§61. Trail on a ToF Measurement of Gamma-rays and Neutrons by a Diamond Radiation Detector with Fast Time Response

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In Fast ignition, a momently change of neutron yield, i.e., burn-history, gives information on physics of fusion burning in the extremely compressed target. This information is indispensable to optimize fusion reaction.

For burn-history measurement, energy range of generated neutrons becomes wider with increase of plasma temperature. Thus, distance between a target and a detector is limited within 30 cm. In addition, time resolution of 100 ps is minimum requirement. To satisfy these requirements, a combined system of plastic scintillators and a streak camera was developed and used in NIF [1)]. In the case of FIREX, the fast ignition method, extremely high-intensity bremsstrahlung X-rays are accrued by irradiation of ignition laser, and then ordeal measurement systems are paralyzed. Even for the fast plastic scintillator[2)], accurate change of neutron yield is buried in scintillation with relatively slow decay time.

To solve these problems and measure burn-history with fast ignition method, single crystal CVD diamond radiation detectors with fast time response have been developed at Hokkaido University. In this paper, response for extremely intense X-rays is reported

Single diamond crystals were homoepitaxialy grown by a chemical vapor deposition (CVD) method on high-pressure/high-temperature (HP/HT) grown type IIa diamond single crystal substrates in size of 5×5×0.3 mm with off-axis treatment. A self-standing single crystal CVD diamond in thickness of c.a. 100 μm was obtained by a lift-off method. An aluminum Schottky contact and a Ti/Au ohmic contact in size of φ3 mm were fabricated by evaporation method on the both sides. The thicknesses of these contacts were 100 nm and 200 nm, respectively. To obtain high analog broadband width, the Ti/Au ohmic contact was directly connected on a SMA coaxial cable by silver paste.

Induced charge distribution measurement using 5.5 MeV alpha particles from an ^{241}Am source was carried out in advance. Charge collection efficiencies of diamond radiation detectors fabricated in section were 100±0.7% for hole and 97%±1.1% for electron; these values were averages obtained by three detectors.

A diamond radiation detector was settled at 30 cm from a target in a vacuum target chamber. A lead shield in length of 3 cm was attached in front of the detector. Bias voltage was supplied through a bias tee (Picosecond Lab, B.W.:16 GHz) by a high-voltage power supply (Ortec428) An oscilloscope with 600 MHz analog bandwidth (Lecroy Wavesurfer 64x, 2.5GS/s) was used taking account of fault due to large output signal. All instruments were settled in an electromagnetic shielding box. Furthermore, the detector and a measurement port were completely insulated from the target chamber.

In figure 1, solid line shows an example of output signals from the diamond radiation detector with a fast ignition shot by LFEX laser. High intensity bremsstrahlung X-rays with pulse width of c.a. 1 ns, and there was no slow component was obtained successfully. In the case that target and detector distance is settled in 30 cm, DD neutrons arrive 13 ns after an irradiation of ignition laser. The pulse caused by the bremsstrahlung X-rays returned to a base line within 7 ns without any paralyze. We confirmed the detector has potential to measure neutrons coming after intense bremsstrahlung X-rays flash.

Present DD neutron yield of FIREX with fast ignition is only 10^6 to 10^7n/shot; detection efficiency of the present detector was not sufficient at all. In the case that a diamond radiation detector in size of 5x5x0.1 mm is settled at 10 cm from a target; a time resolution of the diamond detector is assumed at 400 ps. DD neutrons of 10^8n/shot is expected to arise an output signal of c.a. 10 mV. With increase of DD neutron yield, we intend to improve performance of diamond radiation detectors and the measurement system, i.e, increasing of saturation drift velocity, reduction of charge trapping in a diamond crystal, optimization of thickness and capacitance of a detector and improvement in RF shielding. Moreover development of an unfolding method is indispensable to achieved required time resolution that is faster than 100 ps.

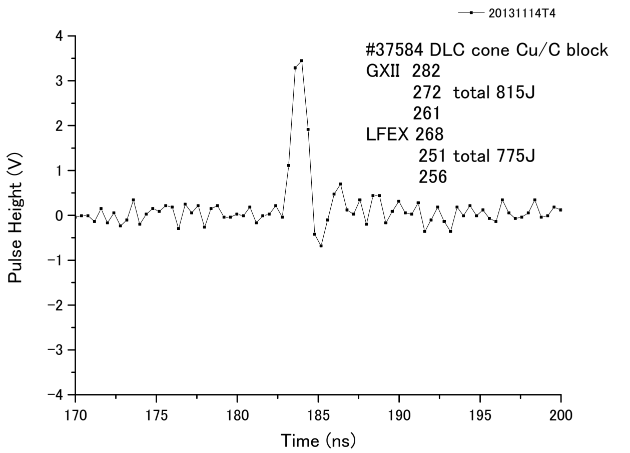

Fig. 1. An example of output signal for FIREX target shot Solid line is output signal from diamond detector.

1)Watanabe, K.et al :J. Crystal Growth 362(2013)288.
2) Schmid G. J. et al. Rev. of Sci. Inst. 74(2003)1828