Mie Scattering Diagnostic

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National Security Technologies, LLC

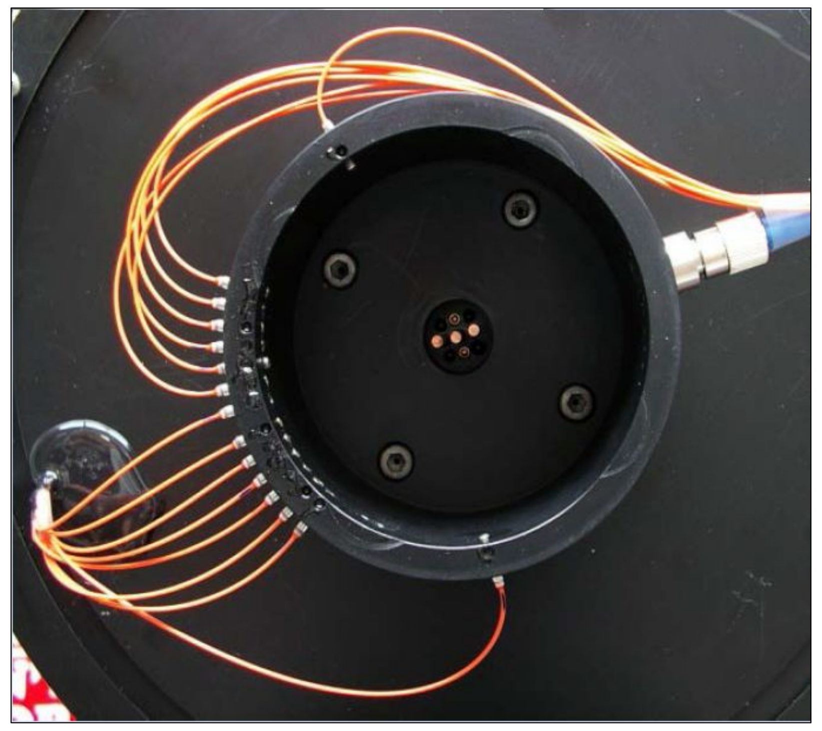


Figure 1: *A picture of the diagnostic setup.*

Background

One way to explore special nuclear material properties is to study how a metal surface breaks up into ejected particulates after it is shocked by a high explosive. To understand the physical processes that govern these ejected particles, it is necessary to measure the size distribution of them. This is troublesome because the particles travel at many kilometers per second and the whole experiment occurs so quickly, high speed measurement systems are required to measure the data. The diagnostic being investigated relies primarily on Mie Theory, a solution to Maxwell's equations that describes the scattering of light by a sphere.

