Plasma expansion into a vacuum

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Laser created plasma expansion into a vacuum leads to energetic ions which present a strong interest for various applications such as hadron (proton) therapy, proton imaging, nuclear physics, ion accelerators, fast ignition, etc. This has revived studies in plasma expansion into a vacuum in the last 15 years. In this presentation we will review some of its aspects.

The one-dimensional expansion of a plasma into a vacuum has been first studied in the semi-infinite limit, with an electron temperature independent of time [1, 2]. The charge separation creates an electric field which prevent electrons to escape and drag ions from the plasma surface. The kinetic ion energy eventually becomes a linear function of time with no upper limit.

However, in the case of a thin plasma foil the total energy is finite and has to be conserved so that the electron cooling has to be taken into account. We will discuss how this cooling limits the growth of the kinetic energy of the ions and modifies the shape of the electron distribution function.

When the electron distribution function is initially bi-maxwellian, a rarefaction shock may appear in the expansion and we will analyze the signature of this shock on the ion spectrum.

Simple solutions for the expansion are obtained in some limiting cases (plasma with sharp boundaries, or gaussian plasma in the quasineutral limit). However there are cases (in particular with finite initial density gradient) where a wavebreaking of the plasma expansion occurs and we will explore this regime.

Finally we will discuss the coupling of the longitudinal direction (along the plasma expansion) with the perpendicular directions, either by collisions or by a magnetic field resulting from electromagnetic instabilities.

References

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