Spectroscopic evidence for the significant role of optical field ionization in the interaction of 10 PW laser pulses with high-Z materials

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Combined with X-ray spectral plasma diagnostics, studies on the interaction of intense laser pulses with matter provide essential information on the basic properties of plasmas. Introducing X-ray spectral plasma diagnostics into the ELI-NP 10 PW laser facility [1] promises a unique research environment. In the interaction of 10 PW laser pulses with high-Z materials, using the spectroscopic method, we observed a quite strong emission from the H-like state of elements with Z up to 30. It is important and challenging to clearly distinguish the impacts of optical field and collisional ionization on the evolution of the ion charge state in the plasmas.

The time-dependent calculations of plasma kinetics demonstrate that the spectral features measured in our experiment can be realized only if ~30 % of the ions were ionized up to H-like states in the very early moments (a few tens of femtoseconds) of the interaction. With physically meaningful plasma parameters, such a quantity of ions cannot be produced by collisional ionization in such a short period of time. Therefore, optical field ionization becomes dominant. 2D particle-in-cell (PIC) simulations also support that optical field ionization becomes dominant at the laser focus region in the early time scale. According to the ADK formula [2], the threshold value of laser intensity required to remove an electron from a He-like Ni (Z=28) ion and generate an H-like ion is $I_{ADK} = 3 \times 10^{22}$ W/cm^2. Therefore, the presence of intense H-like lines in the spectra could be evidence of the achievement of laser intensity beyond I_{ADK} on the target surface. The X-ray spectral plasma diagnostics could allow estimation of the lower limit of the actual intensity of the laser pulse within a focal spot.

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