# Detecting Laser Beams Underwater


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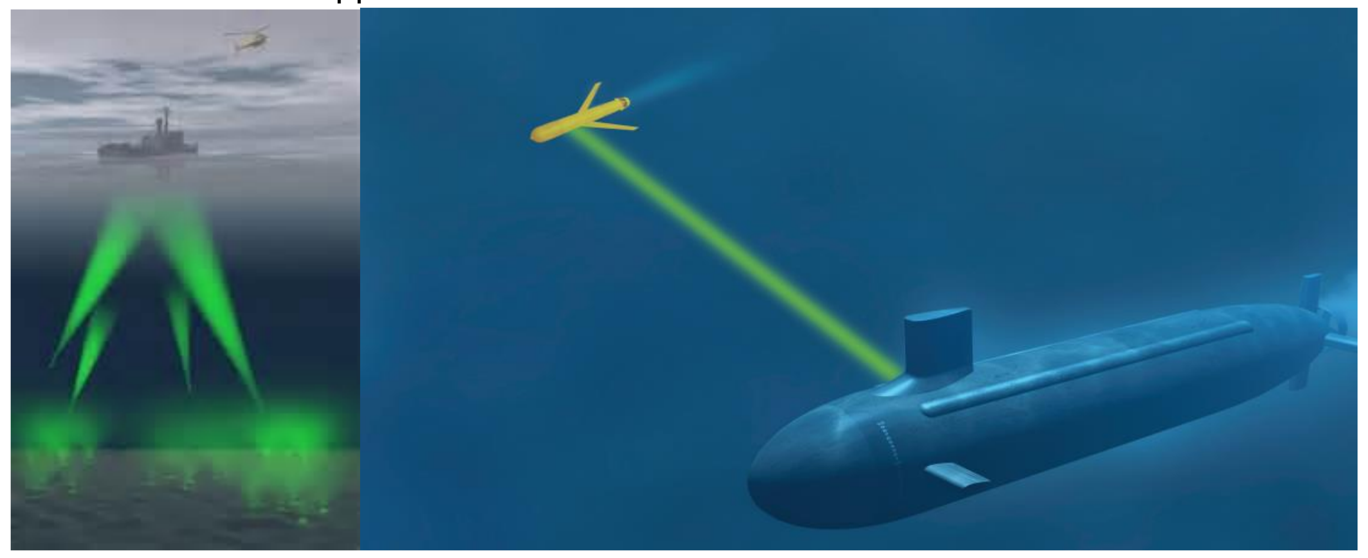
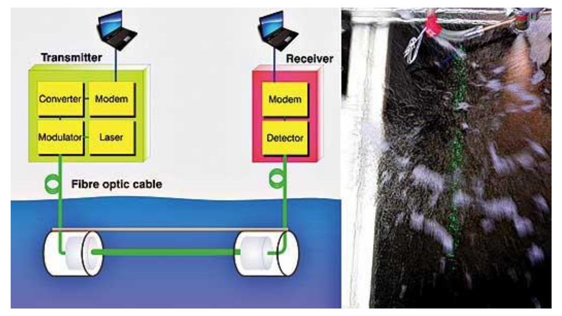
## Motivation

- Laser Communication Systems
  - Line of site communication between two entities
  - Unlike radio and other types of omnidirectional forms of communication, laser communications are unable to be intercepted unless they are intercepted directly through the line of site
  - To further increase the security of the communications, it is important that the friendly beam be as hard to detect as possible by the enemy and vice verse

