Theoretical studies on the fluorescence spectra of solid density Al plasma heated by intense X-ray free electron laser

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Synopsis The Kα fluorescence spectra of the warm dense Al plasmas produced by the intense X-ray free electron laser (X-FEL) at the Linac Coherent Light Source are observed recently. We analysis and simulate the experimental Kα fluorescence spectra theoretically by considering various related atomic dynamical processes, which is in good agreement with the measurements. Based on our theoretical simulations, we elucidate the mechanisms of the detail dynamics of the interaction between the X-FEL photon and "warm dense plasmas" in the experimental pulse durations.

The intense X-FEL is a powerful tool to study the matter in astronomy, fusion plasma and so on. When the X-FEL pulse of appropriate energy impacts the Al target[1,2], a "hot spot" region is generated, which consists of "warm dense plasmas" with Al ions of various ionization degrees. Such warm dense plasmas may not be in local thermodynamical equilibrium and will evolve with space and time due to various dynamical complex processes. As the powerfully incident driving X-FEL pulse with an appropriate photon energy can also be regarded as a probing X-ray beam, the appropriate Al ions with inner 1s vacancies (relatively long-lived comparing with the short X-FEL pulse duration) can be detected by observing X-ray fluorescence spectra as shown in the beautiful 2-D plot (X-ray florescence spectra vs. X-FEL photon energies, which is a space and time integrated measurements) published in the Ref.[1]. Theoretical studies of the fluorescence spectra will help understand the detail dynamics of the interaction between the X-FEL and materials greatly.

Since the experiment is a time and space integrated measurement, our simulation aims for an overall understanding of the physics of the "hot spot". We fit the total ionic distributions from the experimental spectra[1], which should be related to the time and space integrated results of "full atomic-kinetic" simulations[3]. Based on this integrated distribution, and using the atomic parameters of the elementary processes such as photoionization, radiative emissions, Auger process and so on, we can successfully simulate the experimental fluorescence spectra. Our method should be useful to assign various physical processes of the fluorescence spectra clearly and quickly. Furthermore, our obtained ion distributions can also serve as a benchmark for various simulations.

References

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