



# Laser Beam Propagation in Fog

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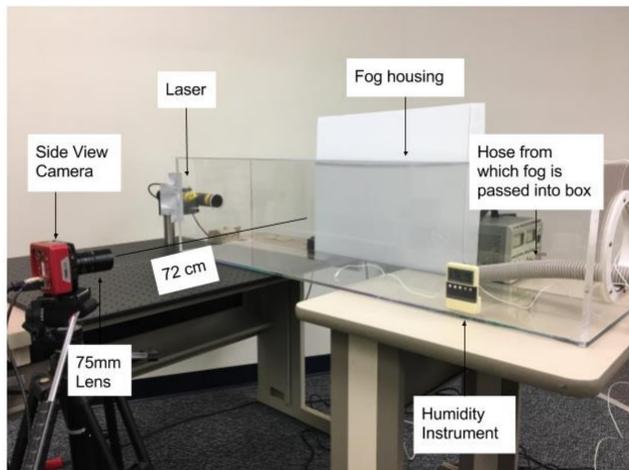
## Motivation



- Directed Energy Applications
  - Directed Energy Weapons
  - Laser Communication Systems
  - Goal -To direct energy onto a given target with a calculated effect
- Beam Propagation
  - As the beam propagates through space, it begins to scatter, diffract, refract, reflect, etc.
    - Difficult to predict the laser beam propagation through the complex and ever changing the medium
    - Laboratory experimentation provides close to ideal conditions so that proof of principle of a given effect, could be studied
- In Naval applications, dense fog is a common environment
  - Naval laser with the 30 kW laser mounted aboard the USS Ponce
  - Some Adversaries, such as China, are developing mobile “fog machines” mounted on trucks, to disrupt a use of directed energy weapons.
- Experimenting with laser beam propagating in fog
  - Objective :To observe scattering of a laser beam propagating in fog by changing the radius of the beam .
  - Laser source used
    - Wavelength 632.8 nm, Power 2 mW
    - unexpanded beam diameter = 0.63 mm
    - expanded beam diameter = 12.6 mm



Chinese Smoke Truck



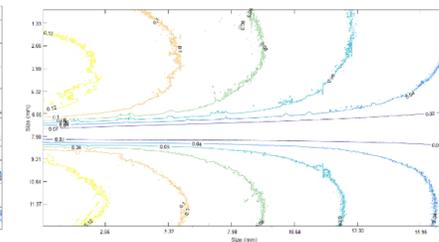
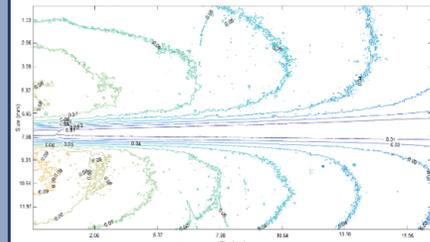
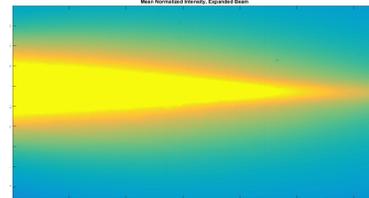
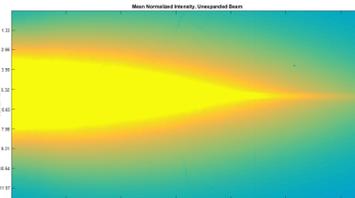
Laboratory Setup

## Results

- Scintillation Index
  - Way to measure the relative change in intensity over time.
  - Superior to simply measuring variance in that the scintillation index is normalized, not skewed if power levels are varying
  - $Scintillation\ Index = Variance / mean^2$
- Measuring scenarios unexpanded and expanded beams
  - Beam Scattering (Side View)
    - Used focused 75 mm lens from 72 cm away perpendicular to the laser propagation path
    - Focused to most clearly see the path of propagation
    - 40 ms exposure time
  - Beam Propagation (Direct View)
    - 1.5 power neutral density filter, red notch filter
    - 17.5 ms exposure time
- Environmental Conditions
  - Temperature between 69.3°F-69.6°F
  - Humidity-49%

