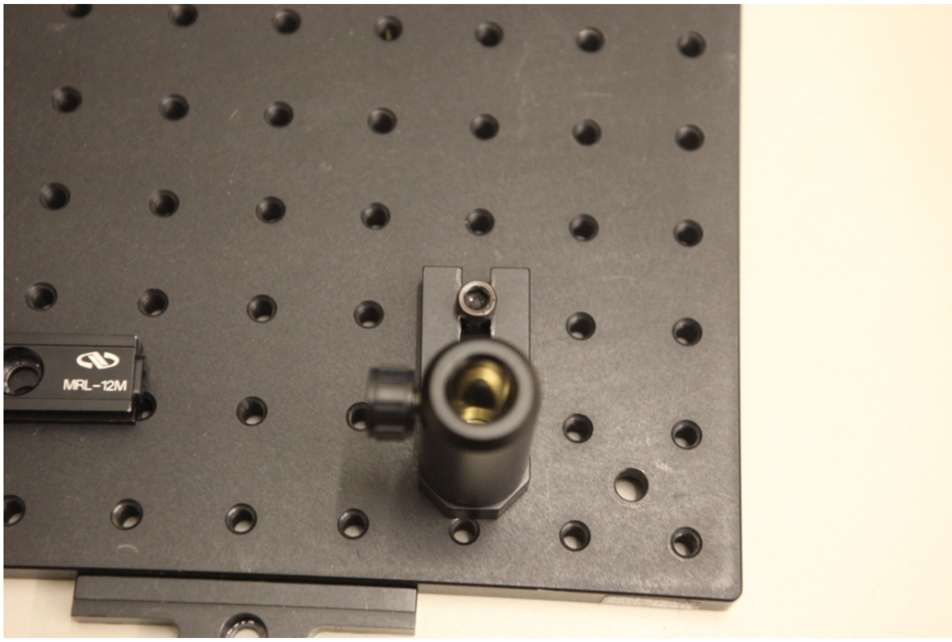


Figure 3: Post holder for laser

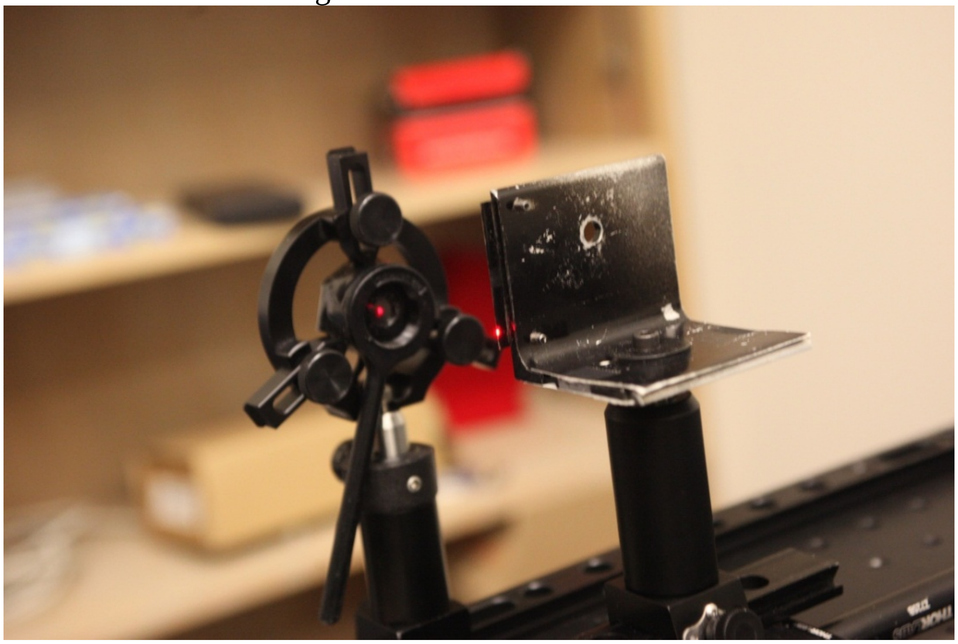


Figure 4: Silicon Detector (left) and knife edge on y axis motor (right)