- **UNDERWATER LASER APPLICATIONS**
- US Naval Underwater Applications

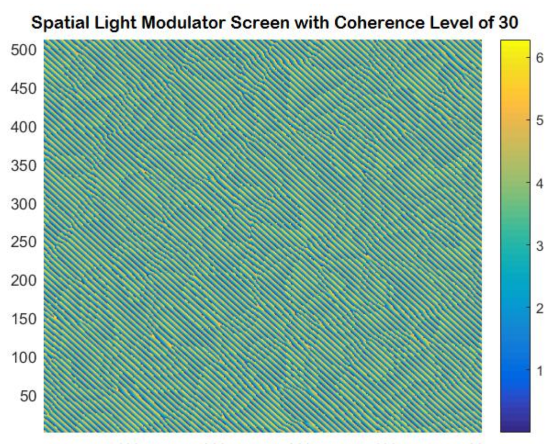


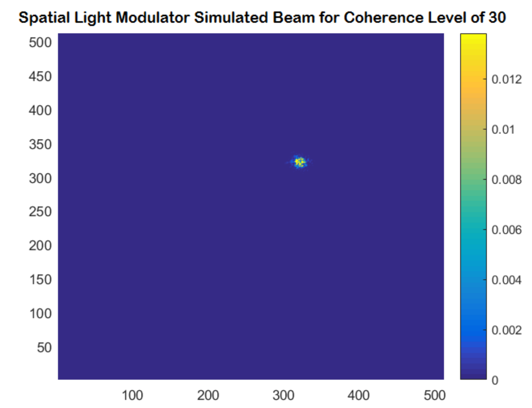
- German Naval Experimentation
  - In German Navy, integrating laser communication technologies :Data sent via a laser beam through a medium of water characterized as coastal water.
  - Main challenge was overcoming the environmental conditions in the type of water

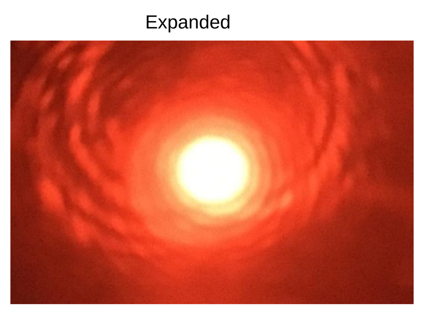


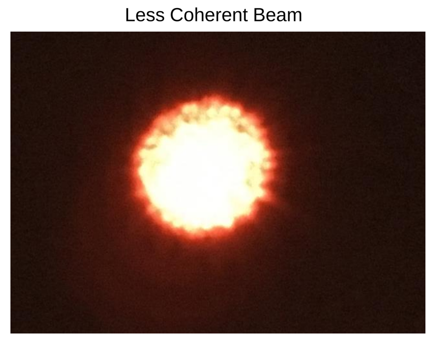

- **EXPERIMENTING WITH DETECTING LASER BEAM PROPAGATING IN WATER**
  - Objective :To observe scattering from a laser beam propagating through water using four different sources under calm and turbulent water conditions
  - Laser sources used
    - Wavelength 632.8 nm, Power 2 mW
    - Unexpanded beam diameter = 0.63 mm
    - Expanded beam diameter = 6.3 mm
    - Less Coherent Beam as produced by Spatial Light Modulation
    - More Coherent Beam as produced by Spatial Light Modulation
- SLM- Spatial Light Modulation
  - Characterized by creating multiple Gaussian Beams that constructively interfere in order to create a relative "flat top" beam. This number of Gaussian beams can be changed to fit the needs of the experiment. As the number of Gaussian beams increases, the finer of a flat top the beam possesses

