

# Lab Report: Laser Beam Propagation in an Outdoor Environment

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**Course:** ES485A Laser Propagation in the Maritime Environment

## Introduction

The purpose of this experiment was to observe how laser beams spread over great distances in an actual outdoor environment. The main objective of this lab was to compare the propagation beams of two differing diameters (larger diameter achieved through 20x beam spreader) and to document the delivered power and corresponding final beam diameter at increasing distances. The goal was not only to observe the spreading over distance but also to compare to theoretical values derived from Maxwell's equations. In addition to the main objective, a secondary objective was to observe the effects of the environment (specifically the meteorological conditions) on the laser beam over distance and document what effect these has on the power and concentration of the beams.

## Background Research

Two 1 milliwatt Melles Griot 25-LHP-213-249 lasers were used to conduct the experiment. These specific lasers are Class IIIA and can be described as are red cylindrical HeNe laser emitters. The emitted light has a wavelength of 632.8 nanometers. According to the manufacturer's specifications, the lasers have a head length of 177.8 millimeters with head diameters of 31.8 millimeters.

## Materials

The materials used in this experiment are listed as:

- 1 Camera with usb cord and power cable
- 1 Laptop with portable charging cable
- 1 Midshipman laptop
- 1 Survey-grade tripod
- 1 Camera tripod
- 1 presentation board stand
- 1 Gas-powered generator
- 1 Portable battery
- 1 Nikon Laser Range Finder

- 1 meter stick
- 2 Headlamps with red-light capability
- 2 1 milliwatt Melles Griot 25-LHP-213-249
- 2 portable laser power supplies
- 1 power meter
- 1 Laser spreader
- 2 Presentation boards with grid covers
- 1 Large metal breadboard with threaded holes
- Various laser mounting pieces

## Setup

The setup is crucial to both the success and brevity of the lab's execution, therefore most of the lab's setup was done in the controlled environment of a well-lit classroom. The entire laser setup was mounted on top of the geological survey tripod, pointing at the presentation boards. The camera was mounted on top of the camera tripod, and set approximately 2 meters from the target boards. The camera itself was fitted with an extremely powerful optical lens with an adjustable aperture for light as well as both a coarse and fine focus. The lens settings were calibrated to see the laser beams on the presentation board, yet not saturate the image at a distance of 2 meters away from the board in complete darkness (in classroom). Finally, the image processing software was configured to make sure that images captured were not saturated, yet could still be seen. The calibration settings that were obtained for our lab was a completely open camera aperture with an exposure time of around 50 ms. Only after all equipment was calibrated in class room, did the experiment proceed outdoors. On the day of the experiment, the setup was moved to the testing field at 1930, and setup was completed by 2000. Once outside the generator was set up to power the lasers, while the portable battery was used to power the camera and associated laptop.



Figure 1: The initial set-up of the experiment outdoors

## Weather

Weather was a very important factor in the results obtained from this experiments, as such, it was felt that it was important to document the exact weather conditions experienced during the experiment on October 5. The data found in Table 1 was obtained from the [weatherunderground.com](http://weatherunderground.com) database.

**Table 1. Hourly Weather History & Observations for 05 October 2017**

Time (EDT)	Temperature (°F)	Dew Point (°F)	Humidity	Pressure (in)	Visibility (mi)	Wind Direction	Wind Speed	Conditions
7:54 PM	73.9	68.0	82%	30.12	10.0	Calm	Calm	Clear
8:54 PM	72.0	66.9	84%	30.12	10.0	Calm	Calm	Clear
9:54 PM	72.0	68.0	87%	30.12	10.0	Calm	Calm	Clear
10:54 PM	72.0	66.9	84%	30.13	10.0	Calm	Calm	Clear

The lab was conducted from 1945 until 2230. During that time period the average temperature recorded was 72.48 °F with an average humidity of 83.75%. Throughout the experiment the

winds were calm and the visibility was excellent at 10 mi. Finally, it is important to note that a full moon was present on the night of October 5.

## Experimental Procedure

The procedure for data collection was simple in execution. The calibrated equipment from the classroom was brought out to the field and set up as shown in figure one. The generator was started according to the procedure listed on the unit and the two laser power supplies were plugged in and the camera and its associated laptop were plugged into the portable battery. The site chosen to set up was on the north side of hospital point near the gazebo. This site was chosen because of easy access to the road and the ability to shoot down the entire length of the field. The distances chosen were 1m, 11.5m, 49m, 122.5m, 237.5m, and 380m and the laser shot lines can be seen below in Figure 2.