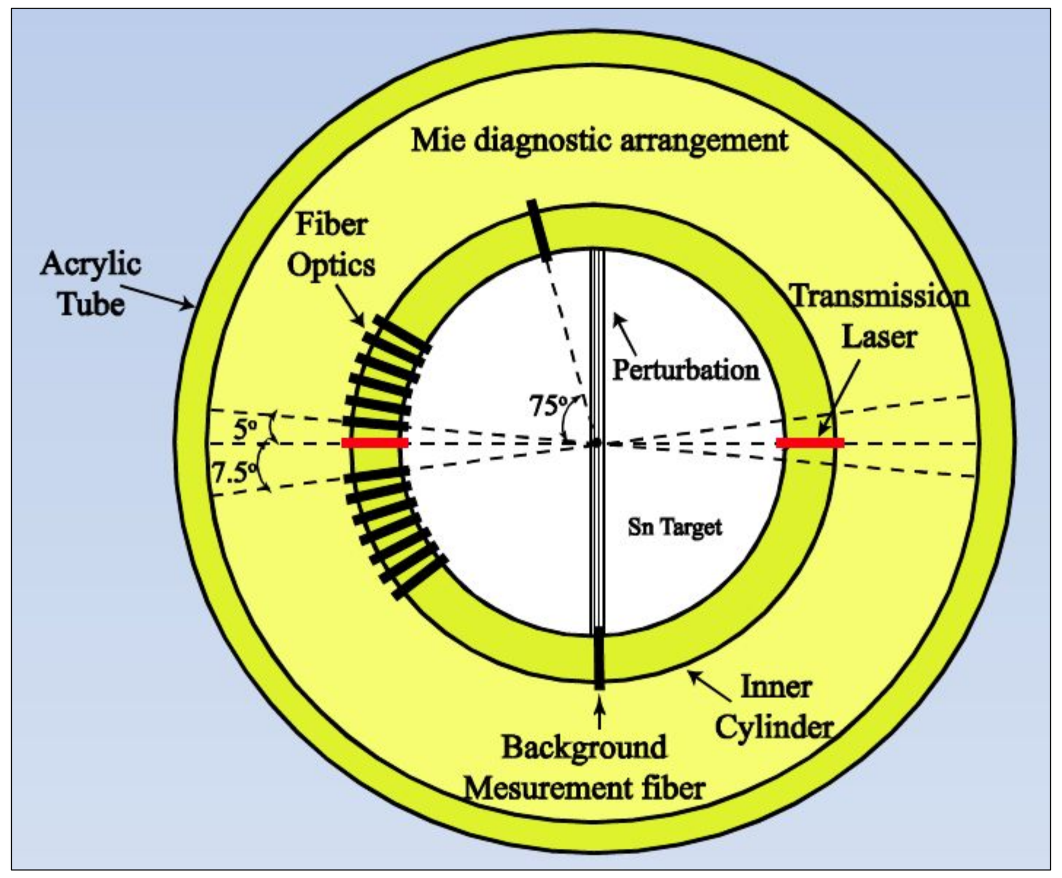


Figure 2: *A diagram of the diagnostic setup, depicting the incident laser light and the sensors at specific angles to detect the scattered light.*

Question and Challenge

Question: Can we measure the distribution of particle sizes that are emitted from a metal surface when it is shocked by explosives using Mie Theory?

Challenge: Using a technique from the air quality industry used to measure aerosol particulates and provided with a MATLAB code for simulating scattering from particles, **(1)** determine whether or not the code accurately simulates the particles being ejected. Then, after determining whether the diagnostic code is performing as expected and correctly forward modeling the light scattering, **(2)** determine how many fiber optic sensors should be used in the system and where they should be positioned in order to most accurately capture the particle distribution.

