# Laser Beam Focus with SLM

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## Abstract

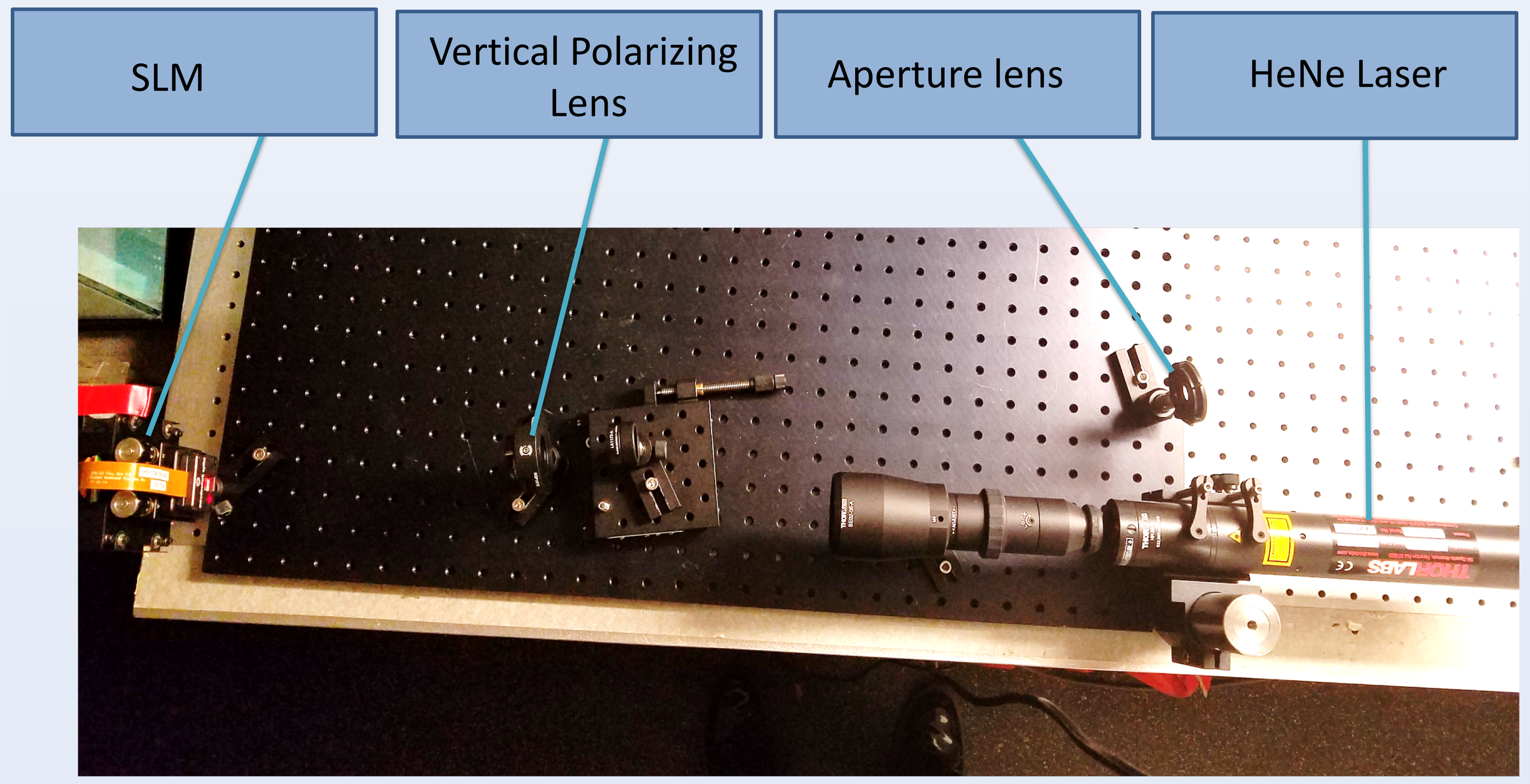
The motivation behind our experiment is to determine the feasibility of programming the Spatial Light Modulator (SLM) to function as a lens to focus a laser beam. Our experiment tested the relationship between parabolic shape and focal point. We were able to produce screens that created parabolas of various steepness which altered the focus of the beam. We observed that using the screens focused at the length the laser traveled would produce a more focused, centered beam.

## Background

There is a fundamental tie between coherent light sources and interference as the beam propagates. One of the greatest challenges to the practical use of lasers in communication is mitigating the speckle, essentially signal impurities, as the beam propagates. There are many different labs working on similar projects, including Dr. Hyde at the Air Force Institute of Technology, where he has been developing methods to use a SLM rather than lenses to improve spatial coherence and reduce speckle. The goal of our project was to test the feasibility of using the SLM to improve the focus of the laser beam.

