Mono-energetic ion beam generation in Phase Stable Acceleration (PSA) with circularly polarized laser

Laser driven ion acceleration team

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Introduction

Ultrahigh-intensity lasers can produce accelerating fields of 10 TV/m, surpassing those in conventional accelerators for ions by six orders of magnitude [1]. Remarkable progress has been made in producing laser-driven ultra-bright MeV proton and ion beams in a very compact fashion compared to conventional RF accelerators. These beams have been produced up to several MeV per nucleon with outstanding properties in terms of transverse emittance and current, but typically suffer from exponential energy distributions. Recently a new ion acceleration method, namely **Phase-Stable Acceleration (PSA)** [2], is proposed by our group, which uses circularly-polarized laser pulses in order to decrease the energy spread and generate a high-intensity mono-energetic ion beam. In the first experiment the quasi-monoenergetic carbon beams driven by a circularly polarized laser with particle energies of 30MeV and energy spread of 15% were observed [3]. At a laser intensity of 7×10^{21} W/cm^2, self-focusing nano-Coulomb GeV proton bunches can be generated from laser foil interaction in PSA regime [4].

Phase Stable Acceleration

Why a CP laser can generate a mono-energetic ion beam in the interaction with a foil [2]?

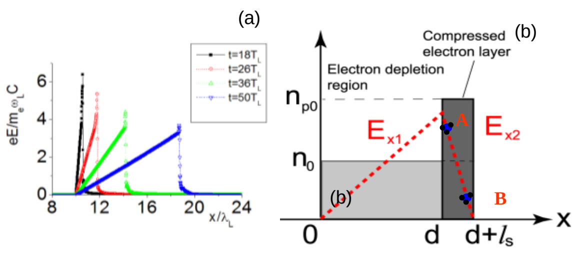

Fig.1 (a) Snapshots of the spatial distribution of the electrostatic field; (b) density profile in PSA model (laser intensity 6*10^{19}W/cm^2)

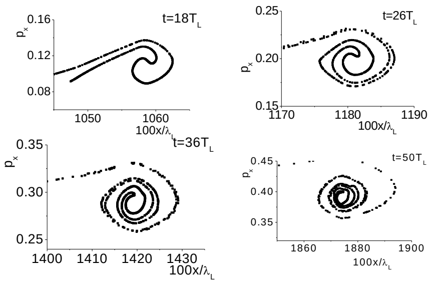

Fig.2 Phase Oscillation

Proof of principle experiments

The first proof of principle experiment was done at Max Born Institute and Munich University, Germany. The laser intensity is 5*10^{19}W/cm^2, pulse duration 45fs. Diamond like carbon (DLC) target with thickness of 5nm(Fig.5b) was used. In the first experiment the quasi-mono-energetic carbon beams with particle energies of 30MeV and energy spread of 15% were observed. It shows the Phase Stable acceleration can generate quasi-mono-energetic ion beam.

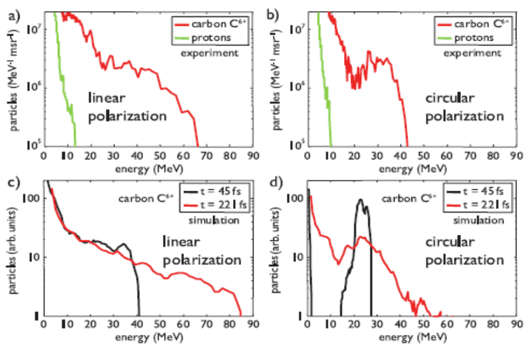

Fig.3 Energy spectrum in experiments and simulations

Self-organizing nano-Coulomb GeV proton

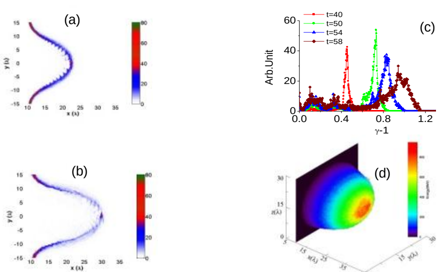

Fig.4 (a,b) Foil density evolution; (c) evolution of energy spectrum for beam ions located inside the central clump ; (d) energy distribution of protons (the colour bar gives ion energy in MeV). [laser intensity 7*10^{21}W/cm^2, pulse duration 66 fs (FWHM)]

Table top proton therapy machine

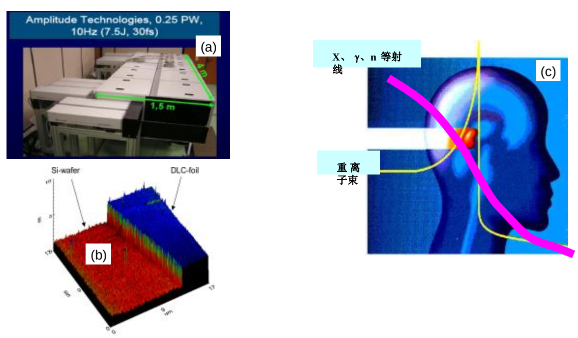

Fig.5 (a) Amplitude laser; (b) Diamond Like Carbon foil of 5nm thickness; (c) ion therapy

References

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2. X. Q. Yan et al., Phys. Rev. Lett. 100, 135003 (2008)
3. A. Henig et al., Phys. Rev. Lett. 103, 245003 (2009)
4. X. Q. Yan et al., Phys. Rev. Lett. 103, 135001 (2009)