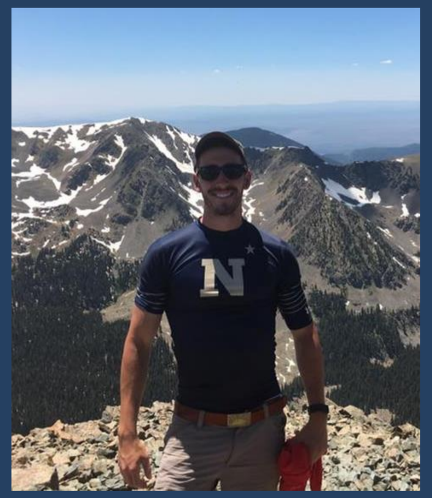
Exploration of Wavelength Diversity in Underwater Laser Propagation



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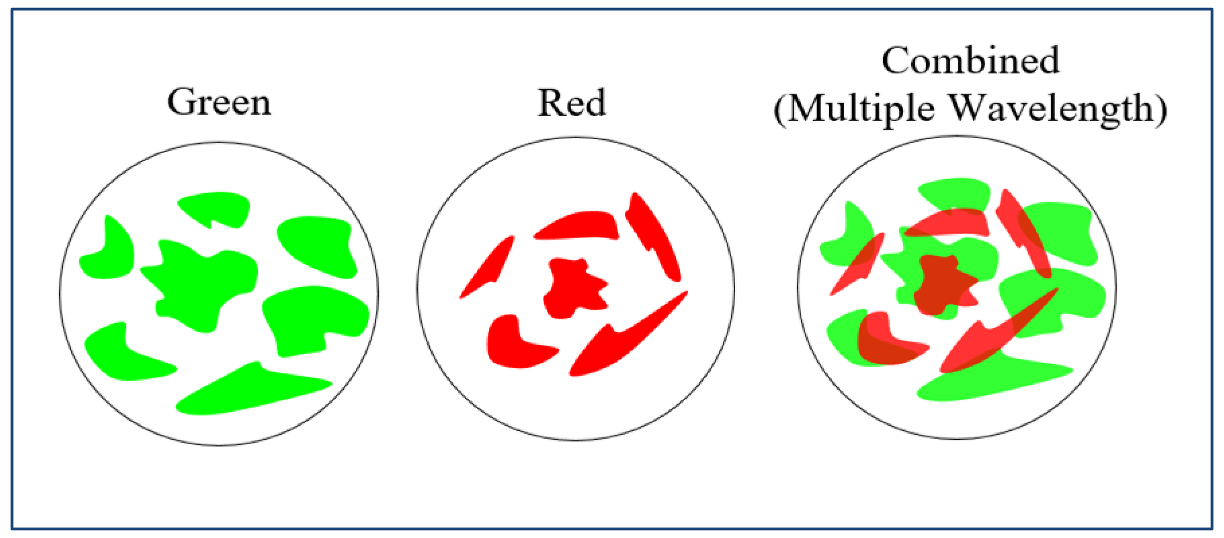
Motivation

Laser beams propagating through complex media commonly experience degradation. This experiment investigates the effects of using multiple different beams frequencies transmitting along the same path onto the same receiver as a method of mitigating distortion. We intend to explore the effects of wavelength diversity on beam propagation in the underwater domain. Additional effects including the changes in scintillation for each transmitted beam will be explored, in order to better characterize the effects of wavelength diversity on laser beams propagating in turbulent environments.

Background

The use of multiple wavelength beams has been investigated for the minimization of scintillation index particularly in the atmosphere. Though experimental evidence is lacking, some initial experimentation and simulation has shown that propagation through atmospheric turbulence with multiple wavelength beams should result in a reduced scintillation index when compared to the beams individually. The below diagram shows in simple ways how increasing the number of wavelengths would increase the incident radiation, since each wavelength creates its own specific interference pattern on the receiver.



Irradiance Pattern on Receiver for Green/Red/Multiple Wavelength Beams through turbulence.

Acknowledgements

Systems Engineering Technical Support Division
MSC Graphics Dept

References

-Avner Peleg and Jerome V. Moloney, "Scintillation index for two Gaussian laser beams with different wavelengths in weak atmospheric turbulence," J. Opt. Soc. Am. A 23, 3114-3122 (2006)
-Purvinskis, Robert and Giggenbach, Dirk and Henniger, Hennes and Perlot, Nicolas and David, Florian (2003) "Multiple Wavelength Free-Space Laser Communications," Proceedings of the SPIE, Vol. 4975, pp. 12-19. SPIE Optical Press. Free-Space Laser Communication Technologies XV, 2003-01-28, San Jose, California, USA.