The SLM used in our project contains cells that have a side length of 24 microns. The cells are laid out in a 256 by 256 matrix. The matrix of cells is filled with liquid crystal. The property of the liquid crystals enables one to change the index of refraction[3]. Through MatLab, one can adjust the matrix of the voltage[2] to be applied. The liquid crystals thus serve as a modulating material[3] because the index of refraction will change depending on what voltage is applied through MatLab. This allows us to systematically[5] modify the beam for our experiment.

The contour plots of the laser focused beams reveal how the shape of the screen has affected the focus and interference of the beam. Since the energy displacement is uniform in all trials, it is important to note where the energy is concentrated. The three primary regions are the Fourier transform (which appears as a cross-hair), the center bullseye, and the speckle surrounding the region. In our contour plots we are looking for a uniform concentration at the center bullseye with decreased concentration in the surrounding speckle region.



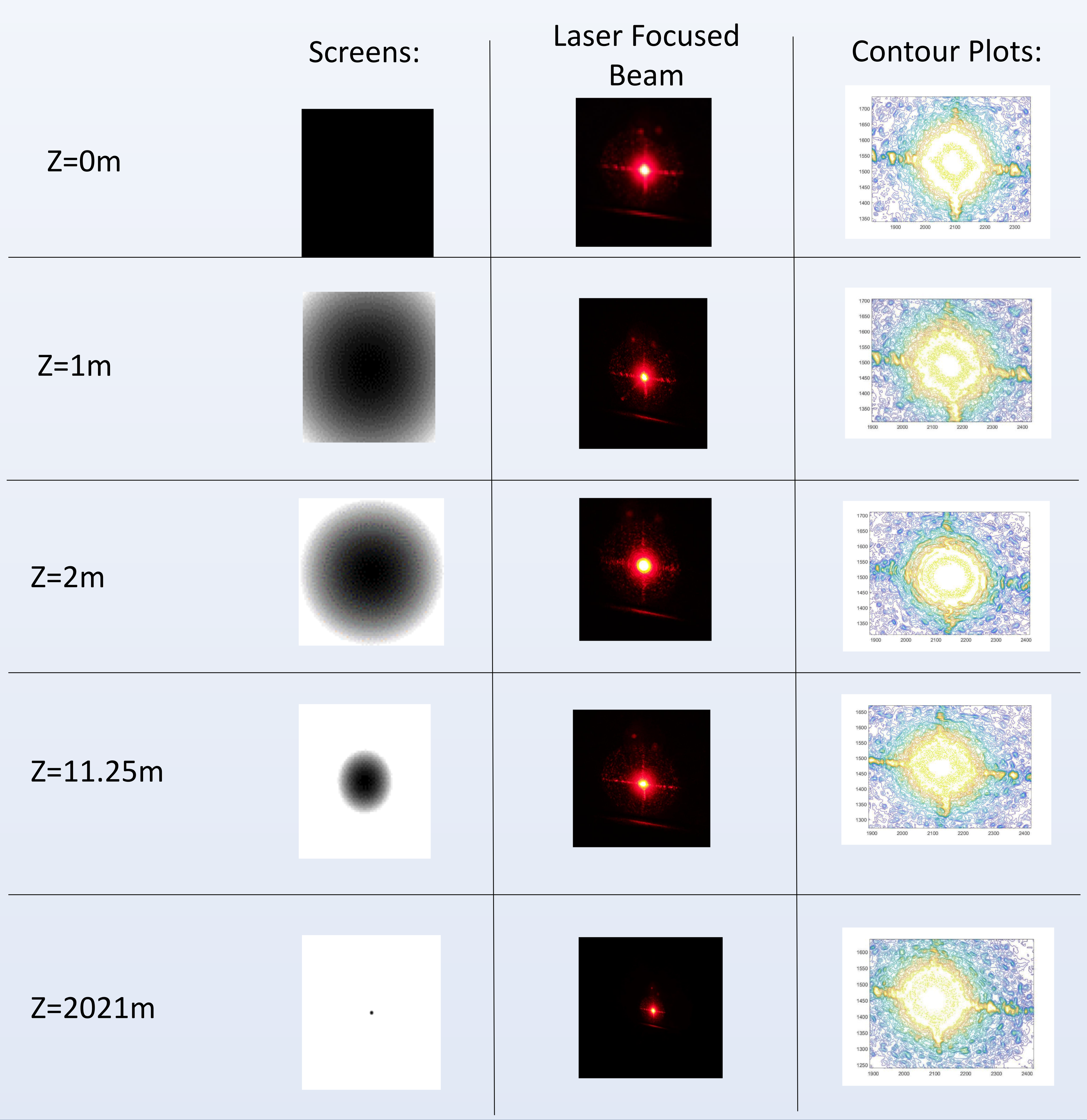

## Methods

The experiment was set up with a laser, an expander, an SLM, and two mirrors to reflect the laser 11.25 meters. The MatLab program copied to the right, provided by Professor Avramov-Zamurovic, was used to input different values for the height of the parabola, represented by Z, to produce different screens on the SLM. After testing the different screens, the results of Z =1, 2, 11.25, and 2021 meters were compared to the the blank screen. A contour plot of each picture was generated and then the plots were compared to each other.

Example code: screen for z = 1

```
format compact
wvl = 632.8e-9;k = 2*pi/wvl;SLM_Pitch = 24e-6;
SLM_PixelsX = 256;SLM_PixelsY = 256;
SLM_Lx = SLM_PixelsX*SLM_Pitch;
SLM_Ly = SLM_PixelsY*SLM_Pitch;
[xslm,yslm] = meshgrid((-SLM_PixelsX/2:SLM_PixelsX/2-1)*SLM_Pitch, ...
    (-SLM_PixelsY/2:SLM_PixelsY/2-1)*SLM_Pitch);
g =( (xslm ).^2 + (yslm ).^2);p=max(max(g));g=g/p;z=1
S = z*g;
figname = sprintf('z-one.bmp' )
imwrite(S,figname, 'bmp');
```

## Results




## Conclusion

Through our experiment we found that it is possible to use the SLM to alter the focus of the laser beam. There is a direct relationship between the slope of the parabola and concentration at the center of the beam spread.

The contour plots graphically display our results quite well. The energy transfer will be a uniform 2 mW since that is the power of the laser, thus the location of the intensity reveals how the SLM screen alters the character of the beam. The white gaps are a standard diffraction pattern that is a result of the self-interference of coherent light sources. The cross-hair is present in every contour plot because it is the Fourier transform of a laser beam reflecting off a square surface, so it can not be removed. However, the speckle surrounding the center of the beam can be minimized since it is a result of the beam's interference as it propagates.