Figure 2. Laser Shot setup on Hospital Point

At each distance tested, the gridded presentation boards were set up on the stand and both lasers were shone upon them. First, the range of the board from the laser source was recorded, using either the laser rangefinder or the meter stick, whichever appropriate. The camera was placed at a distance suitable to capture both laser spots in the same photo (normally around 2m). A headlamp was then used to light up the grid paper. The camera's lens was then focused so that the grid lines could be very clearly made out and a snapshot was taken and saved. This

photo serves two functions: 1) To easily focus the camera's lens for a clear shot of the lasers in the dark and 2) To serve as a reference for later photo measurement and analysis. After the reference photo is taken, the headlamp is turned off, the camera is autoscaled for a clear picture and a snapshot is taken and saved. This snapshot is then moved over to MATLAB and quickly analyzed to ensure that the shot is not saturated and can be analyzed. If the photo is acceptable then it is retained, if not, the exposure time is reduced (to reduce the amount of light coming in) and the photo is retaken and analyzed. After the reference shot is taken, it is imperative not to move camera tripod or adjust the focus of the lens. After the dark photo is taken, the power meter is used to measure the power per unit area of each beam. Note: the meter must be placed in the center of the beam spot as much as possible. After the power has been taken, the stand and presentation boards are moved to the next distance, followed shortly after by the camera-laptop-battery trio. When getting the lasers on the board, it was found easiest to lower the beams and then walk them up the field until they both landed on the presentation board. This process was repeated for all 6 distances tested.

## Analysis Procedure

In order to measure the radius of the laser spots the tif files were uploaded into MATLAB and using the 'imtool' command the image was analyzed. As seen in figure 3, the pixel count of the coordinate grid lines measuring each 1 centimeter by 1 cm was measured and recorded using the 'measure distance' tool. The pixel count of the diameter of each laser spot was measured and recorded. A conversion factor was created from the known size each of the reference boxes and the measured pixel count for each box measured. The product of the spot's radius in pixels and the conversion factor resulted in the radius values measured in meters.

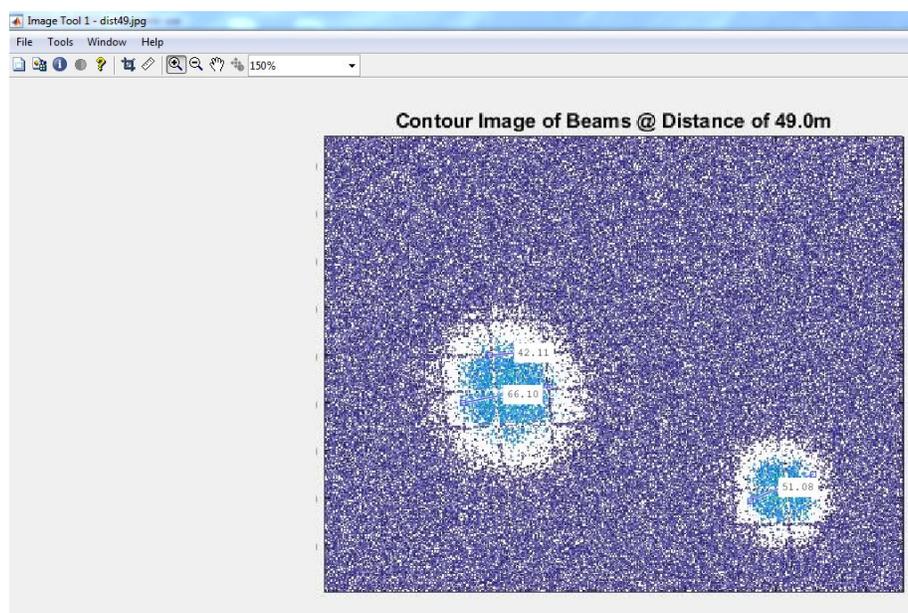


Figure 3. 'Imtool' command in MATLAB used to analyze and measure the pixels within the image