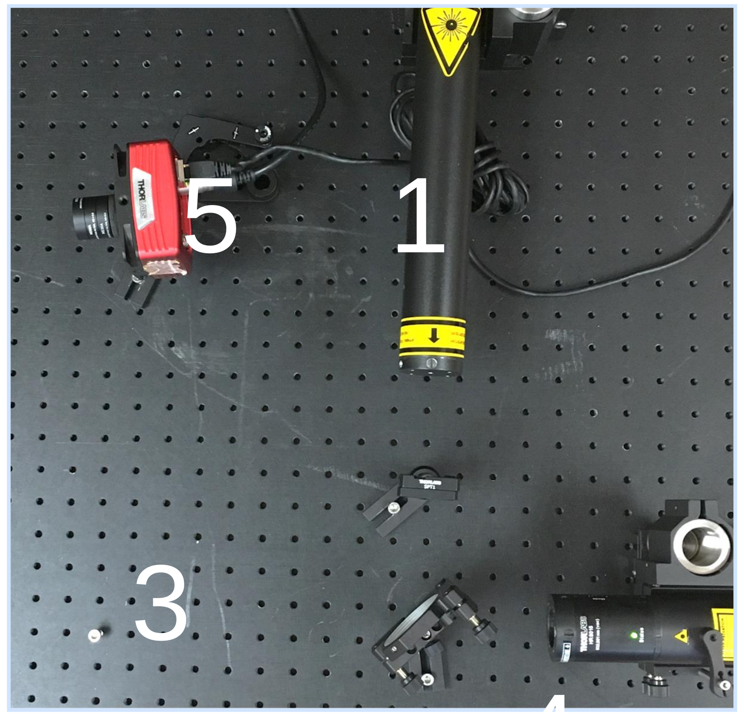
Experimental Method

Purpose

This experiment will involve using two laser beams (green and red visible light) and combining them into a multiple wavelength beam. The two individual and one combined beam will be propagated through a tank of distilled water. Inside the tank is a heating element, which regulates the temperature of the water and produces a slight turbulent mixing. Each of the beams will be collected via a camera for each temperature, and the resulting performance of the beams will be analyzed.

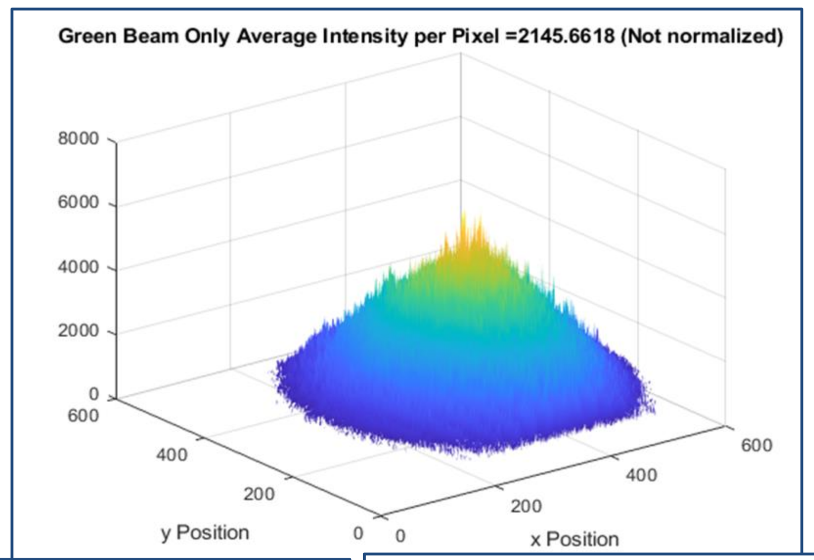
Setup

1- 543 nm (green) HeNe Laser
2- 633 nm (red) HeNe Laser
3- Neutral Density Filter (empty)
4- Beam Splitter
5- Receiving Camera

