Exploration of Multiple Wavelength Laser Beams Propagating Underwater

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Motivation

Laser beams propagating through complex media commonly experience degradation. This experiment investigates the effects of using laser beams with different wavelengths propagating along the same path as a method of mitigating distortion. We recorded intensity measurements of both a red and green laser after passing through a temperature and flow controlled underwater path and explored the effects of wavelength diversity on laser scintillation.. The final experimentation yielded repeatable and significant reductions in the scintillation of the multiple wavelength beam compared to its individual component beams.

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

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References

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- Trinh-Thi-Kim Tran, Øyvind Svensen, Xuyuan Chen, and Muhammad Nadeem Akram, "Speckle reduction in laser projection displays through angle and wavelength diversity," Appl. Opt. 55, 1267-1274 (2016)
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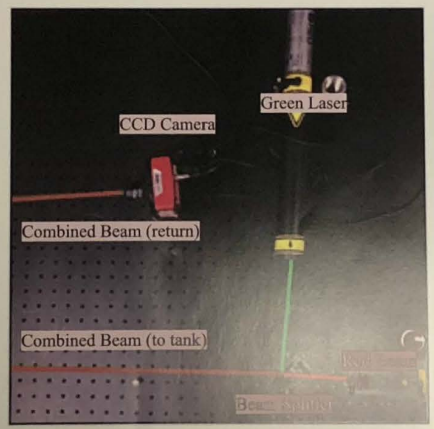
Experimental Method

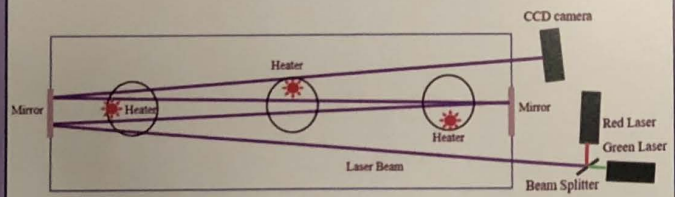
Purpose

This experiment will involve using two laser beams (green and red visible light) and combining them into a multiple wavelength beam using a beam splitter. The two individual and one combined beam will be propagated through a tank of distilled water. Inside the tank are three heating elements, which regulate the temperature of the water and produce 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.



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
- Collections conducted with heaters on (agitated) and heaters off + 5min (calm)



Results

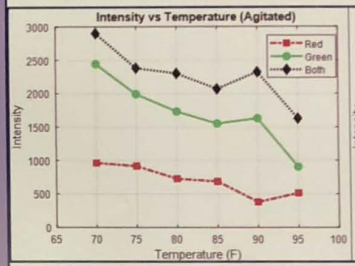
Average Intensity

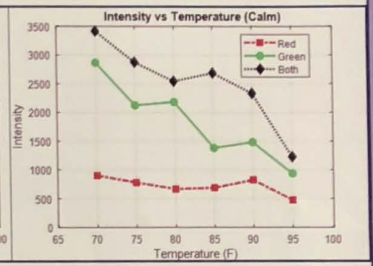
-Averaged per pixel over the collection (~600 screens)

-Red beam experiences highest absorption, experiencing lowest irradiance on receiver.

-Green beam absorbs less than red beam, irradiating better. Combined beam irradiates best

-Very similar trends in intensity vs temperature and intensity vs environmental turbulence.





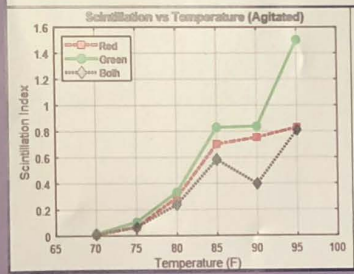
Scintillation (normalized mean variance)

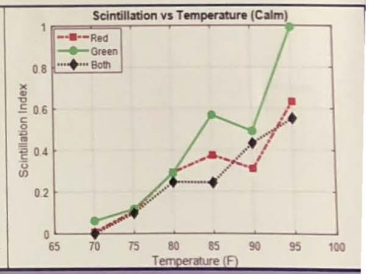
-Positive correlation between temperature and scintillation index

-Scintillation consistently lower for combined beam, higher for red beam, and highest for green beam

-Combined Beam showed 27.77% average reduction in scintillation for Agitated environment

-Combined Beam showed 31.05% average reduction in scintillation for Calm environment





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 would involve the use of particulate matter to simulate in water "scatterers" and investigating methods to continue to combat intensity fluctuations in these environments.