A New Neutron Time-of-Flight Detector to Measure the MeV Neutron Spectrum at the National Ignition Facility[*)]

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A new time-of-flight detector has been developed to measure the neutron spectrum at the National Ignition Facility. This detector allows for a more accurate measurement of the down scattered neutrons as well as the determination of the TT neutron spectrum. First measurements with this detector are being presented.

Keywords: neutron-time-of-flight, fast scintillation detector, ICF plasma, stellar nucleosynthesis

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1. Introduction

The National Ignition Facility (NIF) uses 192 lasers to deliver up to 1.9 MJ of light to a target with the goal to ignite the fuel of a DT capsule. To achieve this, several conditions have to be met which can be observed with target diagnostics. An important target diagnostic is the neutron time-of-flight (nToF), which is used to determine neutron yield, ion temperature and the areal density of the fuel. An accurate measurement of the neutron spectrum following a NIF shot also serves as basis for many basic science studies, including neutron capture measurements relevant to astrophysics or understanding of the break up of the t+t compound system.

With the flight path for NIF nToF diagnostic having a length of ~20 m, primary 14 MeV neutrons and down scattered 12 MeV neutrons get separated by only 30 ns. Therefore a detector with a fast time response is needed in order to separate those.

A new scintillation detector has been designed to improve neutron spectroscopy from 1 MeV to 12 MeV following a NIF shot. This detector uses a new organic crystal, which was found to have an extremely high suppression of the slow decay component of the scintillation [1], improving the measurement of the ratio of neutrons down scattered into the 10 to 12 MeV region relative to the number of unscattered 14 MeV neutrons. In addition, the detector allows for the simultaneous use of up to four photo multiplier tubes (PMTs) to determine the neutron spectrum from 1 to 5 MeV with higher accuracy.

2. New Detector Design Considerations

The 20 m nToF systems have three primary objectives: measurement of neutron yield, ion temperature and the down scattered ratio of neutrons (DSR). The ion temperature measurement accuracy depends mainly on the intrinsic width of the signal, whereas the DSR signal needs low background in the 10 to 12 MeV region. The DSR measurement accuracy suffers from a significant detector background from the primary peak due to scintillation light decay, response from the rather long cables currently in use and local neutron scattering. The design of the new nToF detector mitigates this background and improves the dynamic range over the old nToF detectors, by using the following improvements: A bibenzyl crystal [2] is being used as scintillator, which has highly-suppressed delayed light [1], while having a higher sensitivity than previously used xylene detectors [3]; reduction in mass of material surrounding the scintillator, which reduces background due to neutron scattering events; an increase in the dynamic range of the detector by using four gated PMTs, which look at the scintillator simultaneously; reduction of scintillator thickness which, with a comparable prompt scintillation light decay leads to higher accuracy in the ion temperature measurement.

The PMTs were moved away from the scintillator to assure that there was no direct exposure to the PMT from the beam itself and to reduce the mass located in proximity of the scintillator. Since neutron scattering is forward directed the PMTs are positioned at backward angles (toward the source). This lowers the effect of neutrons scattering into the PMTs, which would affect the time response of the detector. To maintain light collection, tubes of aluminized mylar foil were used as light guides from the scintillator to the PMTs. Figure 1 shows the finished detector.

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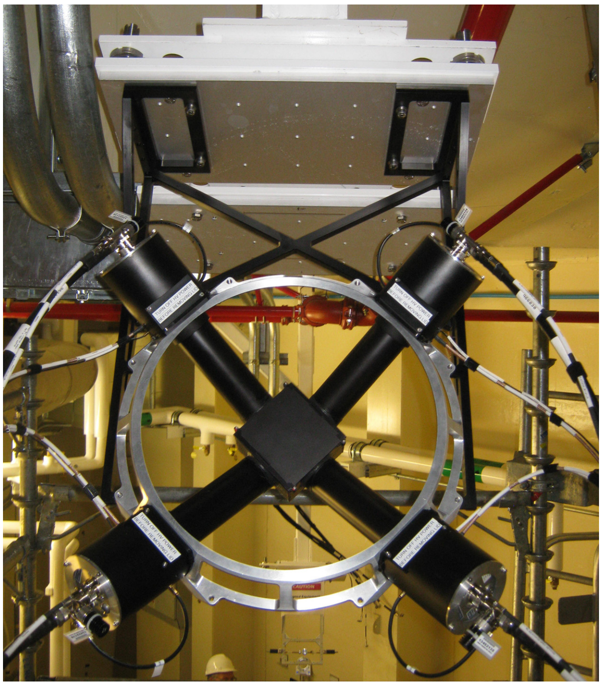

Fig. 1 Picture of the new nToF detector installed at NIF.