# Results

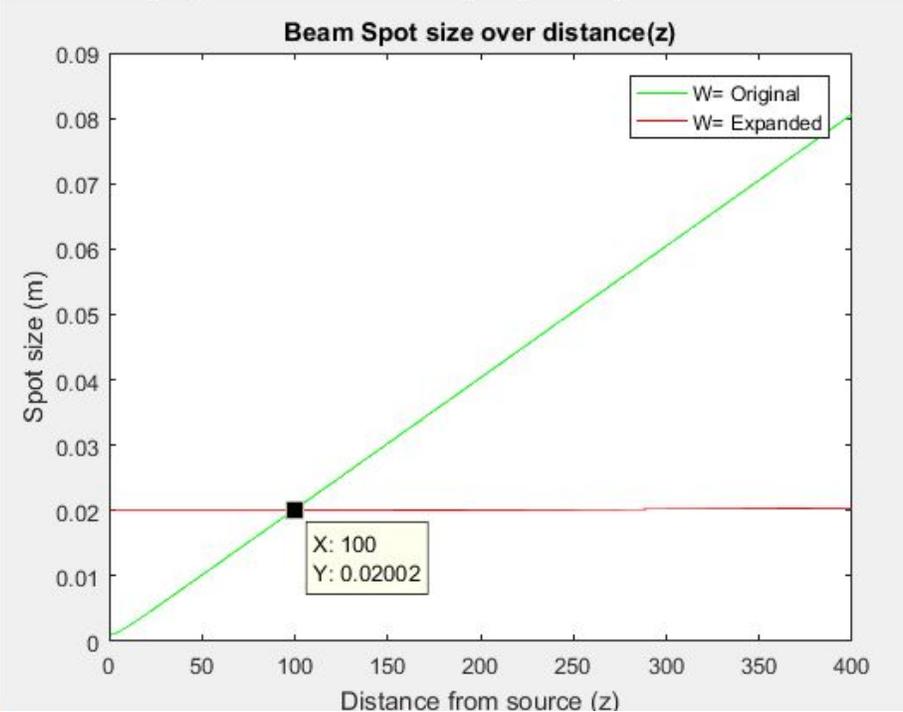


Figure 4. Plot showing beam spot size over distance for both the Original 1 mm beam versus the expanded 20 mm beam.

