THE ISOELECTRONIC METHOD FOR MEASURING ELECTRON TEMPERATURES IN NON-LTE LASER-DRIVEN PLASMAS: LINE OPTICAL DEPTH EFFECTS

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Measurements of the ratio of analogous emission lines from isoelectronic ions of two elements form the basis of the isoelectronic method of inferring electron temperatures in laser-produced plasmas [1][2]. To diagnose multi-keV non-LTE plasmas, a common choice is two He-like ions of mid-Z elements, with ΔZ in the 1–3 range. Spanning a broad range in temperature, He-like ions exhibit only a few bright lines, and are relatively simple to model. Nevertheless, it is impossible to remove all sources of modeling error. The purpose of the isoelectronic method is to mitigate errors by forming the ratio of analogous lines, with the expectation that these errors, roughly speaking, cancel.

Obtaining a sufficiently bright signal in the signature spectral lines sets a lower limit on the sample size, which can, in turn, lead to non-trivial line optical depths. We present modeling results of a combined approach using the SCRAM spectral synthesis code [3], the output of which is post-processed using a Monte Carlo radiation transport code. We find that Heα emission lines ($1s2p$–$1s^2$), although subject to moderately high (>10) line-center optical depths, are almost entirely unattenuated, and escape the emission volume after repeated resonant line scattering. In escaping the emission volume, however, line scattering can induce anisotropy, promoting a tendency to escape preferentially along the geometrically thin dimension. We show that possible ambiguities associated with anisotropy are also minimized by relying on isoelectronic line ratios. By contrast, Heβ emission lines ($1s3p$–$1s^2$) may be prone to line-splitting, which can reduce the escaping line flux relative to the optically thin limit. We further model these effects in an expanding medium, in order to assess the modifications to the resonant scattering process where velocity gradients modify the line opacity. We present modeling results using a Mn/Co tracer (ΔZ = 2) relevant to the first electron temperature measurements inside a NIF hohlraum [4], and results relevant to a V/Fe (ΔZ = 3) tamped sample experiment at LLE [5].

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