High Energy Density Science with High Power Lasers in Japan

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High power laser technologies are opening up a variety of attractive fields in the sciences and technologies that deal with high energy density (HED) states. The HED states consists of many kinds of states of matter such as warm dense matter (WDM), high pressured plasmas, radiative plasmas, fusion burning plasmas, relativistic plasmas and electro-positron plasmas. These extreme states of matter enable us a lot of applications such as particle acceleration, laboratory astrophysics, material science, nuclear science including medical applications and laser fusion. One of the key issues to open these attractive scientific fields and applications is high power laser technologies as well as understanding plasma physics and control of the plasma. In the paper, recent results are presented of HED sciences. As a next step of the HED science, we are now planning the next generation of high power lasers and its potential for the future application.

One of the topics is realization of laser plasma accelerator based on the progresses of high power laser and plasma photonic device[1] technologies. Now we have a well-stable electron beam with a pointing stability through a laser-wake field controlled by plasma photonic devices, i.e. plasma collimator and plasma fiber. By using the stable beam, we have demonstrated staging acceleration of electrons[2]. These technologies could realize a compact GeV accelerator and a laboratory size X-ray light sources in the next decade. Now we are realizing the system under collaboration with an accelerator technology community as the LAPLACIAN: Laser Acceleration Platform as a Coordinated Innovative Anchor project.

We have also realized efficient ion acceleration with ultra-intense laser with a ps pulse[3]. Accelerated ion energy with a few ps lasers is higher than previous results by 2 order of magnitude at the same intensity as compared with that with a pulse of less than ps. The conversion efficiency was 5% from laser energy to proton total energy. By using this efficiently generated proton, we have obtained new neutron beam with a number of $2x10^{11}$ neutrons by a single shot. The number of this neutron was enough to obtain images of low-Z material with a single shot. Higher spatial resolution and signal to noise ratio would be expected in the laser neutron imaging since this neutron source size could be less than a few mm and temporal duration of the pulse would be less than a few 10 ps. The laser-based neutron source could be also useful to study novel process in nucleus and would open nuclear photonics.

We have also developed a plasma photonic device for ultra-fast focusing of laser light, which could be useful for the experiment on laser light-vacuum interactions. Other interesting plasma device is for generation of strong magnetic field with ultra-intense laser light[4]. More than 5kilo Tesla magnetic field was obtained and >10 kilo Tesla is predicted by using a novel target geometry. Such a strong magnetic field will be appropriate for astronomy to calibrate x-ray spectra from white dwarf or magnetor.

Other interesting topics on astrophysics with high power laser is investigation of collisionless shockwaves to generate high energy particles or cosmic rays. The origin of the solar cosmic rays is thought to be a collisionless shock wave by the solar wind. The galactic cosmic Rays could be due to the Supernova Remnant(GRBs). These phenomena would be experimentally simulated with long pulse high power lasers[5]. The extragalactic cosmic rays from gamma ray burst (GRBs) due to relativistic shock wave would be also experimentally investigated with ultra-intense lasers.

An ultrahigh pressure state of 100 GP or more that can be realized with strong shockwaves generated by a high power laser helps exploring the core of the planet and developing new materials[6]. These shockwaves or dynamic compression are experimentally studied with combination of XFEL and optical high power lasers.

All these topics are now investigated with a single-shot base high power laser. On the other hand, the acquisition of a big data with high repetition laser is required from the new method of physics informatics. To respond to such a demand, we have proposed a new high-receptive and high-power laser system called J-EPoCH: Japan Establishment for Power-Laser Community Harvest and started its research and development.

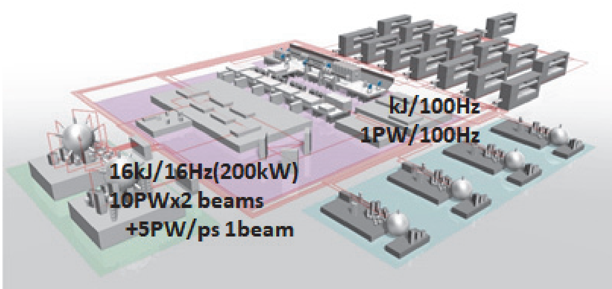

Figure 1 conceptual design of the J-EPoCH

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