Experimental progress of pulse shape integrated implosion on SGIII facility

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The ShenGuang III(SGIII) laser facility was completed in 2015 which has 48 beams with wavelength λ=0.35 μm, at peak power 40-60TW. From 2016 pulse shaped implosion experiment was carried out on SGIII facility with gas filled cylindrical hohlraum. Implosion performance with DD filled capsule was investigated by varying the trough width. Many efforts were engaged in the improvement of the capsule also the assembling arts of the hohlraum last year. In 2017, 2D backlit imaging technique was used for the measurement of the driven symmetry. Symmetry tuning was demonstrated by varying the fraction of the power on the inner versus outer beams. The ratio of shell shape P2/P0 asymmetry to the cone fraction is coincided with the view-factor simulation. The pulse shaped integrated implosion was also demonstrated after the symmetry tuning by varying the power of picket pulse. The highest neutron yield 8.8E9 was obtained corresponding to nearly 30% YoC.

I. Introduction

To achieve the ignition by indirect-driven inertial confinement fusion(ICF)[1], the x-ray is product by the interaction of the high-power laser with the inside wall of the cylindrical cavity called as hohlraum. The outer shell of the capsule which is located in the center of the hohlraum is ablated by the x-ray and imploded to compress the D-T fuel. A series of shocks generated through the pulse shape of the laser are used to minimized the adiabat and to achieve the high gain. The cryogenic capsule is used to enhance the density of the fuel layer for ignition. But the substituted capsule of the cryogenic capsule in room temperature is also widely used to investigate the implosion dynamics process.

In 2015, the SG-III facility was completed which has 48 beams with wavelength λ=0.35μm. The pulse shape with duration more than 10 ns can be realized so the integrated implosion with pulse shape are available. The output of the laser energy is 180kJ which is between the ability of the OMEGA[2] and NIF[3]. It makes the SGIII facility to be a very suitable platform to carry out the research about the scaling problem also the confusions on ignition. From 2016, the integrated implosion experiments were performed on SGIII facility. This paper will introduce the progress about the integrated implosion from 2016 to 2017.

II Experimental Setup

Fig. 1 show the experimental setup including the hohlraum dimensions and a wedged cross section of the capsule. Each capsule contains a CH ablator with Si doping and pure CH layer of 20μm with a radius of 375μm. The Si dopant is used to mitigate preheat from hohlraum M-band radiation. The hohlraum is a cylinder composed of Au with 0.3atm C5H12 gas fill to restrict hohlraum wall expansion. The dimension of the hohlraum is 4000μm×2200μm. A lager hohlraum with 4600μm×2600μm was used in 2017 for better symmetry. Also, the thicker ablator capsules (right-down of Fig1) were used in 2017 to reduce the hydro-instability.

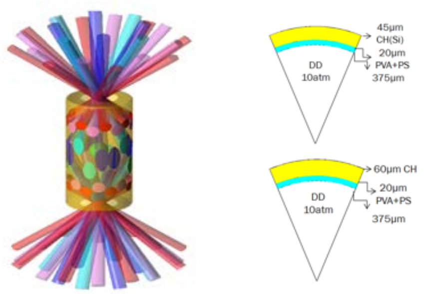

FIG. 1. Schematic of the experimental setup including the hohlraum and capsule dimensions. Right: A wedged cross-section of the target. Left: a cross-section of the hohlraum including dimensions

The laser pulse shape is shown in Fig. 2. It two stages pulse shape. The duration of trough was set as 3ns and varied during the experiment in 2016 and the peak power was set to 0.8TW per beam. The duration of trough was fixed to 1.5ns in 2017 and the power of the picket pulse was changed to investigate the influence on the instability and the mix.

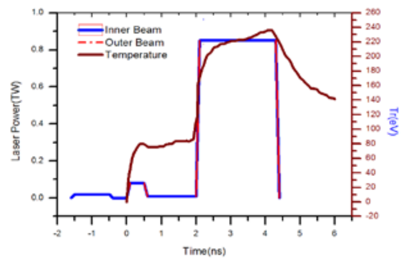

Fig. 2. The design laser power as a function of time. Also the measured radiation temperature for shot256.

III Experimental Progress

A. Tuning Experiments

The probability of ignition is well correlated to five key implosion parameters, described as an ignition threshold factor (ITF)[4] which should be optimized and controlled during the experiment. Different tuning experimental platforms were demonstrated on SGIII facility in 2016. The shock speeds and overtake times were measured by the VISAR technique. Blind was occurred when the main pulse was broken out due to the shock speed was over than the certain value. The monochromatic radiography with bent crystal[5] was demonstrated first time on SGIII facility. The high spatial resolution mesh grid images were obtained. This technique will be used for implosion dynamics diagnostics. The KB microscope with 8 channels was developed to measure the shape of the hotspot. Unfortunately, some images were lost because of the poor efficiency in those channels. The uniformity of different channels and the alignment of both high spatial resolution imaging techniques are the main challenge and expected to be resolved in the next two years.