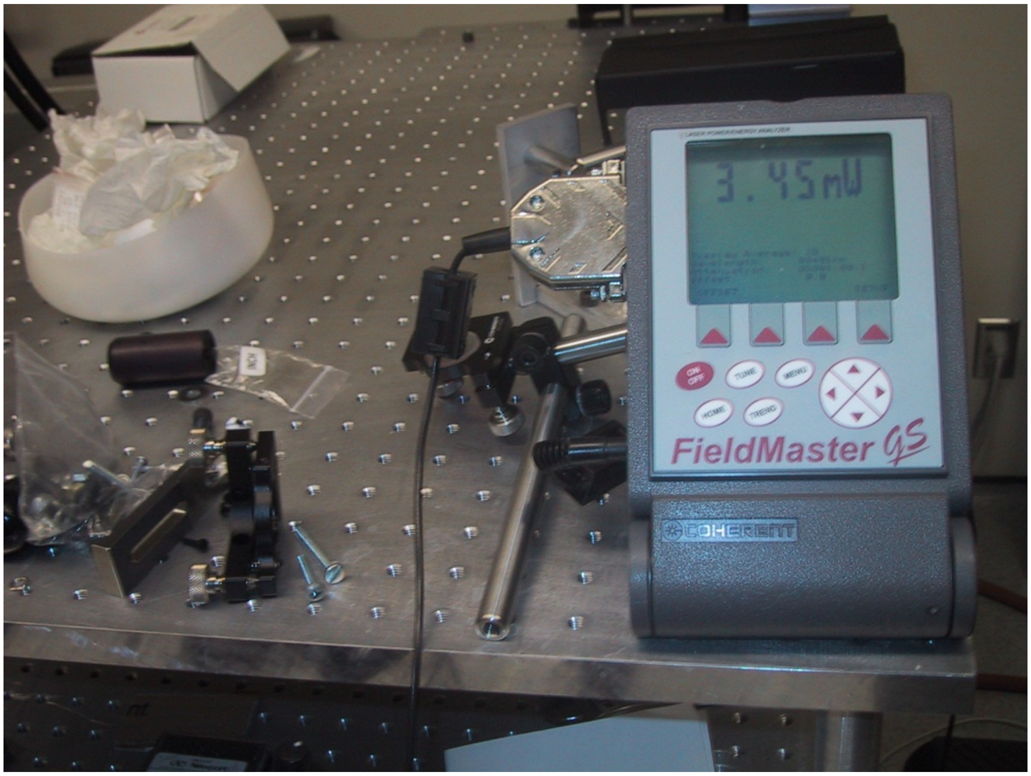


Figure 5: FieldMaster meter

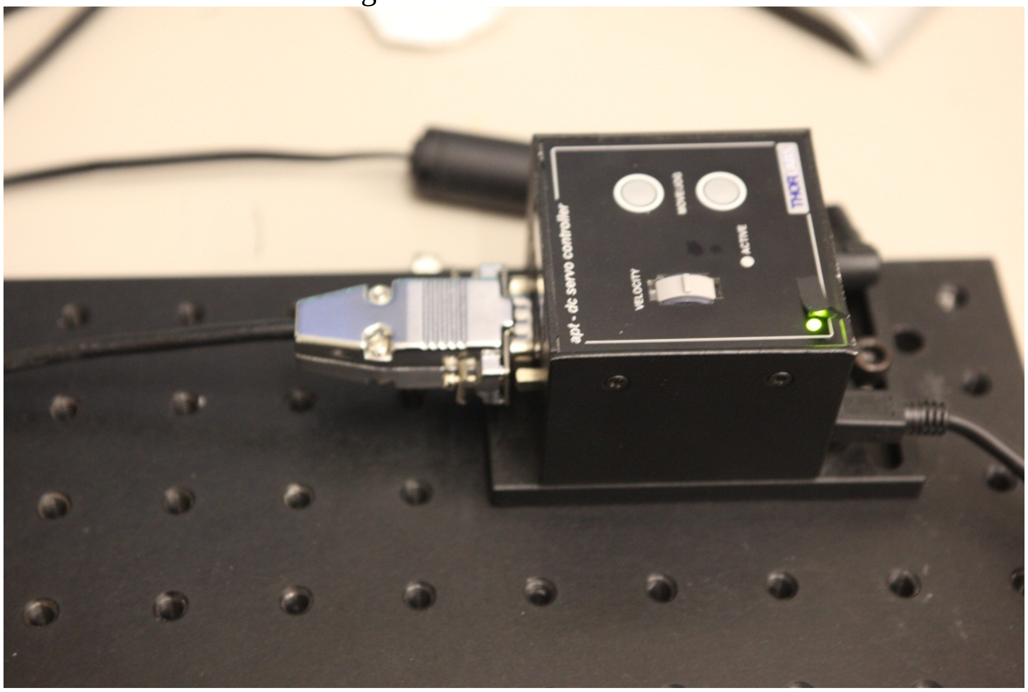


Figure 7: y axis (knife edge) motor controller

(4) First using a simple ruler do an eyeball measure of the spotsize as seen on a piece of paper both at the laser and at the knife edge (this is just a check on your data). Just get a rough guess of the laser beam size so you can set the motion for the experiments. You eye tends to overestimate the beam size.

(5) Next block the laser light (with the piece of cardboard by the lab or a piece of paper) and read the Fieldmaster meter (Figure 5) value of the background light. Note this number for future reference. You can also use the shutter on the laser but make certain that you do not move the laser when doing so. The Fieldmaster meter power supply is on a separate power bar so if the meter is not working please make certain that is on.

