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Ion acceleration and neutron generation with few-cycle, relativistic intensity laser pulses

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Most of the ion acceleration experiments have been carried out with multi-cycle, Joule-class lasers in the TNSA and RPA regime. The recent developments of few-cycle laser systems with 100 W average power created the technological basis for the generation of ion current of tens of microA consisting of ultrashort particle bunches– something that many applications dream of. Here we present an experimental study of proton and deuteron acceleration in both forward and backward directions with ~30mJ, 12 fs laser pulses. With the use of adaptive mirror, the focused intensity of such laser pulses reaches ~10^19W/cm^2 intensity on target.

Protons were accelerated on thin foils made of various materials, with thicknesses ranging from 5 nm to 9 microns. The highest cut-off energy and conversion efficiency was 1.5 MeV, and 1.5 %, respectively, with a beam emittance as small as 0.00032 π-mm-mrad.

Deuterons were accelerated close to MeV by irradiating homemade 200 nm thin deuterated polyethylene foils on a rotating wheel target system. The laser was run at 1 Hz repetition rate in bursts of 75 shots. With a systematic change of the dispersion of the laser pulse, we have revealed that the optimum conditions for achieving the highest cut-off energy particles and the highest conversion efficiency of a particle bunch are significantly different.

The accelerated deuterons hit a 0.1 mm thick deuterated polyethylene disk and induced neutrons with a mean energy of 2.45 MeV. From the ToF signals of four plastic scintillators at various angles around the chamber, we have concluded that an average of ~4000 fast neutrons were generated in a shot. With the development of high repetition rate primary-target systems including thickness optimization, the yield of neutrons in a second may exceed what can be achieved with state-of-the-art PW class lasers.

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