L.1: Fusion neutron generation in deuterated polyethylene target using 10 TW Laser

The advances in laser technology have opened up new and exciting arenas in the field of high intensity laser matter interaction. With the availability of very compact, high repletion rate, multi terawatt laser systems, many potential application have emerged. These include production of high brightness harmonics right into the x-ray region, and generation of electrons, protons, heavy ions, and neutrons. The neutrons produced by high intensity lasers have some unique features unmatchable by conventional neutron sources like : short pulse duration, unique energy spectrum peaked around 2.45 MeV, point source (size smaller than 1 mm) which can be switched on/off at user discretion. These properties make such a source very attractive for various applications such as time resolved pump-probe neutron diffraction experiments and in neutron radiography. However, for such applications, a neutron yield of 10^9 per second or higher is required.

We have carried out an experimental study on the neutron generation at Laser Plasma Laboratory of RRCAT, by irradiating 10 TW Ti:sapphire laser pulses on deuterated polyethylene $(CD_2)_n$ solid target. The p-polarized laser beam of 400 mJ energy, 45 fs pulse duration was focussed to focal spot of 10 μm diameter (FWHM) with a gold coated f/7.5 off-axis parabolic mirror, producing a peak intensity ~ 3×10^{18} W/cm^2 on the target. The target was a 1 mm thick sheet of deuterated polyethylene (D enrichment over 99%) and it was mounted on a translational stage in order to expose a fresh target surface on each laser shot.

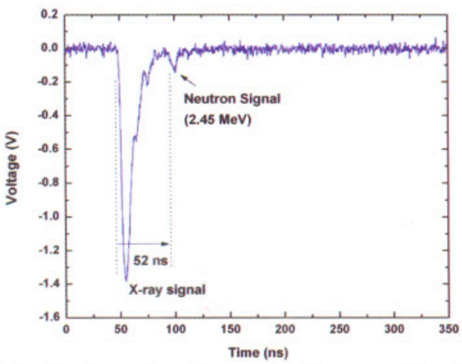

Fig.L.1.1: Neutron signal recorded by a neutron time of flight scintillator detector.

The high intensity laser pulse focussed on the target rapidly ionizes the $(CD_2)_n$ target and turns it into plasma. At intensity > 10^{18} W/cm^2, the electron motion becomes relativistic and they are accelerated to high energy in underdense plasma. As a result, the electrons are removed from the laser path leaving behind positively charged deuterium ions. This plasma column explodes (Coulomb explosion) radially, leading to the acceleration of deuterium ions. The accelerated deuterium ions collide with the cold deuterium ions in the surrounding preplasma, leading to the release of neutrons by D-D fusion reaction. The neutrons generated in the D-D reactions have a characteristic energy of about 2.45 MeV.

The fusion neutrons have been detected in a neutron time of flight (ToF) detector and also confirmed by other detectors like CR-39 detector, bubble detector, and BF_3 counter. Fig.L.1.1 shows the neutron signal recorded with the ToF detector kept at a distance of 1.2 m from the target. The first peak is due to gamma flash (high energy bremsstrahlung) and the second peaks appears at 52 ns after the start of gamma flash, and corresponds to the neutron signal. The time of occurrence of the neutron ToF signal closely matches with expected energy of 2.45 MeV.

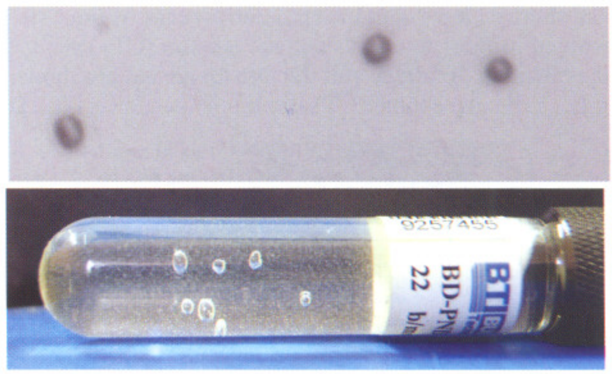

Fig.L.1.2: a) Neutron tracks in the CR-39 detector, and b) bubbles in the bubble detector

The CR-39 plate and the bubble detector were exposed to a large number of neutron pulses by irradiating the $(CD_2)_n$ target with the laser pulses at 1 Hz. The exposed CR-39 was developed for 8 hours in 6N NaOH solution kept at 70°C. Fig. L.1.2a shows the observed neutron tracks in the CR-39 plate. The bubbles were also formed in the bubble detector as shown in Fig. L.1.2b. The neutron signal was also observed in BF3 counter. To confirm on the fusion neutron signal, the $(CD_2)_n$ target was replaced with $(CH_2)_n$ target. In this case, no ToF signal was observed in the neutron detector, and no bubbles were observed in the bubble detector. This confirms that the observed neutron signal is indeed due to the D-D reaction. The neutron yield was estimated by counting the tracks in the CR-39 plate. Assuming an isotropic neutron emission, the neutron yield is calculated to be 9×10^3 per shot, which is very close to the maximum reported neutron yield of 10^4 per shot under experimental conditions similar to those in the present case.

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