Interaction of a Petawatt femtosecond laser with near-critical-density plasma

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The rapid advancements in the area of intense ultrashort lasers have made it possible to recreate terrestrial physical conditions in laboratory [1]. Exotic astrophysical phenomenon can be demonstrated on a much smaller spatial and temporal scale by focusing intense ultrashort laser pulses into a medium to achieve high energy density [2]. Near critical density targets are one such medium where an ultrahigh intensity laser can create a long channel of strongly heated particles [3]. The rapid heating of the medium can lead to the formation of shock wave, which can accelerate background ion species to high energy [4].

Here, physical phenomena behind the interaction of petawatt intense femtosecond laser pulses ($I \sim 1\times10^{20}$ W/cm^2) with near critical density plasma (n_e = 3×10^{20} cm^{-3}) will be discussed. Measured kinetic energy spectrum of transverse ions (shown in Fig. 1(a)) and forward electrons, corroborate with the observed plasma structure. The plateau structure observed in the proton spectra (Fig. 1(a)), indicate an evidence of electrostatic shock acceleration [4]. Moreover, in low energy range (< 0.3 MeV), the presence of order of magnitude higher flux of He^{+} compared to that of He^{++} reveals the charge exchange process occurring in an extended gas medium. Furthermore, a plasma emission diagnostic in the optical regime shows pronounced Raman scattering (Fig. 1(b)) along the backward and the transverse directions. For higher plasma density (n_e = 3×10^{20} cm^{-3}), the modulated Raman scattered signal is linked with the filamentation of a laser beam during its propagation in the near-critical density plasma. The space and time-resolved optical shadowgrams reveal complex interplay of plasma density and laser intensity. The experimental observations are also corroborated by 2D particle-in-cell simulations. In summary, findings of the present study highlight the important role of near-critical density plasmas in particle acceleration, growth of electrostatic instability and advancements of laboratory astrophysics.

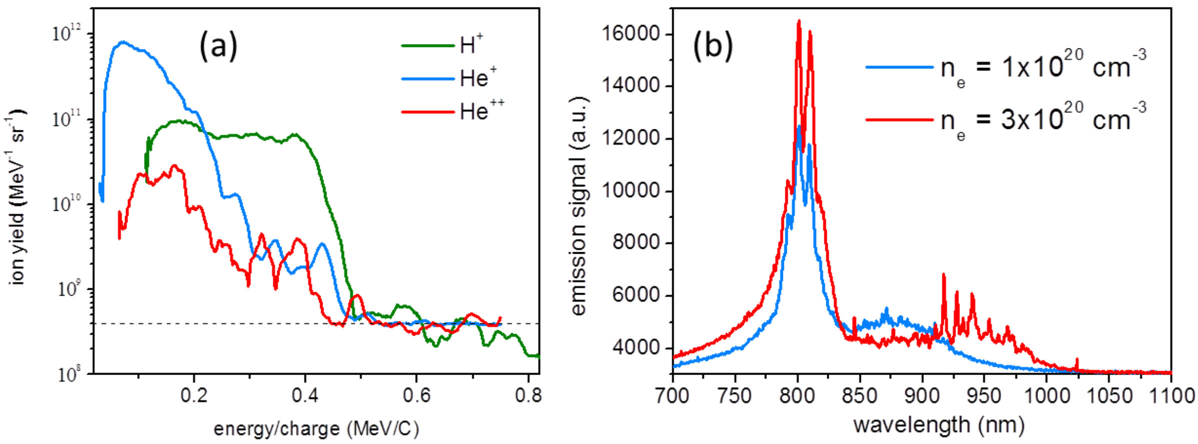

Figure 1. (a) Retrieved spectra of He^{+}, He^{++} and protons as a function of energy per charge. **(b)** Plasma emission spectra recorded at two different plasma densities, showing a modulated Raman signal at the high density.

References

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