Experimental determination of the ion temperature and hydromotion in an imploding plasma: Implications for pressure and energy balance

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Distinguishing between ion kinetic energy placed in hydrodynamic motion from thermal motion in plasma is of fundamental significance for laboratory plasma physics, astrophysics, and hydrodynamics, including high energy density (HED) plasmas, where energy placed in hydrodynamic motion contributes neither to radiation nor to fusion reactivity, whereas ion temperature does.

Yet, distinguishing ion temperature from hydromotion in HED plasmas has been regarded to be very difficult, since the Doppler-broadened line shapes of emission lines can be due to either effect. However, two novel spectroscopic methods have been developed and implemented experimentally for this purpose [1, 2].

The first method is based on the rate of heat transfer from ions to electrons. To this end, we measure the total ion kinetic energy and its dissipation rate, the total radiation from the plasma, and the electron density and temperature (both also required for knowing the ion-electron thermalization time).

The second method is based on the effect of the ion-ion coupling on the shape of Stark-broadened lines; this effect depends on the ion temperature. For this method, transitions of moderately-coupled ions should be selected, the electron density should be determined, and the Doppler broadening of the emission line selected should be small.

The experiments were performed using neon-puff z-pinch plasmas. Required were observations of high-resolution in spectrum , space , and time, augmented by line shape and time-dependent CR and radiation-transport modeling.

The ion temperature was discriminated from the hydro-motion, and was found to be significantly lower than the total ion kinetic energy. The dissipation time of the hydromotion was determined.

Diagnostics and analysis of wire-array experiments on the Z machine (Sandia) were also made. The data from the WIS and Z experiments allowed for assessing reliably the pressure and energy balance in the stagnating plasma. This was used to examine a reflected-shock model, giving a good agreement. This gave the stagnation pressure and energy balances, and inference of the current flowing in the plasma, yielding that the effect of the magnetic field at the stagnating plasma on the plasma energy and pressure balance is small [3]. The results have been modeled at NRL USA [4].

References:

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