20PB-082

The development of laser-driven intensity neutron generation by using photonuclear reaction
光核反応を用いたレーザー駆動高輝度中性子源開発

Masaru Utsugi[1)], Yasunobu Arikawa[1)], Sadaoki Kojima[1)], Takahito Ikenouchi[1)], Shota Tosaki[1)], Akifumi Yogo[1)], Alessio Morce[1)], *et al.*

宇津木卓 [1)], 有川安信 [1)], 小島完興 [1)], 池之内孝仁 [1)], 戸崎翔太 [1)]、余語覚文 [1)], Alessio Morce[1)], 井上峻介 [2)], 寺本研介 [2)], 中島裕人 [2)], 橋田昌樹 [2)], 阪部周二 [2)], 大竹淑恵 [3)], 三間圀興 [4)], 藤岡慎介 [1)], 中井光男 [1)], 西村博明 [1)], 疇地宏 [1)]

1)Institute of Laser Engineering,

2)Institute of Chemical Research / Graduate School of Science Kyoto University,

3)RIKEN, 4)The Graduate School for the Creation of New Photon Industries

1) 大阪大学レーザーエネルギー学研究センター、2) 京都大学化学研究所/大学院理学研究科、

3) 理化学研究所、4) 光産業創成大学院大学

The fast-neutron shadowgraph represents a promising method to observe inside over 50 cm thick reinforced concrete structures such as bridge pillars. A compact size, high flux neutron is strongly required for this aim. Laser driven neutron sources and especially laser driven photonuclear neutron generation scheme is one of the most attractive candidates [1]. The conversion of laser energy to hot electrons with energies above several MeV is essential for the generation of photoneutrons. The long scale length preformed plasma on the target surface can increase hot electron temperature [2, 3, 4]. In this study hot electron spectra generated by high power laser-matter interaction for different preplasma scale lengths are studied. Spectra from Al and Au foils in different laser contrast conditions are analyzed, confirming a clear enhancement of the hot electron temperature for low contrast laser irradiating an Al foil.

1 Introdaction

The photoneutron generation process from high intensity laser pulses can be schematized as follows, (1) electrons are generated and accelerated by the laser pulse focused on the target material, (2) electrons are converted to high-energy X-rays in the target (Bremsstrahlung radiation), (3) neutrons are finally generated via photonuclear reaction in the target. Since the photoneutron yield is proportional to the cross section of the photonuclear reaction, which for a Pb target becomes important for photon energy above 6 MeV, the distribution of x-rays, and consequently the distribution of hot electrons with energies above 6 MeV is important. In several works is shown that the preformed plasma on the target surface can increase the electron energy. In this study we report experimental reults on fast electron generation in different pre-plasma conditions using Al and Au targets. The preplasma scale length was reduced by means of a plasma mirror (PM) device.

2 Setup and Experiment results

The experiments have been carried out on the Table-top Ten TW Ten Hz Tunable*Ti:sapphire laser (T^6 laser) facility at Kyoto university. The Laser was focused in a $5.5\,\mu$m $\times$ $3.4\,\mu$m ellipsoidal spot, carrying 182 mJ of average energy in 40 fs, corresponding to an average peak intensity of 2.3×10^{18} W/cm^2. Electron spectra was compared for the four cases, a $10\,\mu$m thick aluminum and a $10\,\mu$m thick gold target with and without PM. The spectra were collected by using magnet based electron spectrometer (ESM) as shown in Fig.1. The laser incidence angle was 45 degrees for both targets. The ESM was placed on the laser axis at 9.5 cm distance from the focal point. Clear enhancement of the hot electron temperature was observed for low contrast conditions (without PM) for both gold and aluminum target. Aluminum target

