§28. Gamma-ray and Neutron Diagnostics by Used of a Semi-conductor Detector in Laser Fusion Experiment

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The MANDALA neutron time-of-flight (ToF) detector consisting of many plastic scintillators (> 800 channels) coupled to photomultipliers has been employed to evaluate the ion temperature through the measurement of energy spectrum of neutrons produced by fusion reactions at Institute of Laser Engineering Osaka University [1]. Because gamma-/X-rays reach the detector earlier than neutrons, signal pulses produced by neutrons can be discriminated from those produced by gamma-/X-rays in the detection timing. In the fast ignition experiment, however, because of huge flux of prompt X-rays, X-rays-produced large pulse masks neutron pulse and in consequence, neutron pulse can not be picked up. Therefore, it is valuable to explore an alternative neutron detection method. A natural diamond detector (NDD), which have been applied to the Large Helical Device (LHD) to diagnose energy distribution of fast neutral particles originating from neutral beam heating and ion cyclotron resonance heating [2,3], is one of possible candidates for the ToF neutron detector. The diamond itself is known to be fast in time response and has very thin body. Therefore, neutron pulse may be distinguished from X-ray-produced pulse in laser fusion experiments.

Two different NDDs were prepared for this purpose. One NDD, which was fabricated in TRINITI, Russia, has area of ϕ2 mm and thickness of 0.1 mm. Another is a commercial product (D-RAD International Inc.) and has a rectangular body of 3 mm × 1 mm × 1 mm thick. The basic function of the NDD as a radiation detector is principally similar to that of a Si semiconductor detector. High energy photons incident to the sensing volume of the detector create electron-hole pairs through photoelectric events and Compton scattering. In the case of neutron irradiations, a variety of nuclear processes such as elastic and inelastic scattering $^{12}C(n,n')^{12}C$, nuclear reaction $^{12}C(n,a)^{9}Be$ and so on are involved. Compared with a Si detector, the primary advantages of NDD include a high band gap of 5.5 eV, short mean free drift time of ~10 ns, large saturation carrier velocity of 2.2×10^{7} cm/s for E of 10^{4} V/cm), high breakdown voltage of 10^{7} V/cm. The NDD is fast, offering <200 ps resolution [4]. Detailed descriptions of NDD's properties are available in Ref. 4 and 5.

We applied two NDDs mentioned above to the laser fusion experiment in October of FY2006. Figure 1 shows the electronic circuit used in this experiment. Because the time response of GHz range is required, the circuit used in LHD, i.e. pulse height analysis, is not suitable for this purpose. In order to enhance the time response as much as possible, a high voltage bias-T (Picoseconds Pulse Lab./Model : 5531) resistively couples the signal cable to a high voltage power supply and capacitively couples the signal cable to a GHz sampling oscilloscope. NDDs were placed on the target chamber. Output signal coming from NDD in an actual experiment is shown in Figure 2a). In order to make a comparison, signal pulse from one detector of MANDALA system is also shown in Figure 2b). As can be seen, the plastic scintillator produces gamma-ray-produced output pulse having a reasonable shape. On the other hand, the NDD's output signal is very much different from that of the plastic scintillator, looking like noise. The reason is not understood yet. In next year, we will choose the NDD having a larger volume, or the position of detector will be closer to the target compared with the condition of FY2006 to obtain a large solid angle to the target.

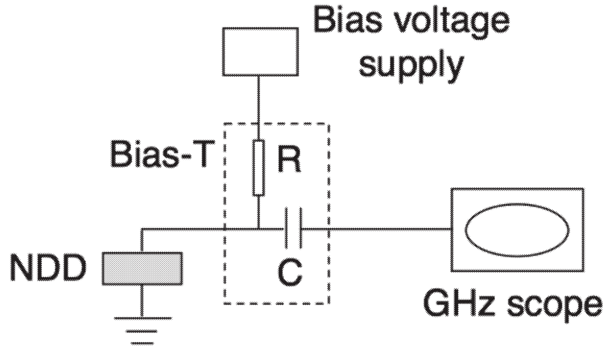

Fig.1 Electronic circuit used for NDD in laser fusion experiment.

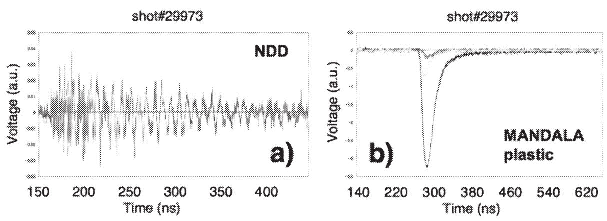

Fig.2 Output pulses from the two different detectors in the laser fusion experiment. a) natural diamond detector (NDD), b) plastic scintillator.

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