Evaluation of Scintillation Index and Intensity of Partially Coherent Laser Light

MIDN 4/C Meredith L. Lipp and MIDN 4/C Kathryn L. Quandt

Professor Svetlana Avramov-Zamurovic, Professor Reza Malek-Madani

Abstract

As laser light travels through space, it interacts with the environment causing a disruption of the beam. Our work intends to analyze different variations of coherent and partially-coherent light. By disrupting the phase of the light at the source, we hope to obtain a more concentrated and consistent (minimal scintillation index) beam at the target as compared to a perfectly coherent beam.

Theory

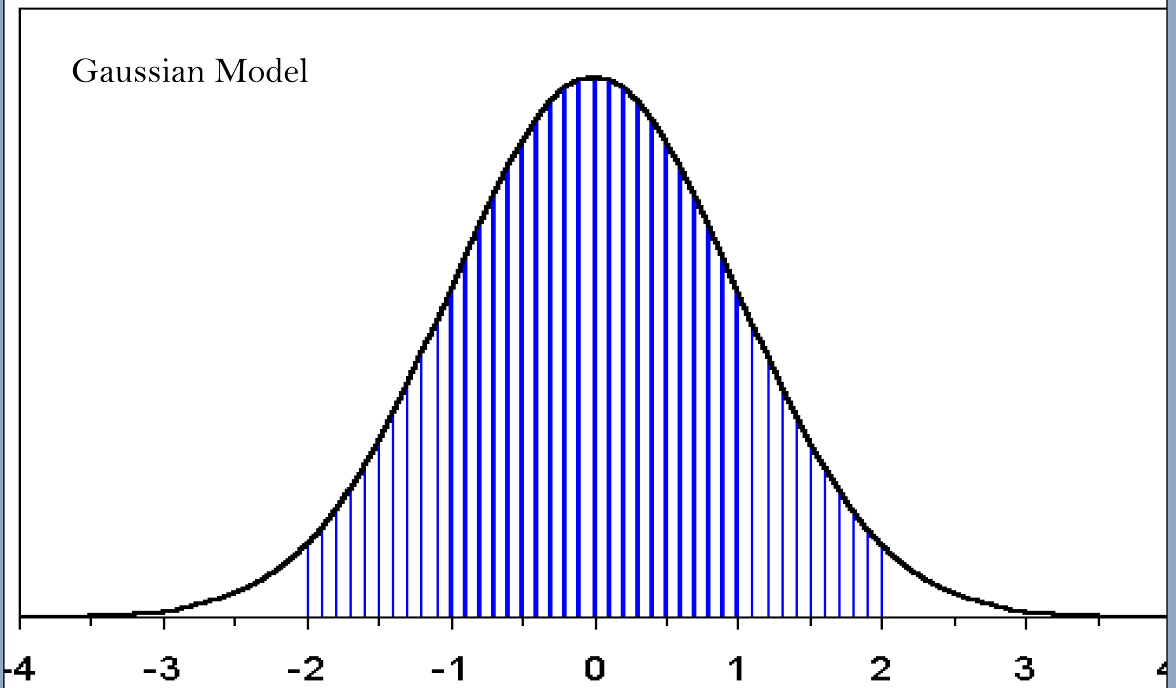
Laser light is a unique type of light with three distinguishing characteristics:

1. **Coherence**: All wavelengths of the light are in the same phase. Visually, a cross-section of light is of all the same intensity.
2. **Monochromaticity**: The light is of only one wavelength, or one color.
3. **Collimation**: The light waves are exactly parallel; thus the light diverges slowly.

The quality of laser light depends upon these factors, and upon *turbulence* (environmental effects that disrupt ideal light propagation). Turbulence scatters the coherent, collimated light into a more disordered state.

