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Novel optical media with adjustable spectra and polarization based on the magnetized plasma dipole oscillation

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Since the discovery of plasma dipole oscillation, it has been used in a variety of applications, including ultra-high power Terahertz sources and plasma diagnostic methods. The new technique for producing terahertz emission using a plasma dipole oscillation (PDO) results in considerably narrower band, spectrum-controllable radiation. Previous researches[1,2] have revealed energy conversion efficiency can be beyond 10^{-2} and has proposed innovative diagnostics methods. Recently we found that response of PDO to the external magnetic field is interesting and beneficial as an optical component. PDO is implemented by colliding detuned electromagnetic (EM) waves (typically laser pulses) to emit linearly polarized THz radiation at the plasma frequency in a radial direction. Magnetized PDO, on the other hand, shows much richer radiation characteristics as it emits in both transverse and longitudinal polarization at diversely different frequencies. These characteristics originate from the PDO dynamics under the magnetized plasma. The magnetized PDO consists of three modes: right circular (R), left circular (L), and upper hybrid modes. Each electron of PDO circulates either right-handed or left-handed. The right circular and left circular modes come out as results of single electron motion under the external magnetic field. However, upper hybrid mode is formed from the average motion. The upper hybrid mode works for sustaining the coherency of PDO.

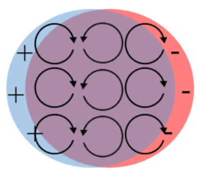

Figure 1 Schematic diagram of single electron motion in magnetized PDO. Averaged electron motion become an upper hybrid mode within PDO, but left or right circulating are dominant in PDO boundary.

Analytic trajectories of PDO are obtained from the fluid and Maxwell equations. The outcomes well fit the particle-in-cell (PIC) simulations. In the non-magnetized case, the PDO is subject to just the longitudinal motion (i.e. longitudinal to the laser propagation axis), oscillating at the plasma frequency, similar to the slab model of the plasma oscillation. Oscillating charged particles coherently emit the transverse radiation. The polarization is simply linear transverse. The trajectory of magnetized PDO, on the other hand, is a mix of left and right circular motion at the right- and left-cutoff frequencies of the X-mode and the charged particles release radiation at each oscillation. It is possible to produce radiation along the longitudinal(parallel) and transverse(perpendicular) direction to the laser axis with both p−polarizations.

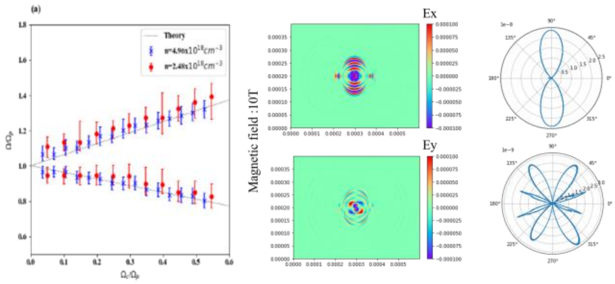

Figure 2 Radiation spectra, longitudinally polarized field and transversely polarized field and light distribution curve correspondingly.

Interestingly, longitudinal p-polarized radiation seems dipolar, while transverse p-polarized radiation appears quadrupole. In the future, we intend to investigate the magnetized PDO merging process, which might be a critical micro-process in the formation of a massive Alfven wave capable of creating astrophysical radio bursts.

In summary, we investigated the characteristics of PDO in a magnetized plasma. Owing to the complicated motion of electrons, i.e. combination of left- and right-circular motions, the radiation emitted from the magnetized PDO show diverse patterns in polarization and spectra. These features can be utilized as a source of Terahertz radiation source and diagnostics of magnetic properties of a magnetized plasma. Furthermore, the study is under progress on the relevance of the magnetized PDO to various astrophysical radio-bursting phenomena.

References

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2.S Kylychbekov *et al Plasma Sources Sci. Technol.* **29** 025018 (2020)