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Development of Laser-driven Neutron Source and its Applications
レーザー駆動中性子源の開発とその展開

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Laser-driven neutron sources (LANS) are attracting attention as a new neutron source to replace nuclear reactors and accelerators. However, because of its low efficiency on the neutron generation yield, the laser-driven neutron source still remains at the stage of basic research at present. Recently, efficient ion acceleration has been achieved with picosecond (ps) relativistic-intensity laser [1]. Here, we report on the efficient neutron generation boosted by efficient acceleration of MeV-energy deuterons with the ps laser pulse. The high neutron yield allows us for the first time to obtain radiographic image by neutrons with a single laser shot.

The laser pulses having a duration of 1.5 ps (FWHM) are delivered from LFEX [2] and focused onto a few-micron-thick foil of deuterated polystyrene (CD) with the intensity up to 1×10^{19} Wcm^{-2}, corresponding to the laser energy 1 kJ. Protons and deuterons (ions of deuterium) are accelerated toward the laser propagation direction up to 20 MeV with the 1-kJ laser, when the laser energy conversion efficiency is evaluated as 3.5% for deuterons over 5 MeV. Detailed mechanism of the ion acceleration will be discussed in the presentation. The accelerated ions bombard a solid beryllium block and converted into fast neutrons via nuclear reactions. The setup is shown in Fig. 1. Using CR-39 track detectors and bubble detectors, we confirm that $1\text{-}2\times10^{11}$ neutrons are generated at maximum in 4π direction.

The fast neutrons are decelerated by a polystyrene block having a thickness of 10 cm down to thermal or epithermal energy region and used for neutron radiography. In order to obtain background-free neutron images, we utilize the neutron capture process of ^{164}Dy. A shadow of boron carbide (B_2C), which is often used as a neutron absorber of a control rod of nuclear reactor, is clearly monitored on the Dy detector, while the B_2C shadow is not recorded on an Imaging Plate detector that is sensitive to plasma-induced x-ray. This fact is the evidence that our radiographic image on the Dy detector is attributed to neutrons, not x-rays.

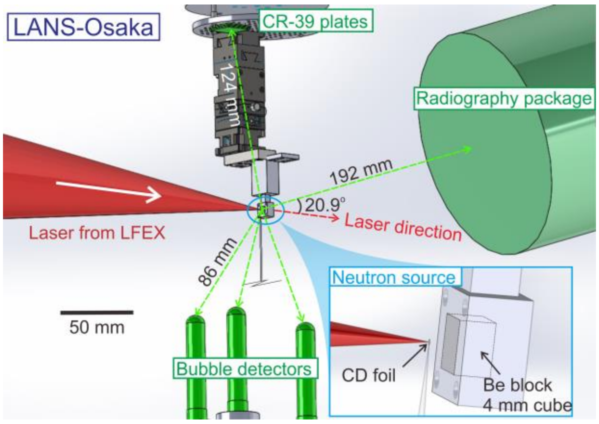

Fig. 1: The experimental setup of neutron generation.

Considering that the temporal duration of the neutrons is around 0.1-1 ns, the neutron flux reaches $10^{19\text{-}20}$ s^{-1}cm^{-2}. The high-flux burst of neutrons achieved here leads to several advanced applications including high-speed imaging of fast phenomena, turbulence in piping for instance, and time-of-flight neutron absorption analysis of matters with higher resolution. At the same time, our LANS can pave a way toward novel nuclear physics and laboratory astrophysics. The feasibility for future applications will also be discussed.

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[1] A. Yogo et al., "Boosting laser-ion acceleration with multi-picosecond pulses." Sci. Rep. 7, 42451 (2017).
[2] J. Kawanaka et al. J. Phys. Conf. Ser. 112, 032006 (2008).