24D14

Neutron diagnostics in Fast Ignition Experiment
高速点火実験における中性子計測

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The fast ignition integrated experiment was conducted by using GEKKO XII and newly constructed LFEX. A new neutron yield detector was developed for overcoming very strong x-ray pulse generated from fast heating beam. Besides the x-ray signal, a large amount of neutrons generated by γ-n reaction from target chamber or diagnostics instruments was confirmed as a more critical origin of the background signal. The background signal was modeled by a MonteCalro simulation, and the detection error for fusion neutron attributed by γ-n was evaluated. The maximum neutron yield observed was $(3.5\pm1.3)\times10^7$, which is larger than previous reported value.

1. Introduction

The fast ignition is one of the most ambitious subjects in the inertial confinement fusion science. The imploded fuel core was heated up by an ultra intense short pulse laser. Kodama, et. al., have reported the 1000 times enhancement in neutron yield by a heating pulse with around 300 J with the pulse width of 0.7 ps [1]. Theobald. et. al., have report a series of the experimental results from OMEGA and OMEGA EP facility with a 1 kJ , 10 ps heating pulse [2]. Fast heating electron generates intense high energy x-ray pulse (we refer as □-ray), which makes neutron diagnosing very difficult in fast ignition experiments. These experimental results of neutron yield include a large error bar originated from the background noises. The construction of the LFEX with the world largest energy [3] was completed in Institute of Laser Engineering Osaka University (ILE), and fast ignition integrated experiment was started in 2009. Many newly developed neutron detector were installed to overcome the harsh γ-ray back grounds problem in 2010. In this paper the neutron yield diagnostics and the analysis of the background in fast ignition experiment in 2011 will be presented.

2. Background from γ-n reaction

The great amount of neutrons which larger than fusion neutron yield was observed from many kinds of detectors. These neutrons were confirmed generated via □-n (photo disintegration) reaction in various materials in such as the iron in the target chamber or experimental instruments, deuterium in fusion fuel. The scattered γ-ray from the target bay concrete wall (γ'-ray) was also found to be critical background. The background signals from γ-ray, γ′-ray and γ-n neutrons were modeled using Monte Carlo simulation code MCNP-5. In the simulation model, a point γ-ray source was set at the center of the target chamber and assumed to have an exponential decay-spectrum with the temperature of 5 MeV based on the typical electron spectrum measured by an electron spectrometer. The anglar distribution of the γ-ray was measured by using Ag-activated glass dose monitors. The simulated γ-n profiles agreed very well with the experimental results. The fluctuation of the detected neutrons originated from γ-n neutron was estimated and added as a γ-n error. The details about the analysis are discussed in Ref. [4].

3. The neutron yield in the fast heating experiment

The DD-neutron signal could be distinguished from the background in only 5 shots in over 30 shots by using the newly developed liquid scintillation detector [4, 5]. These shots were conducted over a period of two consecutive weeks after completion of the detector, and the energy of the LFEX was less than 500 J. Figure 1 shows the observed signal of the maximum neutron yield. The detector was constructed with a fast decay liquid scintillator developed in ILE [5] and a gated photomultiplier tube. The gate open time is after 70 ns of γ-ray arrival, and fusion neutron is seen at 150 ns. The pulse height of the signal seen at 150 ns was determined as the DD fusion neutron with the yield of $(3.5\pm1.2)\times10^7$. The blue dashed line shows γ-n neutrons, and the fluctuation of that within 10 ns around DD fusion arrival time was estimated. Then 6×10^6 γ-n error was added, the final conclusion of the neutron yield was $(3.5\pm1.3)\times10^7$.

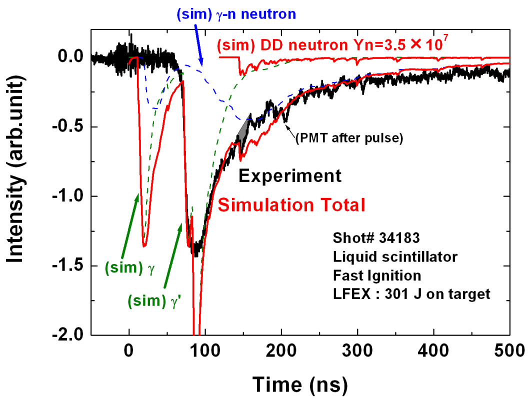

Figure. 1. The signal of the liquid scintillator (black) and simulation (red) observed in fast ignition experiment in 2010.

The injection time of the fast heating laser was monitored by using multi-image x-ray streak camera with a shield slit made by Tungsten. The implosion shell trajectory and the x-ray signal from heating laser were measured. The relative time between the time intensity of the x-ray emission from the core becomes maximum (here we refer maximum compression time) and heating time was measured with the accuracy of 8 ps. The neutron yield against heating time was plotted in Fig.2, where 0 ps is corresponding to the timing of maximum compression. The neutron enhancement from heating laser was observed only in the case that core was heated within 50 ps at maximum compression. This fact confirms the neutron enhancement was attributed from fast heating. This neutron yield was larger than previously reported value [1,2].

However the ion temperature or the ion density of the fuel have not be measured in the experiment 2010. We are still lack of the information to fully understand fast heating mechanism. The next integrated experiment is being planned to be conducted at the summer in 2012 with the heating energy over 2.5 kJ with the pulse width of 1 ps. The neutron collimator for suppress γ-n neutron backgrounds will be developed, and the time resolution of the detector will be improved to measure the ion temperature by neutron spectrum Doppler broadening. The ignition equivalent ion temperature by fast heating will be observed.

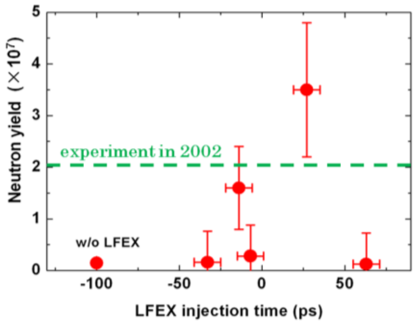

Figure. 2. Relationship between neutron yield and LFEX injection time. Green dashed line is the neutron yield obtained in the experiment in 2002 [2].

Acknowledgement

Authors gratefully acknowledge the support of the GEKKO XII operation group, the LFEX development and operation group, the target fabrication group, and the plasma diagnostics operation group of the Institute of Laser Engineering, Osaka University.

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