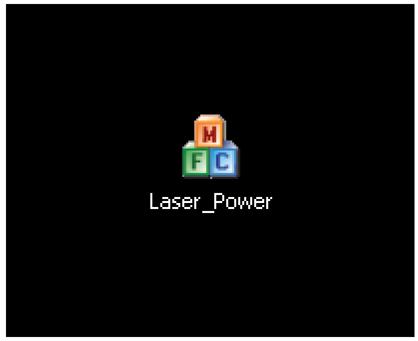


Figure 8: Laser_power icon

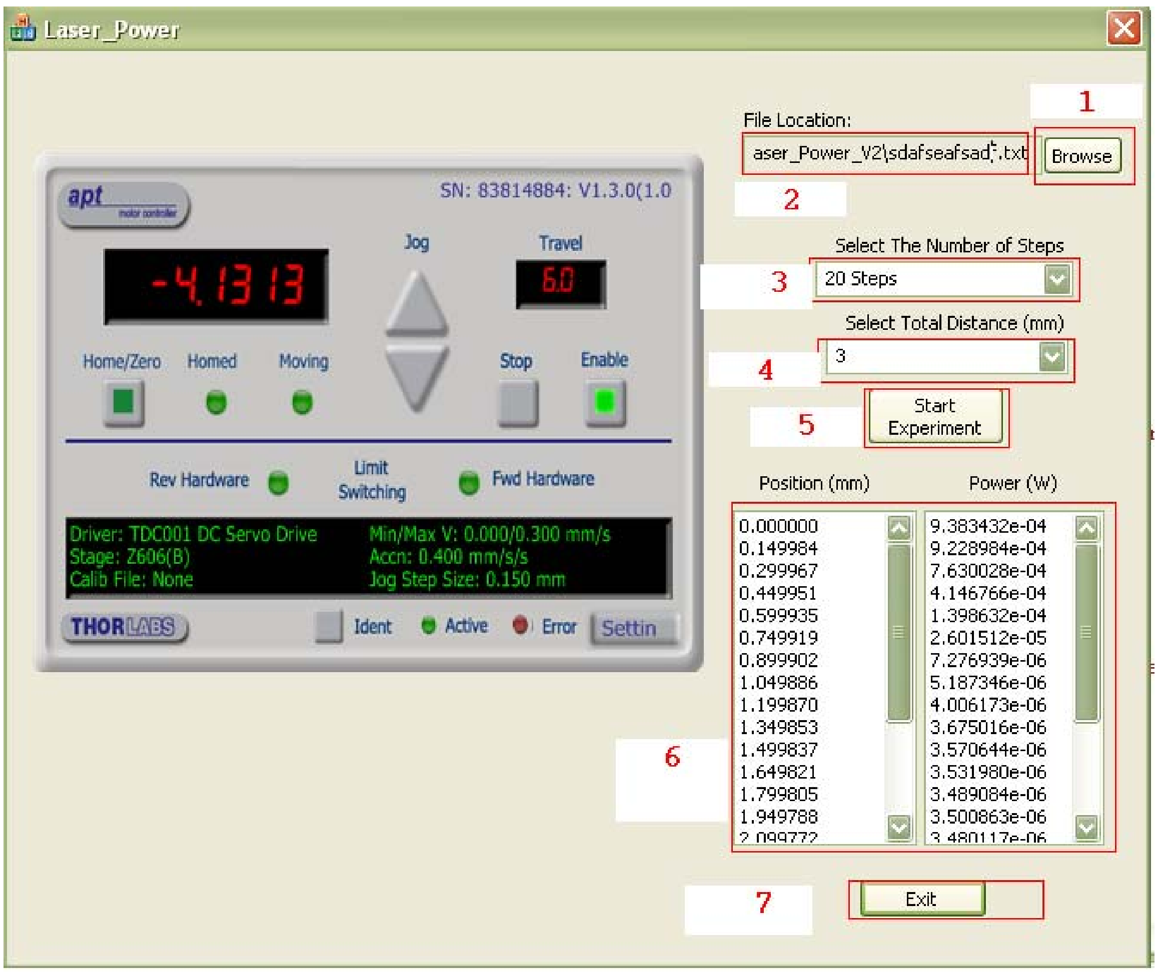


Figure 9: Laser power program control window

(6) Now locate the y axis motor controller (Figure 7) near the screen on the right edge of the optical peg board. Make certain the green light is on showing it is plugged in. Also note the manual control switch (near bottom edge of the controller on the picture as we will be using that.

(7) Now launch the Laser Power program (icon near centre of the desktop – See Figure 8). You should get a control window shown in Figure 9.

(8) Now prepare to measure the spot size of the laser itself. First move the knife edge out of the beam path using the manual control of the y axis motor. Pushing the switch to the right moves it in one direction, the left in the other. You want to make certain the laser is not hitting the knife edge (ie look that there is no spot on the knife edge). Figure 4 shows a partial spot on the knife edge. Watch the field master and make certain that reading is nearly steady (there is always a bit of noise) when moving it. Do not push it to the limit, just move the knife edge just to the point where the beam is steady. Measure the distance from the laser to the knife edge

(9) Now prepare to take a measurement with the Laser Power program using the following procedure. The numbers reference the Figure 9 parts of the controller window.

1. Click the “Browse” button to select a location where the data file will be stored.
2. You can view the location of the data file in the display box next to the “Browse” button.
3. Select the number of steps that the motor will make while moving the sharp edge.
4. Select the total distance that you want the motor to move the sharp edge.
5. Click the “Start Experiment” button to start the system moving.
6. After the system has finished moving the sharp edge, all the data will be located in the two list boxes under “Position” and “Power.”

To exit the program, simply click the “Exit” button (area 7)

Make certain you have a folder to put your measurements in. For this first beam set the distance at 2 mm. and at least 20 steps.

(10) Look in the data window (area 6 of Figure 9). Make certain that the initial window shows almost no change in the power level (less than 1% change) for at least 2 steps. Also make certain at the end of the file the power has fallen to < 2% of the initial power and again changes very little. It should be near the background level you took in part (5). If you are not seeing this you may want to take a second data set (change the file name).