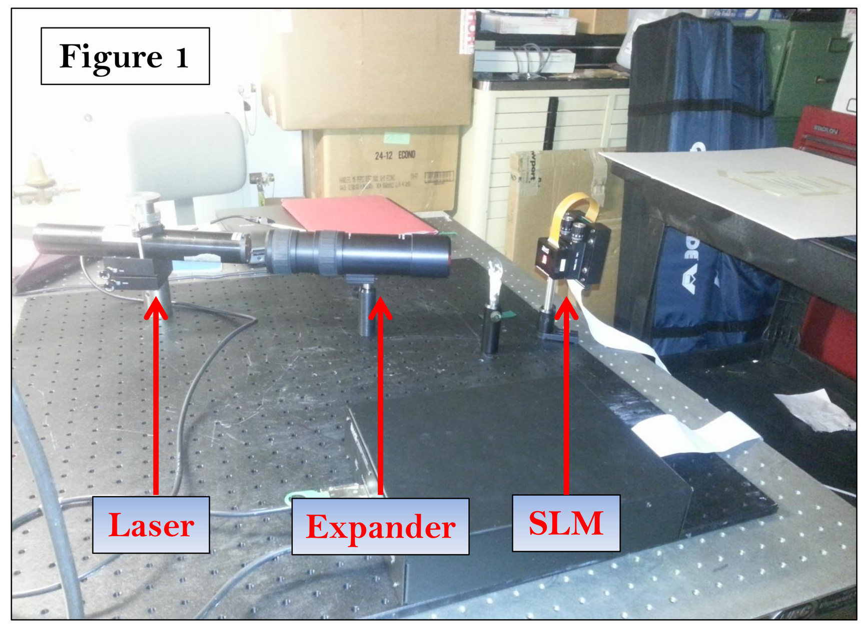
To offset the effects of turbulence, we use a *partially-coherent* beam of light. By randomizing the light waves before propagating them through a turbulent space, the resultant beam remains coherent and collimated over a longer distance than a perfectly coherent beam. Laser light is not found in nature, and the randomness of the environment seeks to disrupt the orderliness of the man-made phenomena.

Standard laser light obeys the Gaussian model (shown below). Intensity peaks at the center of the beam. In our experiment, we tested how partially coherent light disperses in an attempt to randomize the light and achieve higher intensity at the target.



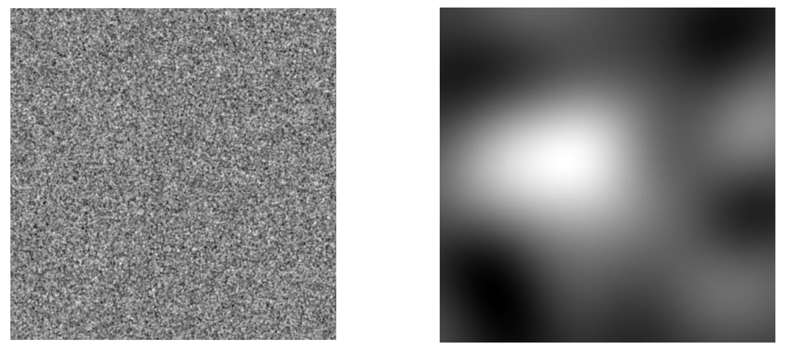
Methods

Figure 1 shows the alignment of the laser, expander, and SLM.

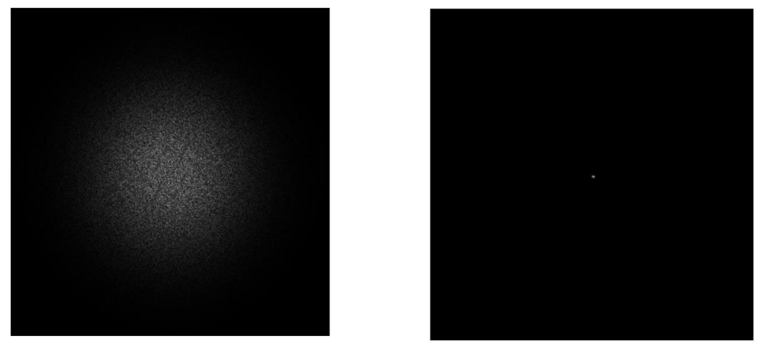


The laser light was then reflected off the mirror in Figure 2 and propagated a total of 100m down a corridor to be recorded by a camera with a red filter. The camera recorded the laser light at a rate of 10 frames per second for approximately 2 minutes per SLM screen.

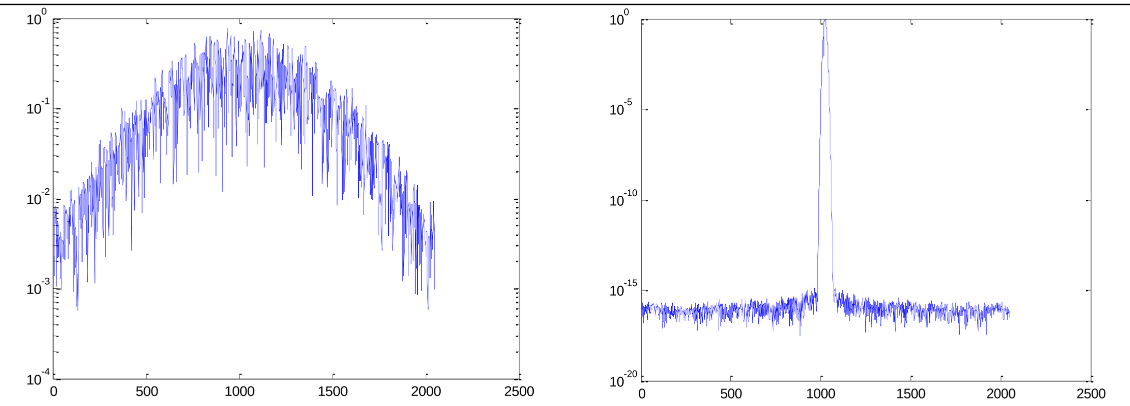
The figures below are examples of the Matlab produced screens for the SLM which determine the degree of coherence of the propagated beam. The more granular picture on the left represents a beam with low coherence, corresponding to Screen 2. The other corresponds to Screen 8192.



