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Modelling nonequilibrium Thomson scattering from above-threshold ionized plasma

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Optical Thomson scattering is now a mature diagnostic tool for precisely measuring local plasma density and temperature. These measurements typically take advantage of a simplified analytical model of the scattered spectrum, which is built upon the assumption that each plasma species is in equilibrium and Maxwellian. However, this assumption fails for plasmas produced using high field ionization of atoms via ultrashort laser pulses. For example, in the above-threshold ionization (ATI) process, electrons are produced with several narrow and equally spaced peaks in energy corresponding to the number of photons absorbed above the ionization threshold. These electrons are born with momentum along the polarization of the laser, and are essentially cold in the two transverse directions. In other words, the plasma is not only nonthermal but also grossly anisotropic. This ATI plasma is unstable to several kinetic instabilities that are not taken into account in the conventional Thomson scattering model. We present a new method for extracting the Thomson scattered spectrum from any plasma (equilibrium or nonequilibrium) directly from fully kinetic particle-in-cell simulations, without simulating the probe laser itself. With this method we can predict the spectrum measured from an ATI plasma, revealing new features in the collective Thomson spectrum that cannot be predicted by Maxwellian Thomson theory.

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