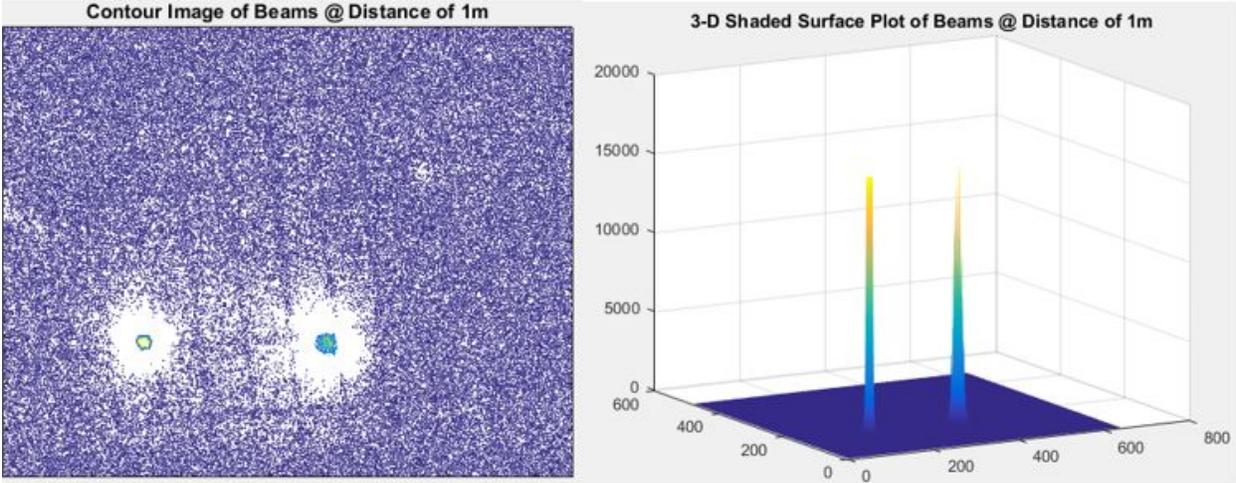


Figure 5. Contour Plot and 3-D Shaded Surface Plot of Beams at a distance of 1 m

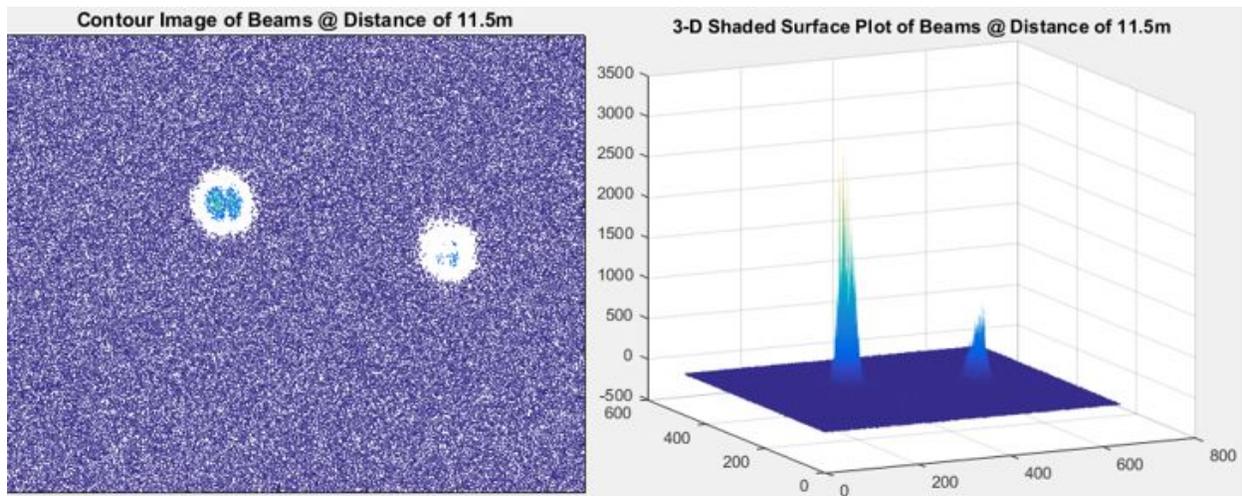


Figure 6. Contour Image and 3-D Shaded Surface Plot of Beams at a distance of 11.5 m

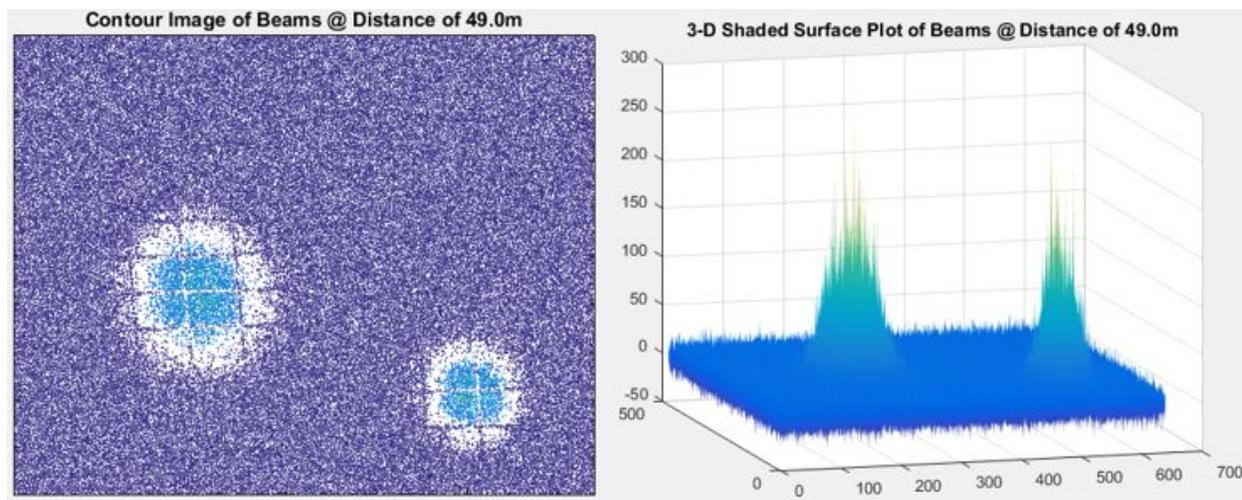


Figure 7. Contour Image and 3-D Shaded Surface Plot of Beams at a distance of 49.0 m

