Exploring of novel extreme states with high power lasers and XFEL

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High power laser technologies are now opening a variety of attractive fields of sciences and technologies using high energy density plasmas, e.g., material science in extreme states, particle acceleration, laboratory astrophysics, medical applications, nuclear science including laser fusion and nonlinear optic in vacuum, which are “High Energy Density Science (HEDS). These applications are well in progress with technologies on high power lasers and related plasma devices[1].

Nonlinear optics in vacuum will be experimentally realized with development of novel focusing optics or a spheroid plasma mirror [2] as well as ultra-intense lasers. Calculating Lagrangian densities of electromagnetic fields with quantum electromagnetic dynamics (QED) and wave optics, feasibility of experiments are discussed on nonlinear optics in vacuum. The polarization and beam pattern after the interaction in vacuum are totally different from those in matter. As other different points, the interaction rate significantly depends on a focusing cone angle [3]. Taking account of the Lorentz invariant and using the novel plasma device, we would open the new stage or nonlinear optics in vacuum at a laser power of a few10PW.

One of other interesting topics is creation of extremely high pressures such as TPa in material with high power lasers. At pressures of more than TPa, most of material would be melted on the shock Hugoniot curve. However, if the temperature is less than 1eV or lower than a melting point at pressures of more than TPa, novel solid states of matter must be created through a pressured phase transition. Carbon is most interesting material at pressures of more than TPa, where the diamond structure changes to BC and cubic at more than 3TPa. The band gap of the cubic structure carbon could disappear and diamond semiconductor changes to a metallic. On the other hand, the BC8 carbon will be still semiconductor and harder than the conventional diamond. Many kinds of novel structure material would exist at >TPa, which has never been presented before. We are now exploring this field, called “Tera-Pascal Science”. To explore the “Tera-Pascal Science”, now we have a new tool which is an x-ray free electron laser as well as high power lasers. The x-ray laser will clear details of the high energy density states and also efficiently create hot dense matter. We have started a new project on high energy density sciences using an XFEL (SACLA) and high power lasers in Japan, which is a HERMES (High Energy density Revolution of Matter in Extreme States) project.