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Present status of CANDY Scheme Direct Heating Fusion
直接加熱核融合キャンディ炉開発の現状

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Toward the kJ-class machine CANDY, a novel direct core heating fusion scheme is introduced, in which a preimploded core is predominantly heated by energetic ions driven by LFEX, an extremely energetic ultra-short pulse laser. Examination of the beam-fusion neutrons verified that the ions directly collide with the core plasma. While the hot electrons heat the whole core volume, the energetic ions deposit its energy locally in core, forming ignition spots. By using a high repetition-rate laser-diode (LD) pumped laser HAMA, we are confirming the direct core heating fusion as well as the high-repetitive pellet injection.

1. Roadmap

Figure 1 shows the roadmap for achieving an ICF power plant, of which the key issue is to develop a high repetition rate, high efficiency laser with output energies of the order of kilojoules.

We divide the roadmap into three phases. The zeroth phase (the low compression phase) involves developing 1-kJ drivers. The output of the phase is a unified mini reactor CANDY, as in Fig. 1, which is not only for an engineering feasibility study of the power plant, but also available for a pulse neutron source. Neutron yield is 5×10^{12}/shot (DT) or 5×10^{10}/s energy and 500 nm in wavelength

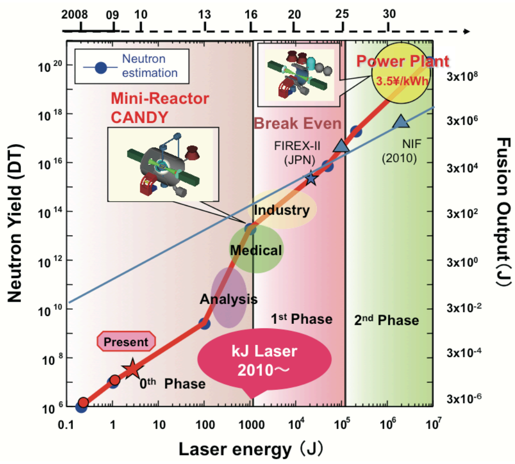

Fig. 1 three phases of Roadmap

on target at 10 Hz. Fast heating laser does 200 fs or 10 ps in duration, and 1000 nm, respectively. Energy Gain is 0.007 [190W] for DT and $1.5\text{x}10^{-5}$ [0.3W] for DD cases, respectively. The first phase (the high compression phase) is to develop a break-even machine that uses a 100-kJ driver. The second phase (the α-burning phase) is to demonstrate a commercial reactor of gain~100. We are currently in the 0th phase to develop the technologies required to construct CANDY, as indicated by the star in Fig. 1. The following sections are the present activities for CANDY.

2. Direct Heating of a Laser-Imploded Core by Ultra-Intense Laser-Driven Ions

The preimploded core of the CD shell target was heated by direct illumination of LFEX, yielding $5\text{x}10^{8}$ DD neutrons by deuteron beam fusion. This result verifies that the local core is predominantly heated by ions. Furthermore, we observed thermonuclear neutrons. STAR 1D results reasonably agreed with the experiments. The LFEX increased the core temperature from 0.8 keV to 1.8 keV. While the hot electrons heat the whole core volume, the energetic ions locally deposit heat to form ignition spots. Our polar implosion scheme places the ignition laser closer to the core than in a spherical implosion schemes. However, since the core density is reduced to 2 g/cm^3, the energetic ions cannot efficiently deposit their energy and the neutron yield remains low. In future work, we will apply a considerably higher power laser (e.g., 10^{20} W/cm^2) and consider the ion contribution to the core heating.

3. High-rep. CD Shell Implosion/ Direct Ignition with Tailored pulses

A couple of a main 0.4 ns pulse HAMA with a foot pulse KURE of 10 ns has imploded a standard CD shell of 500 μm diameter and 7 μm thickness to form a dense core, which the ultra 110 fs S-pulse beams had successfully heated to yield 10^6/ 4π sr DD neutrons. [1, 2].

Figure 2 shows us the direct core heating of the CD shell by S pulse. The neutron spectrum implies both the ion and electron contributions to the heating.

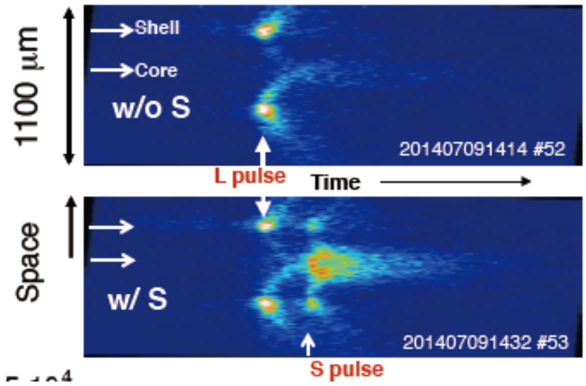

Fig. 2. X-ray steak images of core without (upper photo) and with S pulse (lower photo)

4. Repetitive Target Injection and engage-ment

High–repetition target injection is one of the key technologies to bring the power plant in existence. For the first time, we continuously engaged CD bead pellets, after free-falling for a distance of 18 cm at 1 Hz by using two counter ultra-intense beams from HAMA. The irradiated pellets produce DD neutrons with a maximum yield of 10^6/4π sr/shot [3]. So far, on the continuous 526 shots, the averaged yield is 1328 neutrons/4π sr/shot. Around 2.5% of the shots generated more than 1.0 $3\text{x}10^4$ neutrons /4π sr.

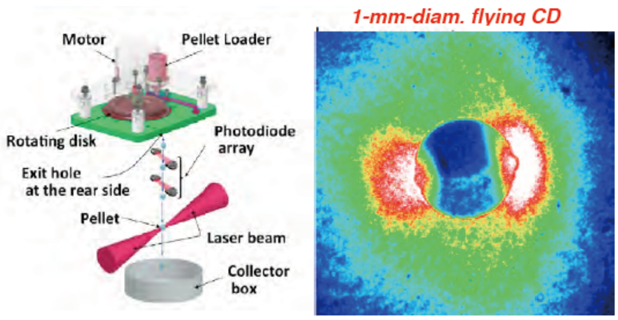

Fig. 3. Laser engagement of flying CD beads using counter-two-beam100 fs lasers.

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