Joint usage/joint research program of GEKKO-XII/LFEX at ILE, Osaka University

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The Institute of Laser Engineering (ILE), Osaka University is Japan's only national user's facility which houses two large laser systems for inertial confinement fusion (ICF) research. The nanosecond laser system, GEKKO XII has twelve beams which deliver 20, 15, and 10 kJ energies in the fundamental, second, and third harmonic wavelengths, respectively. On the other hand, LFEX is the other large laser system which has been installed recently for fast ignition experiments. For a full set of amplifications, LFEX provides 1.0 kJ in 1.5 ps at a moment but will provides 10 kJ in 10 ps and 3 kJ in 1 ps with a full set of amplifications.

LFEX is a Nd:glass laser system based on chirped pulse amplification (CPA) [1]. The full system has four 37 cm x 37 cm square beams, and the 2 x 2 matrix beams are focused simultaneously on a target with a single off-axis parabolic mirror with a multi-layered dielectric coating on a 85 cm x 105 cm Sitall glass (f = 4000 mm). Chirped pulses with 2-ns pulse widths (corresponding to ~ 3-nm spectral width at 1053-nm central wavelength) are compressed down to 1 ps by a large grating pulse compressor with a unique diamond-like design configuration using two 91 cm x 42 cm multi-layered dielectric grating fabricated on silica substrate just before the focusing mirror. The focal spot size of a beam estimated from x-ray images on planar targets is approximately 60 μm in diameter. The output energy is strictly limited below 400 J/beam to avoid the damage of the optics presently used. Hence, at the moment, the irradiation intensity on the target is expected to be as high as a few times 10^{19} W/cm^2.

By using the GEKKO XII and LFEX, we have been doing many investigations on high-energy density physics not only with Japanese researchers but also with international collaborators. From December each year until the beginning of the next year, we call for joint research applications through our dedicated website (http://www.ile.osaka-u.ac.jp/en/collab/application/ index.html). Every year, ILE's steering committee for collaborative research accepts around 20 proposals for basic science experiments using high power lasers aside from the ICF projects. One-third of those adopted proposals are from foreign institutions. We can allocate a few days of shooting on average for a single proposal.

In high-energy density physics, the energy density is one of the important parameters. Heating and compressing target materials using high-power laser beams achieve higher pressures compared to those using other techniques. Under these conditions, the internal conditions of other planets can also be studied. The equation of states and sound velocities have then been measured under various conditions [2, 3]. Furthermore, new phases of materials are investigated by expanding the experimental conditions in the temperature-density field through various techniques [4].

In the context of planetary physics, meteorite collision is another interesting application of high-energy density physics. Macroscopic projectiles can be accelerated up to velocities of more than 10 km/s required to mimic the meteorite collision on planetary and satellite surfaces [5]. We have been able to demonstrate meteorite collision with sulfate-rich anhydrite which generated enough amount of sulfur trioxide leading to ocean acidification and mass extinction at the Chicxulub impact [6].

On the other hand, astrophysical subjects in rather low-density plasma region such as collisionless shock wave, particle acceleration by the shocks [7], and magnetic reconnection have also been investigated. Due to the progress of high-intensity lasers, we can extend our research activities into new high-field dimensions. Generation of the relativistic plasmas and electron-positron plasmas are interesting topics for laboratory astrophysics. Preliminary studies of the electron-positron pair creation using LFEX have been started [8]. LFEX can provide x-ray and proton probes for imaging compressed plasmas and magnetic fields. For the first time, plasma mirrors have been utilized successfully for the LFEX PW laser system with a rather long pulse duration of 1 ps with the expected performance [9]. In this conference, new results of laser acceleration and aviation will be also introduced.

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[1] J. Kawanaka *et al.*, "LFEX-Laser: A Multi-Kilojoule, Multi-Petawatt Heating Laser for Fast Ignition," 26th IAEA Fusion Energy Conference (CN-234), IFE/1-6, Kyoto International Conference Center, Japan on 17-22 Oct. 2016.
[2] T. Sakaiya *et al.*, Earth and Planetary Science Letters, Vol. 392, 2014, pp.80-85.
[3] K. Shigemori *et al.*,Rev. Sci. Instrum. Vol. 83, 2012, pp. 10E529(1-3).
[4] T. Kimura *et al.*, Phys. Plasmas **17**, 054502 (2010).
[5] T. Kadono *et al.*, J. Geophys. Res. Vol. 115, 2010, E04003(1-9)
[6] S. Ohno *et al.*, Nature geoscience 9 MARCH 2014, DOI: 10.1038/NGEO2095
[7] Y. Sakawa *et al.*, EPJ Web of Conferences 59, 2013, pp.15001 (1-5)
[8] H. Chen *et al.*, New Journal of Physics Vol. 15, 2013, 065010 (1-11)
[9] A. Morace *et al.*, Nucl. Fusion 57, 126018 (2017).