Present Operation Status of Target Injection System

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Abstract. The progress of the target injection system is reported, where deuterated polystyrene (CD) beads are injected and engaged by implosion and heating laser beams at the repetition rate of 1 Hz. Since the high repetition rate experiments require to accurately position the injected pellets, for two years we have continuously tested and made the positions of the injected pellets better. Measuring the positions of the injected pellets is a required technology for target tracking and engagement. Newly developed shadowgraph system with two orthogonal probe beams has measured three-dimensional position of the flying targets for the first time. Using this shadowgraph system, we have evaluated the accuracy of the target injection, which will be useful for the future reactor system.

1. Introduction

Repetitive pellet injection and laser illumination are key technologies for realizing inertial fusion energy. Numerous studies have been conducted on target suppliers, injectors, and tracking systems for flying pellet engagement. It is indispensable for tracking and engagement to measure the accurate positions of the flying targets. We are conducting fusion reaction experiments with highly-repetitive DPSSL-pumped laser HAMA [1-4]. Recently, we have developed a target injection system and succeeded in highly-repetitive fusion reaction by irradiating ultra-intense laser on the flying CD beads targets [5].

In this paper, we have developed a shadowgraph system, which uses two orthogonal probe beams, measuring the three-dimensional positions of the targets at the moment of the irradiation of the implosion lasers. The distributions of the target positions after more than10000 target injections are the first experimental evidence as for the target engagements.

2. Target Injection System and Shadowgraph System for Measuring the Position of Flying Targets

Figure 1 shows the target injection system which is installed in a vacuum chamber. The target loader stores CD beads target with a diameter 1 mm. The rotating disk with holes feeds CD beads to the exit hole above the focal point of the implosion laser. The repetition rate of the target injection is 1 Hz. The focal point is 180mm below the rotating disk. Falling targets pass between two-step photodiode arrays. It forecasts the target arrival time at the focal point to the laser system. At the moment when the flying target arrives at the laser focal point, two counter implosion beams irradiate the target. The intensity, pulse duration, and wavelength are 6×10^{13}W/cm^2, 0.4 ns and 800 nm, respectively. Successively two counter heating beams irradiate it from same directions. The intensity and pulse duration are 2×10^{17}W/cm^2 and 110 fs.

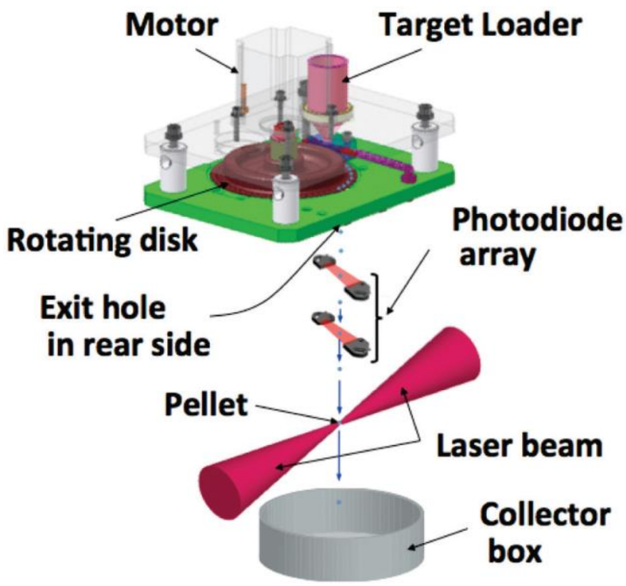


FIG. 1. Target injection system.

The shadowgraph system measures the three-dimensional position of targets at the moment of the heating beam irradiation. The second harmonics of a part of the heating beam is used as probe beams. Figures 2 (a), (b), and (c) show the top, front, and side views of Shadowgraph system for measuring the position of flying targets, respectively. One probe beam illuminates a target from the horizontal direction perpendicular to the implosion beams. The directions of the implosion and the probe beams are defined as x and y axes, respectively. z axis is vertical. The probe beam measure the x and z coordinates of the target position. To measure y coordinates of the target position, the other probe beam is in x-z plane and inclines 30 degree against the implosion beams because of the restriction of the experimental configuration. Figures 2 (d) and (e) show examples of shadowgraph taken by the system. The black circles in the shadowgraphs are the shadow of a flying target. Since the probe beams illuminates a target at the same time as heating beam irradiation, the three-dimensional position of targets at the moment. The shadowgraph can also observe the light emission from plasma.

