Generation of quasi-monoenergetic protons exceeding 200 MeV via intra-cluster collisionless shocks in a laser-irradiated micron-size H_2 cluster

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In laser-driven ion accelerations, the recent advancements in acceleration techniques using thin foil targets now allow the maximum proton energies close to 100 MeV [1,2]. However, the generation of ion beams with low bandwidth and low divergence at a high repetition rate still remains a critical issue. In addition, from a view point of practical applications, high-purity proton beams are quite advantageous. In experiments using thin foil targets, however, protons from surface contaminants along with the high-z component materials are accelerated together [2], making the production of impurity-free proton beams unrealistic.

Here we propose a new way to produce highly-directional, highly-reproducible, impurity free, quasi-monoenergetic proton beams exceeding 200 MeV using micron-size cluster targets. Interaction processes of a PW class, ultrashort (~40 fs) laser pulses and micron-size hydrogen clusters are investigated using 3D-PIC simulations. We found a special parameter regime that highly directional (divergence angle ~8.5 degree) and quasi-monoenergetic ($\Delta E/E$~7%) protons with energies up to 290 MeV are accelerated by collisionless shocks propagating inside the micron-size clusters in the relativistically-induced transparency regime.

The proposed acceleration mechanism can be considered as a future candidate in laser-driven proton sources exceeding 200 MeV with the upcoming advanced multi-PW lasers.

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References

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