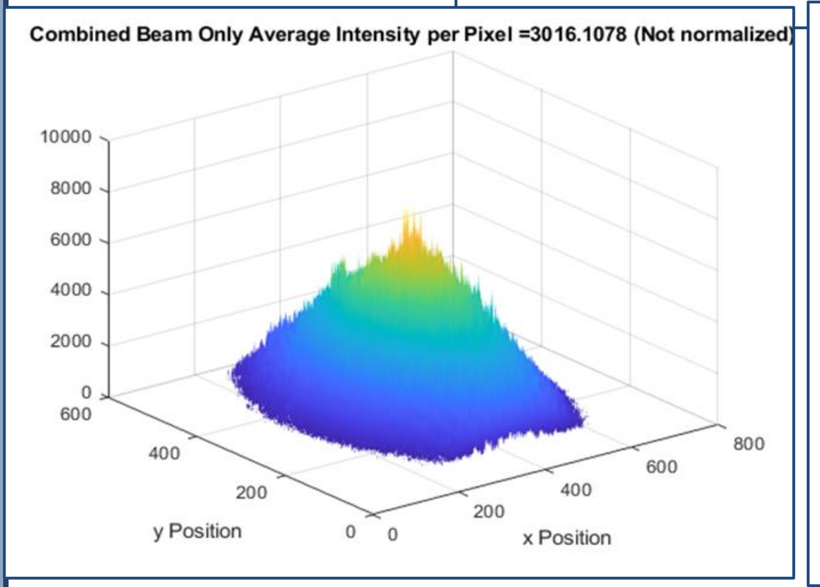


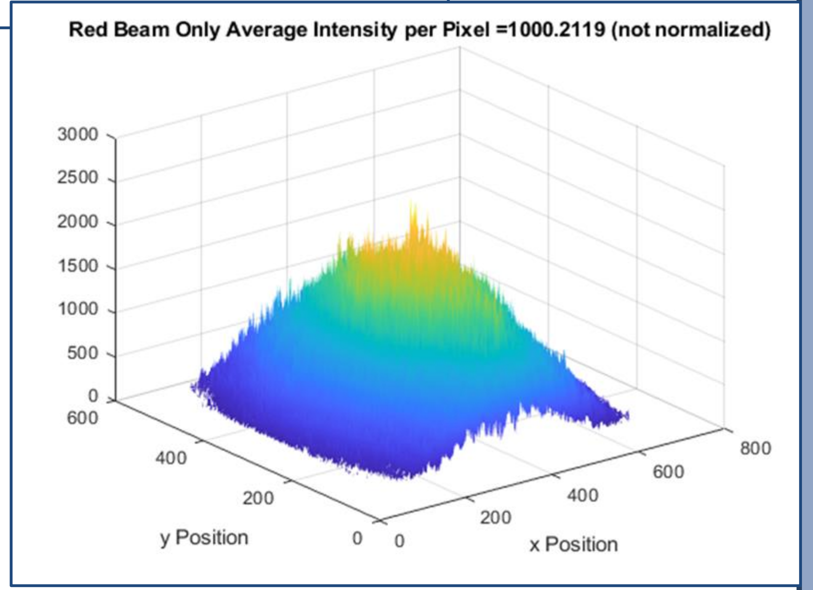
Execution

- Heating elements bring tank to desired temperature
- Beams propagated into beam splitter
- Beam splitter combines beams onto same propagation path, creating multiple wavelength beam
- Beams enter and exit propagation tank
- Beam profiles collected by camera (sample below)