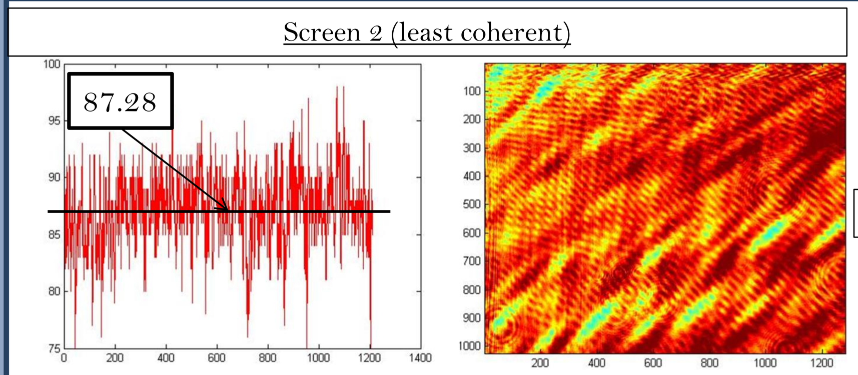
A Matlab program was used to predict the far-field representations at 100m of the resultant beams produced by reflecting the laser off of the screens shown above.

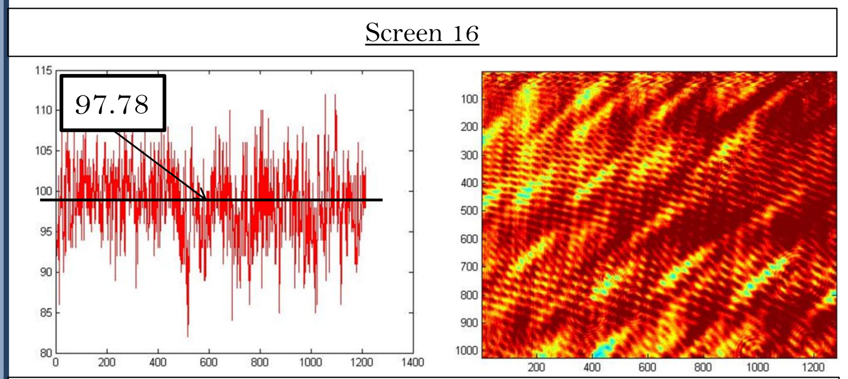


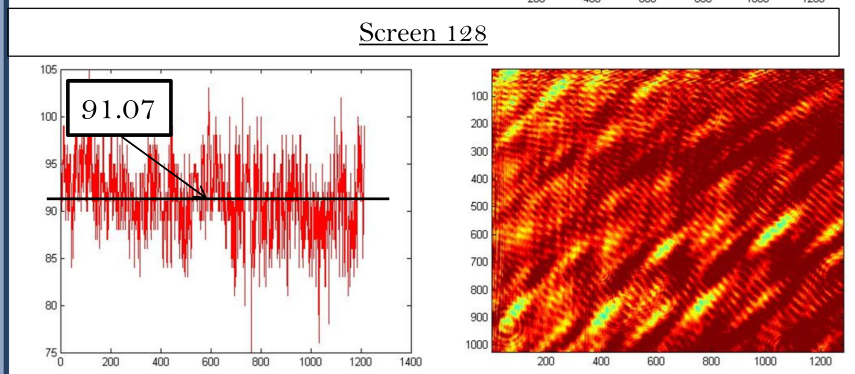
The figures below are the projected intensity graphs for the beam at the target for each coherence level.

