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Numerical simulation of magnetic field generation by relativistic effect in high intensity laser experiments

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It has been a big mystery how the seed (primordial) magnetic field is generated in the universe. In fluid description of plasma, a magnetic filed is coupled with a mechanical vorticity then represented as curl of canonical vorticity. Recently, Mahajan and Yoshida proposed a novel mechanism of vorticity generation by relativistic effect [1, 2]. The relativistic plasma have two vorticity generating terms, one is so-called baroclinic term(S_T). The baroclinic term is known to be weak except for strongly thermal nonequilibrium state (e.g. shock front). Mahajan and Yoshdia proposed that, even if the system is barotropic, there appears another term available to generate vorticity due to the relativistic effect (S_R).

Recent progress in high intensity laser experiment enables us to obtain relativistic electron plasma, and some of the workers established high accuracy measurement of the generated magnetic field [3]. The relativistic vorticity generation (RG) is expected to be verified in such high intensity laser experiments.

In this study, we conducted numerical simulation for the proposal of the experimental verification. We have following objectives; is RG sufficiently working in actual experiment? If not, in what parameters will RG effectively work? What is the characteristics of the magnetic field given by RG? We calculated for parameters relevant to the experiment in Ref. 3. Observing the ratio of relativistic baroclinicity to thermodynamic baroclinicity, we can state that thermal baroclinic effect is governing and RG is not sufficiently working. By raising the hot electron temperature or decreasing the ratio of skin depth to scale length, the ratio is improving (Fig).

[1] S. M. Mahajan and Z. Yoshida, Phys. Rev. Lett. 105, 095005 (2010).
[2] S. M. Mahajan and Z. Yoshida, Phys. Plasmas 18, 055701 (2011).
[3] S. Mondal et al., PNAS 109, 8011 (2012).

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