Unveiling preplasma dynamics via collisional processes with nanosecond and sub-picosecond laser pulses

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We present experimental results from the PHELIX laser facility in Darmstadt, Germany, utilizing both components of the PHELIX laser system: a nanosecond (ns) laser pulse and a 500 fs laser pulse [1]. Our study aimed to understand the interaction dynamics of Cu targets by inducing intentional preplasma formation with the ns laser and heating electrons to a suprathermal distribution with the sub-ps laser.

The experimental method involved recording time-integrated x-ray line emission spectra of highly ionized Cu atoms, focusing on the He-like Rydberg series and Lyman-alpha lines. We explored the impact of different energies in the ns pulse on preplasma formation, the effects of delays between the laser pulses on preplasma expansion dynamics, and the influence of short-pulse laser contrast by varying conditions of the ultrafast optical parametric amplifier (uOPA).

Our results show distinct changes in the x-ray line emission spectrum under different preplasma conditions. The suprathermal electron population generated by the short-pulse interaction serves as a pumping mechanism via collisional ionization in the nanosecond intentional preplasma, revealing the charge state distribution. We interpret these spectral signatures in terms of the plasma dynamics and its transient conditions.

This study enhances our understanding of laser-plasma interactions and provides insights into optimizing experimental conditions for future high-energy density physics research with both optical lasers and XFELs.

References

[1] Rosmej, O. N., et al. "Interaction of relativistically intense laser pulses with long-scale near critical plasmas for optimization of laser based sources of MeV electrons and gamma-rays." *New Journal of Physics* 21.4 (2019): 043044.

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