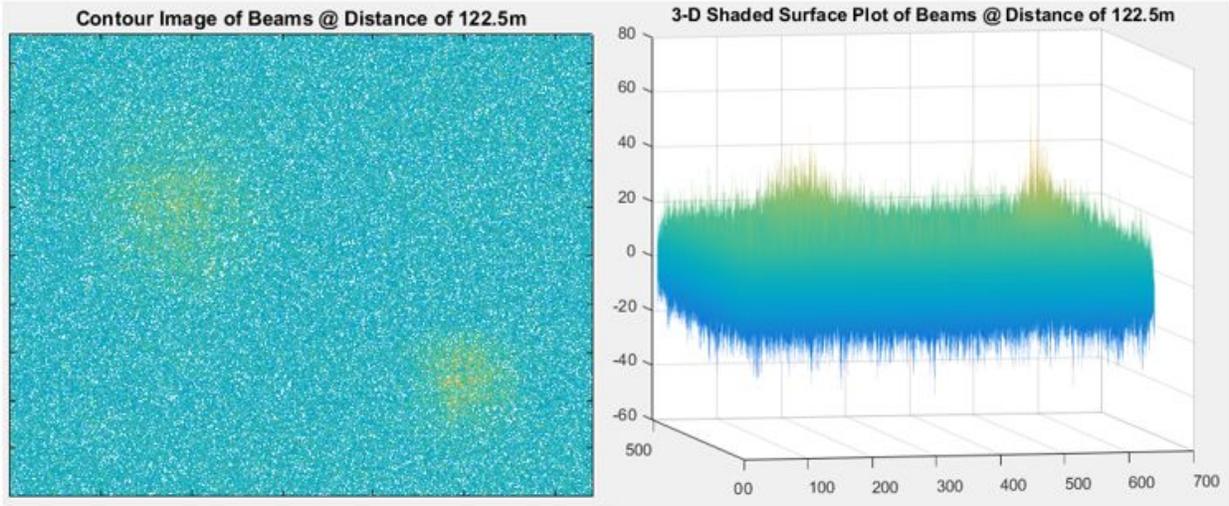


Figure 8. Contour Image and 3-D Shaded Surface Plot of Beams at a distance of 122.5 m

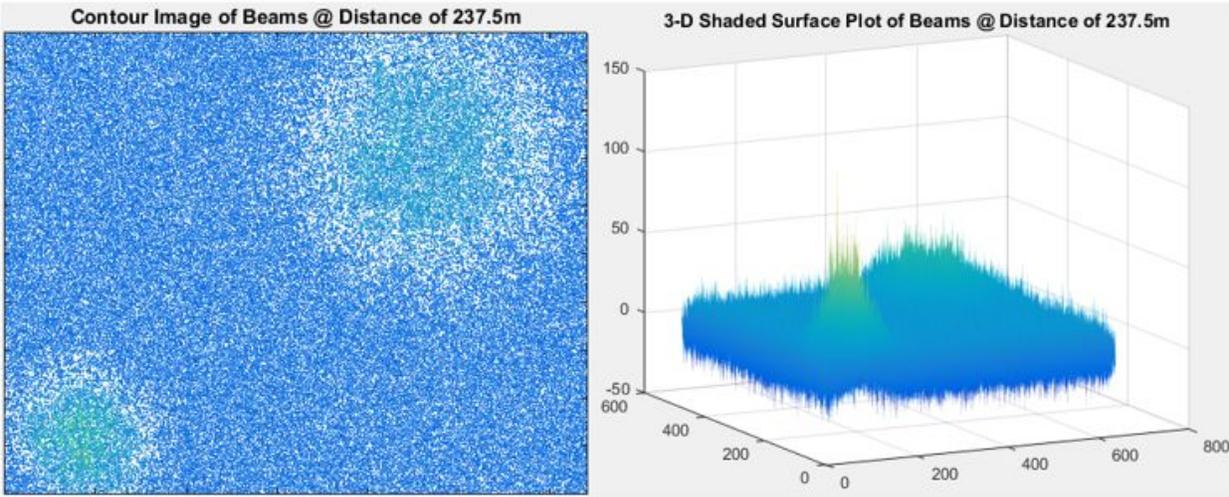


Figure 9. Contour Image and 3-D Shaded Surface Plot of Beams at a distance of 237.5 m