The time-dependent driven symmetry was measured by the Bi sphere re-emission, thin capsule implosion and 2D radiography in 2016. The Bi sphere re-emission technique is the best way to measure the asymmetry in the first 2 ns for ignition capsule. But the picket pulse used in our experiment was only 0.5ns. So the thin capsule implosion was chosen to measure the early symmetry in 2017.

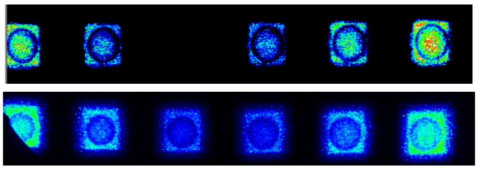

Fig. 3. The 2D radiography images for symmetry tuning experiments. Top: 2D radiography results of thin capsule implosion. Bottom: 2D radiography results of in-flight shell shape.

By varying the fraction of the power on the inner versus outer cone beams(CF), the P2 asymmetry of the implosion can be changed. The beam geometry was originally chosen so that the optimal symmetry would have about 1/3 of the power in the inner cones. We change the early asymmetry by changing the CF of picket pulse and change the implosion asymmetry by changing the CF of main pulse. The CF values for symmetry driven given by experiments in 2016 were obviously bias from 1/3 for both picket pulse and main pulse. The glue existed on the equator of the hohlraum caused the abnormal absorption of the laser energy in inner cone beams. To improve the assembly technique, the glue is gotten rid of. And the change of the driven asymmetry by tuning the CF is a better coincide with the expectation.

B. Integrated Implosion experiment

The integrated implosion experiments were performed after the tuning of symmetry. The duration of trough was chosen as 3ns at first. The pulse shape was an optimum design for a low adiabat implosion of cryogenic capsule. But the implosion performance was degraded around 3 orders. The performances were improved rapidly when the durations of trough were reduced. The durations set as 2.5ns, 1.5ns and 1ns were investigated as shown in Fig. 4.

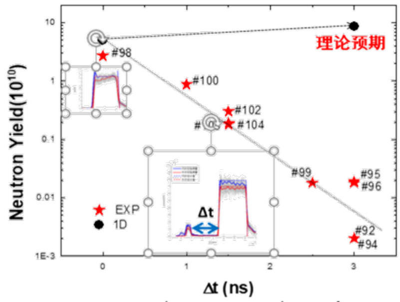

Fig. 4. The implosion performances were improved as the durations of trough were reduced

The degradation was supposed to come from the growth of the hydro-instability and mixing which were originated from the defects in the capsule shell. The capsules used in the experiments were inspected by SEM and isolated voids were found in each layer. Many efforts were made to improve the quality of the capsules in 2017. And the isolated defects were almost extinguished.

The high-quality capsules were used in the integrated implosion experiment in 2017 and the duration of the trough was fixed to 1.5ns. Corresponding to the shorten trough, the peak power of the picket pulse was enhanced. We also changed the power of the picket pulse with fixed trough duration to investigate the implosion performance. With a lower picket power, the best implosion performance is obtained and the highest neutron yield are achieved as 8.8×10^9.

A pinhole camera was also used to diagnose the X-ray bangtime emission of the hot spot at the north pole. The pinhole camera was not calibrated and could not supply the absolute X ray yield measurement. But the ratio of the X ray yield of hot spot and the neutron yield was still analyzed for each shot. The value is increased rapidly when the YoC(yield of clean) is decreased. This is partly established that the mixing of the ablator into the hot spot is perhaps the main reason to cause the degradation of the implosion performance.

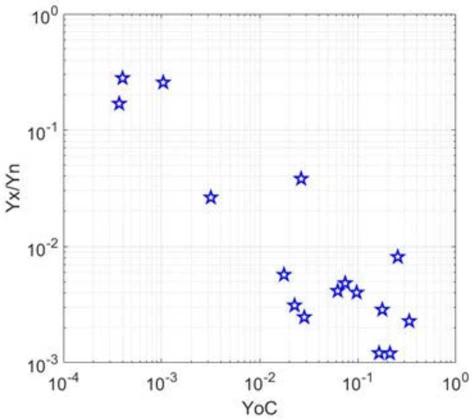

Fig. 5. The ratios between the x ray emission yield and the neutron yield

IV Summary

The integrated implosion experiments with 2-stages pulse shape were carried out on SGIII facility in 2016 and 2017. Most of the basic diagnostics and tuning techniques were demonstrated during the experiments. Especially two kinds of high spatial resolution imaging techniques as KB microscope and monochromatic bent crystal imaging system were tested and would be widely used in the future experiments. The integrated implosion was performed after the tuning of symmetry and implosion performance was investigated by changing the duration of trough and power of the picket pulse. Mixing of the ablator into the hot spot is supposed to be the reason of the degradation. The experiments to change the power ratio of the picket pulse and trough is planned recently. A well comprehension of these consequences will be helpful for the cryogenic capsule implosion experiments which would be carried out in the next two years on SG-III facility

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