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Distortions in the Angular Distribution of Nonlinear Thomson Scattering as a Focal Diagnostic

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Abstract: We present measurements of nonlinear Thomson scattering out the side of an intense laser focus, showing how subtle defects in laser field including spatial chirp imprint on the angular distribution of the scattered light.

1. Measurements of Polarization Resolved Nonlinear Thomson Scattering

We measure light scattered from low-density free electrons in an intense laser focus using single-photon counting techniques. A polarizer in the collection system resolves fundamental, 2nd, and 3rd harmonic photons into orthogonal component corresponding to azimuthal and longitudinal lines on the emission sphere.

Figure 1 shows a schematic of the experimental setup. A lens collects scattered photons over a range of 25° and send them into single-photon counter. Azimuthal rotation is accomplished via rotation of the laser polarization.

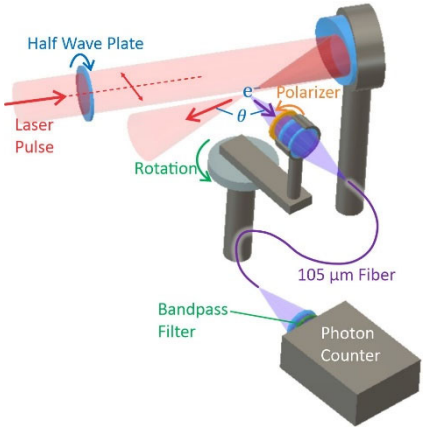

Fig. 1 Photon collection and detection setup.

Electrons are donated from helium in an otherwise evacuated chamber, backfilled to a fraction of a Torr. The 800 nm, 40 fs, 50 mJ, 10 Hz laser pulses ionize the helium early during the rising edge of each pulse. The pulses are focused to a $w_0 = 3\ \mu$m radius using an off-axis parabola. The intensity in the laser focus exceeds 2×10^{18} W/cm^2, which causes electrons to move relativistically. Electrons execute the well-known figure-8 motion as they drift forward in the laser, pushed by the rising edge of the pulse. This induces a redshift when the scattered photons are viewed from the side. In previous work, we demonstrated how scattering patterns measured over the entire emission sphere confirm predictions of electron dynamics in the focus. In this work, we use measured asymmetries in the emission patterns to diagnose anomalies in the laser focus.

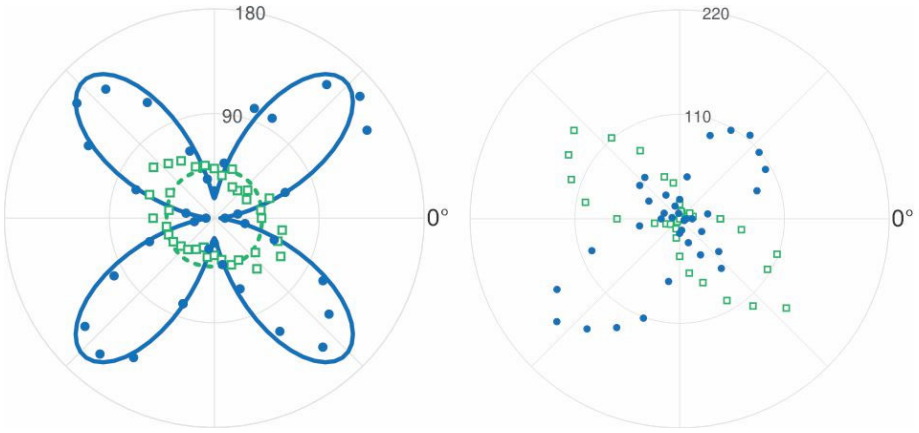

Fig. 2 Measured angular distribution of 2nd harmonic nonlinear Thomson scattering in a plane perpendicular to laser propagation. The left panel shows scattering from a particular laser focus together with theoretical prediction. The left panel shows scattering from a less-than-ideal laser focus with similar intensity. Blue indicates photons polarized in the scattering plane while green indicates scattered photons polarized perpendicular to that plane.

2. Distortions

Figure 2 shows measured 2nd harmonic photons, scattered out the side of the laser focus (in the plane perpendicular to laser propagation). Two orthogonal polarizations of the scattered photons are shown separately. The left panel shows nonlinear Thomson scattering computed using an ideal symmetric laser focal spot (solid lines) for each polarization component, while the data points represent measured data. In this case, the laser focus is optimized and the data and theory match well. The right panel shows scattering from a focus with asymmetries in its scattered radiation patterns, due to non-optimal focal parameters in the laser. The nonlinear nature of the interaction makes the angular pattern of the scattered light sensitive to subtle distortions in the laser.

We explore how subtle amounts of spatial chirp and other typical distortions in a laser focus can imprint on the angular pattern of the scattered photons emitted in nonlinear Thomson scattering. This effect may provide a sensitive way to diagnose non-ideal focal problems in large high intensity laser systems.

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3. References

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