Anisotropic heating and magnetic field generation due to Raman scattering in laser-plasma interaction

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The interaction of intense electromagnetic waves with plasmas is a rich research topic because of its importance in basic plasma science and in potential scientific and societal applications, ranging from advanced fusion devices to compact plasma based accelerators and radiation sources. Magnetic fields play a crucial role in this context: they may stabilise hot electron currents against beam-break up instabilities, are vital to reproduce extreme astrophysical scenarios in the laboratory, and make plasma-based radiation emission processes more efficient. There are several processes that can lead to the generation and amplification of magnetic fields. Recent experiments, for instance, demonstrated the generation large-scale [1] due to hot electron currents in underdense plasmas, and determined the turbulent [2] dynamics of intense magnetic fields in laser-solid interactions.

In general, magnetic field generation depends on the specific temperature distribution of hot electrons. Thus, controlling how heating occurs is important to enhance magnetic field generation in laser-plasma interactions. In this work we explore a novel mechanism to drive the Weibel instability in laser-plasma interactions by controlling the temperature of background plasma electrons in each direction, independently. The scheme employs an intense laser pulse propagating in an underdense plasma. Using two and three-dimensional particle-in-cell simulations with the code OSIRIS [3], we show that the interaction is subject to Raman side-scattering. We find that electron heating is stronger along the direction where the scattered plasma wave phase velocity is lower due to Landau damping. Thus, our work shows that this setup creates an angle-dependent temperature distribution capable of driving the Weibel instability. We discuss the role of the laser polarisation in our findings.

References

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