Atmospheric Effects on Laser Propagation

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Abstract

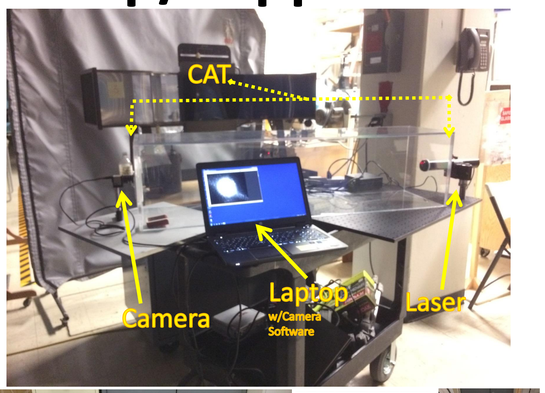
The goal of this experiment was to investigate the effect of a foggy environment on a laser's performance. When a laser propagates through such an environment, interference from the fog causes the beam to scatter, significantly decreasing the heat delivered to the target. To simulate these conditions, we contained white smoke in a Plexiglas chamber known as the CAT and analyzed the beam and phase front of a laser projected through this chamber.

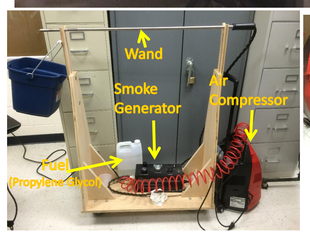
Background

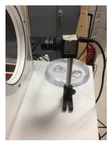
In recent years, the Navy has explored the use of directed-energy weapons— most notably—the design and testing of the Laser Weapon System (LaWS) aboard the *USS Ponce* in 2014. One of the challenges in producing a laser weapon is the decrease in performance that it inherently experiences in poor weather conditions. This experiment was an opportunity to tangibly analyze these effects on a smaller scale.

LaWS System
www.Navy.mil

Setup/Supplies



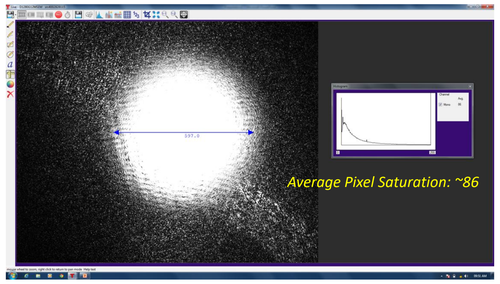




Supply Details:

- Laser: ThorLabs Laser; 2mW, 632.8nm, class 3R
- Camera: ThorLabs Camera with 2 Neutral Density Filters to protect camera and a Red Filter to block out extraneous wavelengths.
- Smoke: Aerolab Smoke Generator filled with Propylene Glycol

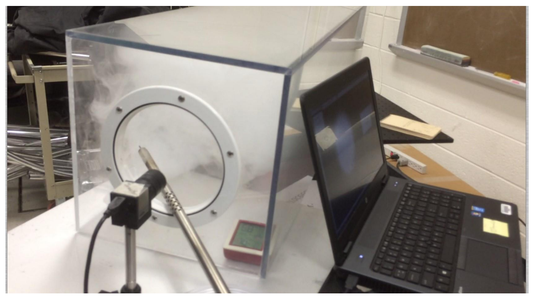
Methods

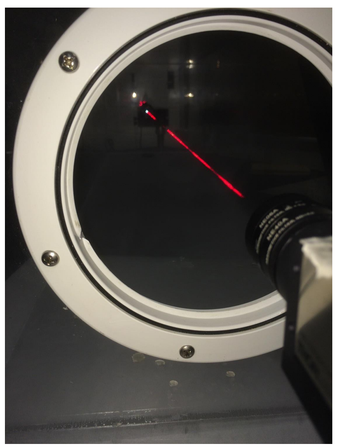


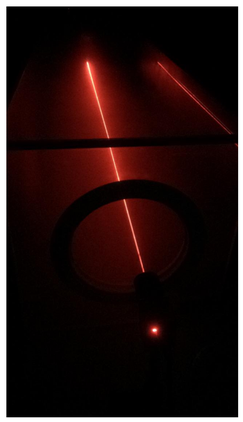
Screenshot: Phase Front without any smoke in the CAT

