LPL-1 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Exploration of high energy density science in various scales of structures with high power lasers

Ryosuke KODAMA[1, 2]

[1] Institute of Laser Engineering, Osaka University,

[2] Graduate School of Engineering, Osaka University

e-mail: ile-director@ile.osaka-u.ac.jp; kodama@eei.eng.osaka-u.ac.jp

Progress of high power laser technology is now expanding the field of sciences, especially of high energy density science. Increases in the energy and/or peak power of high power lasers are opening new doors such as fusion ignition and vacuum quantum physics. The other progress of high power laser and its related technologies will also make a paradigm shift in the high energy density science in various scales of structures under the extreme states such as high pressure, high density, high temperature, high magnetic field, high electromagnetic field, high acceleration field and highly non-equilibrium state.

In the large scale of high energy density state, astrophysics and planetary physics are studied with high power lasers. The structure of collision less shock in a macro scale relevant to the turbulence of plasmas as an initial structure in a micro scale could be one of the mechanism to create high energy cosmic ray. These structures could be studied with high power lasers in laboratories [1]. Laser fusion research is also one of the subjects related to the astrophysics in a large scale. Contrary to the large scale, there is vacuum physics as an extremely small scale physics, which would be opened with high power laser and plasma devices. One of the examples in the mesoscale or ubiquitous scale is development of new material under high pressures induced by high power laser. As one of the progresses of high power laser, couple of XFEL and optical power laser is well useful to explore the high pressure condensed matter science [2].

We are now proposing a new type of high power laser system for high energy density science in various scales of structures, which is called "J-EPoCH". This facility integrates all the high power laser technologies, which is based on the 160 beams of 100Hz /100J laser module, providing high repetition 10kJ long pulse laser, 20PW short pulse laser and different kinds of laser plasma accelerators and laser-driven radiation sources such as x-rays and neutrons. This system would be well controlled by advanced information technologies to response to many different kinds of user requests in various scales of sciences.

More than 10 beams of the 100J/100Hz laser, named SENJU: Super-Energetic Joint Unit are used for a 1kJ beam let and 10 kJ is realized with numbers of the kJ beam let. The module is also used for the high repetition PW short pulse lasers as pumping sources. 100J/100Hz laser: SENJU will be the base of all the system of the J-EPoCH and now under development. The SENJU:100J/100Hz will be feasible with an active mirror amplification scheme using 10 cm Yb:YAG ceramics pumped by laser diodes. 10J/100Hz has been realized as SENJU-light and the development of the SENJU:100J/100Hz would be completed in a few years. The J-EPoCH based on the SENJU lasers would open a new frontiers of science in the difference scales of structures under the extreme states or high energy density states.

In the largescale, we could access to a new stage of laser fusion research with big data based on the high rep. of the J-EPoCH. We will deepen understanding of laser fusion plasmas with a statistical approach. It is also possible to realize a laser subcritical fusion reactor, as a small fusion power generation system (multi-watt power reactor) [3], and to demonstrate tritium fuel proliferation. In addition, it contributes widely to fusion reactor engineering as a high dose neutron source ($10^{13\text{-}15}$ n/sec; $10^{16\text{-}18}$ n/m^2 sec @ 1 cm). This would be approach of a new horizon of the laser fusion energy development.

In the extremely small scale, quantum vacuum could be explored with a combination of plasma optics and high repetition 10PW laser in the J-EPoCH. Scattering of light from vacuum polarization could be detected by focusing 10 PW laser light into vacuum with a <0.5 f-number plasma optics[4], taking account of the polarization of the scattered light, which is totally different from the original light and scattered light from material[5]. Reliable image of the scattered light would be obtained in 10 minutes' accumulation with the J-EPoCH.

In the mesoscale, exotic structures will appear in the lattice at more than 10 TPa with a solid state, where you can quest for quantum material physics. The energy density at 10 TPa is comparable to that of the inner core electrons, so the atoms themselves change. This high energy density condition with a solid state will create a new quantum regime where the interatomic separations is less than the de Broglie wavelength as well as the Bohr radius. This opens an entirely new quantum mechanical domain, where core electrons determine material properties and gives rise to a new structural complexity in solids. Such a solid state conditions above 10 TPa will be realized by a long pulse laser with well-controlled 100 pulse waveforms from the J-EPoCH.

References

[1] Y. Sakawa et al., HED Physics **23**, 207(2017).
[2] K. Katagiri et al., Rev. Laser Eng., **47**, 47-51 (2019).
[3] A. Iwamoto and R. Kodama, IFSA2019,2P01 (2019).
[4] Nakatsutsumi, et al.,. Opt. Letts. **35**, 2314 (2010).
[5] Y. Monden and R. Kodama, Phys. Rev. Letts **107**, 073602 (2011); Phys. Rev. A **86**, 033810(2012).