Ion acceleration during isothermal expansion of plasma slab into vacuum

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The interaction of short intense laser pulses with solid targets allows record-breaking ion energies to be attained at the laboratory scale. It has already been shown, that significant increase of ion energy arises in laser pulse interaction with ultrathin foil. Recent improvements of the intensity contrast ratio of pulses and advances in the technology of producing ultrathin targets warrant laser pulse interaction with ultrathin foils to be of practical interest. The electrons of the foil are capable of being heated up to MeV energies and recirculated around the target. This triggers plasma expansion into a vacuum that provides acceleration of ions. A strong laser field can even knock out all electrons from a thin target that causes Coulomb explosion.

Quasineutral plasma outflow and the regime of plasma expansion with charge separation effects in collisionless isothermal expansion of a semi-bounded plasma have been theoretically studied in great detail [1, 2]. However, at high electron energy (temperature) the model of semi- bounded plasma becomes inapplicable as far as the electron Debye lengthapproaches the foil thickness. This is why analytical theory of plasma slab expansion into a vacuum is of high demand. From the other hand, analytically well studied regime of ion acceleration from plasma foil is a Coulomb explosion [3].

Going beyond previous studies we have developed a theory of plasma slab expansion into a vacuum with the Boltzmann’s electrons for arbitrary electron temperature. The electron temperature is a controlling parameter of our theory and matches laser intensity. By increasing it our theory smoothly switches from the quasineutral expansion approach to the Coulomb explosion limit. We derived both space-time and spectral characteristics of the accelerated ions for arbitrary value ofelectron temperature. In the limits of very small Debye radius and very large onesour theory agrees with known results [2, 3]. The validity of the theory is proven by comparison with kinetic simulations [4].

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