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Progress of Impact Fast Ignition

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The concept of fast ignition of ICF targets is to separate fuel compression from fuel ignition and to ignite precompressed fuel by separate external trigger [1, 2]. The advantage of the fast ignition over the conventional central spark ignition [3] is that it can achieve higher energy gains at lower invested driver energies. In an orthodox fast ignition scheme, high energetic particles such as electrons [4, 5, 6, 7], protons [8], and macro particles [1, 9] are expected to be transported into the core of the compressed DT fuel and to heat it successfully enough beyond the ignition temperature. On one hand, however, this scenario bears still many unknown physics such as the interaction between relativistic electrons and matter and the resultant energy transport.

Recently, we have proposed a totally new ignition scheme - impact fast ignition (IFI) [10, 11]. Figure 1 shows the initial target structure of the impact ignition overlapped with the compressed fuel image at maximum compression. The target is composed of two portions: a spherical pellet made of DT shell coated with an ablator and a hollow conical target, which is stuck to the spherical pellet. The conical component has a fragmental spherical shell (impact shell) also made of DT and an ablator. The key idea is to accelerate the impact shell to collide against the main fuel. On the collision, shock waves generated at the contact surface transmit in two opposite directions heating the fuels to produce an igniting hot spot. In this case, the impact shell itself becomes the ignitor by directly converting its kinetic energy into the thermal energy rather than to boost the main fuel heating as in the particle (electrons or ions) -driven fast ignition. It is then necessary for a high coupling efficiency from the driver energy to the thermal energy of the ignitor that the impact shell is accelerated ablatively.

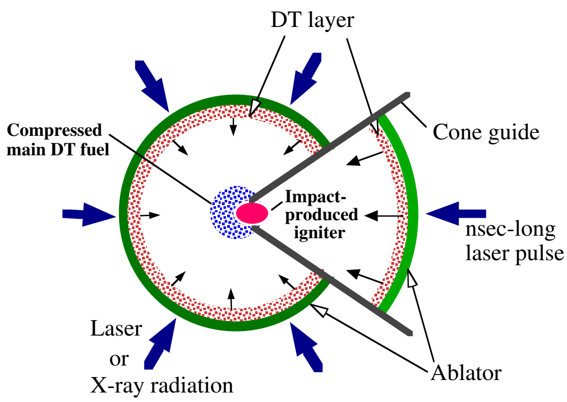

Figure 1: Impact fast ignition (IFI) target

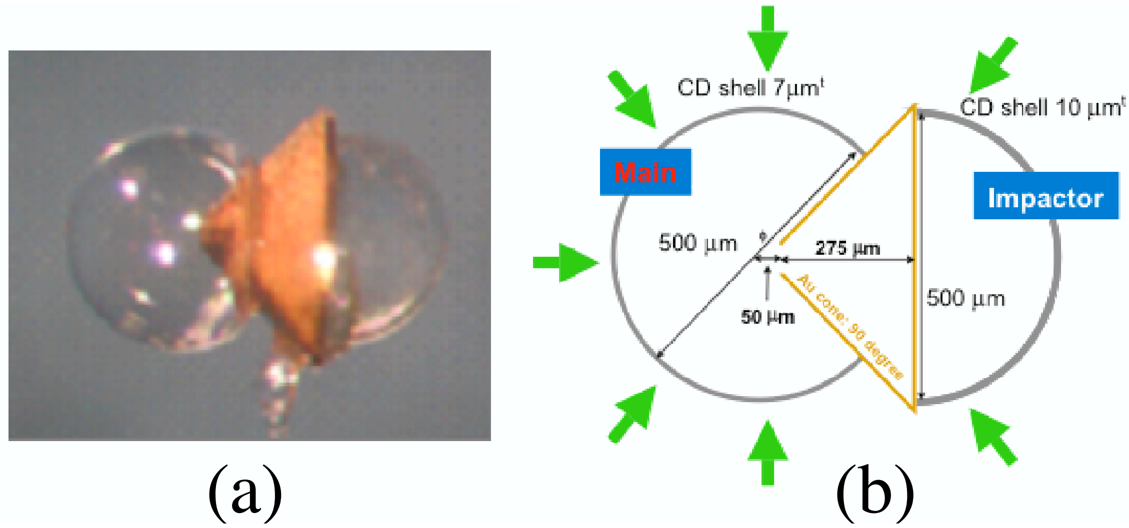

Figure 2: (a)Side-view of the integrated target (b) Schematic view of the target.

We have recently done experiments with an integrated target, which is composed of two CD semispherical targets bonded by the gold cone as can be seen in Fig. 2. The gold cone has an open hole of 50 μm in diameter at the tip. In the experiments, 3 beams for 1.0 kJ and 9 beams for 3.2 kJ of Gekko XII laser system with 0.35 μm of wavelength, 1.3 ns (FWHM) of pulse length in Gaussian pulses were used to irradiate the impactor and the main fuel hemispheres respectively. Figure 3 shows the timing relation between the implosion laser and the impactor laser (a) and the resultant neutron yield as a function of the laser timing. For example, the laser timing of -1 ns means that the impactor laser beams are irradiated 1 ns prior to the implosion lasers. As can be seen in Fig. 3, there is an optimum laser timing to maximize the neutron yield to achieve the neutron yield of 2×10^6. The neutrons are produced mainly in the impactor CD shell, which follows and supports the very original idea of the impact fast ignition scheme. Furthermore, Fig. 3 (right) shows that the laser timing is an crucial parameter in designing the IFI target.

