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Advanced neutron sciences on high power laser driven neutron sources

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High-power laser sciences, including laser fusion and laser-driven neutron sources, have emerged as leading areas of cutting-edge research. Laser-driven neutron sources are particularly significant due to their potential applications in industrial applications, material science applications, medical applications, and nuclear physics sciences.

Laser-driven neutron sources have been extensively studied worldwide. Various approaches exist for generating neutrons using lasers, such as laser-accelerated ions injected into beryllium [1,2], laser-driven x-rays generating neutrons via photonuclear reactions [3], and laser fusion reactions [4]. Recent research has demonstrated the use of laser-driven neutron sources in neutron radiography [5,6], neutron resonance spectroscopy [7,8], and pharmaceutical production [9].

Despite these advancements, conventional neutron sources still suffer from poor beam collimation since neutrons are generated almost isotopically, making collimation difficult. There is a strong demand to generate highly collimated neutron beams with good beam quality.

Thermal neutron sources (0.025 eV) or cold neutron (less than meV) [10] are widely used in various applications. Traditional thermal neutron sources employ neutron moderators to reduce neutron energy from MeV to meV, a process in which a large proportion of neutrons are absorbed. Our study proposes a new method to produce mono-energetic thermal neutrons with a highly collimated beam (less than 1 degree in spread) and an energy variation of only 10% (dE/E). This approach eliminates the need for neutron moderators, resulting in good beam collimation, point source size, and ultra-short pulse duration.

On the other hand, laser fusion represents the most intense laser-driven neutron source, characterized by tens of picoseconds in time duration and tens of microns in source size. To enhance neutron flux, controlling fusion burning with high-speed and high-resolution neutron diagnostics is essential. The physics underlying fusion burning plasma and neutron production remain not yet understand. There is an urgent need to measure the temporal history and spatial distribution of neutron generation. A neutron detector with 1-picosecond time resolution has been developed [11]. The detector demonstrated a full width at half maximum (FWHM) of 3 ps time resolution at the LFEX-Gekko XII laser fusion facility using a short pulse γ-ray source. It also functions as a high-resolution spatial-resolved neutron detector. Using this detector, we aim to deepen our understanding of nuclear fusion burning plasma, potentially leading to novel research opportunities in plasma physics.

In this talk we discuss on these advanced neutron sciences on high power laser driven neutron souces and its applications.

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