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Measurements of Electron Distribution Functions in Laser-Produced Plasmas Using Angularly Resolved Thomson Scattering

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Electron velocity distribution functions (EDF's) are the foundation of most plasma physics. Here we present the first measurements of the complete EDF without any assumptions on its shape or the underlying physics that generated it. This first-principle measurement showed that during significant inverse bremsstrahlung heating by laser beams, the bulk of the distributions were measured to be super-Gaussian in shape, while the electrons above 3the thermal velocity were distributed according to Maxwell–Boltzmann (Maxwellian) statistics. When the inverse bremsstrahlung rates were negligible, Maxwell EDF's were measured. To enable single-shot temporally and spatially resolved measurements, an optical diagnostic was invented that uses the collective nature of plasmas and the angular dependence of the scattering to enable the EDF to be determined over several orders of magnitude without any assumptions on its form. This novel Thomson-scattering technique encoded the electron motion to the frequency of scattered light and used collective scattering to increase the signal at velocities where the number of electrons are limited. The ability to measure the EDF beyond 4the thermal velocity with high precision allowed the results to address long-standing physics questions regarding the relaxation of high-velocity electrons toward a Maxwellian. These results are in excellent agreement with pioneering computational work by J. P. Matte *et al.*[1] that describe the evolution of the bulk electrons to a non-Maxwellian distribution due to inverse bremsstrahlung heating. The response of high-velocity ($>3v_{\mathrm{th}}$) electrons was compared with Fourkal *et al.*,[2] which suggested electron–electron collisions dictate the shape of the tail while the isotropy of the electric field dictates the amplitude of the tail. This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856.

[1]J. P. Matte *et al.*, Plasma Phys. Control. Fusion **30**, 1665 (1988).
[2]E. Fourkal *et al.*, Phys. Plasmas **8**, 550 (2001)