Spectroscopic analysis of electronic structures in dense plasmas.

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Powerful x-ray free electron lasers (XFEL) can heat solid materials isochorically and create novel states of matter under extreme conditions in high density plasmas. X-ray photons of $\sim 10^{12}$ within the beam pulse of 1-100 femtoseconds interact with a small volume of solid target (target radius ~ 1 microns or less) and deposit energies in the target by photo-ionization and photo-excitation processes. Atoms in the target will be ionized within a few femtoseconds to create solid density plasmas with negligible hydrodynamic motion during the XFEL pulse. At the x-ray photon energy range, the inner-shell electron ionization is much stronger than the valence electron ionization and the Auger processes follow the photoionization further increasing the ionization processes in the plasmas.

The solid density plasma states created by XFEL pulse are unique. It is highly transient and yet relatively uniform spatially during the pulse. Spectroscopic observations provide diagnostic information of such states during the pulse as the XFEL created inner-shell hole states vanish almost instantaneously without the pulse. Recent spectroscopic measurements have demonstrated that the electronic structures of hot and dense plasmas created by XFEL are different from those of ideal plasmas due to the continuum lowering or ionization potential depression (IPD) and the theoretical model used by plasma community for more than 50 years does not agree with observations. In this talk, the analysis of measured spectra from the transient, XFEL produced hot dense plasma is presented as well as its interpretation on electronic structures of ions in the plasmas.