THE DEPOSITION OF ENERGY OF A RELATIVISTIC ELECTRON BEAM IN A MAGNETIZED PLASMA

Šunka P., Jungwirth K., Kováč I., Piffl V., Stöckel J., Ullschmied J., Zajíc V.

Institute of Plasma Physics, Czechoslovak Academy of Sciences, Prague, Czechoslovakia

Conditions for the maximum and minimum deposition of energy of a relativistic electron beam (REB) in a magnetized plasma (plasma heating and beam transport) are investigated. As the beam current is below the Alfvén limit $I_b < I_A$ and $L \ll t_i v_b$ in our device, the energy losses of the propagating REB are given by the collective processes originating from the two-stream instability. A higher beam energy deposition is observed in regimes with a virtual cathode /1,2/. With improving the efficiency of accumulation of the beam electrons and with shortening the plasma column length, the energy content increases (diamagnetic measurements). The single reflection of the REB electrons from the virtual cathode leads predominantly to the extension of the effective interaction length without changing the nature of the REB-plasma energy coupling. With increasing the accumulation rate, however, the energy content changes more rapidly than the REB-plasma coupling efficiency. Thus, the diamagnetic signals should be interpreted with caution. An attempt to distinguish between the role of the heated plasma particles and the accumulated electrons is one of the main goals of the contribution. This involves the determination of the critical interaction length for the two-stream instability L_{crit}, the accumulation efficiency and the lifetime of the accumulated electron cloud.

The measurements were performed on the improved REBEX machine /1,2/. The beam (I_b= 20-30 kA, U_b= 500 kV, Q_b= 400-600 J, t_i= 70ns, diameter 30mm) is injected into a puff of gas or into an externally produced plasma. The magnetic field has a mirror geometry (B_o=0,5T, R= 1,5), the conducting vacuum chamber is 0,15m in diameter and 2m long. The plasma column of variable length (0,6 - 2 m) and maximum density $2.10^{20} m^{-3}$ is produced by a conical plasma gun (aperture diameter 70mm) placed near the anode foil.

As it follows from the diamagnetic measurements, the plasma energy content Q (and the energy loss of the propagating beam) increases with the interaction length L ($Q= 0,1Q_b$ for L= 2m, and $n= 10^{20}m^{-3}$). In this case, calorimetric and Faraday cup measurements show about 10% beam energy loss and 15% beam current loss. At lower plasma densities the energy deposition and beam current losses are higher. These data fit well the theoretical results based on the estimate of anomalous collision frequency derived from the beam-plasma and turbulent spectrum dynamics.

The maximum value of Q was achieved with the shortest gun-produced plasma column and with the effective accumulation of the REB electrons ($Q= 0,3Q_b$, L= 0,7m, $n > 10^{20}m^{-3}$). On injecting the REB into a puff of hydrogen gas a plasma column shorter than 0,5m is created and $Q= 0,15Q_b$ is measured. In all regimes the beam energy deposition decreases with increasing the anode foil thickness (6-90 μm Al foils were used).

The injected beam current is by an order of magnitude higher than the collector current (equal to the critical vacuum current). Due to the formation of the virtual cathode at the plasma vacuum boundary, collective ion acceleration occurs and longitudinally escaping ions with energies up to 1,2 MeV are detected. The maximum number of energetic ions $N= 2.10^{14}$ is observed in the case of the beam-generated plasma. Switching off the magnetic field reduces the number N by an order of magnitude. Ions were detected at z= 2m.

Using a simulation code, we are going to complement the qualitative analytical estimates concerning the processes in regimes with a virtual cathode and accumulated electrons /1,2/ by quantitative computer data. Last but not least, it is of primary interest to get the direct information on changes of the plasma and beam electron energy distribution. We expect to obtain this from the magnetic analyzer and X-ray probe measurements.

REFERENCES

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