Figure 4 shows the comparison of neutron yields between the impact fast ignition thus obtained (the highest record is indicated by the horizontal dotted line) and the PW fast ignition (solid circles). In the experiments of Fig. 3, since only three beams were irradiated on the impactor shell, the two-dimensional behavior of the acceleration is expected quite non-uniform. In the near future experiment, however, more beams will be irradiated on the impactor shell, and even higher neutron yields can be expected.

In summary new ignition scheme utilizing the hydrodynamic impact has been proposed, the crucial advantages of which are (1) simple physics (2)potential for high gain designs (3) low cost (no need for PW lasers). A simple gain model indicates that a high gain of the order of 100

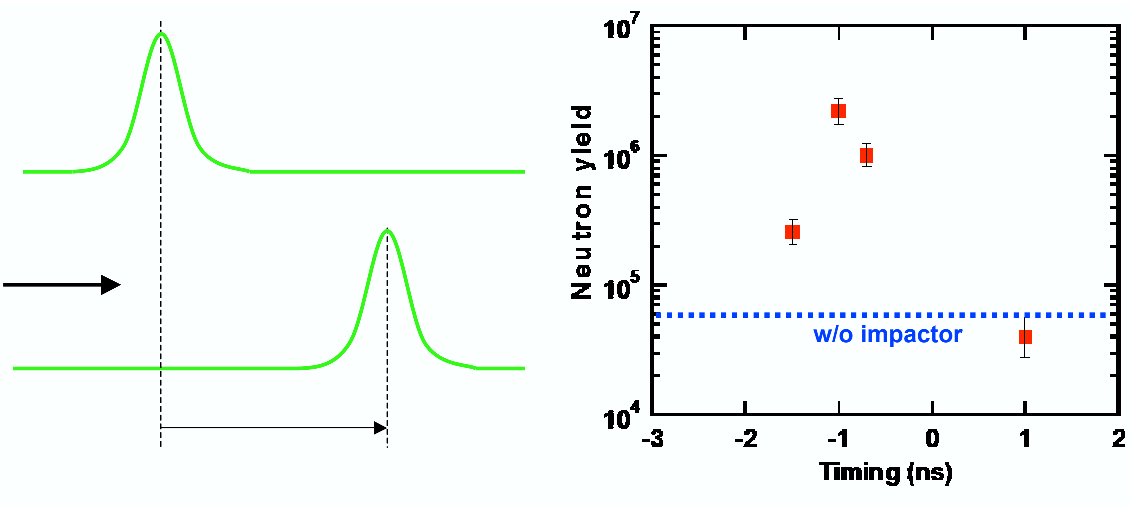

Figure 3: (a) Definition of pulse timing (b)Neutron yields with integrated IFI target.

can be possible to achieve at a few - several 100 kJ. Moreover a preliminary two-dimensional hydrodynamic simulations has shown the generation of a dense hot core and thus the potential of the present scheme. Some key issues on IFI scheme which should be studied have been briefly described.

The first milestone in the IFI research is to experimentally demonstrate an ablative acceleration to a super high velocity $\sim 10^8$ cm/s and simultaneously at a density $\sim$ g/cm^3. It is required to stably accelerate the impact shell at substantially low RT growths. Such highly stable acceleration is expected to be realized by developing the newly found physical effect for RT suppression [12] (not discussed in detail in the present paper).

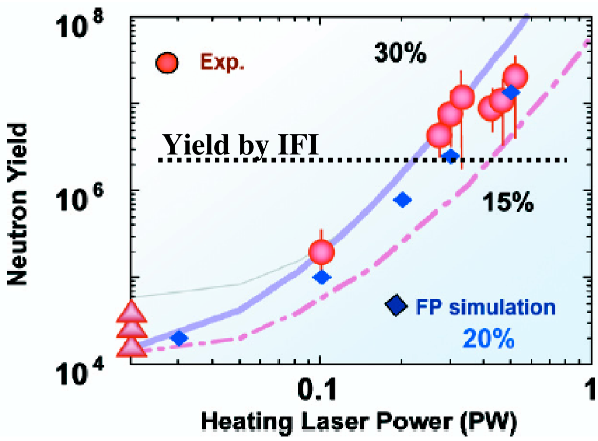

Figure 4: Comparison of neutron yields between Impact and PW fast ignition.

Preliminary experiments have been conducted on the Gekko/HYPER laser system, and a highest velocity of 650 km/s has been achieved [13]. In addition in the first experiment with an integrated target, neutron yields of 2×10^6 have been observed. These results affirm the high potential of the impact fast ignition scheme.

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