Ion motion in a plasma interacting with strong magnetic fields

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The interaction of a plasma with strong magnetic fields takes place in many laboratory experiments and astrophysical plasmas. Applying a strong magnetic field to the plasma may result in plasma displacement, magnetization, or the formation of instabilities. Important phenomena in plasma, such as the energy transport and the momentum balance, take a different form in each case.
We study this interaction in a plasma that carries a short-duration (80-ns) current pulse, generating a magnetic field of up to 17 kG. The evolution of the magnetic field, plasma density, ion velocities, and electric fields are determined before and during the current pulse. The dependence of the plasma limiting current on the plasma density and composition are studied and compared to theoretical models based on the different phenomena.
When the plasma collisionality is low, three typical velocities should be taken into consideration: the proton and heavier-ion Alfven velocities (v_A^p and v_A^h, respectively) and the EMHD magnetic-field penetration velocity into the plasma (v_{EMHD}). If both Alfven velocities are larger than v_{EMHD} the plasma is pushed ahead of the magnetic piston and the magnetic field energy is dissipated into ion kinetic energy. If v_{EMHD} is the largest of three velocities, the plasma become magnetized and the ions acquire a small axial momentum only. Different ion species may drift in different directions along the current lines. In this case, the magnetic field energy is probably dissipated into electron thermal energy.
When $v_A^p > v_{EMHD} > v_A^h$, as in the case of one of our experiments, ion mass separation occurs. The protons are pushed ahead of the piston while the heavier-ions become magnetized. Since the plasma electrons are unmagnetized they cannot cross the piston, and the heavy ions are probably charge-neutralized by electrons originating from the cathode that are "born" magnetized.