PIC-modeling and experimental study of ensembles of the z-pinches and current sheets: From various laser-plasma structures to novel mechanism of solar flares

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We present PIC-modeling and experimental study of novel quasi-magnetostatic structures, mainly the transient multi-scale ensembles of the z-pinches or current sheets with various orientations, produced by Weibel-type instabilities in an expanding laser or cosmic plasma with hot electrons (cf., e.g., [1-6]). We consider an anisotropic plasma cloud with hot electrons expanding into an inhomogeneous background plasma with an external magnetic field in different geometries:
(i) a circular or cylindrical form of a hot-electron spot in the cases of an initial-value problem or a finite-time injection of electrons from a target surface,
(ii) inhomogeneous layers of cold background plasma of different densities with a small or large spatial scale,
(iii) an external magnetic field with three orientations: perpendicular to the target or along its surface and directed either across or parallel to the long axis of the hot-electron spot.

For various combinations of the attributes (i)–(iii), we find necessary parameters and dynamical regimes of the plasma manifesting the Weibel-type instabilities related to different types of the anisotropic electron velocity distribution (see an example in fig. 1). We discuss applications of the obtained results to space and astrophysical problems. In particular, we describe a new mechanism of a solar flare associated with a coronal arch destruction due to the injection of energetic, multi-keV electrons from a chromospheric plasma followed by the Weibel instability in the upper part of the arch. We argue that a small-scale reconnection of the magnetic-field lines, a strong deformation of the large-scale magnetic field, and a coronal mass ejection are possible if there is a sufficiently high degree of the electron anisotropy.

References

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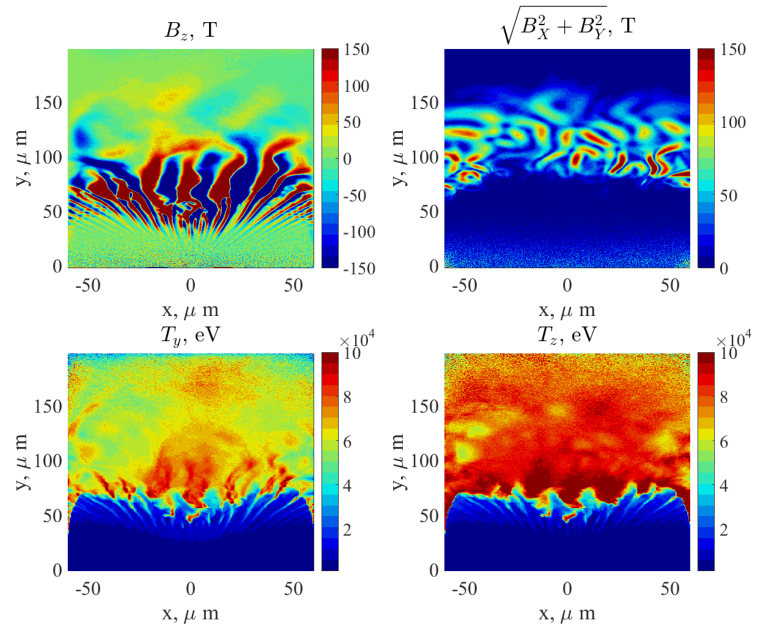

Figure 1. Structure of the longitudinal, B_z, and transverse, $B_\perp = (B_x^2+B_y^2)^{1/2}$, magnetic fields in Tesla (upper left and right) as well as the effective temperatures T_y and T_z in eV (lower left and right) at t = 3.6 ps after the start of the injection of hot electrons (which lasted for 2 ps) from the target surface into the background plasma with an inhomogeneity scale L = 32 μm at an injection ratio n_0^*/N_0 = 0.03 of the densities of hot and background electrons for a semicylindrical form of the hot-electron spot elongated along the surface of the plasma boundary where the cylindrical axis z is lying.