Photon and Electron Impact Ionization of Ions in Warm/Hot Dense plasmas: Modifications due to the Transient Localization of Continuum Electrons

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Continuum atomic processes initiated by photons and electrons occurring in a plasma are fundamental in plasma physics, playing a key role in the determination of ionization balance, equation of state, and opacity. Here we propose the notion of a transient space localization of electrons produced during the ionization of atoms immersed in a hot dense plasma, which can significantly modify the fundamental properties of ionization processes. A theoretical formalism is developed to study the wave functions of the continuum electrons that takes into consideration the quantum de-coherence caused by coupling with the plasma environment. The method is applied to the photoionization of Fe^{16+} embedded in hot dense plasmas. We find that the cross section is considerably enhanced compared with the predictions of the existing free-atom model, and thereby partly explains the big difference between the measured opacity of Fe plasma [1] and the existing standard models for short wavelengths.

We also proposed that the transient space localization of the one electron states involved in the collision processes significantly modifies the wave functions of the scattering and ionized electrons resulting in big enhancements of these parameters. A theoretical formalism incorporating the notion of the one electron states localization is developed and applied to study the electron-ion collision processes embedded in a solid-density magnesium plasma. The results show that not only the collision dynamics and the energy correlation of the two continuum electrons are greatly modified, but also the integrated cross sections and transition rates are dramatically increased in hot dense plasmas. Compared with the results obtained by the isolated ion model, the integrated cross section can be increased by one order of magnitude and the transition rate by two orders of magnitude, which supports the recent experimental evidences that the state-of-the-art theories with the results of isolated atom model underestimate the electron impact ionization cross sections and collision rates in the solid-density Al [2] plasmas produced using X-ray free electron lasers (FEL) by more than one order of magnitude.

References

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