二成分クラスター・クーロン爆発による準単色プロトン生成とコンパクト中性子源

Efficient Neutron Generation by Coulomb Explosions of Multi-Component Cluster Targets

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Irradiating ultra-intense ultra-short laser pulses on nano-size cluster targets, protons are accelerated due to Coulomb explosion, the energies of which are of the order of a few MeV. In terms of the reactions between Lithium and the protons, substantial amount of neutrons can be produced. Optimizing the laser and target parameters, we maximize the coupling efficiency of neutron yields. In particular, the cluster targets are made of two or three atomic components in order to produce quasi-mono- energetic protons. The resultant neutrons are expected to have relatively low temperatures order of or lower than a few 100 keV because of the endothermic reactions.

First, Coulomb explosion of spherical ion clusters is studied, which are composed of homogeneous two- or three-species light and heavy ions. A simple analytical model is developed to describe the explosion performance in terms of two dimensionless parameters, the charge-over-mass ratio, and the charge density ratio. Molecular dynamic simulation, in which every binary collision is taken into account, has been performed to compare with the analytical model and to evaluate the energy coupling efficiency of quasimono-energetic ion generation. It is crucial to preform an iso-Coulomb-potential profile of the light ions in the cluster for efficient generation of quasimono-energetic ions. Furthermore we introduce hollow shell stricture, by which even higher coupling efficiency can be obtained.

The crucial strategy for high monoenergeticity has been shown to preform such nanostructure of an ion cluster that the light ions have iso-Coulomb-potential profile [1] in the radial direction. Such a fine nanostructure would be realized by precise temporal control of atmospheric pressure and material composition in the mist, although this remains as a challenging task. Surprisingly water droplets have turned out to have a preferable mixing ratio between Hydrogen and Oxygen [2]. At the price of the high precision of nanostructuring, the present scheme reduces the requirement on fine design of pulse shaping expected for quasimono-energetic ion production with planar targets in the sense that the electrons are only needed to be brutally blown off in a short enough period under high enough laser intensities. The isotropic emission of the ions is the major defect of Coulomb explosion for future practical use. It is expected however that the defect is to be substantially improved by developing such a magnetic device as quadrupole magnets to collimate the isotropic ion emission toward an intended direction.

References

[1] M. Murakami and K. Mima, Phys. Plasmas **16**, 103108 (2009).

[2] B. Ramakrishna, M. Murakami, M. Borghesi *et al.*, Phys. Plasmas **17**, 083113 (2010).