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Ultra-fast response neutron detector for inertial confinement fusion

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The nuclear burn history provides critical information about the dynamics of Inertial Confinement Fusion (ICF) implosion process. As the confinement time of an ICF implosion is a few 10's of ps, a less than 10-ps time resolution is required for an accurate measurement of the nuclear burn history. Here, we report the development of novel neutron/γ-ray detector based on the electro-optical (EO) mechanism, which provides a few-ps time resolution.

Recent inertial confinement fusion (ICF) experiments are approaching required conditions for fusion ignition and energy gain. To facilitate the final push to achieve ignition, the physics governing the implosion dynamics and ignition must be understood. This can be done in part by measuring the nuclear burn history with high time resolution.

The duration of the nuclear burn history is typically several 10's of ps in. In addition, simulations and current low-time resolution measurements disagree. Less than 10 ps time resolution is essentially needed to approach to the unknown physics responsible for these discrepancies and ignition failures. Conventional scintillation based neutron detectors have a limit of the time resolution around 25 ps due to the scintillation response time. Furthermore, a fast streak camera which is very large cost is indispensable.

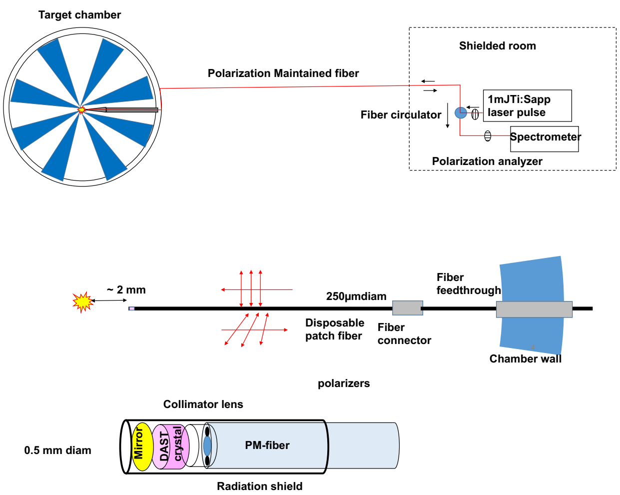

Figure 1 The configuration sketch of the ultra-fast neutron detector

The method of EO sampling has been widely used for detection of the electric field generated by Terahertz waves and electron-bunch [1]. When an electric field is generated in the Pockels crystal, the polarization of the laser traveling through the crystal is rotated by the Pockels effect. "DAST" pockels crystal is an organic crystal which has the largest EO coefficient and an intrinsic sensitivity for neutrons because of the abundant of hydrogen atoms in it. The DAST is attached on the tip of a polarization maintaining fiber and the part is covered by a radiation shield. The front end of the fiber-assembly is located typically 2 mm from the fusion plasma as shown in Fig.1. A Ti-Sapphire laser based chirp pulse laser scans the EO signal that is subsequently analyzed by a polarization analyzer and spectrometers. The duration of the impulse signal from primary DT neutrons was simulated to be 1.0 ps (shown in blue line) which includes the neutron Doppler broadening by 5-keV plasma ion-temperature, and the system response (black). In this simulation, the thickness of the DAST crystal was 10 μm, and with this set up, sufficient signal will be obtained for neutron yields above 10^{14} which is typical for ICF experiments in large scale laser facilities. This technique can be also applied to measure γ-rays and X-rays. Since the time resolution more than 10x better than any conventional ultra-fast neutron detectors, new science of ultra-fast plasms can be made.

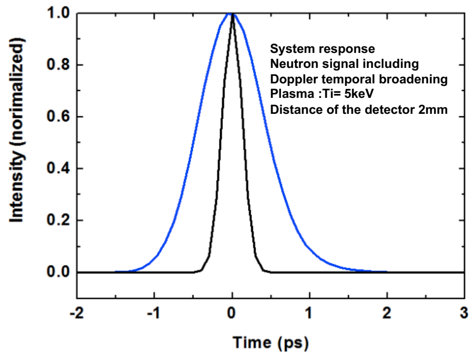

Figure 2 Simulated neutron signal from primary DT neutrons produced in a 5 keV plasma detector (blue curve). This simulation includes the neutron signal including Doppler temporal broadening and system response. For comparison, the simulated detector impulse response is shown in black. The distance between the DAST crystal and the fusion plasma was 2 mm. The thickness of the DAST crystal was 10 μm.

References

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