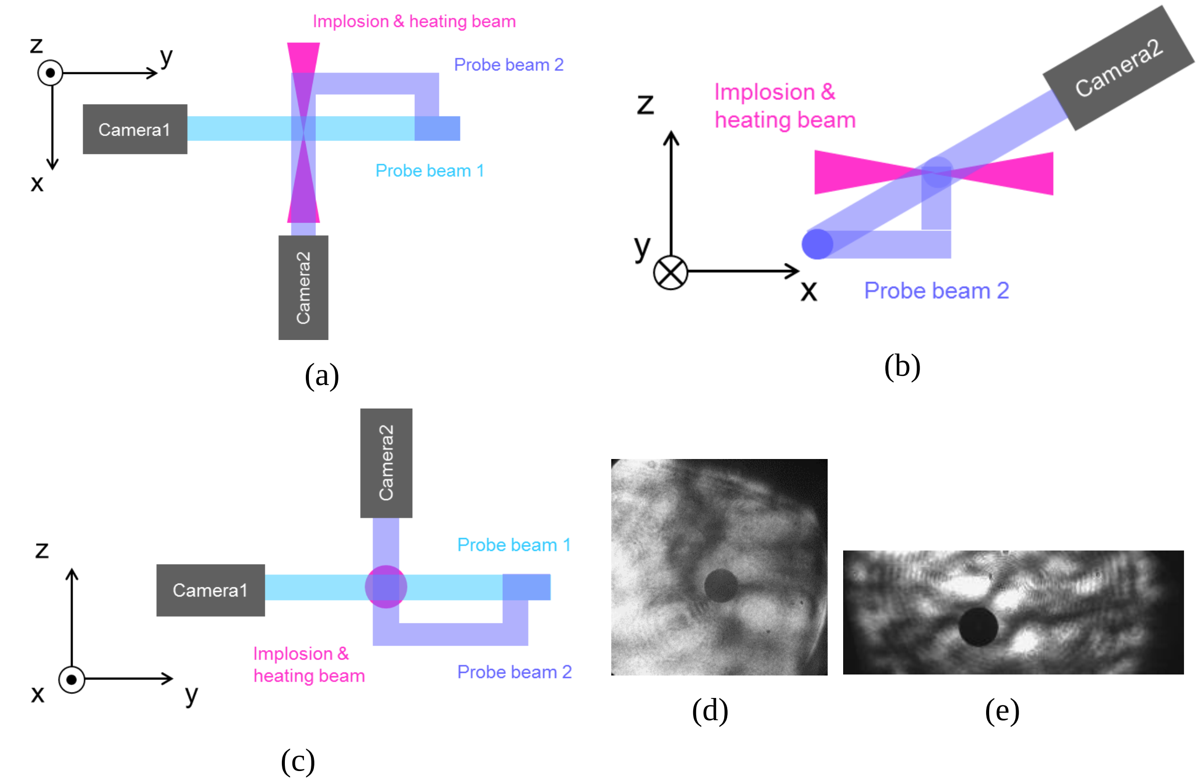


FIG. 2. Shadowgraph system for measuring the position of flying targets. (a) Top, (b) front, and (c) side views of Shadowgraph system. Examples of shadowgraph taken by (d) camera1 and (e) camera2.

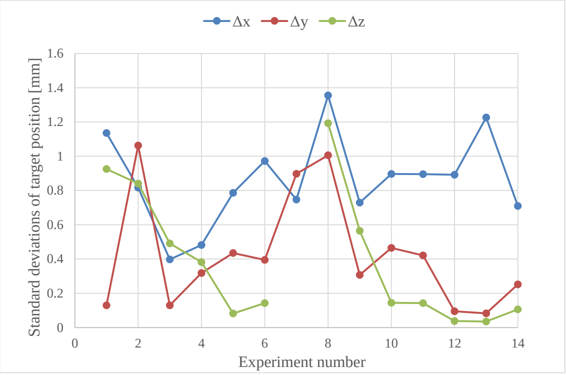
TABLE I: RECORD OF TRAGET INJECTION EXPERIMENTS.

Experiment number	Date	Number of injected targets
1	3/10/2014	300
2	3/13/2014	400
3	5/15/2014	600
4	6/4/2014	810
5	6/19/2014	600
6	8/6/2014	424
7	1/12/2015	334
8	2/9/2015	600
9	2/11/2015	600
10	2/17/2015	1076
11	2/26/2015	600
12	3/3/2015	600
13	3/4/2015	600
14	7/14/2015	147

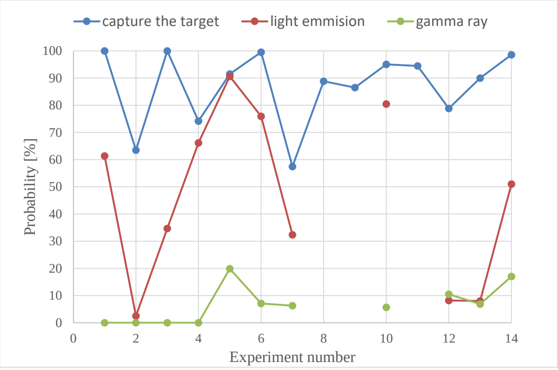
3. Target Injection experiment

We have injected more than10000 targets as shown in Table I. Figure 3 (a) shows the standard deviations of target position in x, y and z directions. Figure 3 (b) shows the probabilities that the shadowgraph system captures the target, the shadowgraph system observes the light emission of plasma, and the neutron detector detects the γ ray. The accuracy of target injection is getting better.

