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Fresnel zone plate imaging and synthetic diagnostic modeling for the OMEGA laser facility

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We acquired high resolution images of laser driven cylindrical implosion experiments using a Fresnel zone plate (FZP), a diffraction driven lens composed of alternating opaque and transparent rings, on the OMEGA laser at the Laboratory for Laser Energetics in Rochester, NY, USA. Our FZP geometrical properties were designed for a standard 25x magnification and include 700 zones of 900 nm thick gold, minimum zone width of 40 nm, and a lens radius of 56 μm to focus an energy spectral peak at 6.127 keV emitted from a Manganese backlighter. This design was informed by our new Python-implemented forward model that model considers 4 diffractive orders and a realistic x-ray spectrum to characterize the spatial resolution of FZP systems. The model supports two methods of exploring FZP designs: optimization via the SciPy library and algorithmic differentiation via the PyTorch library and its neural network module.

The well-resolved images acquired using our FZP reinforce the success of our model as a high-fidelity synthetic diagnostic for experimental design and data analysis. Additionally, the images demonstrate the potential for FZPs to outperform traditional pinhole imagers by increasing resolution without sacrificing throughput. With more detailed images of high energy density physics such as Rayleigh-Taylor and Richtmyer-Meshkov instabilities caused by laser driven implosions, researchers can further understand and control disruptions in inertial confinement fusion.

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