Analyzing Wavelengths of Lasers Propagating Underwater

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Concept

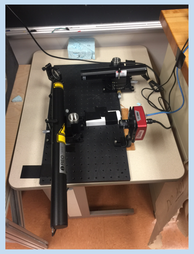
Because of the obstructions caused by the natural fluctuations in ocean currents and temperature, underwater laser propagation presents challenges to maritime communication. In order to understand how to produce the most efficient beam of light that will achieve the greatest intensity through the underwater medium, the wavelength of light will be observed under various conditions. This project will target the wavelengths that will yield the highest intensity of data reception in simulated underwater environments modelling ocean settings.

Background

In considering the complexities of water as a medium for light propagation, two factors will be taken into account: current and temperature. Each of these have significant influence on the refraction of light. This refraction, or bending of light, occurs when light travels into a substance that has a different index of refraction. The index of refraction is a ratio relating c to the speed of light in a particular medium. Thus, as the speed of light changes depending on its medium, the angle at which it propagates also shifts. Disturbances in water caused by temperature or unpredictable flow can increase the abundance of indices of refraction and cause light to scatter. This, in effect, would lower the intensity of the beam in the intended direction. The scintillation index is the displacement or variance of the light produced when propagated through materials such as water when the medium absorbs ionized radiation. In this experiment, we attempt to measure the scintillation index from a beam that has travelled through water with a controlled temperature and sea state and determine the pixel of highest intensity for that beam.

Setup and Materials

The experiment was conducted in the Sebastian, an 800 liter tank designed to allow for a longer propagation path with a adjustable environment. It is made of cast polyethylene and is 43x76x243cm. It contains 500 liters of deionized water. Mirrors at each end double the propagation path of the laser, so the laser travels 980 cm total underwater. A red and green laser were set up in front of the entry window and a beam splitter was placed to allow for a combined beam. A camera was placed in front of the exit window. Intensity fluctuations were collected by the camera for each variation of wavelength.



Data Analysis

The changes in the intensity of the lasers of different wavelengths collected with a CCD camera was downloaded onto a computer as and analyzed using the MATLAB computer program. We used data from tests where the tank was 70°F, 75°F, and 80°F and calm so as to compare temperature difference and maintain other variables that may manipulate the results. Using MATLAB to locate the pixel with the maximum value in the images, we were able to find the point of maximum intensity in each beam.

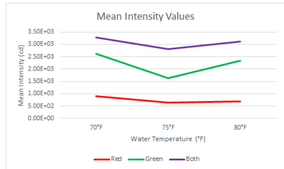
We then used the equation below to determine the scintillation index (SI) for each wavelength at each temperature.

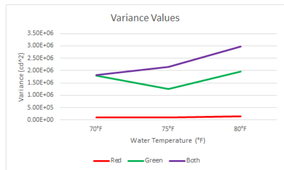
$$SI = \frac{Variance}{Mean^2} = \frac{Mean(x_i^2)}{Mean^2} - 1$$

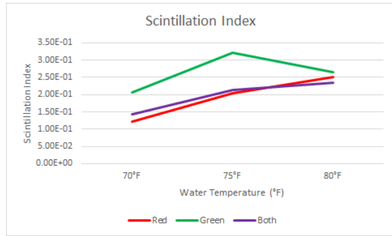
Results

The data shows pixel we calculated to have the highest intensity of the laser light, located at the apex of its respective beam (red, green, and both) and the calculated scintillation at each temperature.

70°F	**Max Intensity**	**Mean**	**Variance**	**SI**
Red	(252, 216)	9.114e+02	1.164e+05	1.229e-01
Green	(330, 173)	2.625e+03	1.792e+06	2.064e-01
Both	(102, 184)	3.287e+03	1.819e+06	1.441e-01
75°F	**Max Intensity**	**Mean**	**Variance**	**SI**
Red	(520, 456)	6.415e+02	1.053e+05	2.038e-01
Green	(403, 247)	1.630e+03	1.265e+06	3.225e-01
Both	(417, 251)	2.805e+03	2.150e+06	2.146e-01
80°F	**Max Intensity**	**Mean**	**Variance**	**SI**
Red	(116, 105)	6.869e+02	1.586e+05	2.516e-01
Green	(247, 40)	2.331e+03	1.969e+06	2.660e-01
Both	(216, 396)	3.115e+03	2.980e+06	2.349e-01







Conclusion

As can be seen in the graphs of our data, the highest average intensity is consistently seen in the combined wavelength, followed by green and red. While the red wavelength shows little change in intensity depending on temperature, the green and combined wavelengths show a clear decrease in intensity when the temperature is increased from 70°F to 75°F, but then a sharp increase to a similar intensity when the temperature is raised from 75°F to 80°F. With regard to variance, little to no effect is shown due to temperature in the red wavelength. We should expect the red beam to yield a greater intensity when coupled with the results of its low variance, however, this isn't the case. The green wavelength, however, shows a decrease in variance from 70°F to 75°F, but it then moves back up with the increase to 80°F. The combined beam variance shows a relatively steady increase. Finally, the red beam shows a relatively constant increase in scintillation as the temperature increases. The combined beam shows a similar constant trend. However, the green showed a fairly obvious spike in scintillation at 75°F, but the values for 70°F and 80°F are more in line with the red and combined values, albeit higher.

These results appear to be inconclusive, as the beam that shows the highest intensity (the combined wave) also shows an increase in variance as temperature increases, seeming to suggest that while the beam is the most efficient in terms of intensity, it is not entirely reliable in a maritime environment where conditions such as temperature are constantly changing. Furthermore, the inconsistent change in scintillation fails to show a discernable pattern in the green wave and seems to suggest error with the data from the 75°F measurements. More investigation into this topic is necessary to come to a full conclusion regarding the effectiveness of increased wavelength in laser communications.

However, this information raises new questions to be answered, such as how a combined beam performs in water that is not pure or deionized, or in water with impurities that scatter the light further. The salinity and turbulence of the water must also be studied if underwater laser communication is to become possible.

References:

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