STUDIES ON THE EFFECT OF SELF FIELDS ON THE PROPAGATION OF RELATIVISTIC ELECTRON BEAMS

by

M.K.VIJAYA SANKAR

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AHMEDABAD 380 009

INDIA

CERTIFICATE

I hereby declare that the work presented in this thesis is original and has not formed the basis for the research of any degree or diploma by any University or Institution.

Vijay Sankar
M.K. Vijaya Sankar

Certified by:

P.I. John

P.I. John
Professor-in-Charge

Place: Ahmedabad

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M.K. Vijay Sankar

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STATEMENT

This thesis reports studies on the effect of self fields on the propagation of rotating relativistic electron beams, formed by injecting a laminar relativistic electron beam through a cusp magnetic field in a neutral gas background. For currents larger than the space charge limiting current, the propagation characteristics will be influenced by the self electric fields until effective charge neutralisation takes place. As the beam current increases, the self magnetic fields of the beam will begin to exert significant influence on the beam dynamics. The present set of experiments and numerical analysis were motivated to gain a better understanding of the deviations from the single particle description due to the effect of self electric and magnetic fields.

A long pulse rotating relativistic electron beam of about 800 nsec duration and peak energy of about 200 KeV, injected through neutral gas ($\sim$100m Torr), has been used for the study. The rise time of the beam ($\sim$ 500 nsec) is long compared to the charge neutralisation time (< 100 nsec). For the long duration beam, the beam self magnetic fields become significant after the beam is charge neutralised, and hence provides temporal seperation of the phases when the propagation is influenced by self electric and magnetic fields. A variety of diagnostics were used for the measurement of plasma, beam and magnetic field parameters.

The beam propagating through neutral gas has been shown to be stable against the microscopic instabilities like diocotron and filamentation. For a rotating beam, radial equilibrium has been shown to be possible for a value of charge neutralisation factor low compared to that required for a laminar beam.

The net beam potential was seen to be minimum at the central region of the chamber. The charge neutralisation factor has been estimated from a measurement of the beam potential. Charge neutralisation of the beam, which involves expulsion of the plasma electrons, was seen to be influenced by the external axial magnetic field. For magnetic field above the value required for magnetic insulation for the plasma electrons against radial loss, the plasma electrons were seen, in the numerical calculations, to escape to the axial walls. Here, the inductive axial electric field was seen to cause electron avalanche in the region between the position of potential minimum and the far end wall. This was seen to result in a faster charge neutralisation, creating an axial asymmetry in the beam potential structure. The charge netralisation time has been observed to decrease inversely proportional to pressure. Oscillatory decay of the beam potential was observed in certain parameter range.

External cusp magnetic field was seen to be drastically modified by the beam self magnetic fields. The diamagnetism produced by the rotating beam of the postcusp side has been found to result in a shift of the cusp plane towards the post cusp side.

Trajectories were obtained for the beam electrons in the numerical calculation using a model for the self fields based on measurements. Self magnetic fields were seen to reduce the radial extent of the beam. The beam diamagnetic field, radial loss at the cusp etc as given by the single particle description were also obtained in the numerical calculations done with the external fields alone present.

A measurement of the radial loss of beam electrons in the cusp region showed the peak to occur along the shifted cusp plane. Total radial loss in the cusp region was seen to depart from the value given by single particle description for self fields comparable to the external field. Radial loss saturated at external field comparable to single particle critical field for cusp cutoff.

The diamagnetic field produced by the rotating beam in the post cusp region was also observed to be enhanced over the value estimated from single particle description in the range of beam self fields comparable to and larger than the external field. The enhancement is partly explained by the density enhancement caused by the reduction in parallel velocity due to the energy lost by the beam in setting up the self magnetic fields. Addititional enhancement comes from the increase in the ratio of number of axis non encircling to the axis encircling electrons transmitted through the cusp.

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