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Dynamical structure factor for dense plasmas: Theory and application to x-ray scattering for dense plasma diagnostics

Scattering of x-rays from short pulsed, bright, narrow bandwidth sources has become a major diagnostic method for investigation of matter under extreme conditions of temperature, pressure, and density.

The X-ray Thomson Scattering technique probes the dynamical structure factor (DSF) of the scattering target. The DSF reflects the electron distribution function within the target and the collective excitations (e.g. plasmons). Thus, the spectral distribution of the scattered photons allows to directly infer important plasma parameters such as the plasma temperature, ionization, and density. Furthermore, transport and optical properties are analysed. This technique requires a solid theoretical understanding of dynamical correlations and structure in a strongly non-ideal system, such as laser-excited plasmas or matter under shock-compression. I will give an overview over recent theoretical and experimental progress in the field of X-ray Thomson Scattering and dynamical structure factor calculations.

Within our approach, the DSF is calculated using the extended Born-Mermin approximation going beyond the standard mean field random phase approximation. It incorporates dynamical electron-ion collisions as well as electron-electron local-field corrections. The Born-Mermin approximation is complemented by finite temperature density-functional molecular dynamics simulations for the static structure factors.

Our approach allows to study systematically the impact of these many-particle effects on the dynamical response of strongly correlated plasmas. Our calculations are well supported by experimental data, which cover a large range of phase space parameters. Experiments have been executed primarily at mid and large scale laser facilities, using K-shell emission lines from laser excited plasmas as the probe.

Recently, first x-ray scattering experiments were performed using the free electron lasers LCLS and FLASH. The highly promising results open up new perspectives and opportunities towards time-resolved measurements on a fs time scale and investigation of non-equilibrium processes through x-ray scattering.

Host: Robin Santra, CFEL Theory Group