§62. Progress on the Laser Driven Neutron and a New Approach to the Nuclear Science

Arikawa, Y., Nagai, T., Abe, Y., Utsugi, M.,
Fujioka, S., Nakai, M.,
Shiraga, H., Azechi, H. (Osaka Univ.)

Introduction

We have been promoting the fast ignition fusion experiments using ultra-high-intensity LFEX (laser for FIREX). A neutrons cleated via nuclear fusion is much smaller than that of NIF (about 10^7), the flux of X-ray or neutrons generated from a LFEX experiment is very high. As will be described later, peak fluxes at the target surface achieved to 10^{21} / cm^2 / s for neutrons, 10^{27} / cm^2 / s for X-ray were demonstrated [1]. This source is very attractive because we can examine the astro nuclear science, especially with very short lifetime. For instance a nucleus in an excited states can capture the neutron in these condition. This reaction can simulate the nuclear reaction in the supernovae.

The program NIFSKUGK 070 has been started from FY 2013, and in FY 2013 was have developed low-energy neutron instruments. In FY 2014, we conducted a photonuclear reaction neutron generator as described above, and the numerical simulations for evaluating the efficiencies. In this report a progress in FY 2014 are discussed.

Estimation of the X-ray /neutron flux by using simulations

The spatial flux distribution was simulated assuming an typical experimental condition by using a Monte Carlo simulation PHITS. An electron beam was injected to a gold target with a size of 2-mm diameter 1-mm thickness. The electron spectrum was experimentally measured in the experiment with a LFEX laser of 1.6 kJ on target on 2011 and the electron spectrum was input in the simulation. The electron total energy was assumed to be 40 % of the incident laser energy (640 J). Neutrons are generated from almost entirely target, and the neutron peak flux at the target surface was resulted to be 10^9 / cm2 / ps, then it was simply estimated to be 10^{21} / cm^2 / s. On the other hand, X-ray (the energy above 1MeV) reached 10^{27} / cm^2 / s on the target surface. The yield of the neutrons above 1 MeV was resulted to be 7.5×10^9. This value agreed with the experimentally observed one within a order of magnitude. This work was published in the plasma fusion research [1].

Neutron generation experiment

Two-shot using the LFEX on 19 th to 20 th November 2014 were conducted. Gold target with 2-mm diameter, 1-mm thick was irradiated by LFEX. The laser energy with maximum 700 J was focused in to the target. The pulse width was 1.5 ps, and focused spot size was 80 μm full width at half maximum, the pulse contrast of the laser was 10^9 at the 100 ps before the peak. Pulse contrast used in FY 2011 was not measured but estimated to be 10^8. The neutron yield was compared to that was measured on FY 2011 with the same target [2] as shown in Fig.1. Neutron yield as the function of the laser energy was agreed with the previous data. As discussed below the decrease of the neutron yield was expected due to the improvement of the laser pulse contrast, however the these difference was not observed.

The numerical study for the optimal experimental condition

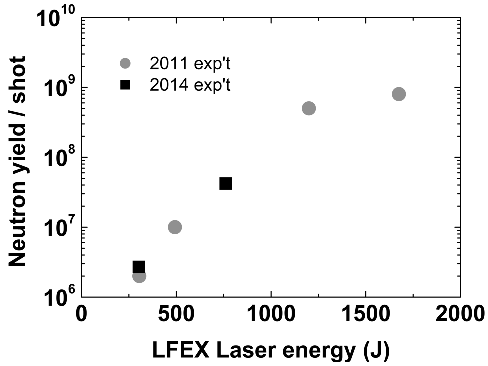

Figure 1 Neutron yield measured on the LFEX experiment

For enhancing the neutron flux, the electron spectrum should be optimized. The photo-nuclear reaction cross-sectional of the 197Au is large for more than 10-MeV X-rays. Since it is necessary to generate an electrons above 10 MeV for generating 10-MeV x-ray, the generation of the 10s MeV electron is crucial. The energy spectrum of fast electrons accelerated by ultra-high intensity lasers have been investigated widely in the world, and it has been known that with the presence of a pre-plasma high energy electrons are accelerated efficiently. A longer scale preplasma (more than 30 μm) was resulted to create high energy part, which indicated we should create preplasma artificially on the target surface before LFEX coming. GEKKO XII laser can be used in this purpose. In the next campaign GEKKO XII and LFEX joint shoot will be designed.

[1] Y.Arikawa, et al., Plasma Fusion Reseach,10, 2404003, (2015)
[2] H. Chen, et al, New Journal of Physics 15, 065010, (2013)