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Mechanism of drilling for continuously injected solid CD target and neutron generation

連続投入されたCD固体ターゲットのドリリング機構と中性子発生

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We succeeded in injection of spherical deuterated polystyrene bead pellets at 1 Hz and symmetrical engagement and irradiation of them with two ultra-intense laser beams. (i) This is the first demonstration of ultra-intense laser engagement of injected flying pellets. The laser intensity was high enough to produce a DD neutron yield of $9.5\times10^4/4\pi$ sr/shot. (ii) We observed channel formation through the free-falling pellets, which might be the evidence to support a scheme for fast ignition.

1. Introduction

Pellet injection and repetitive laser illumination are key technologies for realizing inertial fusion energy [1,2]. Numerous studies have been conducted on target suppliers, injectors, and tracking systems for flying pellet engagement. Here we for the first time demonstrate the pellet injection, counter laser beams' engagement and neutron generation [3].

2. Pellet injection system

Figure 1 shows the pellet injector, installed in the illumination chamber. Deuterated polystyrene (CD) beads whose diameter is 1mm are used as pellets. Each pellet free-falls to the laser focal point 18 cm

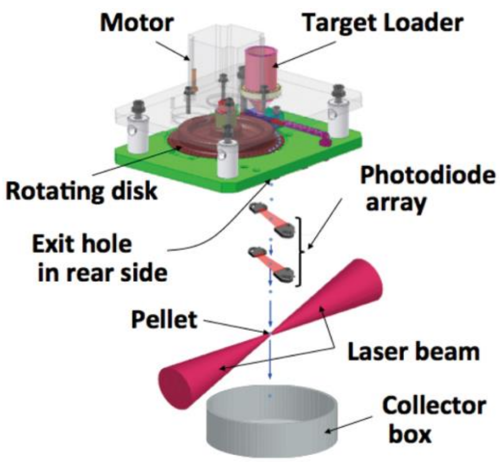

Fig. 1 Schematics of pellet injection system

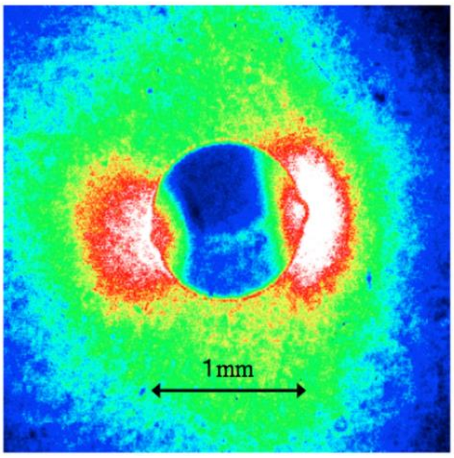

Fig. 2 Snapshot of an injected pellet at the instant of engagement

below at 1 Hz. The signals from the two photodiodes above the focal point are sequentially sent to a laser controller, which forecasts the arrival time at the focal point and sends a shooting-request signal to the diode-pumped, ultra-intense laser HAMA [4] appropriately. In experiments, up to 1,300 continuous injection was successfully demonstrated. The laser beams only hit the beads falling inside a circle of 0.5 mm radius around the laser's focal point. Currently, 68% of the beads can be placed into the circle. These pellets are successfully engaged by two counter laser beams at the probability of about 70%, corresponding to the pellet placement accuracy.

Figure 2 shows a snapshot of an injected pellet at the instant of counter beam engagement. The laser energy, pulse duration, wavelength, and the intensity were 0.63 J per beam, 104 fs and 811 nm, 4.7×10^{18}W/cm^2, respectively. In 7% of engaged shot, neutron generation was observed. The maximum yield of produced d(d,n)^3*He*-reaction neutrons is $9.5\times10^4/4\pi$ sr/shot.

3. Channel boring for injected pellets

Moreover, the laser is found out to bore a straight channel with 10μm-diameter through a bead. Figure 3 shows the cross section of a bored bead. The bored hole was also observed by micro focus X-ray tomography. The result shows it was through hole. When a stainless steel (SUS) support was attached to a bead, we did not observe any bored holes nor traces. One possible explanation about channel boring is as follows: Free-electrons generated by the pre-pulse and pedestal components of the laser pulse might work as a guiding wire for the fast-electrons generated by the main high intensity pulse. Leblanc [5] reported the result of theoretical discussion about resistive guiding of laser-driven fast-electron currents in solid targets. When the fast-electrons propagate along the free-electron wire, the return current heats the pellet along the free electron path by the ohmic heating. The heating energy is enough to give thermal loads to the pellet and to create the hole inside the pellet. The intense laser is expected to transport sufficient energy along the path from the focal point to the core. We conceived this idea of hole boring, as a means for obtaining a clean path from the focal point to the core. The hole boring observed in this experiment can be applied for the fast-ignition.

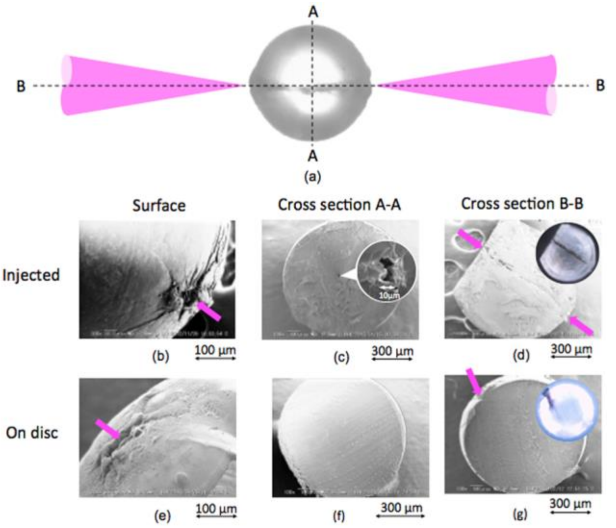

Fig. 4 Laser boring of an irradiated CD pellet. A comparison between injected pellets and pellets attached to the disk.

4. Conclusion

We succeeded in injection of spherical deuterated polystyrene bead pellets at 1 Hz and symmetrical engagement and irradiation of them with two ultra-intense laser beams. We observed channel formation through the free-falling pellets. It was thought that fast-electrons propagate along the laser axis and heated the pellet along the free electron path by the ohmic heating. The fact might be the evidence to support a scheme for fast ignition.

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