Development of fast-ignition fusion by using a high repetition laser and its industrial application: 10 Hz target injection in counter illumination laser fusion

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0.1 10 Hz injector

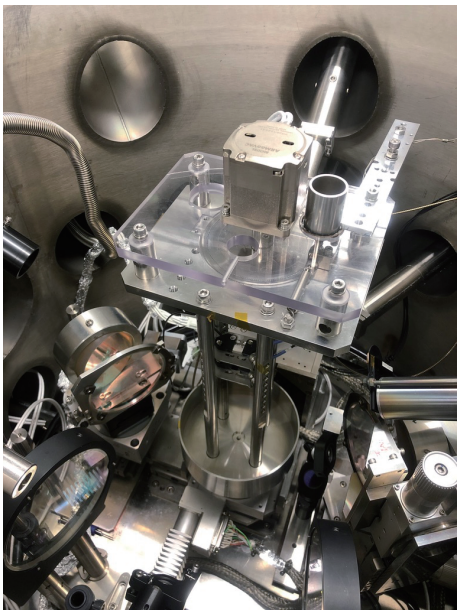

Figure 1: 10 Hz target injector in OIRAN Chamber.

We propose A kJ-class mini reactor CANDY for an engineering feasibility study of the power plant in the counter beam fast ignition scheme fusion. To develop the CANDY, we are performing fast ignition experiments using both single-shot petawatt lasers[1, 2, 3], and a high-repetition-rate laser-diode(LD)-pumped laser with counter beam configuration[4, 5]. In the last workshops, we had reported the CD beads injection at 1 Hz into the counter-propagating short pulse lasers[6]. Now we have succeeded in 10 Hz injection of CD beads. It continues for longer than 10 minutes. Figure 1 shows the injector installed in the counter laser beams illumination "OIRAN Chamber". A

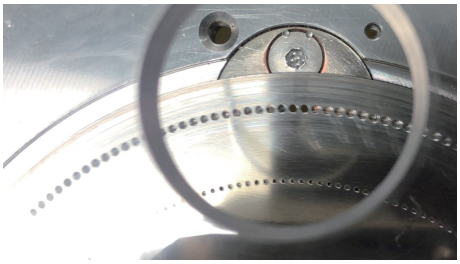

Figure 2: Disk rotor with 200 large holes(upper in figure) rotates at 20 s period. Lower small holes are for monitoring the injection timing.

Pulse motor at the top, going round in 20 seconds, directly drives the disk rotor, which has 200 holes on the periphery, as shown in Fig. 2, to sequentially inject 1mm-diameter CD beads at 10 Hz into the laser illumination point. So that the initial velocity of a bead is 0.785 cm/s to the peripheral direction, or to x direction. Figure 2 shows two lines of holes on the disk. The upper hole lines are for injecting beads, while the lower holes are for monitoring the injection timing. Through the holes a LED right pulse synchronizes to an injected bead, which falls down to the laser focused point. On the target flight, two light sensors sequentially detect the passing times and cal-

culate the arriving time to the laser focused point, which is 18.0 cm down under the disk rotor. Then they command the laser system to trigger firing.

0.2 10 Hz engagement of bead target and detection

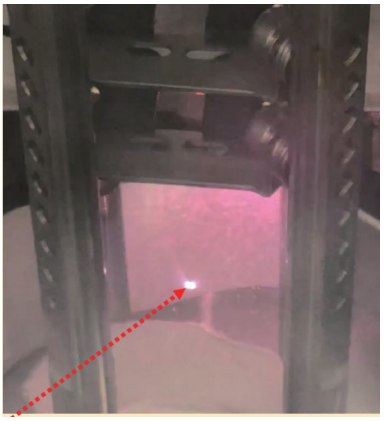

Figure 3: Two counter beams have just engaged one fallen bead at the chamber center. Red arrow shows two adjoined bright spots of the laser hits.

We have succeeded 10-Hz CD beads injection for longer than 10 minutes and repetitive fusion reaction. A chirped pulse amplified ultra-intense laser "BEAT LASER" is divided by a beam splitter into counter two beams and then focused onto the bead surface by a pair of two off-axial parabolic mirrors with focal lengths of 16.5 cm (f-number 2.58) onto the center of the bead injection chamber[5, 6]. So that the separation of two focal points is 1.0 mm, as shown by two adjoined two emission spots in Fig. 3. The wavelength is 800 nm and the total output is 200 mJ in 160 fs at 10 Hz operation.

Using second harmonic laser light, two-directional probe shadowgraph has succeeded in measure the 3 dimensional target position(to the laser axial, to the perpendicular and to the vertical direction, respectively). Since the bead diameter is 1 mm, the positioning deviation is allowed as long as is within 0.5 mm. Engaged beads rate was $396/1767 = 0.22$. Figure 4 shows during 4 min injection period, the standard deviation of the positioning is as Δx is 0.8335 mm and Δy is 0.8539 mm. Δz is also detected to be 0.1815 mm during 3 min. Because a feed-foward system adjusts the hit timing, z is always within a strike zone. The resulting engagement rate will be $\sim 0.5/0.8335 \cdot 0.5/0.8539 \cdot 1.0 = 0.35$. The discrepancy is so far unresolved. Note that beads, injected out of the timing jitter limit of 15 ms, are not hit, which may explain missing shots of 1901-1767= 134.

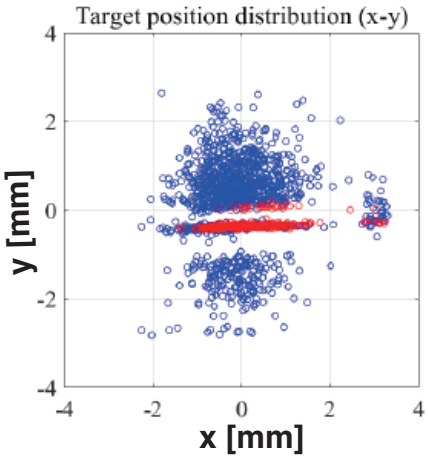

Figure 4: Bead target positioning on the focusing space, at the timing synchronized to the laser illumination. Total injected bead number is 1901 during 3 minutes. Blue 1767 points are captured with the detection system. Red 396 points are engaged by two counter beams. x is laser axial direction and y is perpendicular.

References

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