(11) Shutter but do not turn off the HeNe laser so the beam is not seen. You will be given a specific laser pointer for your group. Hold the laser pointer using the 3 point supports mounted on a rod and post holder as was done in lab 2 and is shown in Figure 10. You may need to use two 3 point supports to get the laser properly aligned to the knife edge as in Figure 10. Repeat the measurements of parts (3) to (10) but for the laser pointer. You may need to use tape or a clamp to keep the laser pointer on and steady. rwuNote the

beam size of the laser pointer is generally much larger so you may need to adjust the step size to get 3 – 5 mm depending on the laser type of pointer you are given.

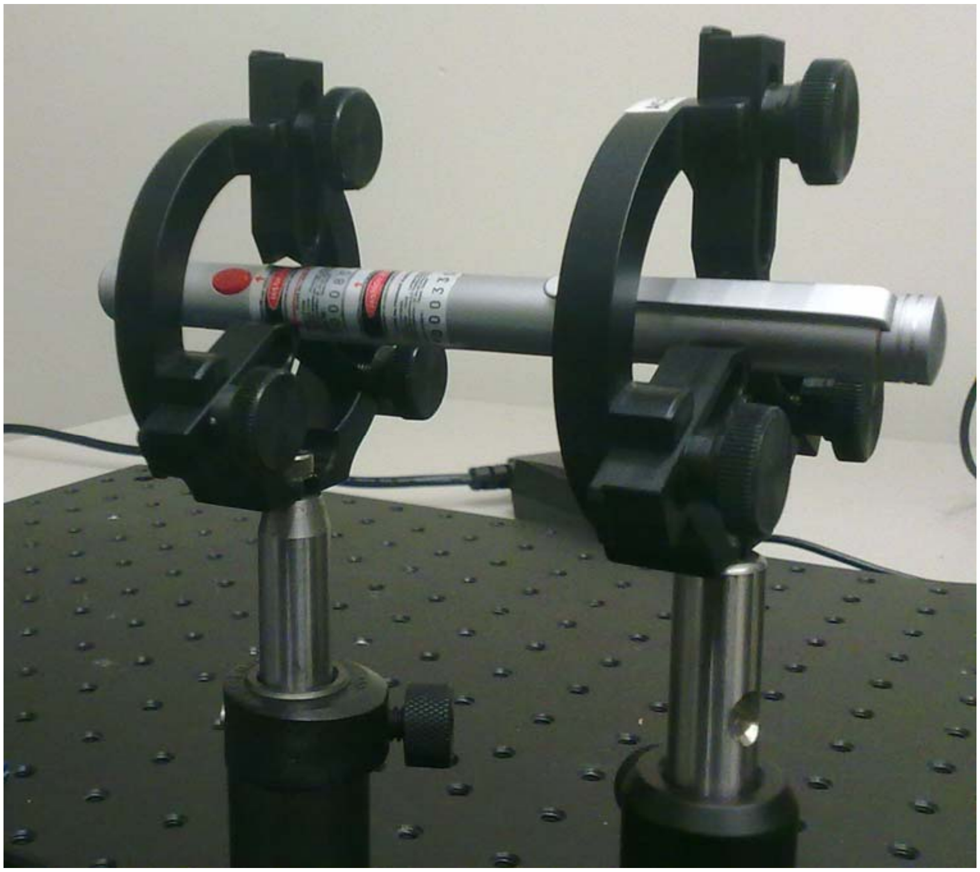


Figure 10: Laser pointer mounting

(12) Now we move onto the beam expander section. Remove the laser pointer and again use the HeNe laser. Start to build up the designed beam expander with the equipment available (see Figure 1). To build this telescope, first insert the far lens (long focal length) in the lens mount. Adjust the height so the beam is in the centre of the lens. Make certain it is perpendicular to the rail. To do this watch where the reflected spot from the lens hits the laser – it should be near the laser emission window. Rotate the lens until you get this. This is called to autocorrelate the lens. If you are using plano convex lenses use the flat side of the lens towards the laser for this.

