Measuring Plasma Parameters of Warm Dense Matter from X-Ray Thomson Scattering at the LCLS and the NIF

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A The thermal and electrical conductivity, equation of state and the spectral opacity in warm dense matter (WDM) are essential properties for modeling, e.g., fusion experiments or the evolution, interior and magnetic field generation of planets. In the last decade, it has been shown that x-ray Thomson scattering (XRTS) is an effective tool to determine plasma parameters like temperature and density in the WDM regime [1]. Recently, the electrical conductivity was extracted from XRTS experiments for the first time [2]. The spectrally resolved scattering data of aluminum, isochorically heated by the Linac Coherent Light Source (LCLS), show strong dependence on electron correlations. Therefore, the damping of plasmons, the collective electron oscillations, has to be treated beyond perturbation theory. Furthermore, an ongoing experimental campain at the National Ignition Facility (NIF) measures XRTS spectra of imploding beryllium capusules for the first time in forward direction under extreme conditions, i.e. beyond 20 times compression.

Here, we present results for the dynamic transport properties in warm dense aluminum and beryllium using density-functional-theory molecular dynamics (DFT-MD) simulations.
The choice of the exchange-correlation (XC) functional, describing the interactions in the electronic subsystem, has significant impact on the ionization energy of bound electrons and the dynamic dielectric function.
Our newly developed method for the calculation of XRTS signals including plasmon and bound-free transitions is based on transition matrix elements together with ionic contributions using uniquely DFT-MD simulations. The results show excellent agreement with the LCLS data if hybrid functionals are applied [3]. The experimental finding of nonlinear plasmon damping is caused by the non-Drude conductivity in warm dense aluminum. Here, we show further validation by comparing with x-ray absorption data [4]. These findings enable new insights into the impact of XC functionals on calculated properties of WDM and allow detailed predictions for ongoing experiments at the extreme densities reached at the NIF.

REFERENCES

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