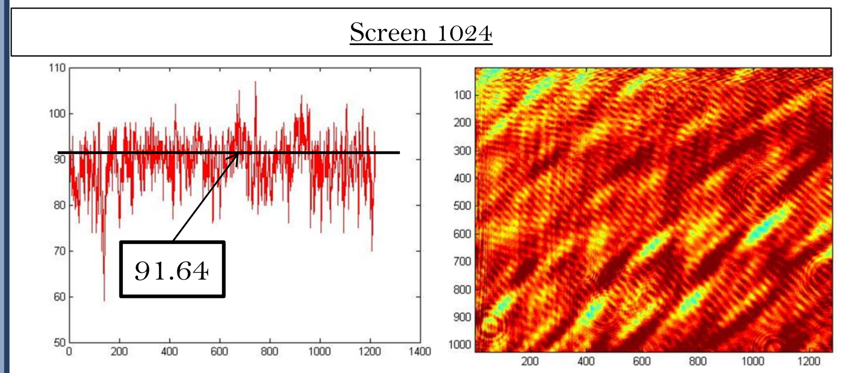


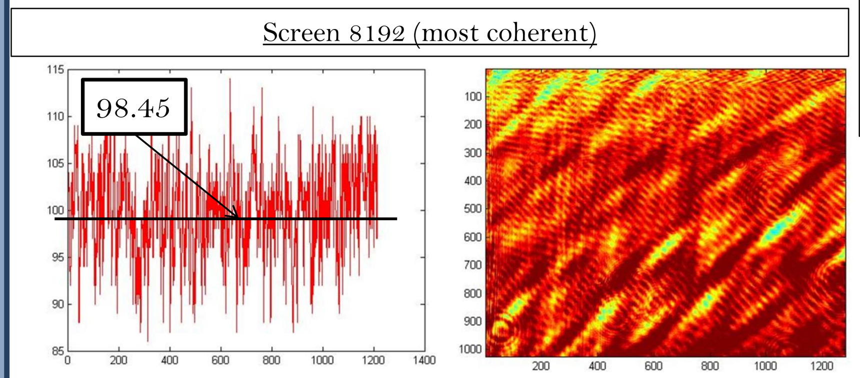
Results

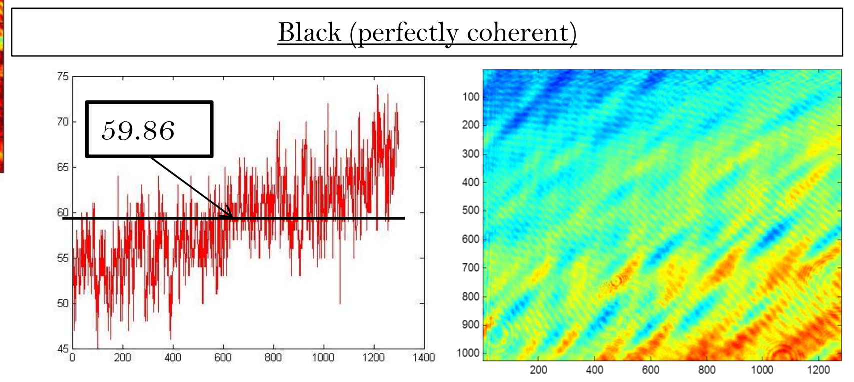


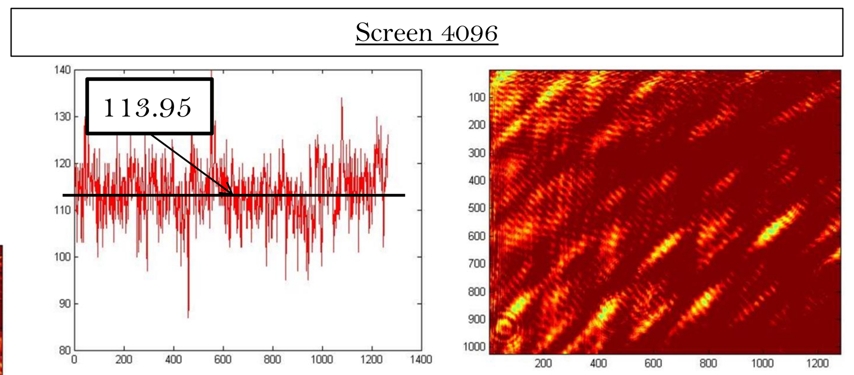




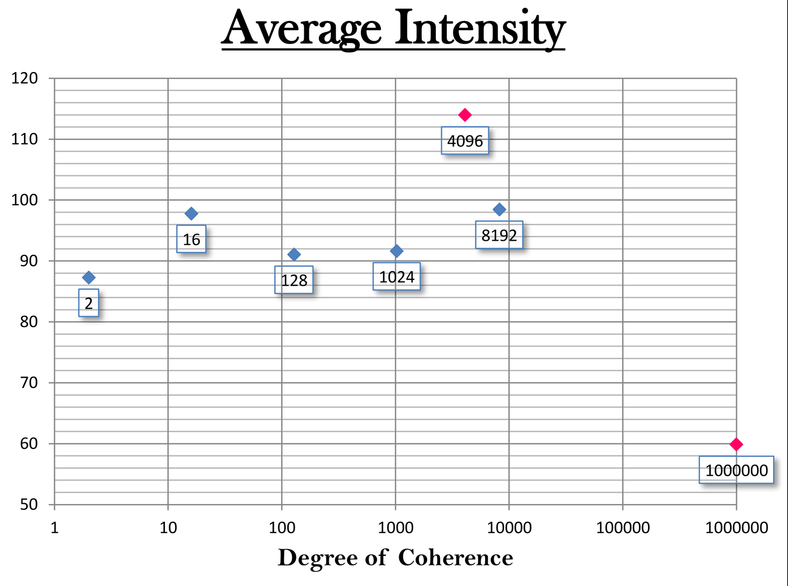


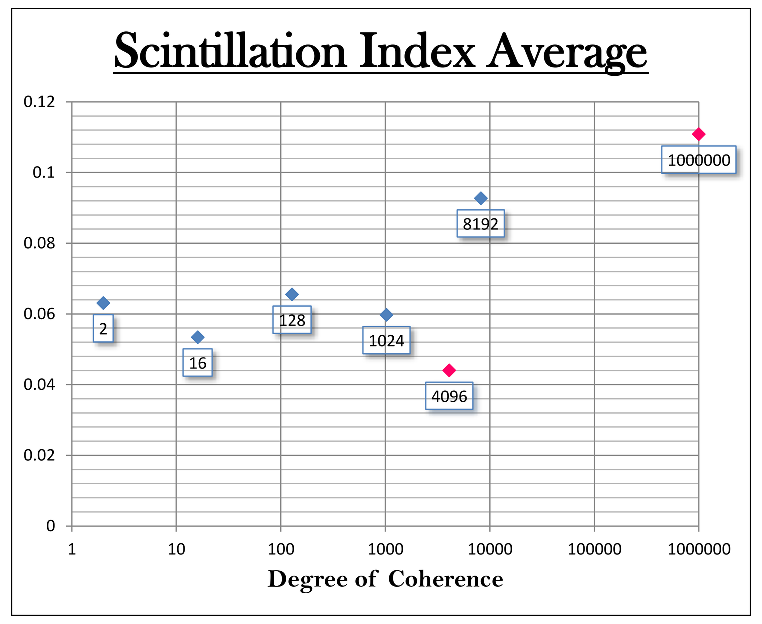






These images were produced by Matlab and indicate the scintillation index and intensity of the laser light at the target. It was expected that as coherence increased, so too would intensity; however that is not the relationship seen here. The coherence level at 4096 (pictured in the center) had a significantly higher average than any of the other partially-coherent beams. Also, the perfectly coherent beam had a lower intensity than all of the partially-coherent beams. This is a unique finding; however, some theory does support that partially coherent beams will have greater success propagating in a non-ideal environment than perfectly coherent beams.





The charts above simply reinforce that the partially coherent beams have higher intensities and lower scintillation indexes than a perfectly coherent beam. Of special note again, the 4096 coherence level performs outstandingly well.

Description of Equipment

ThorLabs HNL020L 632.8 nm Helium Neon Laser