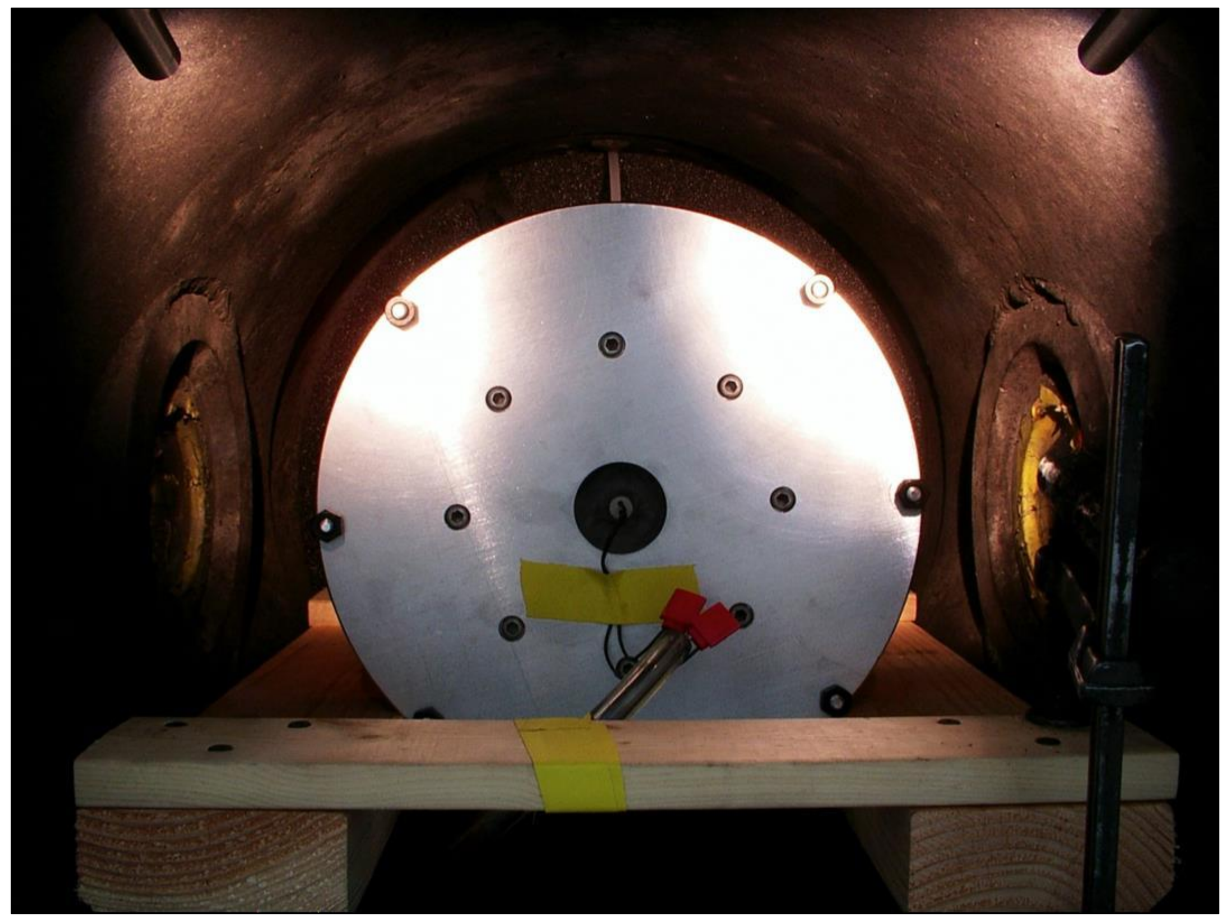


Figure 3 (left): *Experimental package with metal surface, laser, and sensors in place ready to be shocked.*
Figure 4 (right): *Experimental package shocked (post high-explosive detonation).*

Results

After investigating and experimenting with the provided code, it was decided to also implement the Weibull distribution (in additional to the already implemented Lognormal distribution) as a possible distribution for the ejected particles. The Weibull distribution was chosen for its use in describing ground, milled, and/or crushed particles.