Figure 4 shows a distribution of target positions and histograms of the target position in the recent experiment. In this experiment, 147 CD beads were repetitively injected. The standard deviations of target position in x, y and z directions were 0.71mm, 0.25mm, and 0.11mm, respectively. The standard deviations of injection angle in x and y directions was 3.9 mrad and 1.4 mrad, respectively. The standard deviations in z direction corresponds to 59 μs in the timing of the laser irradiation. The dispersion in x direction is larger due to the initial velocity. The reason why the dispersion is so large is that the CD beads are charged. By reducing the charge as well as tuning up the target injection system, we have made the dispersions of the target position small. In this experiment, 145 targets was injected in the measuring range of the shadowgraphs. Both the implosion and heating beams hit 99% targets, 17% shots of which resulted in the fusion reaction, yielding gamma rays. The detection probabilities of the strong gamma ray and neutrons were 7.5% and 14%, respectively. The positions of the targets in these shots were in the ranges of Δx=0.075mm, Δy= 0.033mm and Δz=0. 12mm.



(a)



(b)

FIG. 3. Record of target injection experiments for two years. (a) Right figure shows standard deviation of target. (a) Left figure shows the probabilities that the shadowgraph system captured the target, the shadowgraph system observe the light emission of plasma, and the neutron detector detect the γ ray.

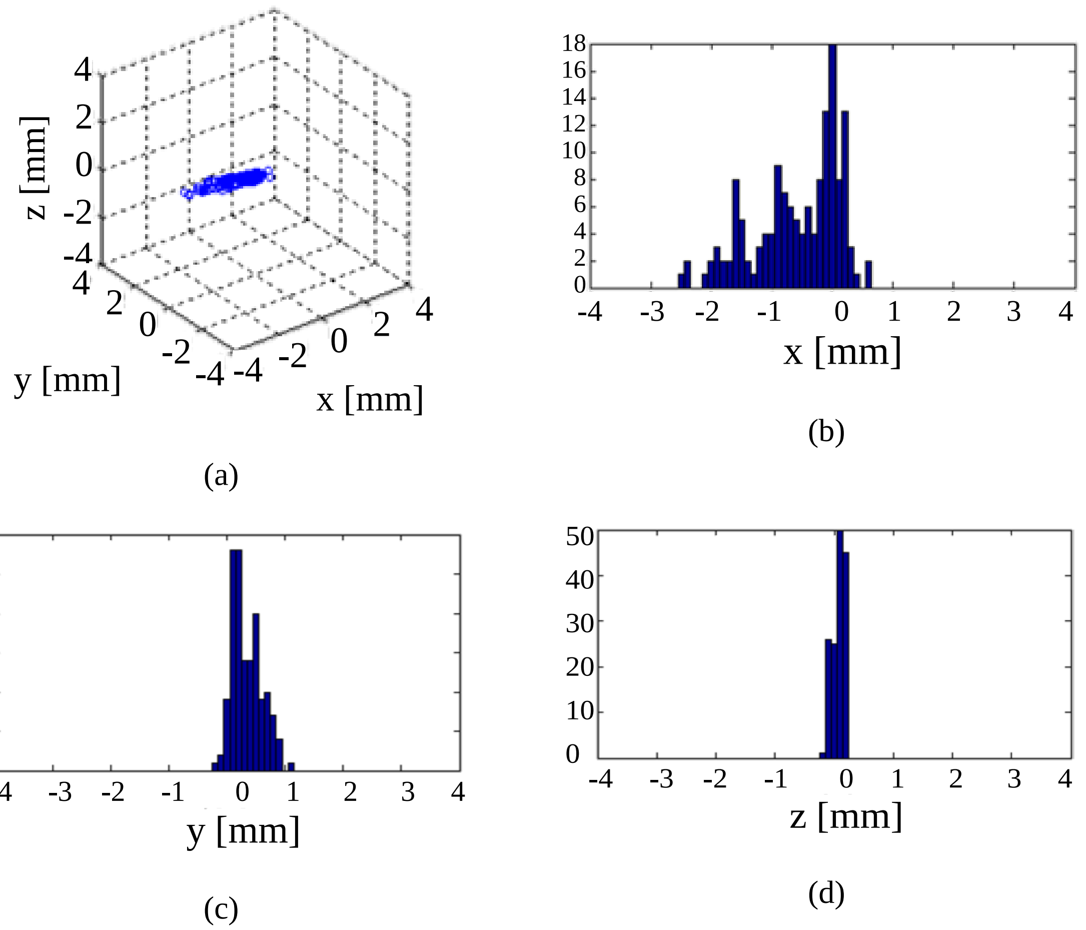


FIG. 4. (a) Distribution of 145 targets and histograms of (b) x-, (c) y-, and (d) z-coordinates of the target position.

4. Summary

We newly developed the shadowgraph system with two orthogonal probe beams. In repetitive target injection, we have measured the three-dimensional positions of injected targets for the first time. The shadowgraph system has evaluated the accuracy of the target injection as the standard deviations of injection angle in x and y directions were 3.9 mrad and 1.4 mrad, respectively. The results will be useful for the future reactor system. However, since the future reactor system will demand the dispersion of injection angle to be less than 0.1mrad, we must more improve the present target injection system probably reducing the charges on target.

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