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דינמיקה של יונים בפלסמות חמות וצפופות תחת השפעה של שדות מגנטיים גבוהים
Ion Dynamics in Hot and Dense Plasmas under Intense Magnetic Fields

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Abstract

The time-history of the ion-kinetic energy was determined throughout the stagnation phase of a hot and dense imploding plasma in a puff z-pinch experiment. In this experiment a cylindrical neon puff was imploded under a 500-kA, 500-ns current pulse to form a 10-ns-duration plasma stagnating on axis. The ion kinetic energy was obtained from the Doppler contribution to the line shapes of optically thin lines (Ly_α satellites) emitted by H-like neon ions. To this end, a spectroscopic system with doubly-curved crystal, giving a resolving power of 6700 was employed together with an image dissector, which provides four consecutive time-gated ($\lesssim$ 1 ns) spectra with a 0.1 mm resolution. The spectra were analyzed for different segments of the pinch column, where the plasma properties were seen to be nearly uniform over each of the segments selected (usually the segment lengths were $\simeq$ 2 mm).

The ion kinetic energy was found to be $\simeq$ 12 keV at the earliest phase of the stagnation, consistent with the final implosion kinetic energy expected. The ion kinetic energy was then seen to drop down to the electron thermal energy ($\frac{3}{2}T_e \simeq 300$ eV), during the 10-ns long stagnation period.

The time-history of the ion-kinetic energy allows for investigating conversion of the ion-energy from a radially-directed motion at the implosion stage to ion heat, and then to the electrons and to radiation during the stagnation. The analysis of the ion-kinetic energy loss rate showed that, during the process of the energy conversion, non-thermal ion motion develops, in which most of the implosion energy is stored, whereas a smaller fraction of that energy is transformed into ion thermal energy. It is suggested that this hydro motion causes a slowing down of the ion energy transfer to electrons.

The electron density, inferred from the satellite-intensity ratios, and from the Stark broadening of the H-like-neon Rydberg states, measured with the aid of a cylindrically bent crystal, was observed to be almost constant ($\simeq 8.5 \times 10^{20}$ cm^{-3}) during the entire stagnation phase.

The time-resolved K-emitting plasma radius, obtained from time-gated pinhole photography, was seen to vary slowly in time, rising from 0.25 mm to 0.5 mm at the peak of the x-ray pulse, and falling to 0.25 mm at the end of the x-ray emission period.

Based on the measured plasma parameters, collisional-radiative and radiation-transport calculations were performed, in order to obtain the time-dependent electron temperature and mass of the H-like-emitting plasma. The z-imaging of the spectra allowed for performing this modeling separately for different plasma segments, seen along the z-pinch axis.

The modeling also allowed for examining the energy balance in each segment of the stagnating plasma. The analysis showed that, within the experimental uncertainties, the observed ion-kinetic energy accounts for the total radiation, emitted by the stagnating plasma.