§47. The Study of the Low Energy Neutron Spectrum in the Inertial Confinement Fusion

Arikawa, Y., Nagai, T., Abe, Y., Iwasa, Y., Fujioka, N., Sarukura, S., Nakai, M., Shiraga, H., Azechi, H. (Osaka Univ.),
Murata, T. (Kumamoto Univ.)

The areal density (ρR, unit of g/cm^2) of the compressed core plasma is one of the most important for archiving efficient heating in the fast ignition (FI) inertial confinement fusion (ICF). The method to diagnose of ρR is one of the key issues in FI ICF. The down-scattered neutron (DSN) method has been widely studied as a powerful method of ρR. In this method, the low energy neutron created by the elastic scattering between the fusion neutron (primary neutron, PN) and fuel atom (D or T). The ρR can be measured From the ratio between PN and DSN. DSN diagnostics has recently established in the NIF [1] with the very high ρR of 1.5 g/cm^2. However, in the FI experiment at GEKKO XII, achievable ρR is less than central ignition scheme (~0.1 g/cm^2) because the target used in the FI is asymmetrical and the laser energy is much less than that of NIF. Furthermore since deuterated polystyrene (CD) shell targets for Deuterium-Deuterium (DD) fusion are used GEKKO XII facility, the energy of down scattered neutron is lower (~0.27 MeV) than that of Deuterium-Tritium (DT) experiment (~3 MeV) used in NIF. In these regard the detection of down scattered neutron in the fast ignition experiment in GEKKO XII is very challenging. A high sensitive, low energy sensitive, very fast response neutron spectrometer must be developed. In our recent study, Pr-doped ^{6}Li glass scintillator named APLF80+3Pr was developed for this aim [2]. The down scattered neutron detector has been developed and tested in the implosion experiment by using GEKKO XII in FY 2013.

The detector configuration

The DSN detector was installed in the GEKKO XII target chamber with the distance from the target to the detector-front of 23 cm, as shown in Fig.1. Scintillator array with the2-mm-pixel size was coupled to a multi-anode-photomultiplier tube (MA-PMT). 256-channels of anode signals were separately recorded by a-256-channel-bunndled analog-to-digital convertor (ADC).

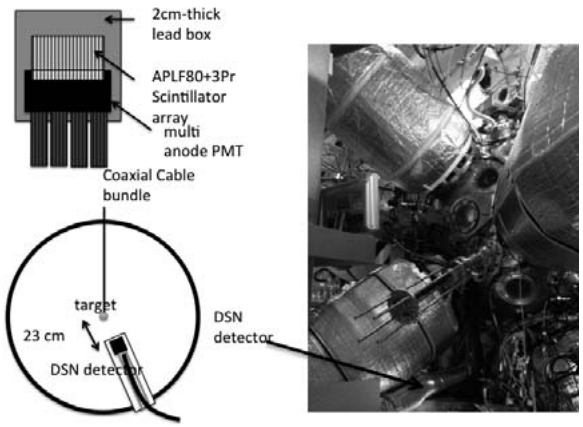

Figure 1 The configuration of the detector implemented to the GEKKO XII target chamber.

shot#	Target	Energy ave (J)	Laser invalance %	D/R	Neutron yield	Ion temp	down scatterd neutron	D-3He Proton
36987	CD 2.2μmt	261.4	17.8	-3	1.5E8	3.2± 0.9	△	NA
36989	CD 7.1μmt	239.8	10.6	-5		/	×	NA
36994	CD 7.1μmt	241.7	6.2	-3	7.0E5	/	×	NA
37002	CDBr 7.1μmt	252	4.7	-3	3.8E5	/	×	NA
37007	CD 5.1μmt	255	6.4	-5	1.3E6	/	△noise	NA
37015	CD 4μmt	261	7.6	-5	1.8E7	1.1± 0.3	△noise	NA
37020	CD 4μmt+D-^{3}He	243.2	7.1	-5	4.9E6	0.8± 0.4	1 count	6
37023	CD 4 μmt+D-^{3}He	240.7	10.3	-5	4.4E6	1.5± 0.6	0 count	4
37028	CD-Br 6.2μmt +D-^{3}He	258	7.5	-5	6.4E5	/	0 count	10
37031	CD 6.4μmt +D-^{3}He	252.9	5.1	-5	1.9E6	/	1 count	15

Table 1 The summary of the shots and diagnosed plasma parameters. A DSN was detected in the two shots.

The evaluation of the detector performance

The several implosion shots were conducted at GEKKO XII as listed in the table 1. The CD shell targets with the 500-μm-diameter with the various thicknesses from 2.2 μm to 7 μm were imploded. The neutron yield, ion temperature were measured by using plastic scintillator TOF detector. The impulse response of the DSN detector was evaluated by using PN signals, and the time duration of the PN signal was resulted to be 8.3 ns in FWHM, in which over-256 counts (every channel detects more than one count) of the PN was detected. This response time was enough fast for the DSN detection in the theoretical estimation. One count of the (very likely) DSN signal was observed as shown in the list, however we could not evaluate the ρR from only a count of signal. The more detailed description of the detector is reported in the manuscript [3].

The D-^{3}He gas filed target development

The D-^{3}He gas-filed CD shell target was developed for measuring the ρR by the proton with the energy of 15 MeV generated via D + ^{3}He →p+ ^{4}He. The ρR can be evaluated by from the energy of the proton attenuated in the core plasma. This diagnostics can be used as cross check of the DSN diagnostics. A CD shell target with the 230-nm aluminum coating filled with the total 2-atm atmosphere of the D_2 and ^{3}He gas was developed. Four targets were used in the GEKKO XII implosion experiment as listed in the table 1. The D-^{3}He proton was successfully observed in every shot. This target will be used in the next experimental campaign in FY 2014.

[1] O. A. Hurricane, et al., Nature **506**, 343, (2014)
[2]Y.Arikawa, et al., Rev. Scient. Instrum, **80**, 113504 (2009)
[3]Y. Arikawa, et al., Europian Physical Journal, **59**, 13011, (2013)