P 15: High Energy Density Physics II

Time: Thursday 11:00–12:30 Location: KH 01.020

Invited Talk P 15.1 Thu 11:00 KH 01.020
Demonstration of X-ray Diagnostics for Heavy-Ion-Heated Matter — •Julian Lütgert — Universität Rostock, Germany.

In the transition between solid and plasma, a sample reaches the Warm Dense Matter regime, characterized by ambient densities and temperatures between 10,000 and 1,000,000 K. Typical schemes for the generation of such conditions use ultra-fast heating or shockwaves. However, these methods only create states with lifetimes up to tens of nanoseconds. Heavy ion beams can provide a different driving scheme enabling probing times on the order of microseconds, and thereby close the gap between experiments in the lab and real-world phenomena. Such experiments are now within reach, with the next generation of heavy ion synchrotrons, like FAIR at GSI (Germany), or HIAF (China), currently under construction.

As optical measurements typically fail for dense plasmas, X-ray based methods have been developed by the community. Here, we present first experiments combining heating by accelerated ions with laser-driven X-ray diagnostics, conducted at the currently available GSI infrastructure. We measure temperature and the graphitization threshold of a diamond target by comparison of spectrally resolved scattering signal to *ab-initio* simulations. Simultaneous X-ray diffraction and imaging measurements give insight into the integrity of the sample, indicating the onset of a temperature-driven phase transition around 2000 K. We identify unique challenges in integrating the established diagnostics with ion beams and propose initial mitigation strategies toward successful experiments at upgraded facilities.

P 15.2 Thu 11:30 KH 01.020
Model-free interpretation of X-ray Thomson scattering experiments with warm dense matter — •Tobias Dornheim — Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01328 Dresden, Germany — Center for Advanced Systems Understanding (CASUS) at Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-02826 Görlitz, Germany

Warm dense matter is an extreme state that occurs in a variety of astrophysical objects (brown dwarfs, giant planet interiors, ...), and which is of key importance for technological applications such as inertial fusion energy. There are many ways to generate warm dense matter in the laboratory, but diagnostics even of basic parameters such as the temperature is difficult and often depends on models. Here, I summarize recent progress on the model-free diagnostics of warm dense matter from x-ray Thomson scattering measurements [1,2].

[1] T. Dornheim et al., Nature Commun. 13, 7911 (2022) [2] T. Dornheim et al., Nature Commun. 16, 5102 (2025)

P 15.3 Thu 11:45 KH 01.020
Electron dynamic and static structure factors in warm dense matter from density functional theory — •Zhandos Moldabekov[1] and Tobias Dornheim[1,2] — [1]Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01328 Dresden, Germany — [2]Center for Advanced Systems Understanding (CASUS), D-02826 Görlitz, Germany

Understanding the behavior of warm dense matter is crucial for modeling compact astrophysical objects and advancing research in inertial confinement fusion. Density functional theory (DFT) is the standard theoretical tool used in this regime. We introduce a new approach that combines time-dependent DFT calculations of the dynamic structure factor with static DFT results for the density response [1], enabling accurate predictions of the electron-electron static structure factor in warm dense matter. We also present our recent methodological and computational advances in applying linear-response time-dependent DFT (LR-TDDFT) to calculate the electron dynamical structure factor [2-8].// [1] Z. Moldabekov et al., Matter Radiat. Extremes 11 (2), 025401 (2026).//[2] Z. Moldabekov et al., Matter Radiat. Extremes 10 (4), 047601 (2025).//[3] Z. Moldabekov et al.,J. Chem. Theor. Comput. 19, 1286*1299 (2023).//[4] Z. Moldabekov et al., Prog. Part. Nucl. Phys. 140, 104144 (2025).//[5] T. Gawne, Z. Moldabekov et al., Phys. Rev. B 109, L241112 (2024).//[6] T. Gawne, Z. Moldabekov et al., Electron. Struct. 7 025002 (2025).//[7] Z. Moldabekov et al., Phys. Rev. Research 6, 023219 (2024).//[8] D. Bespalov, U. Zastrau, Z. Moldabekov et. al., arXiv:2509.10107 (2025).

P 15.4 Thu 12:00 KH 01.020
Collective modes of dense hydrogen plasmas from semi-classical molecular dynamics simulations — •Hanno Kählert and Daniels Krimans — Christian-Albrechts-Universität zu Kiel, ITAP, Germany

Dense hydrogen occurs in the interior of giant planets and during laser-driven fusion. Its properties, such as the equation of state or transport coefficients, are of high interest for modeling applications. The dynamic structure factor (DSF) is related to many thermodynamic and transport coefficients. Here, the DSF is computed from semi-classical molecular dynamics (MD) simulations [1] using the improved Kelbg potential [2]. It is shown that the structural properties are in good agreement with first-principle quantum Monte Carlo simulations. The DSF is compared with wave-packet MD simulations [3]. While the electron-electron DSF from the two methods agrees qualitatively, excellent agreement is found for the ion sound speed extracted from the ion-ion DSF. The latter can be reproduced accurately with a Yukawa one-component plasma (YOCP) model. A method to determine the screening and coupling parameters of a YOCP solely from structural properties is discussed [4].

[1] H. Kählert, submitted (2025).
[2] A. V. Filinov, V. O. Golubnychiy, M. Bonitz, W. Ebeling, and J. W. Dufty, Phys. Rev. E **70**, 046411 (2004).
[3] P. Svensson, Y. Aziz, T. Dornheim, S. Azadi, P. Hollebon, A. Skelt, S. M. Vinko, and G. Gregori, Phys. Rev. E **110**, 055205 (2024).
[4] D. Krimans and H. Kählert, submitted (2025).

P 15.5 Thu 12:15 KH 01.020
Opacity of Jupiter's and Saturn's interior from ab initio simulations — •Martin Preising[1,2] and Ronald Redmer[1,2] — [1]Universität Rostock — [2]Helmholtz-Zentrum Dresden-Rossendorf

We calculate the Rosseland mean opacity along the pressure-temperature conditions of Jupiter's and Saturn's interior by using ab initio molecular dynamics simulations based on density functional theory. We evaluate the Kubo-Greenwood formula for the dynamic conductivity and derive the absorption coefficient and, thereby, the opacity via the dielectric function.

The opacity determines the effectiveness of radiation transport mechanisms from the hot center to the cool surface of a planet. Our results will inform interior and thermal evolution models for Jupiter and Saturn as prototypical gas giant planets, in particular for the region of warm dense matter in their deep interior where quantum and correlation effects are important.