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Present status of pellet injection system for repetitive inertial confinement fusion experiments

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The injection and engagement of pellets using laser illumination is dispensable technologies to realize a laser-driven inertial fusion energy reactor. In laser-driven inertial fusion energy reactors, injected fuel pellets are continuously delivered into the reaction chamber and irradiated by laser beams injected at a frequency of a few to tens of Hertz as noted in several reactor designs; KOYO-F [1], FALCON-D [2], LIFE [3], and HiPER [4]. We propose a mini-reactor CANDY (Fig. 1) [5] that driven by a kJ-class repetitive laser driver based on diode-pumped solid state laser [6,7] for an engineering feasibility study of the power plant in the counter beam fast ignition scheme fusion [8, 9, 10].

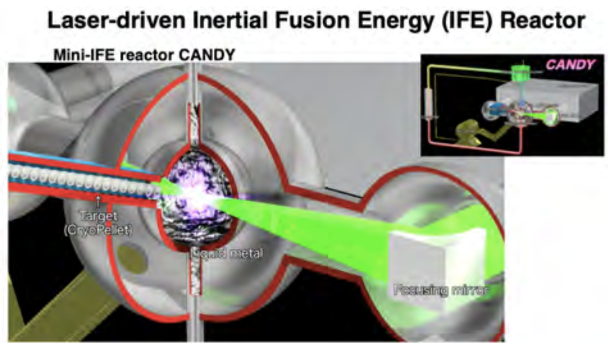

Figure 1: Illustration of mini-Reactor CANDY.

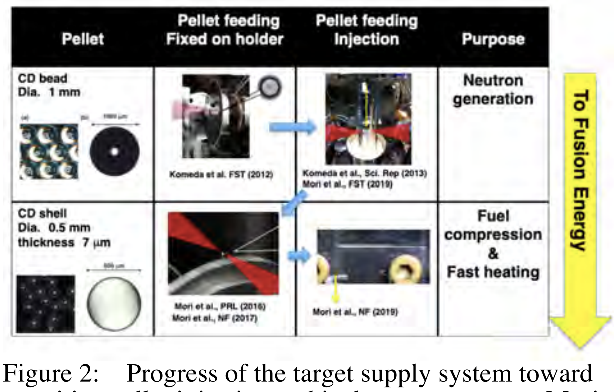

Figure 2: Progress of the target supply system toward repetitive pellet injection and its laser engagement Mori et al., Nuclear Fusion 59 (2019).

As a feasibly study for CANDY, we have developed two pellet injection systems: (i) beads (diameter of 1mm) injection system under operation [11-13] and (ii) spherical shell (diameter of 0.5 mm with 7 μm thickness) injection system as a testbed [14]. Figure 2 shows progress of the target supply research & development in GPI with collaboration team toward repetitive pellet injection and its laser engagement [14]. From Fig. 2, the development of target supply for repetitive laser fusion experiments is conducted with two-steps: fixed on holder and injector without supporter.

The beads palette injection system was operated at 1 Hz for more than 4 years and now up-grated to10 Hz. Using beads injection system, we irradiated ultra-intense laser (11 TW: 0.6 J/110 fs x2 beams with a focal intensity of $5\text{x}10^{18}$ W/cm^2) in counter configuration on flying 1-mm-diameter deuterated polysterene beads beyond 600 pellets on average at 1 Hz and 10 min per cycle for 4 years. The resulting shot probability was beyond 70% for laser engagement and 22% for fusion neutron generation with maximum yields of $4\text{x}10^5$ n/shot [13]. The repetition rate is now up-grated to 10 Hz, the same frequency with laser repetition.

As for shell injection system, the testbed demonstrate that (i) repetitive (maximum frequency:0.5 Hz) of shell injection was possible for more than 10 shells at a shell speed of 191 mm/s, and (ii) the distribution of the injected shell after 18 cm free-fall was within a circular region, 6.4 mm in diameter resulting in the estimated laser-hit-ratio of on the order of 10%.

In this presentation, we will present a current status of pellet injection system for repetitive inertial confinement fusion experiments toward the mini reactor CANDY.

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