Intensity profiles of each beam at 80 F

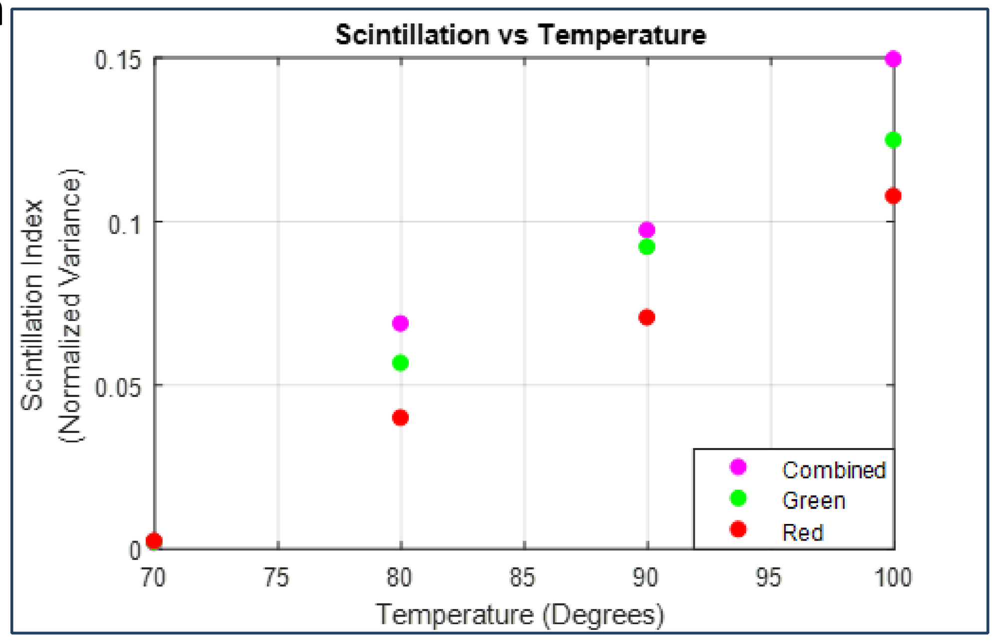




Results

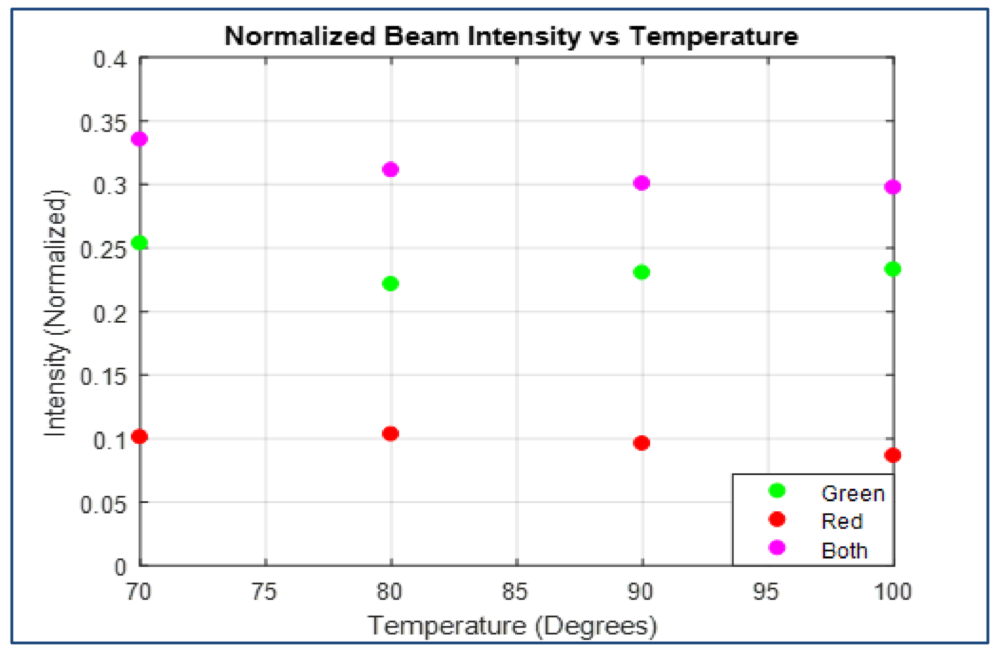
Scintillation (normalized mean variance)

-Positive correlation between temperature and scintillation index
-Scintillation lower for red beam, higher for green beam, and highest for combined beam
-Results unexpected from atmospheric modeling



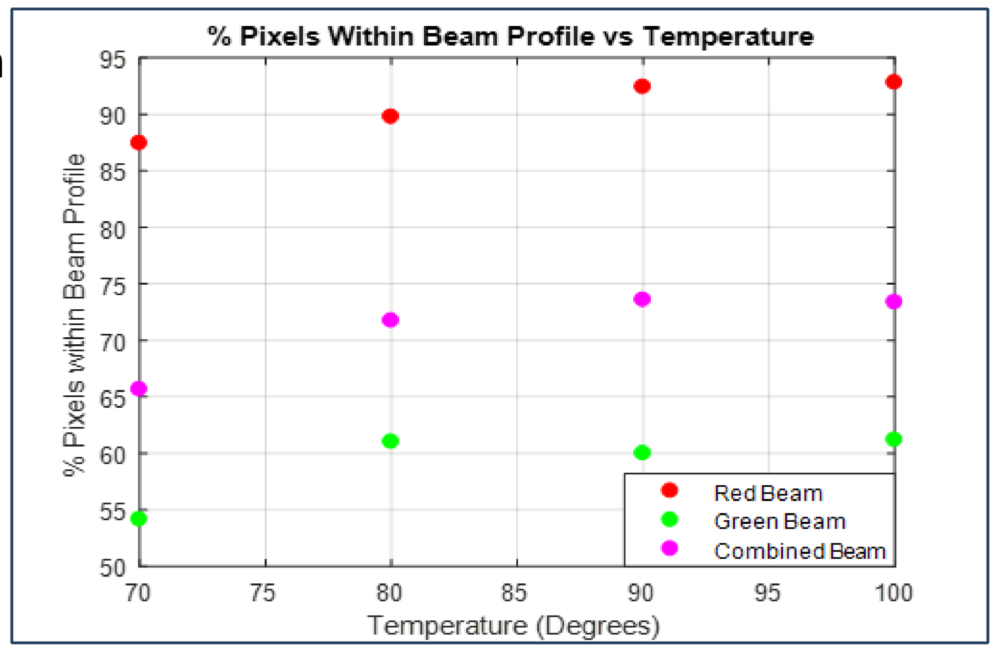
Intensity

-No correlation between intensity and water temperature
-Red beam has lowest intensity, due to absorption
-Combined Beam intensity slightly lower than sum of intensity of the two component beams



Beam Size

-Positive correlation between Beam spot size and temperature
-Beam spot defined as beam profile with intensity greater than I_{max}/e^2, when I_{max} is the max intensity for each individual beam



Moving Forward

Looking forward, there are a lot of potential permutations which could be investigated regarding the beams, their properties, and the environment they propagate through. Ideally, further investigation into reducing the scintillation index through the use of multiple wavelength beams.