THE NON-LTE STAGNATION PHYSICS OF A Z PINCH: SPECTROSCOPY COUPLED WITH RAD-HYDRO SIMULATIONS*

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Targets in inertial fusion experiments often involve moderate and high atomic number material. This presentation will review some work done at the Naval Research Laboratory on modeling of the non-LTE ionization kinetics in radiation-MHD simulations of Z pinches. In particular, we will focus on the origin of the large effective ion temperatures and the energy balance during the stagnation phase of the Z pinch.

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, rotation, 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, and 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 non-LTE ionization kinetics coupled to 3D radiation transport. 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 [2].

It is generally thought that a stagnating pinched plasma is near Bennett equilibrium, i.e., the plasma pressure is confined by the self magnetic field of the current. Detailed spectroscopic data, both from Al/Ti arrays on the high current Z generator at SNL and gas puffs on the Weizmann generator indicate that the stagnating pinch is defined by an accreting shock with the pressure behind the shock balanced by the ram pressure of the imploding material [3]. In this configuration the radiation energy is provided instead by the thermalization of the inward plasma kinetic energy, somewhat akin to the stagnation of an ICF target. Indeed, polarization spectroscopy using oxygen indicates that the magnetic field does not penetrate deeply into the stagnating plasma [4].

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[1] Kroupp, et al., PRL, 98, 115001, 2007; PRL, 107, 105001 (2011).
[2] Giuliani, et al, PoP, 21, 031209, 2014.
[3] Maron, et al., PRL, 111, 035001, 2013.
[4] Rosenzweig, et al., APS-DPP, #BO7-9, 2014.