Research Progress on Laser Inertial Confinement Fusion at RCLF in China

Yongjian TANG

Research Center of Laser Fusion, China Academy of Engineering Physics, P. O. Box 919-981, Mianyang, 621900, China

(Received 20 November 2008 / Accepted 25 March 2009)

In past years, the Research Center of Laser Fusion (RCLF) at the China Academy of Engineering Physics has developed many facilities and technologies in the field of ultrahigh-intensity lasers, physical diagnoses, and target fabrications for ICF experiments. This paper briefly reports some of the latest advances achieved and future plans at RCLF.

Keywords: ICF, ultrahigh-intensity laser

DOI: 10.1585/pfr.4.S1002

The laser inertial-confinement fusion (ICF) is an alternative way to achieve the controlled thermonuclear fusion. The basic elements of ICF are the driver and the target, requiring a high-power laser, precise diagnostics, and target fabrication. The success of an ICF experiment based on a large and complex laser facility depends largely on the size, components, and structure of tiny ICF targets. The Research Center of Laser Fusion (RCLF) at the China Academy of Engineering Physics (CAEP) was organized in 2000 and has developed into a specialized institute for pursuing ICF science and technology in China after many years of effort. It consists mainly of several research departments working on optical devices, high-power solid-state lasers, precise diagnostics, target science and technology, and functional materials for extreme conditions. The RCLF's mission is to understand the physical processes and mechanisms in the interaction of an ultrahigh-intensity laser with an ICF target and explore the physical properties of materials under extreme conditions (high temperature and high pressure).

The RCLF has designed and setup the SILEX-I laser facility (300 TW, 15 fs) (Fig. 1 (a)) and the technical integration lines of SGIII (TIL-SGIII) (Figs. 1 (b) and (c)) with eight beams to generate a laser energy of 10-15 kJ (3ω, 1 ns) with a position accuracy of 30 μm [1]. The SILEX-I laser facility has been widely used to study the interaction of ultrahigh-intensity fs-TW lasers with matter. The TIL-SGIII examines the feasibility of the technology and engineering for the SGIII facility. It also serves as a platform for ICF physical experiments. The SGIII facility is under construction and will begin operation in 2012. Some key unit technologies have been developed or improved such as large-diameter neodymium (Nd) glass, single-crystalline KDP, and full-fiber front ends.

To understand hohlraum and target physics, a large number of experiments on the TIL-SGIII facility have been performed since 2003 to study direct-drive and indirect-drive physics, as well as the equation of state of solid-state materials. In this manner, a series of physical projects have been conducted in the interaction of a high-intensity laser with plasma, ablation and radiation opacity, the technology and method for diagnosing plasma, high-intensity field physics, and R-T hydrodynamic instability.

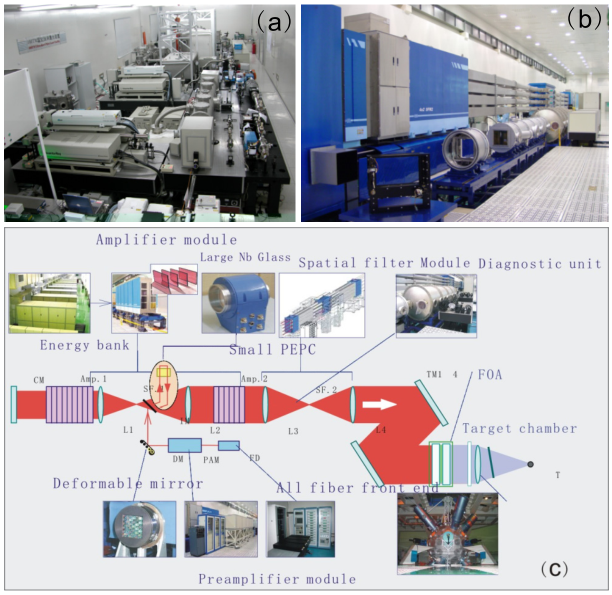

Fig. 1 (a) SILEX-I laser bay, (b) one-beam laser bay in TIL-SGIII, (c) main subsystems in the TIL-SGIII.

In the TIL-SGIII facility, we first tested the shot positions of the eight-beam lasers incident on the internal wall of a hohlraum (see Fig. 2), which were well consistent with expectations. Afterward, we accomplished indirect-drive implosion with a neutron yield of 10^8/shot and a radiant temperature of about 2.5×10^6°C with D-D plastic capsules

author's e-mail: tangyongjian2000@sina.com

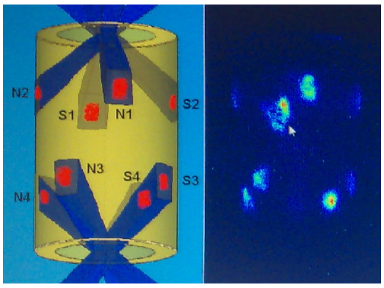

Fig. 2 The shot positions of lasers in the TIL-SGIII incident on the internal wall of a hohlraum. (left) The expected and (right) the actual positions determined by an x-ray pinhole camera with a 200-μm-thick Be filter film. The x-ray energy is more than 2 keV.

