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Fast neutron production with kHz repetition rate, few-cycle lasers

Recent development of ultrashort, high repetition rate laser technology resulted in systems with reliable and stable performance (<1%) over day-long operation. In addition to the several TWs peak power, these systems can produce 100 W average power at industrial standards. Hence, in neutron production they offer an alternative to the PW peak power lasers for applications which need a quasi-continuous source of neutrons.
Here we show a laser-based neutron source developed by the National Laser-Initiated Transmutation Laboratory of the University of Szeged, with the few-cycle lasers available at ELI ALPS. The heart of the beamline is a flat heavy water jet with a thickness of a few hundreds of nanometres. The laser pulses accelerated deuterons up to 1 MeV energy, which then induced 2H+2H fusion reaction in a deuterated polyethylene disk. The resulting fast neutrons were measured with three independent detection systems. A time-of-flight (ToF) detector system, within which each detector consisted of a plastic scintillator and a photomultiplier; a liquid scintillator, the ToF signal of which was evaluated with the pulse shape discrimination method; and a bubble detector spectrometer calibrated against a conventional PuBe source.
The system worked with high stability (10%) for several hours, shooting with 21 mJ, 12 fs laser pulses at 10 Hz repetition rate. Most recently, stable operation has been also demonstrated at 1 kHz repetition rate with 35 mJ, sub-10 fs laser pulses. The highest neutron yield so far (over 10^8 neutron per second) was achieved at 1 kHz repetition rate with 80 mJ laser pulses on target. The paper outlines one of the first related applications, i.e. the irradiation of zebrafish embryos with such laser-generated neutrons and planned experiments in nuclear astrophysics.

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