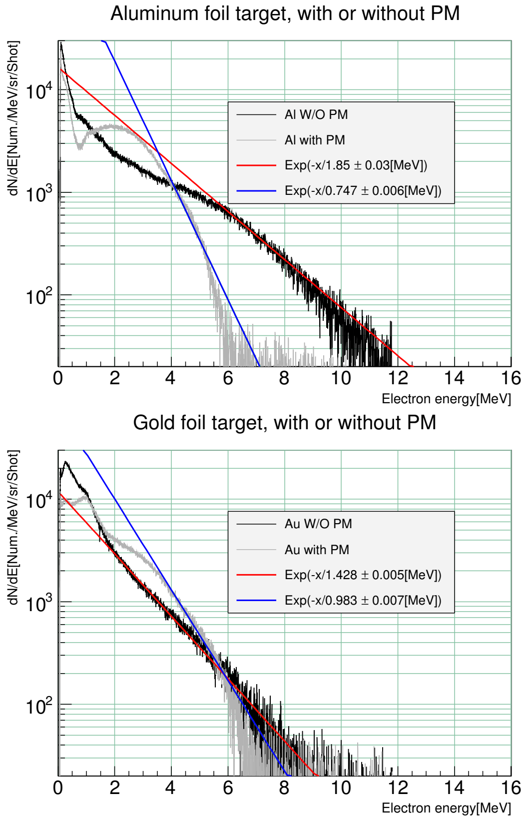

Fig. 1: Electron spectra were generated by the Al (upper) or Au (under) foil target with (gray) or without (brack) PM. Those datas were averaged 5 Shot.

show higher electron temperature compared to Au targets in same contrast condition, this can be considered by the faster preplasma expansion for Al compared to Au, corresponding to a larger pre-plasma scale length. We also measured bremsstrahlung x-ray by using filter stacked x-ray spectrometer HEXS to infer the absolute number of hot electrons [see T. Ikenouchi, presentation in this conference]. In order to increase the amount of Bremsstrahlung produced photons, a 200 μm lead plate, was attached on the rear surface of the Al and Au foils. The energy conversion efficiency from laser to fast electron was determined to be 6.4 % for the Aluminum case. In such way we successfully evidenced the enhancement of the photonuclear relevant hot electrons by varying target material and pulse conditions. Neutron generation was also carried out with a similar experimental configuration, using an aluminum plate target with 4 cm thick lead block on the rear, separated by a 100 μm gap. The lead was used to converte electrons into x-rays and subsequently x-rays into neutron. The laser average energy in this phase was 317 mJ. The neutron yield was measured by using bubble neutron detector-600 (BDS-600) [5], which has a sensitivity for neutrons with energies above 600 keV. A 1000 shots were integrated but unfortunately no neutron signal was obtained. A count of neutron signal on the Bubble detector was estimated to be 1.3 × 102 neutrons/shot, therefore the neutron yield was less than 1.3×10^2 neutrons/shot. The neutrons generation in this conditions was simulated the Monte Carlo code PHITS [6], injecting a fast electron population wich spectrum was provided by previous measurements and angular distribution of 22 degree full width half maximum[7]. The simulated neutron yield was resulted to be 2.8×10^3 /shot, which doesn't agree with the experimentally observed one. This may be due to the discrepancy of the angular distribution of the electron beam between the experiment and the simulation and will be studied in more detail in future.

3 Summary

The progress in laser driven photonuclear generation for neutron radiography application was presented. The key issue was to maximize the hot electron temperature. In this regard, the electron spectrum in various preplasma conditions were examined by using Al or Au targets and Plasma Mirror. We demonstrated a clear enhancement of the hot electron temperature using an Al target in low contrast condition. This information will be applied to future experiments of neutron generation using higher energy lasers.

Acknowledgment

This work was supported by JSPS KAKENHI Grant Number 26246043.

References

[1] Y. Arikawa, *et al.*, Plasma a Fusion Research will be published (2014).

[2] S. C. Wilks, *et al.*, Phys. Rev. Lett. **69**, 9 (1992).

[3] A. Pukhov, *et al.*, PHYSICS OF PLASMAS **6**, 2847 (1999).

[4] T. Johzaki, *et al.*, Nucl. Fusion **51** 073022 (2011).

[5] H. Ing, R. A. Noulty, and T. D. McLean, Radiat. Meas. **27**, 1 (1997).

[6] T. Sato, *et al.*, Particle and heavy ion transport code system (PHITS), Version 2.52, " J. Nucl. Sci. Technol. 50(9), 913?923 (2013).

[7] L. Willingale, *et al.*, PHYSICS OF PLASMAS **20**, 123112 (2013).