Procedure:

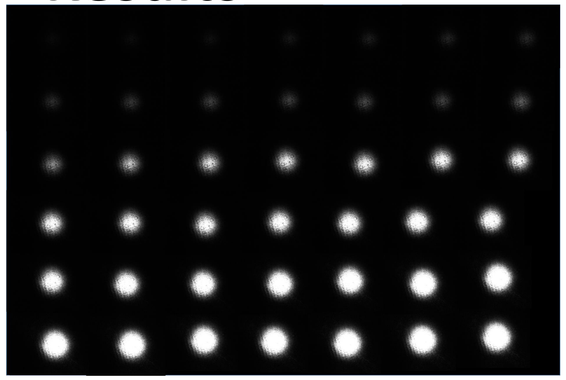
- Filled the CAT with an arbitrary amount of smoke dense enough to scatter virtually all laser light from reaching the camera.
- Gradually let the smoke diffuse out of an opening in the CAT.
- Camera recorded images of the laser at 1 second intervals until average pixel saturation was near 80 and spot size was near it's initial diameter.





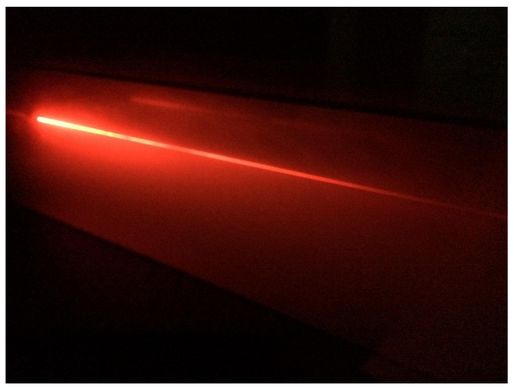


Results



Progression of spot size with decrease in smoke density

- In the early stages of observation, the phase front was not even visible on the camera.
- Average Pixel Saturation was ~2 initially, working back towards 80 at a relatively constant rate.



- Notice how the beam appears significantly thicker near the source of the laser; this is due to the scattering that occurs when the laser is diffracted by the smoke.
- Near the source, there are more photons still on the axis of propagation; thus, there are more photons able to be scattered off axis, and the beam has the thicker appearance in that area.
- In denser smoke, so many of the photons were scattered that the beam was barely detected by the camera.

Conclusion

This simple experiment made it clear that areas of dense fog or smoke are detrimental to laser performance. However, this effect is likely not proportionate—in other words, it would be less adverse with a more powerful laser. The Navy's LaWS System and others, such as Boeing's HEL MD System, have performed exceptionally in poor weather tests, showing that fog, dust, rain, or otherwise are not an issue with a laser that well-directed and powerful enough.

Areas for Improvement

The initial intent of this experiment was too look for a relationship between humidity and laser performance. Unfortunately, humidity was not effected as the smoke was made from propylene glycol.

A second test would include an analysis with water vapor, relating measurements to humidity and temperature

References

"All Systems Go: Navy's Laser Weapon Ready for Summer Deployment." *All Systems Go: Navy's Laser Weapon Ready for Summer Deployment*. United States Navy, 07 Apr. 2014. Web. 28 Apr. 2016.

Szondy, David. "Neither Rain, nor Fog, nor Wind Stops Boeing's Laser Weapon Destroying Targets." *Neither Rain, nor Fog, nor Wind Stops Boeing's Laser Weapon Destroying Targets*. Gizmag, 08 Sept. 2014. Web. 28 Apr. 2016.

Acknowledgements

MSC Graphics

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