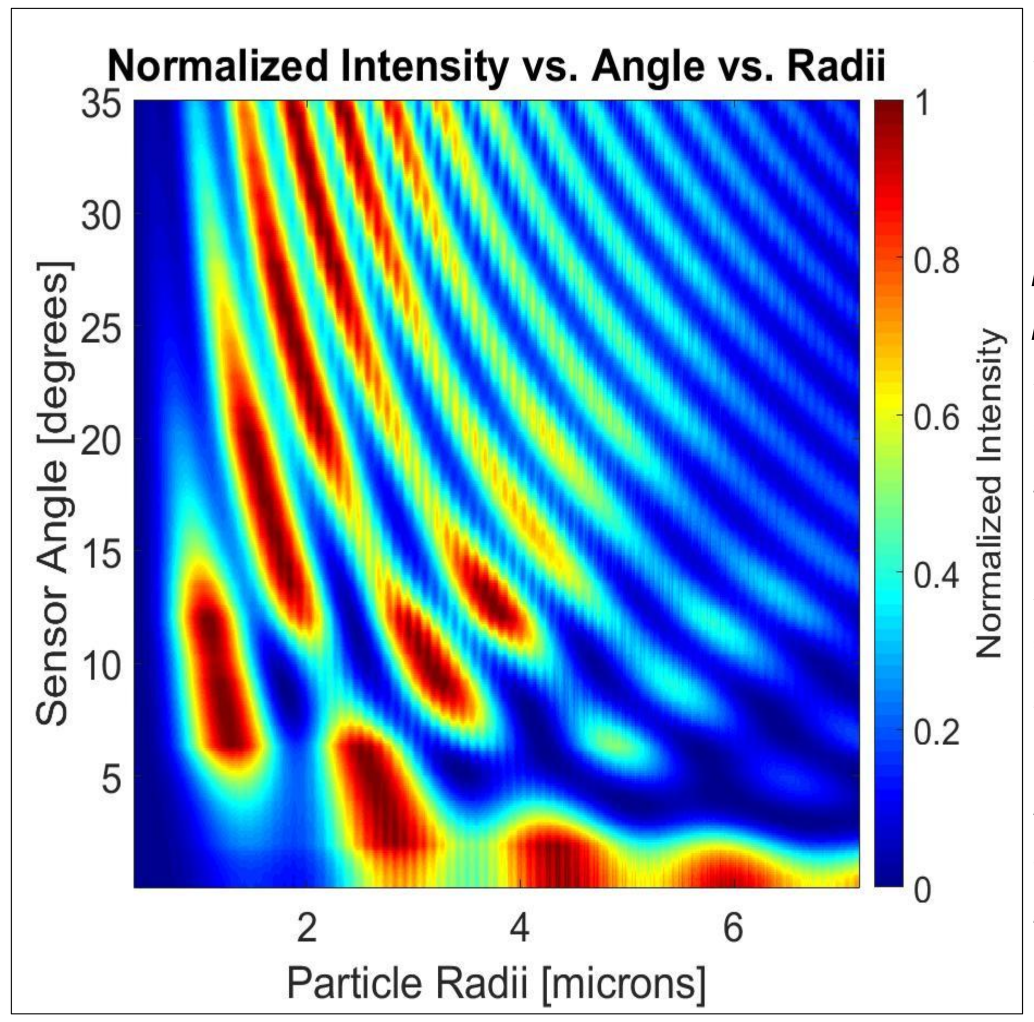
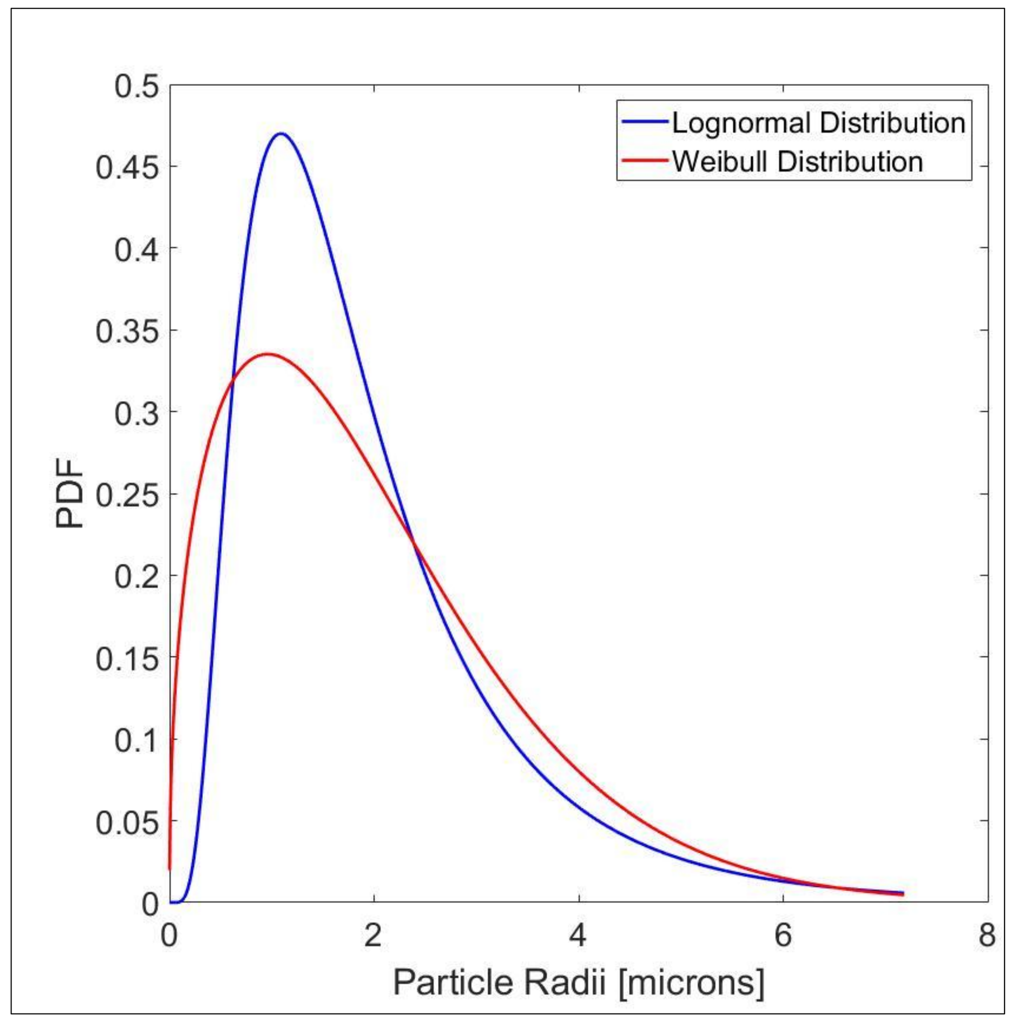


Figure 5 (left): *Intensity normalized (color map) shown vs. angle and particle radii for particles Lognormally distributed with a mean of 2 and a variance of 2.*
Figure 6 (right): *A comparison of a Lognormal and Weibull distribution, both with a mean and variance of 2 respectively.*



Results Continued

All results were assessed using an incident laser with a wavelength of 638 nanometers, a medium index of refraction of 1 (vacuum), and a particle index of refraction of 1.2. Running a multitude of different angle configurations, it was found that angles closest to zero had the most significant impact on the results of reconstructing the particle size distribution accurately.