Autocorrelation is more accurately done by using a pinhole in a sheet of paper and letting the laser go through the pinhole. Then look at point on the paper where the beam bounces off the flat lens side. Then align the lens so the return beam goes through the pinhole. For this experiment you can just use the regular beam reflection if you want to.

(13) Now add the first lens in the lens on its mount and autocorrelate the lens. Measure the beam diameter roughly. Make certain all lenses have their flat side is towards the laser (if using plano lenses). Use autocorrelation to align the lens (looking at the laser beam reflected from the lens and aligning it with the source). This makes certain the lens

is accurately aligned to the laser source. Describe the expanded beam and measure it roughly for use in the program. Make certain the full laser spot is within the silicon detector shinny silicon area. The expanded beam will be about 15% less than the power seen without the expander (due to reflection from the lenses). In an idea expander you would use anti-reflection coated lenses that would

(14) Measure the distances from all the lenses to the laser and the knife edge, as well as the distance between the lenses. This is important if you are to understand the results. Using a simple ruler do an eyeball measure of the spotsize, at the laser, before the beam expander, and at the knife edge. You will use this to check that you calculations are in the right range.

(15) The exact separation of the lens is important but you would need the principal points for this. Check that the beam is not expanding or shrinking after the beam expander with a piece of paper near the output of the beam expander and at the detector. The beam expander goes from slightly expanding to slightly contracting as the separation between the lenses changes for the exact value. Make certain that this does not appear to change over the lengths of the system.

(16) Center the power meter detector head in the beam path and again move manually the y-axis knife edge out of the path as in step 6. You may need to reduce the optical density to get a good reading. Again set up the Z-axis range and step size to move the edge across the beam width in at least 10 points in the beam width.

(17) Now measure the beam expander spot size with the Laser power program as in steps (9-10). In this case set the distance for at least 4 mm and steps for 40

(18) Again using a simple ruler do an eyeball measure of the spotsize both at the knife edge and at the laser. You will use this to check that you calculations are in the Z_R right range.

(19) Do not turn off the laser when finished (it needs to remain stabilized). However close the shutter on the laser so the beam is not hitting anything. Remember to check you files are there before leaving.

Write-up

The aim of the write-up (one write-up per group) will be to see what you have learned in the lab. Note that what you are doing is having a slit cutting into a Gaussian beam shape. Thus this is the integral of a Gaussian, which is called and Error Function. Download the lab analysis description from the website to aid in this. See the Appendix 2 section for notes on using your data files. In particular, you are to do the following in the report: For both the the laser pointer and HeNe laser (initial and expanded) measure the following.
(1) Estimate the laser spot size from the initial measurements using the ratio between the peak point and the point were the power reduces by half.

(2) Using all the data do a curve fit of the data to an expected curve. Calculate the spot size using this. Do this for both the manual and automated data.
(3) Calculate the Z_R of the laser system.

(4) Now repeat these calculations for the HeNe beam expander.
(5) Compare the results of both: note the spot size at the knife edge may or may not be the same as that at the laser itself (use Z_R to calculate the size at the laser and the output of the beam expander). Use the rough eyeball number to see which of the two Z_R solutions are reasonable. If the Z_R is small then the beam size will differ significantly to your eye from the laser to the beginning of the beam expander.