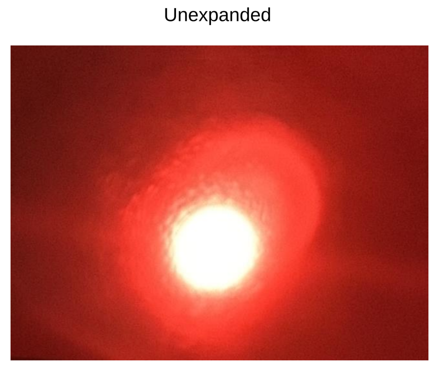
## Beams Before Propagation



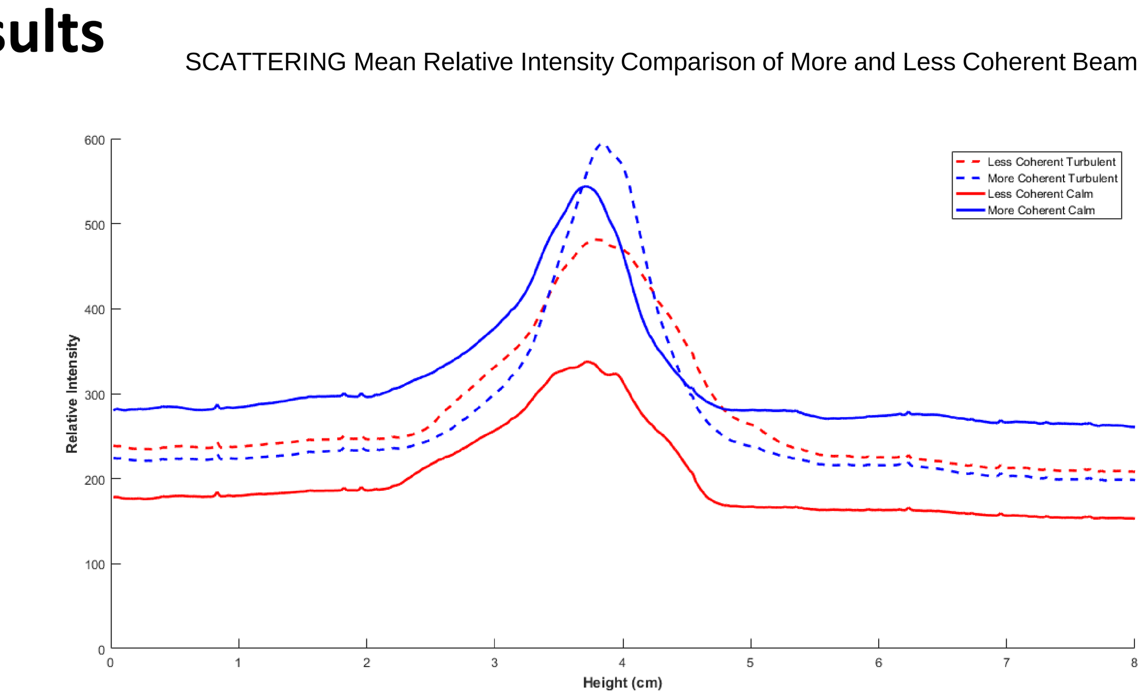



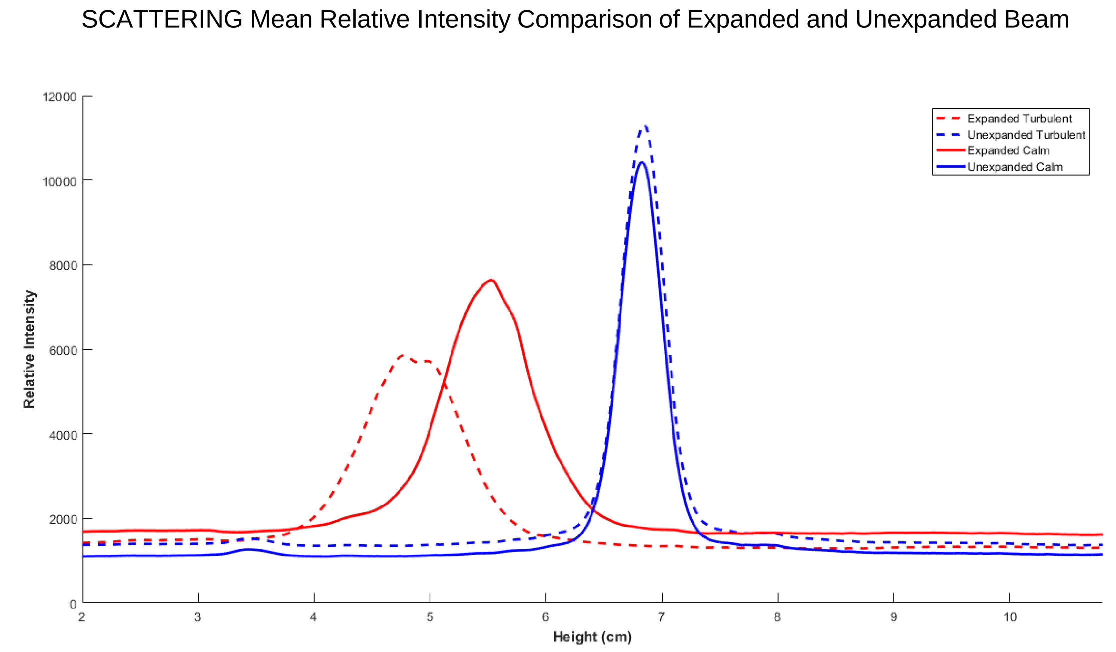



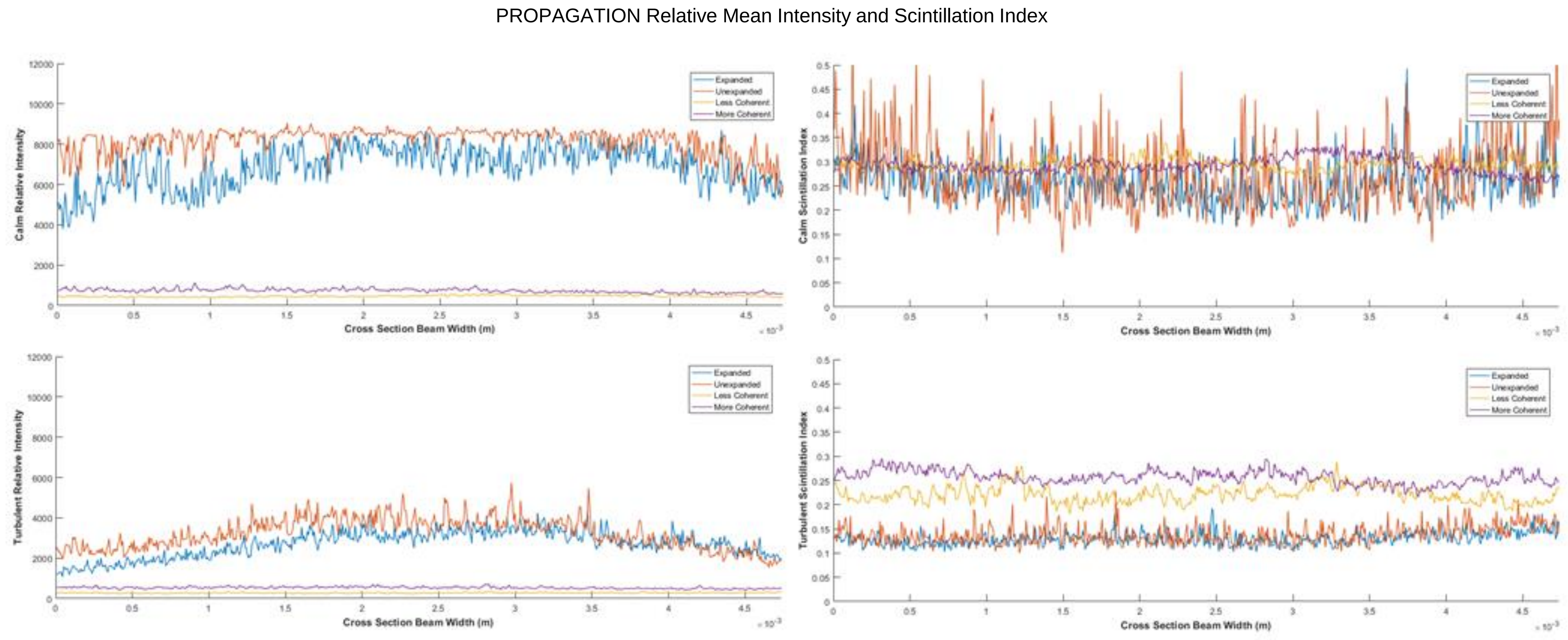



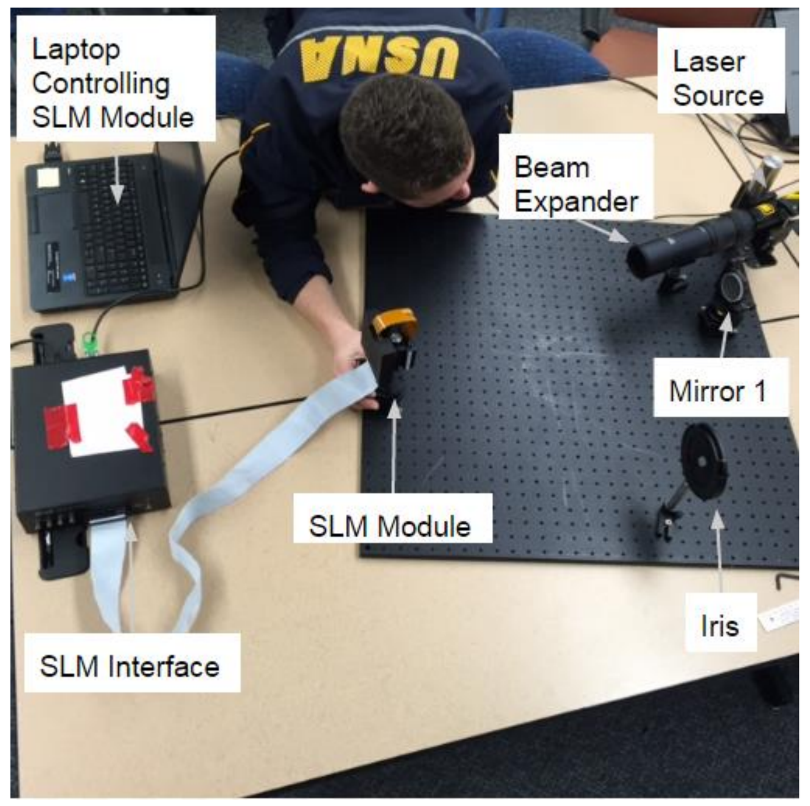

## Results

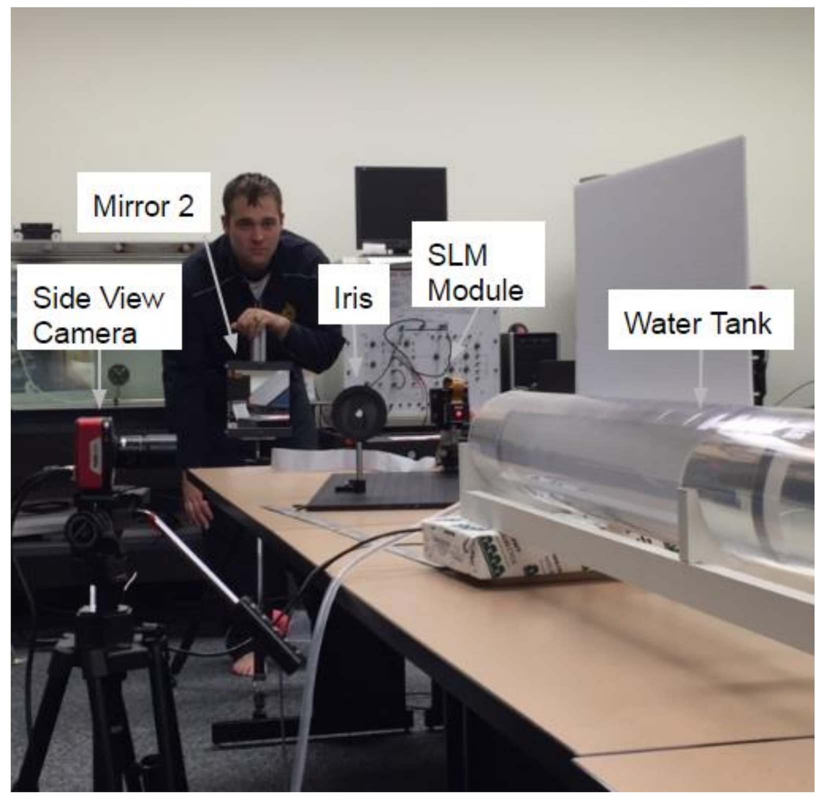


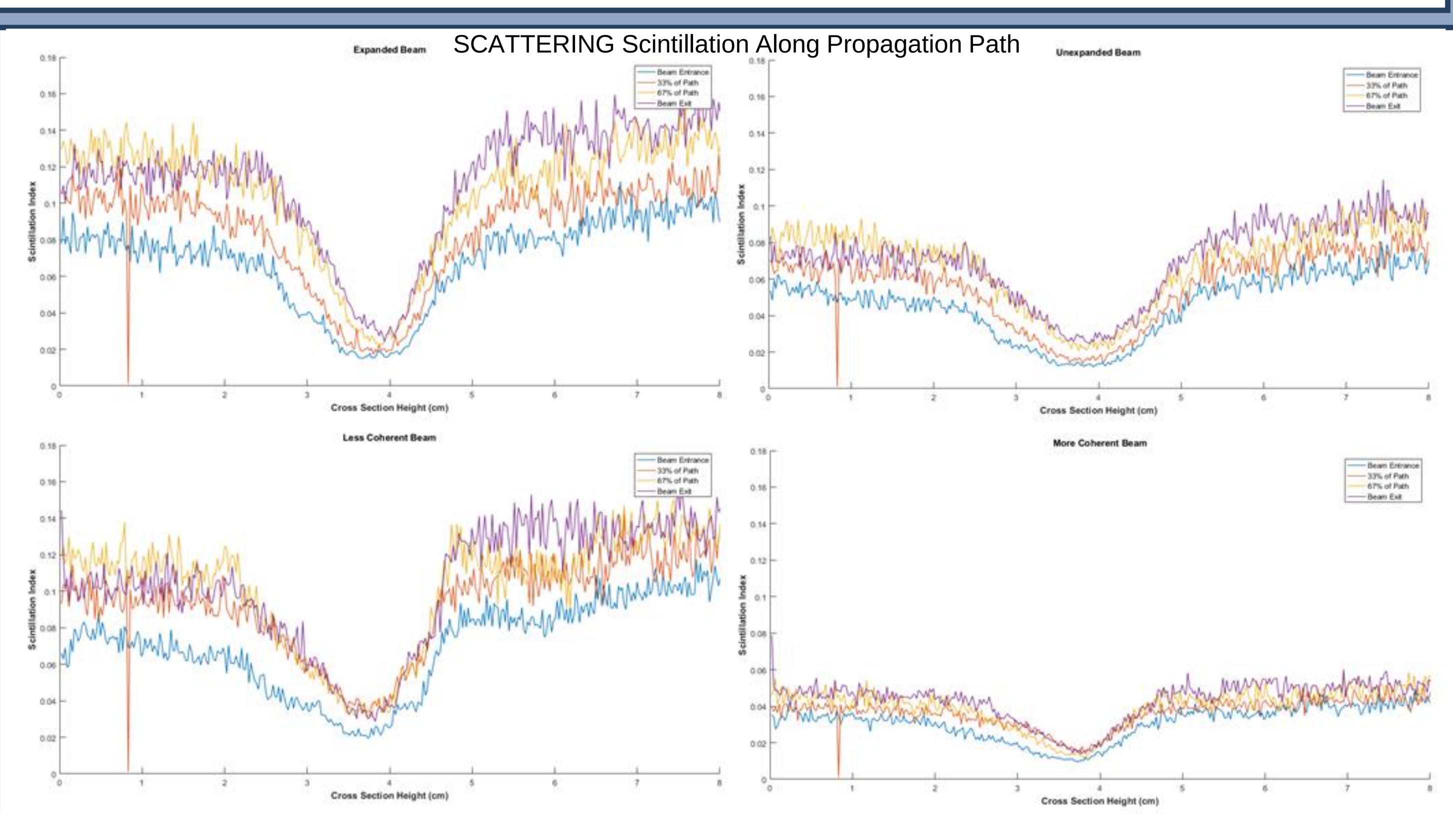



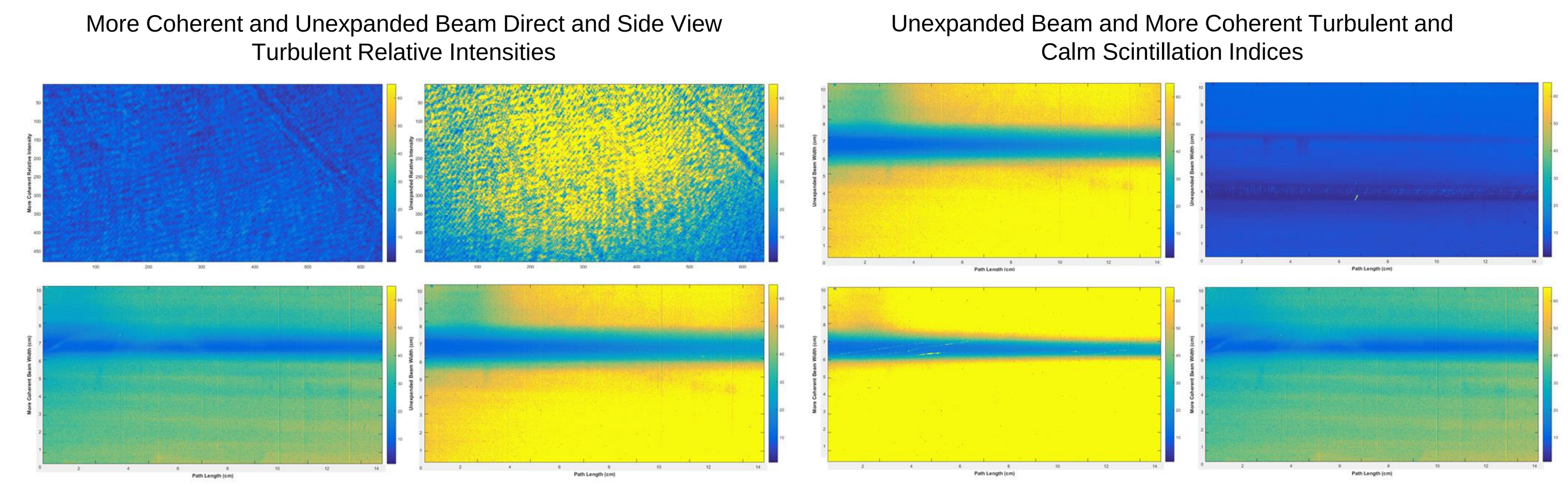