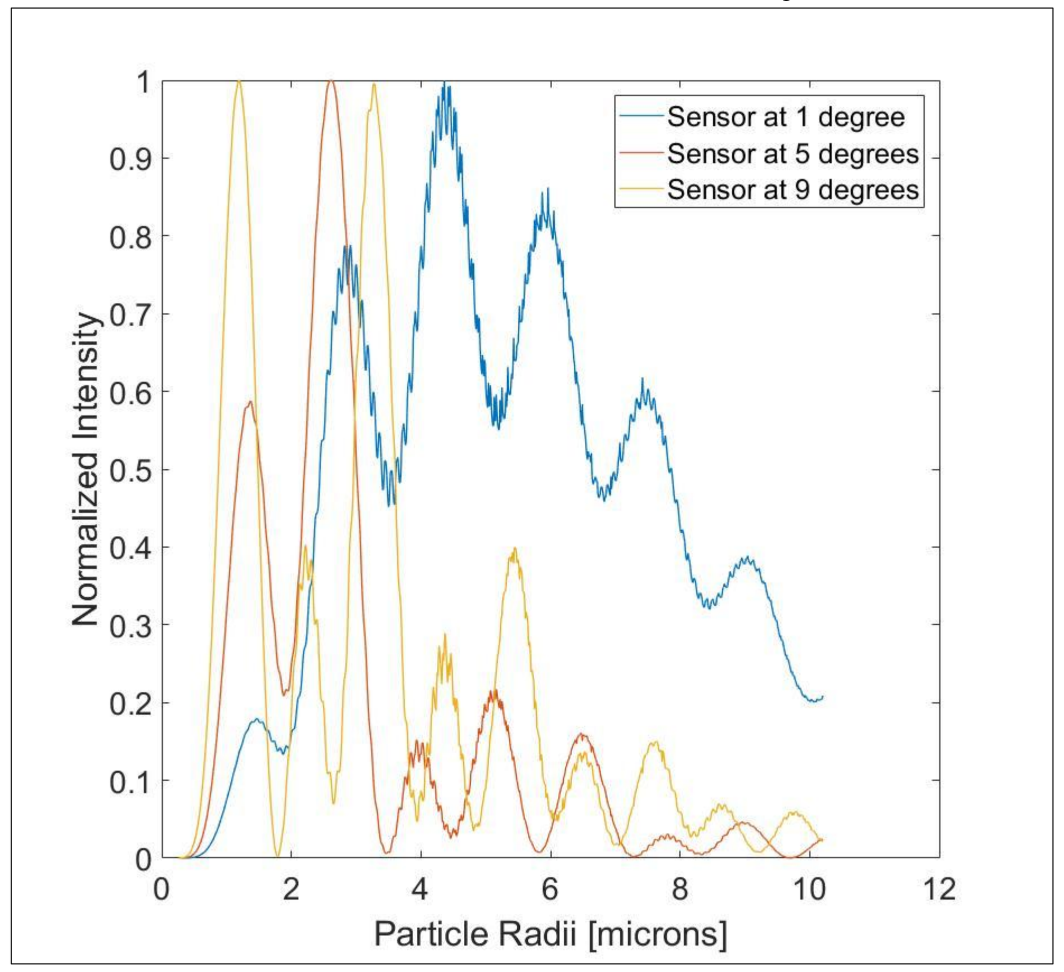


Figure 7: *A plot showing the vastly different scattering properties of particles at different scattering angles (particle distribution is Lognormal with a mean and variance of 2.*

Recommendations

For future work, it is recommended that the importance of smaller angles and their significance in accurately reconstructing distributions be further understood and quantified. Analysis should also be done with regards to quantifying how the diagnostic handles uncertainties of the indices of refraction.

Acknowledgements

Figures 1 through 4 are courtesy of National Security Technologies, LLC.

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