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Effective vs Thermal Ion Temperatures in the Weizmann Ne Z-Pinch: Modeling and Stagnation Physics[1]

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Effective ion temperatures (Ti,eff), based on the widths of emission lines in Z-pinches, have been reported for over a decade to exceed the electron temperature by more than an order of magnitude. This is observed in mid-size current generators (3.5 MA) as well as on high current (>15 MA) ones. Proposed explanations include turbulence, ion viscous heating, or 3D effects. Recent experiments with a Ne gas puff on a low current (0.5 MA) generator at the Weizmann Institute of Science also display this effect, but also provide extensive time and space resolved measurements of the plasma during stagnation [1]. The radiation-MHD code MACH2-TCRE at NRL has been used to model this Ne pinch in R-Z cylindrical geometry with a moving grid, and a non-LTE ionization kinetics coupled to a 3D radiation transport. The computed implosion dynamics depends on the initial density profile and shows flaring as seen in visible imaging. The computed electron temperature agrees with the data as does the peak K-shell power, but the pulse width is less. The calculated electron density varies strongly during stagnation, especially in the early phases, but is within the observed range during the radiation pulse. Ti,eff is computed analogously to the experimental technique: the simulation is post-processed for the emission profiles of the satellite lines, including the Doppler shifts due to the velocity structure in the K-shell emitting region. The resultant Ti,eff for the 2D model are significantly larger than the ion thermal temperatures early in the K-shell pulse, in agreement with the data. This implies that the broad line widths reflect strong radially velocity gradients near the axis. The underlying stagnation physics of thermalization and equilibration, and its relation to the detailed data, are examined for this pinch.

[1] E. Kroupp, et al., PRL, 98, 115001, 2007; PRL, 107, 105001 (2011).

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