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Neutron resonance spectroscopy using a single pulse of laser-driven neutrons

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In recent decades, neutron resonance diagnosis technology has been developed and significantly concerned for non-destructive detection and isotope identification. Meanwhile, a new approach of neutron generation, a Laser-Driven Neutron Source (LDNS) has been attracting a broad interest because of its ultra-short pulse duration and high flux. Here, we apply the LDNS to the Neutron Resonance Spectroscopy (NRS) [1] and explore a new direction of Nuclear Photonics research.

The LDNS was developed using LFEX laser at Institute of Laser Engineering, Osaka University. As shown in Fig.1, the LDNS consists of a foil target and a secondary target which work as ion source and neutron source respectively. The secondary target (neutron generator) is set downstream from the foil target (laser-accelerated ion source), the high energy ions generate neutrons with a yield of up to $\sim 10^{11}$ within 1 ns via nuclear reactions such as $^{9}Be(p,n)^{9}B$ and $^{9}Be(d,n)^{10}B$ [1]. The fast neutrons generated by LDNS are decelerated by a neutron moderator to meet experimental needs. For example, typical resonance energy levels exist in the region of several eV. In this study, we designed a compact neutron moderator with HDPE (high density polyethylene). The size of moderator was optimized by a Monte Carlo simulation, taking a best balance between high neutron flux and short pulse duration in eV energy. A clear neutron resonance spectroscopy was obtained in single shot of LDNS [1], as shown in Fig 2. This method greatly reduces the limitations of conventional NRS measurements, when the spectrum is obtained by time integration over a few hours[2].

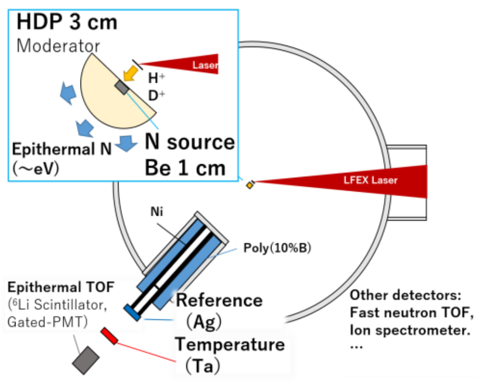

Fig.1: The experimental setup.

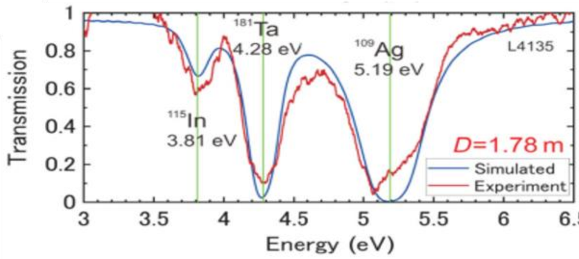

Fig.2: Neutron transmission of resonance[1].

Using the technique of the single-shot NRS, we try to realize a "nuclear thermometer"[2] by the LDNS. The experimental setup is shown in Fig.1. A ^{6}Li-glass scintillator was coupled with a Gated-PMT to work as an epithermal neutron TOF (time-of-flight) detector which was set at 1.8m far from main target. A neutron collimator made by 10% Boron dopped polyethylene was set alone neutron beam line. Two resonance samples, plates of silver (Ag) and tungsten (Ta), were put on the beamline toward the epithermal neutron detector. The Ag plate was kept at room temperature, as a reference sample, and the Ta plate was heated to high temperature. The resonance peaks of ^{109}Ag at 5.19eV and ^{181}Ta at 4.28eV were clearly identified, when the resonance peak of ^{181}Ta showed the Doppler broadening depending on the temperature, suggesting that temperature of nuclei in the sample can be analyzed by the evaluation of the Doppler broadening. Meanwhile, the pulse duration of moderated LDNS was evaluated by analyzing resonance width. With the compact source, neutrons around energy of 5 eV have pulse duration less than 1µs.

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