Scattered X-ray Imaging as a High Energy Density Experimental Diagnostic

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Defining the Forward Problem

Any imaging application involves the correlation of measured quantities with theoretical parameters. To do this one must establish the forward problem, which maps the range of theoretical parameters into observable, measured data. The function for total signal reaching the detector can be written as:

\[ N_{\text{det}} = E_{\text{in}} \rho N_{\text{scat}} \rho \eta_\text{in} \eta_\text{att} \]

where \( E_{\text{in}} \) is the photon number, \( N_{\text{scat}} \) is the energy of photons created, and \( \eta_\text{in} \) is the conversion efficiency associated with this process. The scattering process is quantified by the second term where \( n_{\text{scat}} \) represents scattered light attenuation. This also implies the output is dependent on the location of scattering. This model also neglects the outgoing scattering, which would introduce another exponentially decreasing term proportional to the exit path length.

Model Scattering Images

The simple discretized model assumes that all of the scattering from a given resolution element is concentrated at its center, and that the incoming beam travels through only one material (constant mass attenuation coefficient, but varying density) before reaching the location of scattering. The model also assumes that the outgoing scattering, which would introduce another exponentially decreasing term, is concentrated at its center. The model image which best reflects the density map shown corresponds to 22 keV incident x-rays (approximately the K\text{L} conversion efficiency associated with this process. The scattering process is quantified by the second term where \( n_{\text{scat}} \) represents scattered light attenuation.

Future Work

The most significant challenge to imaging x-ray scattering is the small scattering cross section, which leads to low photon count on the detector. Increasing the incident photon number will be a focus of future experiments. In particular, we hope to:

- Develop novel x-ray production methods, including the use of a laser pre-pulse to create an underdense plasma, or using lined hohlraums to backlight a directly-driven target package.
- Work towards collimating the incident radiation, either with a laser pre-pulse to create an underdense plasma, or using lined hohlraums to backlight a directly-driven target package.
- Increase the configuration options in HED experiments.
- Investigate methods to increase imaging quantum efficiency.

Acknowledgements

This research was supported by the Center for Radiative Shock Hydrodynamics and through the NNSA Stewardship Sciences Academic Alliances and the National Laser User Facility through DOE Research Grants DE-FG52-07NA28505 and DE-FG52-04NA00064, and by other grants and contracts.