Our control, which was the blank screen has a standard diffraction pattern, and relatively homogenous spread across the viewing board. When Z = 1, the Fourier transform has greater definition but the speckle actually fills the region more than it had when Z = 0. At Z = 2 the Fourier transform is reduced but the center focal point has substantially less flux than the control, which is undesirable for communication. Z = 11.25 has the most homogenous dispersion in the center focal point and a sharply defined Fourier transform while surrounding speckle became more sparse. For completeness we tested 2021 to see behavior at the other end of the spectrum, but we observed that the center point has almost total data loss, and most of the energy concentration is in the surrounding speckle.

The future implications of this result are enormous. We believe the Navy and DoD would benefit from the development of this technology to create active tracking when communicating via lasers. It would be interesting to expand the scope of our experiment by considering moving targets and focal points. Recently, the U.S. Department of Energy Office of Fusion Energy Sciences conducted research on focal points by examining the focal velocity through the concept known as "flying focus."[4] The goal of their research was quantifying the focal point's propagation at speeds 50 times greater than the speed of light.[4] The hope is that this research will lead to the next big improvement in high-powered lasers.[4]

In further research, it would be interesting to consider changes in PSNR or peak signal-to-noise ratio as the value for Z changed.[1] In a project published by the Optical Society (OSA), an SLM was used to observe hologram generation. PSNR, which quantifies reconstruction fidelity, was calculated to measure the quality of the intensity generated by each beam. PSNR would be an interesting metric to consider in future work done on our own experiment as a way to quantify what was observed in the contour plots.

Some of the results we observed may have been skewed by a phenomena known as hot spot. At the shorter distances of the experiment, the deficit in the intensity of the focus may have resulted from the hot spot phenomena. Mathematical calculations on how to account for this phenomena and research on how to minimize the effects of hot spot would be interesting and necessary for future research.

## References

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4. University of Rochester. (2018). *'Flying focus' used to better control lasers over long distances.* Science Daily.
5. Vyas, Roopashree, and Prasad. (2009). *Digital Long Focal Length Lenslet Array Using Spatial Light Modulator.* International Conference on Optics and Photonics.

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