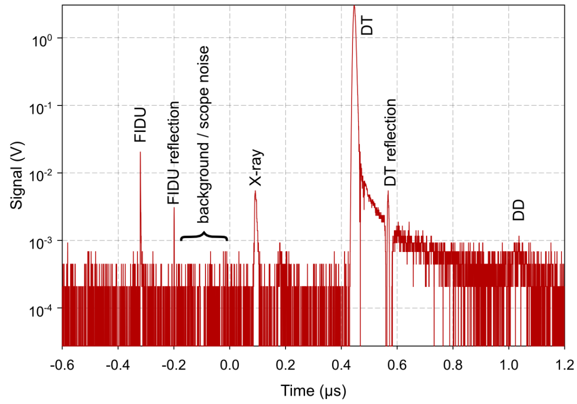

Fig. 2 Time-of-flight spectrum of the new nToF detector from an exploding pusher shot. Several features of the spectrum are visible: Fiducial signals for timing the X-rays from the shot as well as the DT neutron signal with a cable reflection.

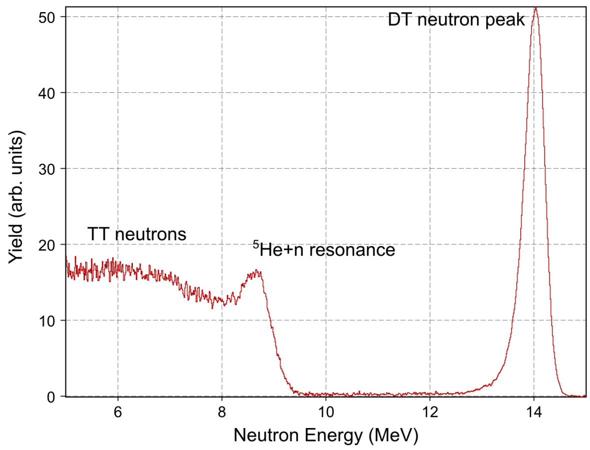

Fig. 3 TT neutron spectrum obtained from new nToF detector.

3. First Data from New Detectors

The newly designed and constructed detector was tested at OMEGA before its installation at NIF [4]. A total of three of these detectors have been constructed so far. Two of them have been installed as permanent diagnostics at NIF. The third was used for astrophysics measurements on OMEGA and is planned to be used as an upgrade to another NIF nToF detector.

Due to their isotropic nature and their low areal density, exploding pusher shots are being used to calibrate the nToF detector relative to neutron activation diagnostics. By using DD and DT exploding pushers the detector sensitivity can be calibrated for 2.45 MeV and 14.03 MeV neutrons. Figure 2 shows the spectrum of the detector for a DT exploding pusher on NIF.

4. Data from Pure Tritium Filled Capsules

Due to the big difference in the reaction cross section even a small deuterium contamination in a tritium fill will lead to the DT neutrons being the dominant part of the spectrum. To obtain a good measurement of the TT neutron spectrum a fast detector response will significantly reduce the background from the always present DT signal. Figure 3 shows the neutron spectrum for a NIF TT shot recorded with the new detector. Clearly visible is the peak from the $t + t \rightarrow {}^5\mathrm{He} + n$ reaction. In addition the new detector was used on two shot days at OMEGA in November 2012. The analysis of this data is currently in progress.

5. Conclusions

A new nToF detector with a bibenzyl crystal as a scintillator was designed and manufactured for the NIF. First data taken with this detector shows that it has a fast response time and lowers the background from the primary DT signal in the down scattered region significantly. It can measure ion temperature and neutron yield on DD shots at NIF with yields as low as 10^9 neutrons. TT neutron spectra have been recorded from shots at NIF and OMEGA; the analysis of this data is currently work in progress.

Acknowledgments

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