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P4.4009 Weibel and Biermann fields simulated self-consistently in laser-plasma interaction

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The Biermann battery [1], driven by the perpendicular temperature and pressure gradients, is often dominant source of magnetic fields generated in laser-plasma experiments. A detailed study of Biermann generated magnetic fields in collisionless systems has been carried out [2] in an expanding plasma bubble, showing that for large system sizes (L/d_e >=100), where d_e is the electron inertial length, the Weibel instability dominates as the major source of magnetic field. However, these Weibel generated magnetic fields have yet to be demonstrated in the context of laser-plasma interaction.
We model, using ab initio PIC [3] simulations, the interaction of a short (~ps) high intensity laser pulse, thus generating a collisionless system. We demonstrate the first 3D kinetic simulation of the Biermann battery which is self-consistently driven by laser-plasma interaction. We have shown that when the laser hits the plasma, target electrons are heated and expand away from the front side of the target. The expansion causes a density gradient and the heating causes a temperature gradient, which are perpendicular to each other. As a result, a toroidal magnetic field is generated.
Although the length scale of the 3D simulation is too small for the Weibel instability to dominate, we also carry out 2D simulations with a target of sufficiently large gradient scale length, L, and observe Weibel filaments. The expanding hot energetic electron population generated by the laser produces an anisotropy in the velocity distribution. This anisotropy provides the free energy that drives the Weibel instability that appears on the surfaces of the target and dominates over the Biermann battery field.

References

[1] J. A. Stamper et al, PRL 26, 1012 (1971)
[2] K. M. Schoeffler et al, POP 23, 056304 (2016)
[3] R. A Fonseca et al, Lec. Notes Comput. Sci. 2331, 342 (2002)

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