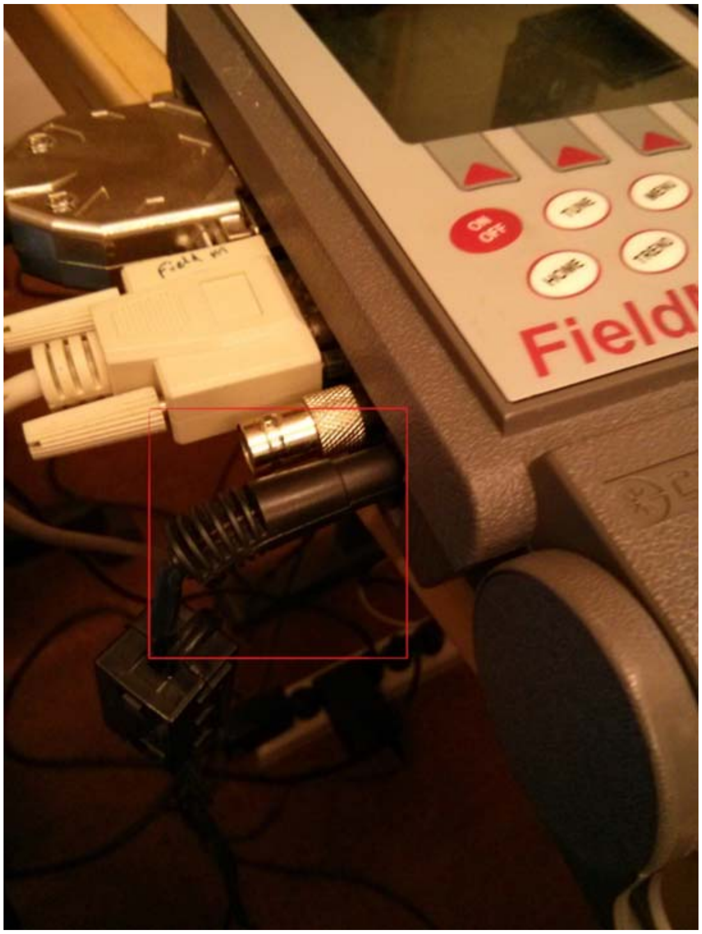
Use both derivative techniques (take the numerical derivative to see the beam shape) and fitting of the results to the integral of a Gaussian beam. Include error readings when doing these calculations. See calculations note file for the data analysis method (lectures and in lab note files).

In this write-up the theory/introduction/ section need only cover your analysis method. Cover the procedure in showing your setup, design calculations and how you did the measurements. Also cover the results/analysis and conclusion. Note the importance in the Z_R formulas in understanding the results from the laser and the beam expander. Hence you must solve the Z_R equation to calculate the beam waist size at the laser itself (the waist is located at the front of the laser). Include copies or originals of your lab notes. Final report length should be less than 10 pages. In the report you are to calculate the beam sizes from the measurements and compare the results at each stage with what theory says you should get.

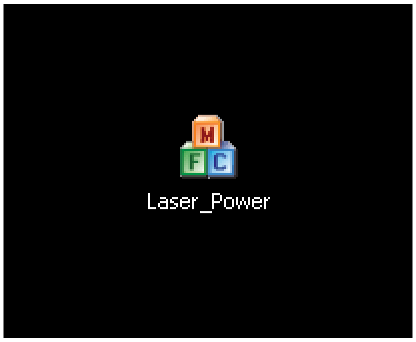
Curve Fitting and Data
The Gaussian and Error function equations that appear in the data can best be obtained using curve fitting methods. This is most easily done in Excel or similar spread sheets. The best method is called the least squares procedure. First create a table area for the estimates of any fitting functions (eg. Gaussian or error functions) and put some initial estimates in from the table. You will need to estimate the z positions of the peak, the beam width (w), the peak power level and the background level for either of those. Then create a table that has the z axis position, the power meter reading, your fitting function, the difference between your fit and the data (the residuals) and the square of the residuals. Then create a point for the sum of the square of the residuals. The method is called the least squares fit. In Excel or other spread sheets this can be done easily using the solver function. Invoke the function from the tools/solver section. Set the **target cel**l as the sum of the squares, the column of the optimized values in the **changing cells** section, click on the minimize for the result, the initial guesses in the other column (click on **Guess** to give that).Then just press solve. Note if your initial estimate is too far off it may not converge. I recommend creating a plot of the result in comparing the data and the initial fit before beginning – they should look reasonable. Compare the plots after also. Look at the residuals for the existence of any unusual results. You must email in an electronic copy of the program when you submit the lab so we can compare your programs to others done in this lab or past ones

