

# **Magnetic turbulence and self-organization via magnetic reconnection in laser produced non-equilibrium extreme radiation plasma**

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## ***Abstract***

We study a plasma produced by the interaction between high power laser and high-Z structured medium, which we refer it as “*non-equilibrium extreme radiation plasmas*”, and discuss the characteristics. Such a plasma is highly non-stationary and non-thermodynamic equilibrium, and consists of multiply charged high-Z ions, high energy relativize electrons, quasi-static and/or low frequency electromagnetic fields, high energy X-rays and  $\gamma$ -rays resulting from Bremsstrahlung and also from radiation damping [1]. The nonlinear response of such plasma leading to various kinds of structure formation and their thermodynamics property are of specific interest to understand the extreme state in universe and to explore applications such as heavy ion acceleration.

We have developed a comprehensive particle based integrated simulation code, EPIC3D, which includes key elements to reproduce such interaction between high power lasers and high-Z structured medium, e.g. various atomic process and relaxation process, radiation process such as Bremsstrahlung and radiation damping, and their transport [2,3].

Here, we introduce a lattice-like assembly consisting of 2-dimensional sub-micron Au-rod embedded in strong magnetic field in the order of 10kT, which is irradiated with high intensity short pulse laser in the range of  $10^{20-22}$  W/cm<sup>2</sup>. The high absorption of laser energy is realized causing ionization of Au-rods to high charge state and expansion leading to high energy density plasma. The applied ambient magnetic field is scrambled by the complex plasma motion leading to *magnetic turbulence* exhibiting power-law spectrum. The magnetic turbulence is then self-organized to coherent strong magnetic vortex around the rods, which field strength is the order of magnitude higher than that of initially applied magnetic field. The structure is similar to that of z-pinch, so that high energy density plasma is confined in longer time scale, which emits high intensity x-rays.

The generation mechanism of the magnetic vortex results from the successive reconnection between closed magnetic field-line around the rod and open magnetic field-line advected by the background plasma flows, which is similar to the collision between the Earth’s magnetic field and that of solar wind. Furthermore, collision and merge of different magnetic vortexes take place with slower time scale through reconnection, which play a role in thermalizing and/or accelerating ions. Various kind of electromagnetic radiation including Alfvén wave are observed.

The present scheme can be a tool in studying magnetic turbulence and associated self-organization through reconnection in plasmas with various magnetization level, e.g. fully kinetic, electron MHD, or near ideal MHD, in non-equilibrium extreme plasma.

[1] Y. Kishimoto et al., High Energy Density Science 2016, May 17, 2016, Yokohama.

[2] D. Kawahito, Y. Kishimoto, *et al.*, IFSA. Mo.Po.24, 339(2015)

[3] N. Iwata et al., accepted for publication in Physics of Plasma (2016)