- $1/e^2$ beam diameter: 0.63 mm
- Divergence: 1.3 mrad
- Output Power: 2.0 mW

BNS Spatial Light Modulator (SLM) – XY Series

ThorLabs DCU224M - CCD Camera

- Red Filter with Absorptive Filter ND = 3.0
- 1280 x 1024 pixel resolution

References

"ThorLabs HNL020L-EC – HeNe Laser." *Thorlabs.* 2013. Accessed 29 April 2013. http://www.thorlabs.us/thorproduct.cfm?partnumber=HNL020L-EC.

"ThorLabs DCU224M - CCD Camera." *Thorlabs.* 2013. Accessed 29 April 2013. http://www.thorlabs.com/thorproduct.cfm?partnumber=DCU224M.

Conclusion

Analyzing the graphs shows a distinct relationship between the coherence of the beam, intensity, and scintillation index. Turbulence in the environment causes greater dispersion of the perfectly coherent beam than of the partially-coherent ones. Screen 4096 produced a particularly good beam, with a high average intensity and low scintillation index. Possibly, further exploration into this "hot spot" would reveal the beam with the best probability of reaching the target at a maximum intensity and low scintillation index. This could be used for long distance communication and laser-targeted weapons in the military. Currently, research in these areas is of extreme interest to many organizations.