Exploring "Nuclear Photonics" with Laser-driven Neutron Source -between plasma science and nuclear physics-

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Recently, "Nuclear Photonics" is emerging as a new transdisciplinary field of science including plasma physics, laser science, nuclear physics, accelerator science, particle physics and astrophysics.

We are exploring the Nuclear Photonics by using a laser-driven neutron source (LDNS) exhibiting two outstanding characteristics, compactness of the source size and short duration of the beam, which are unique compared to conventional neutron sources. Recently, we have developed the LDNS having finger-tip size (10 mm) and extremely-bright (10^{11} neutrons in a 1-ns bunch at source) in ILE, Osaka University.

The neutrons having MeV kinetic energies (fast neutrons) are generated from a beryllium block (5-mm dia.) bombarded by MeV-energy deuterons and protons, that are accelerated from the region of a few tens micrometers focal spot of a high-intensity laser pulse (1 kJ, 1.5 ps, 1.5×10^{19} Wcm^{-2} at maximum) delivered from LFEX laser facility. We demonstrate that the yield of fast neutrons is scaled by the 4th power of the laser intensity [1].

The fast neutrons are decelerated by a hand-size moderator located downstream of the LDNS down to epi-thermal (~1-100 eV) and thermal (around 25 meV) regions with a polystyrene moderator in room temperature. We have measured distinct dips on the neutron energy spectra, which is attributed to the resonance absorption of neutrons transmitted through the plates of metal samples (Ag, Ta, In) located on the beamline of 1.8 m [2], which is about 10 times shorter than the beamlines of accelerator-based neutron source. As a further achievement, we have demonstrated for the first time the neutron moderation down to the cold region (meV) with a cryogenically cooled solid hydrogen (11 K) [3].

As a latest result [4], we demonstrated that (n, 2n) reactions are induced by a high-flux pulse of fast neutrons (~10^{10} neutrons in ~1 ns) provided from LDNS. Several kinds of metal targets are exposed to the fast neutrons. As a result, unstable isotopes such as ^{54}Mn, ^{58}Co, ^{175}Hf, and ^{196}Au are produced by (n, 2n) reactions and ^{180}Hf^{m},^{181}Hf, ^{56}Mn, ^{198}Au, and ^{60}Co are produced by (n, 2n) reactions. We evaluate the neutron fluence and energy spectrum using the activation method in conjunction with a time-of-flight (TOF) measurement. The neutron fluence is determined to be $(4.3\pm0.5)\times10^{8}$ neutrons/cm^{2} in the energy range from approximately 8 to 20 MeV at 8-mm downstream of the neutron source.

Our LDNS demonstrates the generation rate of ~10^{20} n/s at peak for fast neutrons, which is higher than the inner-stellar environment of typical red Giant Strs. This characteristic of our LDNS will enable a broad range of applications such as non-destructive material inspection using neutron resonance absorption, and nuclear astrophysics [5].

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References

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