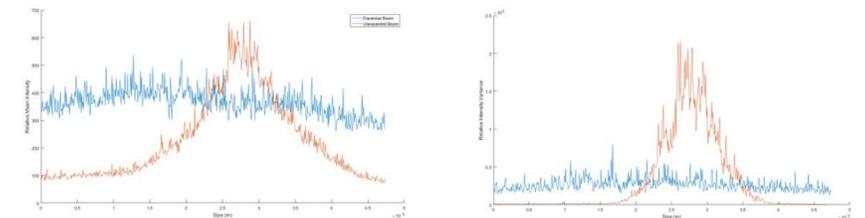
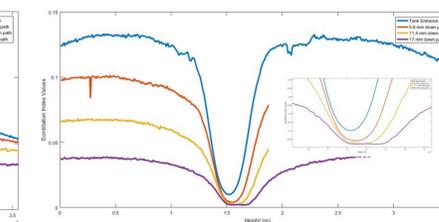
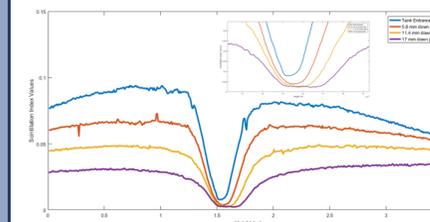
Beam diameter = .63 mm

Beam diameter = 12.6 mm



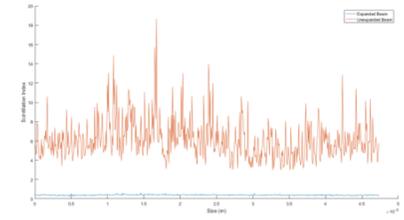
Contour map of the scintillation index of the unexpanded beam. The contours are labeled with the value levels they represent.

Contour map of the scintillation index of the expanded beam. The contours are labeled with the values of scintillation they represent.



Mean intensity of the unexpanded and expanded beams shot directly into the camera.

Variance of the unexpanded and expanded beams shot directly into the camera.



Scintillation index of the unexpanded and expanded beams shot directly into the camera.

## Conclusion

- Expanded laser beam performed better than unexpanded beam in the propagation and scattering scenarios.
- Intensity mean, Intensity variance, and Scintillation index were used as performance matrices. Higher scintillation equates to more fluctuations of relative intensity of the beam over time, suggesting deteriorated performance.
- Beam Propagation (Direct View)
  - Unexpanded beam size is smaller than the sensor area, as seen at the peak on the Mean intensity graph.
  - Expanded beam is larger than the camera sensor, giving a uniform intensity across the sensor area
  - Intensity Variance plots across the sensor area show increased variations of the unexpanded beam due its higher intensity
  - Scintillation index graph clearly shows how the normalized variations in the intensity of the beam are more significant for the unexpanded beam.
  - This metric establishes the superior performance of the expanded beam.
  - Although the unexpanded beam has a higher mean intensity, it is affected more when propagating through the fog compared to the expanded beam, according to the scintillation index direct view graph.
- Beam Scattering (Side View)
  - Mean intensity graph shows the amount of energy scattered by the fog
  - The unexpanded case shows more beam scattering than the expanded case
  - Noticeable level of energy absorbed by the fog in the case of unexpanded beam
  - Side View Contour Map visually shows regions of scintillation index values
  - The rate of change in scintillation for unexpanded beam is from 0.0075 to 0.002 and for the expanded beam it is 0.01 to 0.002 suggesting lower trend in scintillation on target for expanded beam over extended distance.
- Scintillation index is related to the initial beam size: At the entrance point into the fog cloud the expanded beam has higher scintillation index, both beams exit the fog enclosure with approximately the same scintillation index values at the same beam width at exit.
- When considering beam propagation, the power transfer of the expanded beam is therefore more efficient, the scintillation index of the expanded beam is more stable than the unexpanded beam.

## Acknowledgements

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## References

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<http://www.popsi.com/navy-is-going-to-test-big-laser-son>