DYNAMICS OF AN IMPLODING PLASMA AT STAGNATION

Thesis for the degree of Ph.D.

Submitted by

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Abstract

Spectroscopic systems with doubly bent crystals, giving a resolving power of 7000 and time-gated (1ns) spatially-imaged spectra with 0.1 mm resolution, are used to obtain the kinetic energies of [H] ions as a function of time throughout the stagnation phase in a neon-puff, 350 kA Z-pinch experiment. The spectrographs were so designed to allow for Rocking-Curve-limited spectral resolutions, verified by double-grating measurements. Optically thin lines (mainly satellites) are utilized in order to obtain the Doppler contribution to the line profiles. The data show that the mean ion kinetic energies drop down to the electron thermal energy at the end of the radiation phase of the plasma. The z-imaging of the spectra allowed this result to be seen for both plasma regions dominated by the H-like or He-like states as they appear along the axis of the nonuniform Z-pinch column. The data also yield the electron density from the satellite-intensity ratios and the total ion densities from line-shape measurements and analysis of the opacity effects. In addition, the time-resolved plasma radiuses were obtained from time-gated pinhole photography. Absolutely calibrated, time-dependent, Ross filter measurements of the continuum emission yielded electron-density-values that agree with the values obtained from the satellite measurements. In addition, the ratios of the resonance and intercombination lines of He-like ions were investigated, demonstrating slow response to rapid changes in the electron density in situations of considerable opacities. This slow response is shown to lead to errors in obtaining the electron density from time-nondependent analysis of observed ratios. Using collisional-radiative and radiation-transport calculations, these data were used to obtain the time-dependent mass of the H-like-emitting plasma. The Z-imaging of the spectra allowed for performing this modeling separately for the different plasma regions seen along the Z-pinch axis. Also this modeling, allowed from comparing the energy spent on ionizations and radiations to the observed ion kinetic-energy deposited in the plasma. This yields that the ion kinetic energy directly deposited in the H-like plasma provides only 1/4-1/3 of the total energy consumed by the plasma. Plausible explanations are dissipation of magnetic-field energy (due to flows of currents at or near the stagnation plasma) or contribution of kinetic energy by the imploding-plasma-ions that do not participate in the H-like emission.

We believe that such detailed experimental investigations of the properties of a Z-pinch plasma at stagnation can be used for examinations of rather complicated radiation-magnetohydrodynamics calculations, used for modeling of dense and hot plasmas in various systems.