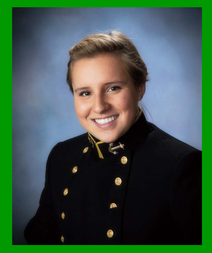

Minimizing Scintillation using Pseudo-partially Coherent Beams

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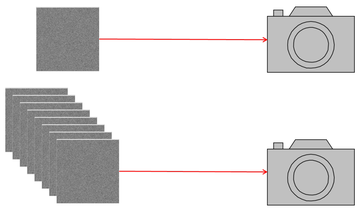
Motivation

The purpose of this project is to produce a method that will allow laser beams to propagate through a maritime environment with minimal scintillation (normalized variance to the mean intensity). This new technique could then be applied as a way to communicate over long distances with lasers rather than radio or as a weapon instead of missiles. Research in this area is being pursued fervently all around the country, and throughout the world as well. This specific experiment aimed to use Pseudo-partially coherent beams to achieve lower scintillation when propagating through a turbulent atmosphere.

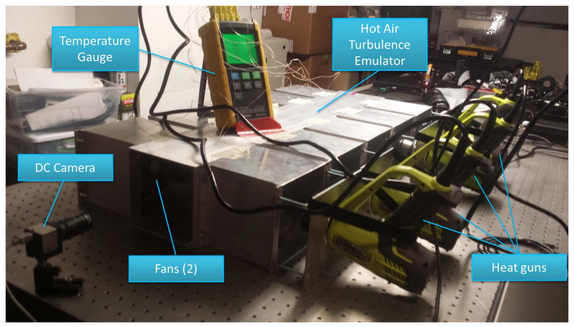
Theory

Theory predicts that a pseudo-partially coherent beam will result in reduced scintillation at the target because of the many realizations per data point.



Hot Air Turbulence Emulator

- Emulator: can be used to mimic some of the effects of high turbulence found by propagating a beam over a long distance.



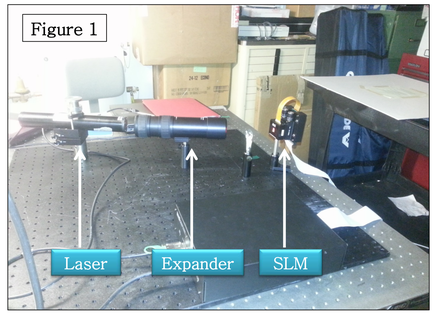
Set up:

- four heat guns providing thermal flow of 200F
- opposed by 4 fans providing ambient air counter flow.
- heat from the guns is dispersed by three diffuser screens set in front of the heat guns.
- Temperature probes spaced evenly throughout taking a reading every second.

Previous analysis of these temperature changes categorized the turbulence as approximately Kolmogorov along the beam propagation axis with an average C_n^2 value of 3.81E-11. (3)

Methods

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



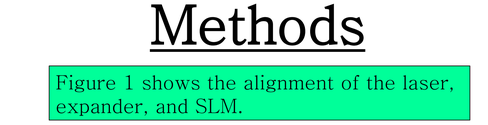
The laser light was then propagated through the hot air turbulence emulator and recorded at the camera, which records at approximately 13 frames per second.

Examples of the MATLAB produced screens for the SLM which determine the degree of coherence of the propagated beam.

This experiment used SLM Screen 0.5 because it most closely matched what was used in the theoretical experiments.

Black (perfectly coherent)	SLM Screen 0.5 (strong diffuser)	SLM Screen 8192 (weaker diffuser)
		

Far field representations of the corresponding beams



Intensity Distributions

Procedure

- 2 types of runs
  - Low turbulence (wind speed 0.05 m/s)
  - High turbulence (wind speed 0.4 m/s)
- Cycle rate (Hz)
  - 0, 1, 2, 4, 10, 20, 40, 100, 200
- Begin temperature collection
- Start camera recording
  - 1000 frames per run

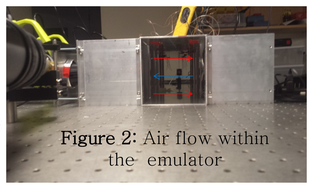


Figure 2: Air flow within the emulator

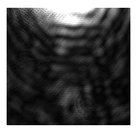
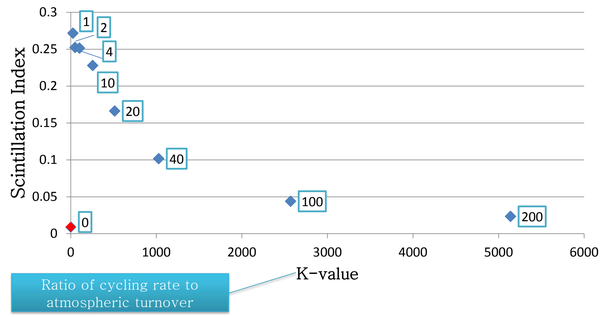
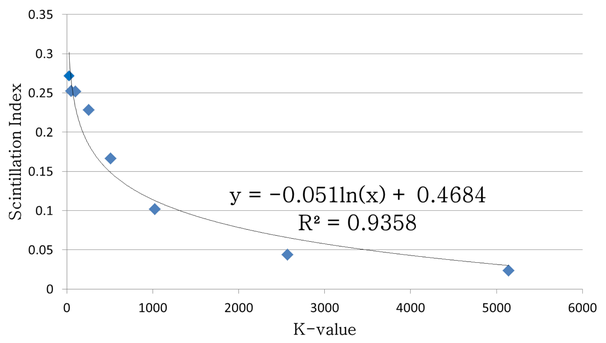


