Contribution ID: **83** Type: **not specified**

A Hybrid Fine-Structure and Super Transition Array Calculation Using a Consistent Bound and Continuum Electron Treatment

Determining plasma opacities requires knowledge of the electronic structure of many atomic configurations. For dense plasmas, the number of configurations required to accurately represent the plasma is often intractably large when using methods that require explicit accounting of each configuration. The superconfiguration concept [1] allows one to use a representative atomic structure for groups of configurations, and the super transition array (STA) technique [1,2] then uses those superconfiguration structures to form an opacity that approximately retains the same statistical properties of opacities obtained using explicit accounting methods. The cost of this STA approach is that many spectral lines are merged into broader features, which reduces the number of so-called "windows"of low opacity in between spectral lines. Though this loss of spectral resolution is necessary to tractably account for the large number of configurations found in plasmas, quantities such as the Rosseland mean opacity are very sensitive to the absence of opacity windows. In this work, we build on prior STA development [3] and present the results from our hybrid fine-structure and STA approach, which uses superconfigurations to incorporate the influence of more exotic configurations and splits configurations that are closer to the ground state in energy into fine-structure levels. This hybrid approach gives an opacity that combines the strength of the STA formalism to capture all possible configurations with the increased spectral resolution obtained from fine-structure transitions.

[1] A. Bar-Shalom et al, Phys. Rev. A 40, 3183-93 (1989).
[2] A. Bar-Shalom, J. Oreg, Phys. Rev. E 54, 1850-6 (1996).
[3] N. M. Gill, C. J. Fontes, C. E. Starrett, J. Phys. B 56, 015001 (2023).

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Session Classification: Poster Session

Track Classification: High Energy Density Plasmas and Powerful Light Sources