Laboratory Measurement of L-Shell Opacity at GEKKO XII/LFEX High Power Laser Facility

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Opacity represents a fundamental parameter in high-energy-density (HED) physics, which controls the process of radiation energy transfer in a HED plasma. Understanding the atomic process in stellar interior conditions depends on the opacities of mid-atomic-number elements over a wide range of temperatures, which can also help us to understand the efficiency of inertial confinement fusion. However, some of the details of the radiative transfer process are neglected due to the complexity of the atomic process calculation, which leads to inaccurate predictions. For example, one possible explanation of the disagreement between solar models and helioseismology observation is insufficient theoretical opacities. [1] Experimental validation of the opacity models is crucial for astrophysics and the HED science.

Approximately ten years ago, the first measurement of plasma opacity at temperatures above 150 eV and electron densities above $10^{22}/\mathrm{cm}^3$, was achieved by the Z facility at Sandia National Laboratory (SNL). [2] The experiment revealed discrepancies between data and predictions of iron plasmas from different opacity modeling codes in the temperature-density region equivalent to solar convection-radiative boundary condition. The study proposes a hypothesis that the existing opacity models are missing some important physics processes that become significant at stellar interior conditions. [3]

In this paper, we present the work done toward verifying the hypothesis mentioned above and discuss the prospects for future research. A platform for measuring opacity has been developed with the GEKKO XII high-intensity laser facility. The bespoke laser-driven hohlraum can heat the calcium and titanium sample to a HED state while avoiding direct laser heating. The enhanced platform is equipped with the capacity for high-temporal resolution measurement utilizing the LFEX picosecond laser system. The experimental campaign yielded confirmation that the radiation temperature achieved by the laser-driven hohlraums with disparate geometric designs and driven laser energy combinations could reach 100 to 120 eV radiation energy. For the first time, several sets of high-temporal resolution spectra of transmission, sample emission, and backlight emission have been measured, which could be used for opacity calculation.

References

[1] S. Basu, H. M. Antia, Physics Reports **457**, 217-283 (2008).

[2] J. E. Bailey et al., Nature **517**, 56-59 (2015).

[3] T. Nagayama et al., Phys. Rev. Lett. **122**, 235001 (2019).

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