Figure 3: Sample image from camera

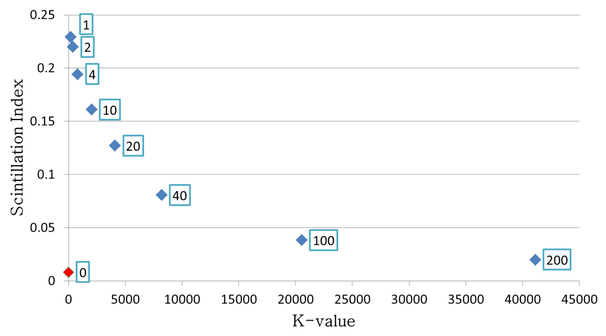
Results

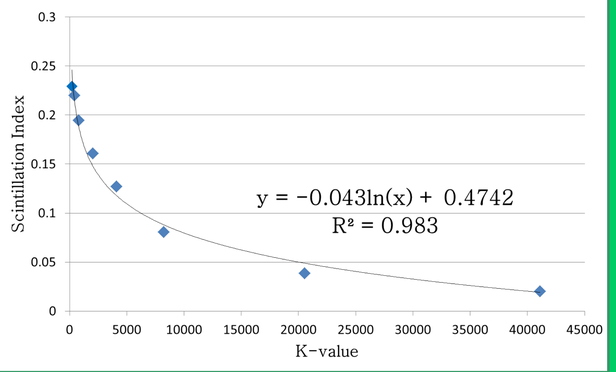
Low Turbulence





High Turbulence

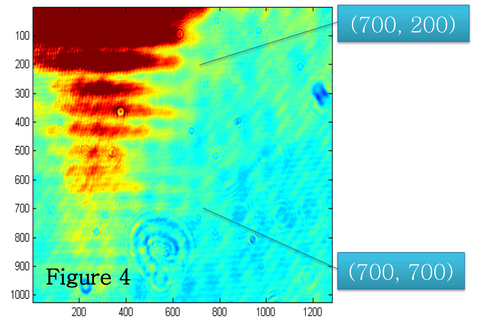


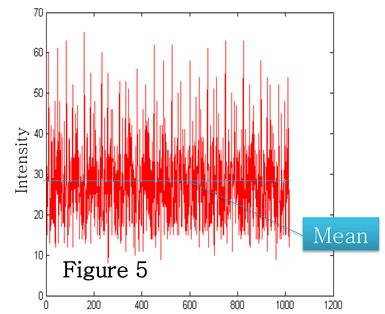


Data Collection

Below are graphs indicating the intensity vs. position (**Figure 4**) and intensity vs. frame number, or essentially time (**Figure 5**). Using this data, we produced the graphs to the left.

$$Scintillation\ index = \frac{variance}{mean^2}$$





The intensity of these two data points was taken for each frame. The average was then calculated for each and used to calculate the scintillation index. These two values were then averaged to produce the graphs to the left.

Conclusion

From this experiment we conclusively proved that increased cycling rates results in lower scintillation, both in low and high turbulence, respectively. In addition, the data suggested that as turbulence increases, faster cycling rates may produce lower scintillation than a simple static beam. The next step will be to investigate pseudo-partially coherent beams in higher turbulence, possibly taking this experiment outside into a truly random environment.

References

(1) C. Nelson, S. Avramoz-Zamurovic, O. Korotkova, R. Malek-Madani, R. Sova, and F. Davidson. "Measurements of partially spatially coherent laser beam intensity fluctuations propagating through a hot-air turbulence emulator and comparison with both terrestrial and maritime environments."
(2) David Voelz and Kevin Fitzhenry. "Pseudo-partially coherent beam for free-space laser communication."
(3) C. Nelson. "Experiments in Optimization of Free Space Optical Communication Links for Applications in a Maritime Environment," dissertation from John Hopkins University, 2013.
(4) Qian, Xianmei, Wenyue Zhu and Ruizhong Rao. "Numerical Investigation on Propagation Effects of Pseudo-partially Coherent Gaussian Schell-model Beam in Atmospheric Turbulence." Optical Society of America. 26 February 2009.
(5) Qian, Xianmei, Wenyue Zhu and Ruizhong Rao. "Scintillation of pseudo-partially coherent Gaussian beam in atmospheric turbulence: application for free-space optical communications."