EuroNNAc Special Topics Workshop

EUROPEAN NETWORK FOR NOVEL ACCELERATORS

EuroNNAc4

NPACT supported by EU via I-FAST

Contribution ID: **94** Type: **Invited talk**

Proton and deuteron acceleration with few-cycle, relativistic intensity laser pulses

Wednesday, 21 September 2022 10:00 (20 minutes)

According to recent theories, ion acceleration is predicted to achieve high efficiency with the use of single-cycle laser pulses. Few-cycle, high-repetition-rate laser systems with modest energy (10s of mJ) have been developed recently with remarkable stability. With the use of adaptive optics, such laser pulses can be focused down to relativistic intensities, providing a platform for exploring the laser-plasma interactions with very few cycle pulses. Here we present an experimental study of proton and deuteron acceleration in both forward and backward directions with 12 fs laser pulses, providing ~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 0.00032π-mm-mrad. Deuterons were accelerated close to MeV by irradiating homemade 200 nm thin deuterated polyethylene foils. Dependence of the cut-off energy and the conversion efficiency on the dispersion of the pulses have been also measured. The demonstration of MeV deuterium ions can lead to the production of bright neutron flux via D-D reaction, which could be a pathway to drive a sub-critical reactor for transmutation of spent nuclear fuel.

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Session Classification: Special Topic