## Instrumentation




## Analysis




- Observing both scintillation index and relative intensity are effective methods of detection
  - The medium surrounding a beam will have a higher relative scintillation index than the beam propagation path
  - An unexpanded beam will have a lower change in scintillation index than a coherently formed beam due to the greater spreading of the beam in the surrounding medium.
  - In the beam path, the unexpanded beam has a higher change in scintillation index.
- Leaving a beam unchanged increases chances of detection underwater.
  - On average, the unexpanded beam has a higher scintillation index value in the medium surrounding the beam when compared to the coherently formed beam, allowing easier detection by sensing change in light intensity.
  - On average, the unexpanded beam scatters in the underwater medium more than the coherently formed beam, allowing easier detection by sensing light intensity.
- More coherence correlates with lower scintillation values and better intensity transmittance when observing the beam off the propagation path
  - This is not the case for direct path observations, however. When observing the beam directly, we found that the coherent beams had higher scintillation values than the Gaussian and expanded Gaussian beams.
- Higher turbulence correlates with higher scattering and scintillation values.
  - This applies to all beam types studied.
  - Comparing coherent beams, more coherence corresponds to higher intensity transmittance, suggesting less scattering occurs.
  - Comparing Gaussian beams, expansion of the beam corresponds to higher intensity transmittance, suggesting less scattering occurs.

## Acknowledgements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## References


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