1st Asia-Pacific Conference on Plasma Physics, 18-23, 09.2017, Chengdu, China

Realization of hypothetical plasma dipole oscillation leading to burst of coherent radiation

Min Sup Hur[1], K.B. Kwon[1], T. Kang[1], U.-J Ra[1], Y.-K. Kim[1], B. Ersfeld[2], D. Jaroszynski[2]
[1] Department of Physics, UNIST, Korea, [2] Department of Physics, Univ. Strathclyde, UK

Radiation at the plasma frequency has been a subject of controversy. It is generally accepted that a plasma wave, which is usually generated by the ponderomotive force of a laser pulse or a relativistic electron beam, does not radiate in a homogeneous plasma. Underlying physics of non-radiating plasma wave in a homogeneous plasma is that the curl of the electric field of the plasma wave is zero. Equivalently, no-crossing dispersion curves of the electrostatic plasma wave and the electromagnetic wave indicate that there cannot be coupling of those waves for effective electromagnetic radiation. Although the curl E of the plasma wave can be non-zero in highly nonlinear regime, the radiation at the plasma frequency is a negligible effect.
By tapering the plasma density, thereby breaking the homogeneity, however, it is well known that the curl E of the plasma wave can become significant, resulting in generation of electromagnetic radiation. When the plasma has a random nonuniformity like thermal fluctuation, the scattering of Langmuir wave leads to the dipole-like radiation. This description is employed commonly to explain the solar-radio burst type III. In the laboratory plasmas, inverse mode conversion was suggested for controlled emission of coherent wave from a plasma wave.
In this talk, I discuss interesting behavior of electromagnetic fields, which is opposite to previously known features in many perspectives. First, I demonstrate that the electromagnetic fields can propagate through a homogeneous plasma. The propagation occurs in a special environment; by colliding two slightly detuned, ultrashort laser pulses in a homogeneous plasma, an oscillating dipole moment can be generated at the position of the pulse collision. The length of the dipole block is comparable to the laser pulse width. The dipole block oscillates at the plasma frequency of the plasma. From the dipole oscillation of the electron block, electromagnetic field is emitted in spherical phase front (Fig. 1).
The interesting point in this simulation result (Fig. 1) is in understanding how the electromagnetic field can propagate through a homogeneous plasma, although it is screened by the ambient plasma, that is, cut-off. To explain this, we resort to our previous research on the diffusion-growth of electric field from a current source embedded in a plasma-like medium [1]. According to Ref. [1], the electromagnetic field emitted from a current source grows temporally at every position, which compensates for the decaying of the fields over distance. In the present case, the dipole oscillation serves as a quasi-current source, resulting in field propagation over more than tens of wavelength. Theoretical prediction of the frequency drift is also observed from the dipole field in a homogeneous plasma.
When the plasma is properly tailored so that the dipole closely faces the vacuum side, the dipole oscillation emits a very strong THz burst at the plasma frequency. The spectrum from the dipole is quasi-narrow, and controllable over 5 ~ 20 THz, by adjusting the plasma density. The projection of the 2D PIC simulation results to 3D indicates that the energy of the THz burst reaches mJ with efficiency 0.5x10-3. Theoretically the efficiency can be increased beyond a few percent.

References
[1] M.S. Hur, B. Ersfeld, A. Noble, H. Suk, D.A. Jaroszynski, Sci. Rep. 7:40034, 2017

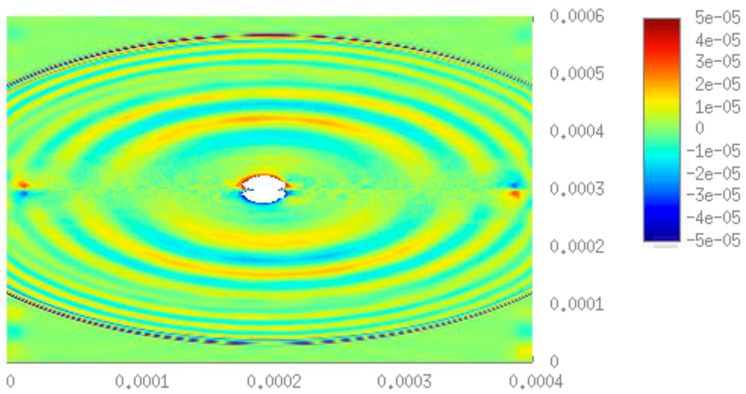

Fig. 1. Magnetic field propagation from dipole at the center, embedded in a homogeneous plasma.