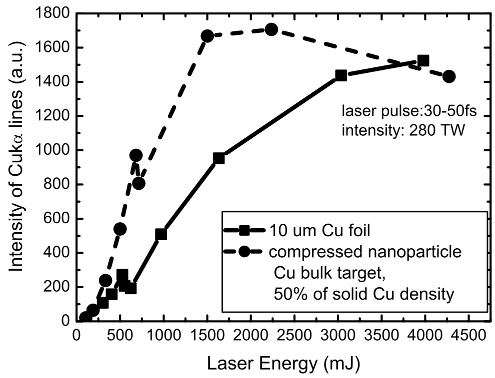

Fig. 3 The intensity of emitted CuKα lines as a function of incident laser energy.

in 2007 [2]. Spatiotemporal characteristics of plasma radiation inside a hohlraum have been measured at the TIL-SGIII to study the movement of an x-ray emission region inside a hohlraum [3]. Experimental results can help us understand radiation hydrodynamic processes during laser irradiation into the hohlraum.

Using a compacted Cu nanocrystal with 50% of the density of the normal Cu crystal [4], the interaction of the intense fs-TW laser with the Cu nanocrystal was studied in SILEX-I. The results for the intensity of emitted CuKα lines as a function of incident laser energy are shown in Fig. 3. Obviously, the laser-to-x-ray transition efficiency in the Cu nanocrystal is strikingly enhanced relative to that in the standard Cu crystal. This fact suggests an alternative way to increase the laser-to-x-ray transition efficiency.

Targets for ICF experiments can be divided mainly into hohlraums, ablation shells, fuels in the shells, EOS targets, and cone-shaped targets for fast ignition. Research into the design, production, and characterization of ICF targets has become an integral part of the RCLF. Because the power density of the laser limits the size of the target, the target cannot be very big, and must generally be within the range of a few millimeters. Consequently, subunits in

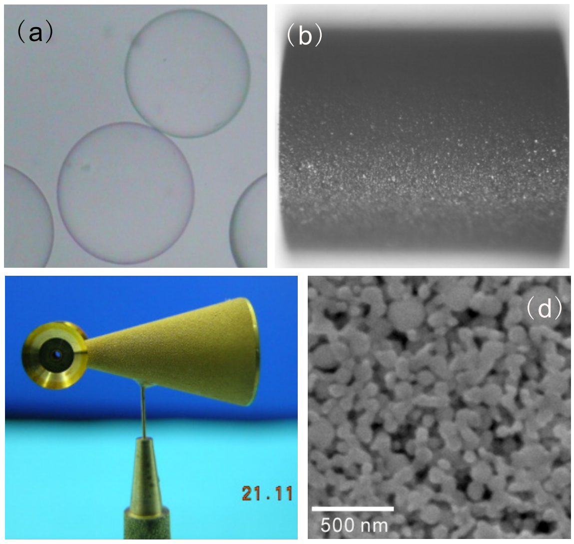

Fig. 4 (a) PAMS hollow microspheres with the diameter of 1 mm-1.6 mm and the wall thickness of 2-6 micron; (b) a $\phi 600 \times 650$ μm carbonized resorcinol-formaldehyde (CRF) microcylinder with a density of 788 mg/cm^3; (c) hohlraum target for radiation opacity; (d) the SEM image of nanocrystalline Cu by compacting Cu nanoparticles.

the target must be smaller than a micrometer. To fabricate these targets, some relevant technologies have been developed to synthesize, grow, fabricate, assemble, and characterize the films, foams, and capsules. With the development of nanotechnology, we have begun to turn to it for improving target performance or opening new research fields. Nanotechnology has been applied in designing and processing ICF targets. Some results are shown in Fig. 4. Nanostructured Cu and Au porous foams with 0.5∼10% of the density of standard materials have been successfully grown by means of vapor-phase deposition [5].

The RCLF has come a long way since 2000. It has met and overcome many scientific and technical challenges. Some new research fields have been opened. The SGIII facility with 48 laser beams is in the final stages of design and construction. This facility will begin to shoot targets for physical experiments by 2012.

I am very grateful to all my colleagues at RCLF for their excellent work and discussions. This work is largely supported by and performed in collaboration with many researchers at other institutes in China.

[1] H.S. Peng, X.M Zhang and X.F. Wei, SPIE. **3492**, 25 (1998).
[2] J.T. Sheng *et al.*, High Power Laser and Particle Beams **14**, 865 (2002) [in Chinese].
[3] S.W. Li *et al.*, unpublished.
[4] Y.J. Tang *et al.*, Proceeding of the International Conference on Nanomaterials (India, 2005) p.175.
[5] F-H. Jiang and L.-Q. Zhang, Atomic Energy Science and Technology **33**, 309 (1999) [in Chinese].