Appendix 1 Lab #3 Tips

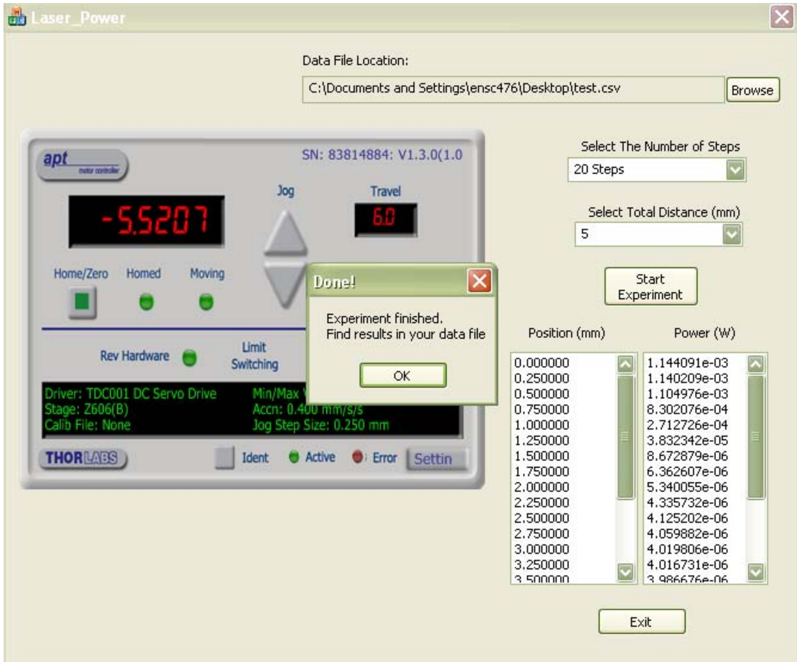
- Before starting the program, make sure the motor controller, and FieldMaster GS are both plugged in, and ON.
- If the FieldMaster is not turning on when the ON/OFF button is pressed, simply unplug and plug in the power connector on the FieldMaster, then try turning it on again. See picture below.



- To start the program, click the "Laser_Power" icon on the desktop



- Wait about 2-3 minutes once you have clicked the "Start Experiment" button in the program. A dialog should pop up letting you know that the program is finished collecting data, as shown below:



- Remember to choose a new save file every time you collect a new set of data
- DO NOT turn off the laser! It needs to stay on throughout the day so that groups can collect stable data.
- Use the "Velocity" rocker on the motor controller to move the knife edge close to the beam.

- In order to know when the knife edge is very close to the beam, look at the FieldMaster GS display, and determine when the power value just starts to decrease.

Appendix 2: Converting you data files

The following sets of instructions describe how to use the data for Lab3 using the laser setup and computer control. measurements using the FieldMaster power meter while stepping a knife-edge through an expanded He-Ne Laser beam. The data file will look like the sample in table 1. The data is an ascii text file which is written as a csv file type.

Table 1: Example file

```
Distance (mm)       Power (W)
================================
0      ,        9.775695e-04
0.100017      ,        9.359478e-04
0.200032      ,        9.847312e-04
0.300049      ,        1.012393e-03
0.400065      ,        1.016673e-03
0.500081      ,        9.998669e-04
0.600098      ,        9.588868e-04
0.700114      ,        8.835719e-04
0.800131      ,        7.414232e-04
0.900146      ,        5.081653e-04
1.00016      ,        3.009619e-04
1.10018      ,        1.266296e-04
1.2002      ,        3.664909e-05
1.30021      ,        1.128278e-05
1.40023      ,        5.420790e-06
1.50024      ,        4.239491e-06
1.60026      ,        3.273444e-06
1.70028      ,        2.608904e-06
1.80029      ,        2.407965e-06
1.90031      ,        2.260229e-06
2.00033      ,        2.183683e-06
```

To use this file edit the file as follows.
Now you can open the file with as excel spreadsheet. Cut and past this into your analysis program (spreadsheet) or change to the format you use if using excel.