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Time resolved opacity maps of warm dense Ti: a Bayesian search of coupling parameters

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Dense, strongly coupled plasmas are challenging to model due to the difficulty of treating the quantum many-body interactions at elevated temperatures. Electron-electron and electron-ion collisions determine the basic plasma properties, yet are difficult to calculate. Moreover, isolating and measuring the different scattering rates in thermal equilibrium is impossible. Here, we describe a femtosecond pump-probe experiment that drives a solid into the plasma state to measure the electron-electron and electron-ion coupling.

An experimental set up consisting of an ultrashort infra-red laser pulse (10^{14} W/cm^2, 50 fs, 800 nm) was used to create up to tens of eV solid-density plasma in the skin depth of a Ti metal film. The electronic structure of the heated sample was probed by sending a XUV pulse with energy close to that of the $M_{2,3}$ absorption edge. The transmitted XUVs spatial profile is recorded in a single-shot with 10 μm resolution, and scanned with 50 fs resolution. Thanks to a reproducible gaussian irradiation profile of the IR beam and 2D imaging, a map of transmission for variable laser fluences was recorded in every shot.

To interpret the experimental data, a forward model was constructed using a few basic physical assumptions and quantum kinetic calculations that can be performed in a laptop. A screened Coulomb potential and uniform heating through the depth of the material were considered and a nearly free electron gas interacting with fixed scattering centres and other gas particles was assumed. The free parameters are thus the electron-electron and electron-ion screening coefficients and the effective electron mass.

Finally, an evolutionary algorithm was deployed to find the optimum of our likelihood function and a MCMC search was performed so as to estimate the posterior distribution of the free parameters. This approach allows to properly account for the multiple leading order contributions and their correlations.