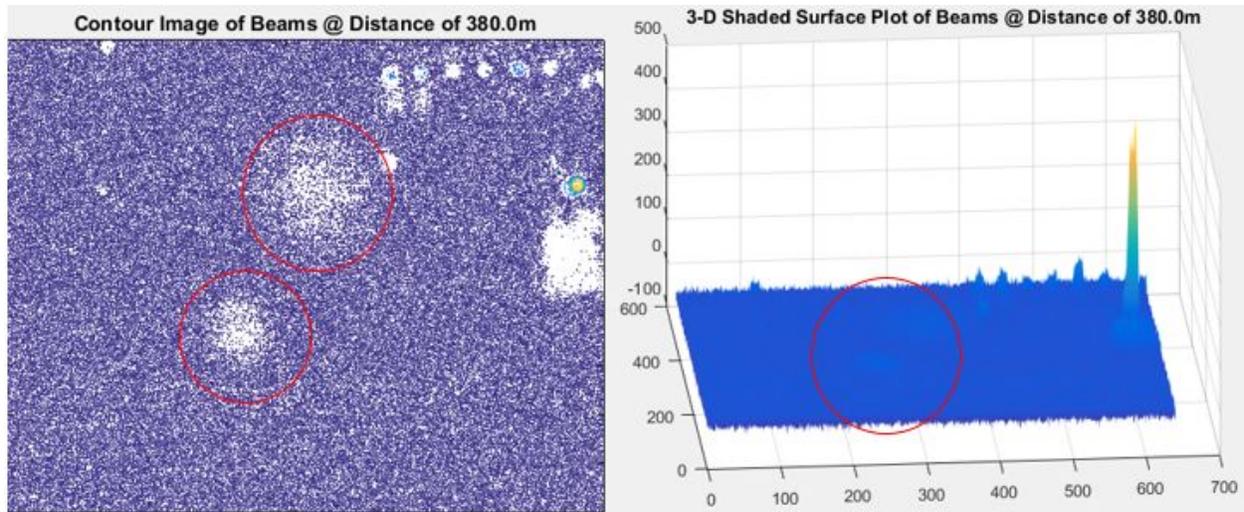


Figure 10. Contour Image and 3-D Shaded Surface Plot of Beams at a distance of 380.0 m. Beam spot locations enclosed in red circles.

**Table 2. Tabulated results of Power and Radius of Laser Beams.**

Distance (m)	Power (Spreader)	Power (No spreader)	Spreaded Radius (pixels)	Non-Spreaded Radius (pixels)	2 cm (pixels)	Conversion Factor (m/pix)	Spreaded Radius (m)	Non-Spreaded Radius (m)
1	.244 mW	.855 mW	8.26	5.5	32.14	0.000622	0.00514	0.00342
11.5	107.8 $\mu$ W	277.4 $\mu$ W	13.5	10.51	31.02	0.000645	0.00870	0.00678
49	16.8 $\mu$ W	10.5 $\mu$ W	33.64	22.59	39.12	0.000511	0.0172	0.0115
122.5	3.1 $\mu$ W	2.67 $\mu$ W	20.36	29.04	19.1	0.00105	0.0213	0.0304
237.5	1.1 $\mu$ W	.55 $\mu$ W	37.52	64.03	11.05	0.00181	0.0679	0.116
380	0.89 $\mu$ W	226.2 nW	19.17	40.96	4	0.005	0.0958	0.205

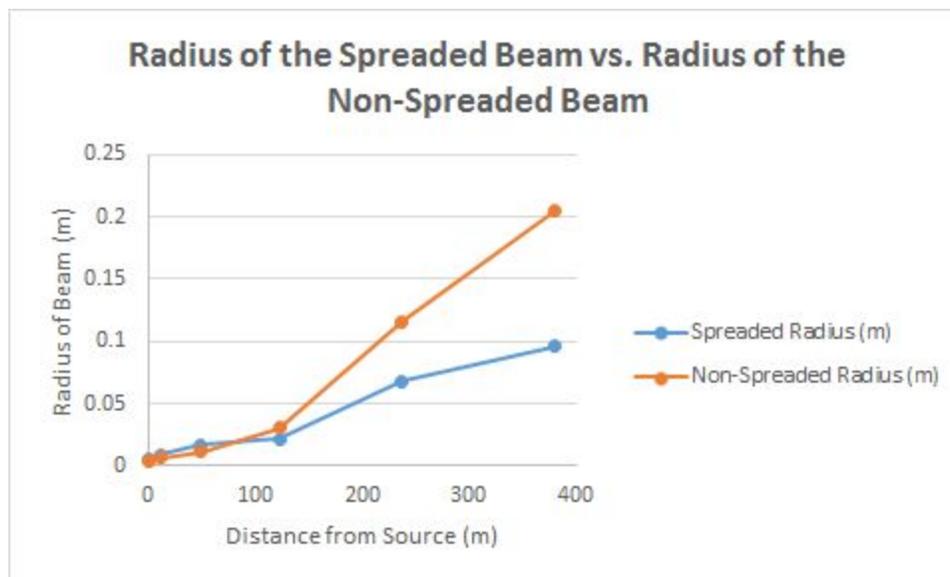


Figure 11. Plot comparing the radius size of the Spreaded and Non-Spreaded Beam at varying distances

# Conclusion

As expected the expanded beam carried more power over range and spread less.