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Developments of laser neutron source and diagnostics in Japan

Akifumi YOGO[1], Yasunobu ARIKAWA[1], Yuki ABE[1], Seyed R. MIRFAYZI[1], Akifumi IWAMOTO[2], Mizuho NAGATA[1], Daniil GOLOVIN[1], Yuki HONOKI[1], Takato MORI[1], Satoru SHOKITA[1], Takashi ISHIMOTO[1], Zechen LAN[1], Mitsuo NAKAI[1], Tomoyuki JOHZAKI[3], Natsumi IWATA[1], Hideo NAGATOMO[1], Shunsuke FUJIOKA[1], Kunioki MIMA[1,4], Hiroaki NISHIMURA[1], Yasuhiko SENTOKU[1], Satyabrata KAR[5], and Ryosuke KODAMA[1]

[1]Institute of Laser Engineering (ILE), Osaka University, Japan,
[2]National Institute for Fusion Science, Japan, [3]Hiroshima University, Japan,
[4]The Graduate School for Creation of New Photonics Industries, Japan,
[5]Centre for Plasma Physics, Queen's University of Belfast, UK
e-mail: yogo-a@ile.osaka-u.ac.jp

The emergence of ultrahigh-intensity laser enabled to accelerate particles by photons. Recently, the rapid progress on laser technology has opened a new field of science, known as Nuclear Photonics, which includes an attempt to control nuclei by photons.

We are exploring Nuclear Photonics by using a laser-driven neutron source (LDNS) exhibiting two outstanding characteristics, compactness (5 mm) and short duration (1 ns), which are unique compared to conventional neutron sources. We report the generation of 4×10^{11} neutrons [1] by a single laser pulse (1 kJ, 1.5 ps, 1×10^{19} Wcm^{-2}) delivered from LFEX system, ILE Osaka University. The setup is shown in Fig. 1. The large number of neutrons is achieved by nuclear reactions between a fingertip-size Be block and high-current deuterons accelerated by laser (Fig. 2) via a new mechanism, Dual Field Acceleration (DFA) [1], where deuterons initially located on the target front surface are accelerated in the laser-propagation direction by the charge-separation field induced by a giga-bar laser light pressure [2], and boosted by the rear sheath field up to several MeV/u.

The high efficiency of this DFA mechanism allows us to obtain neutron radiography images. We have developed a large-aperture high-sensitivity image intensifier panel [3] and applied it to the monitoring of fast (MeV energy) neutrons generated by our LDNS. By a single laser shot, we have successfully obtained shadow images of a PET bottle filled with water, which is transparent to x-rays, as a first step toward future application to non-destructive inspection of large (~ 1 m thickness) infrastructures, including highway bridges.

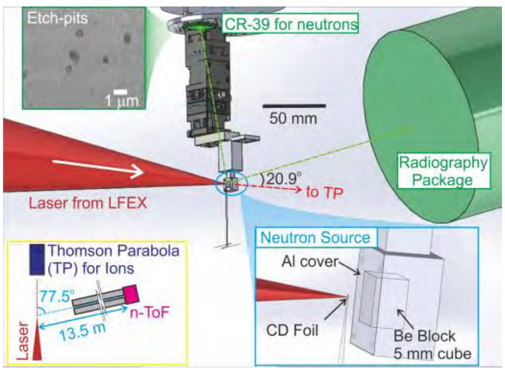

Fig. 1: A setup of laser-driven neutron source (LDNS) in Osaka University.

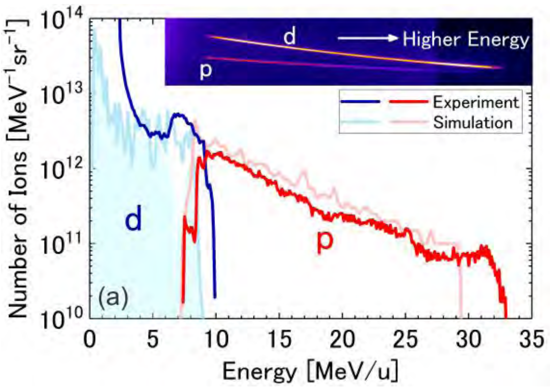

Fig. 2:. Energy spectra of ions accelerated via DFA mechanism from a 5-μm-thick deuterated polystyrene (CD) foil. The blue and red lines indicate the spectra for the deuterons (d) and protons (p), respectively.

By using a hand-size moderator of neutrons located at the downstream of the LDNS, we have generated "cold" neutrons in a range of energies from 1 to 10 meV [4] for the first time. The hand-size moderator consists of a cryogenic cooling cell of solid hydrogen reaching temperature down to 11 K. The fast neutrons from LDNS are injected into the cold moderator and decelerated via collisions with the cold hydrogen nuclei. These low energy neutrons can be applied to a broad range of applications such as nuclear security inspection by resonance absorption, analysis of protein structures by neutron diffraction, and so on.

The brightness and short duration of the neutron pulse allow us to realize a compact and high-resolution beamline, which will enable a broad range of applications such as non-destructive inspection of infrastructures, nuclear security inspection by resonance absorption, analysis of protein structures by neutron diffraction.

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