Interogating the population kinetics in dense plasmas using X-ray Free Electron Laser resonant photopumping

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Atomic physics can provide unique information on the detailed processes at play during the evolution of a plasma [1]. However, it suffers critical issues when invetigated in dense plasma conditions, where reabsorption, opacities and/or broadening mechanisms prevent its precise investigation (e.g. [2]). Fifteen years ago, when X-ray Free Electrons Lasers (X-ray FELs) first emerged as user facilities, they allowed breakthrough studies of some key elements of dense plasmas (e.g. opacity [3, 4], continuum lowering [5], population kinetics [6]). Still, because the X-ray pump and the X-ray probe are coupled, the available plasma conditions to be reached are limited in temperature and density space (due to the limited peak intensity an X-ray FEL can reach) as well as time scales (due to the X-ray pulse duration). In this work, we have investigated the population kinetics of a laser-driven modestly-dense copper plasma via X-ray FEL resonant photo-pumping. While we start by presenting on known state-of-the-art full scale analysis of its kinetics, with 3D hydrodynamic simulations coupled to detailed collisional radiative modeling, the emission spectra obtained during this experiment are found to be remarquably similar to fundamental atomic physics spectra obtained from relatively simple atomic physics code only. This work sheds light on the ability to use X-ray FELs to interogate the detailed atomic physics even in the hot and dense plasmas found in fundamental laser/matter interaction or in plasmas relevant to inertial confinement fusion experiments.

References

[1] D. Mihalas *et al.*, Foundations of radiation hydrodynamics, New York, Oxford University Press, 731 p., (1984)

[2] J. E. Bailey *et al.*, Nature, 7532, 56–59, **517**, (2015)

[3] O. Ciricosta *et al.*, Phys. Rev. Lett., **109**, 6, 065002, 4 (2012)

[4] T. R. Preston *et al.*, Phys. Rev. Lett., **119**, 8, 085001, 5 (2017)

[5] S. Vinko *et al.*, Nature, **482**, 59 EP (2012)

[6] E. Galtier *et al.*, Phys. Rev. Lett., **106**, 16, 164801, 4, (2011)

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