Dynamics of Optical-Field Ionized Helium Plasmas
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Abstract

One unique feature of optical-field ionization (OFI) plasmas is that distinct non-Maxwellian electron distribution functions can be initiated by intense laser ionization of neutral gases depending on the laser polarization. In this work, we apply various Thomson scattering techniques to probe the evolution of optical-ionized helium plasmas produced by linearly and circularly polarized pulses. Polarization-dependent initial distributions have been inferred from collinearly-probe Thomson scattering of a second-harmonic probing pulse generated from a KDP crystal. A 90-degree probe Thomson scattering system with changeable wavelengths has been set up to probe plasma modes induced by nonequilibrium plasmas. Finally, we measured the plasma temperatures after the plasma becomes isotropic by fitting time-resolved scattering spectra. The results indicate the thermalization process of OFI helium plasmas involves the combination of collective plasma effects and collisions.

Introduction

When a high residual energy from tunnel ionization degas is ionized by an intense laser pulse, the plasma electrons can get very pending on the polarization of the incident laser pulse.

Energetic electrons emitted from optical-field ionized atoms have been measured in the past. However, no direct measurements of the resultant non-thermal electron distribution function in a high density plasma have been made.

Electron Distribution of Helium Plasma from Tunnel Ionization: Quasi-classical Theory

Linear polarization

Electron residual energy spectrum

For ia polarization, most of the electrons momentum will distribute perpendicular to the scattering plane. The scattering spectra resemble to the ones from cold plasmas.

Expected Electron Distribution in a Helium Plasma: Osiris PIC Simulation

Circular polarization

Fitting for strongly non-Maxwellian plasmas: Circular polarization

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Dynamics of Optical Field Ionized Helium Plasmas

Nonlinear stage of the two-stream instability

Electron feature of Thomson scattering spectra can be fitted at latter delays (τp > ~ 40 ps)

Conclusions

- Thomson scattering of a ultrashort probe pulse has shown to be an effective tool to study the plasma instabilities as well as plasma evolution with sub-picoscend temporal resolution.

- Polarization-dependent initial distributions have been measured.

- The evolution of OFI plasma generated by circularly polarized pulses involves the development of kinetic instabilities which rapidly isotropize plasmas.