CHAPTER V

CONCLUSION

Experimental studies on interaction of rotating relativistic electron beam with a plasma trapped in a magnetic mirror has been carried out. Determination of the response of the plasma to the rotating beam as well as propagation studies of the rotating beam through the plasma are the main objectives of the experiments described in preceding chapters. In addition, injection of the intense electron beam in vacuum and plasma filled non-adiabatic cusp magnetic field has also been investigated.
The conclusions drawn from the present investigation are:

1. Space charge neutralisation of the rotating relativistic electron beam is necessary for its propagation up to an appreciable distance. The propagation of the rotating beam to distances more than 150.0 cm is observed in the presence of plasma of density $10^{11}-10^{13}\text{cm}^{-3}$.

2. The rotating electron beam loses a significant fraction of its axial energy while propagating through the plasma. No macroscopic beam instability is observed during its propagation through the plasma.

3. An improvement in the beam transmission through the cusp configuration is observed, in the presence of a dielectric tube in the cusp region. The maximum transmitted flux is enhanced by a factor of four compared to vacuum value, due to space charge neutralisation of the beam by background plasma, created by the electrical breakdown of the tube surface.

4. The response of the plasma to the rotating electron beam is of magnetic diffusion type, when the plasma density lies in the range $10^{11}-10^{13}\text{cm}^{-3}$. In this density regime, no radial oscillations of the plasma are observed.
5. The rotating electron beam induces axial and azimuthal return currents in the plasma. The lifetime of the azimuthal return current is longer by an order of magnitude as compared to that of the axial return current, and these return currents are localised at the beam radial position. The experimental results indicate that the azimuthal return current is of resistive nature rather than of drift type.

6. In earlier experiments, the diamagnetic loop signal was attributed to plasma heating. However, the present experimental studies show that by and large the azimuthal return current diamagnetism contributes to the loop signal, rather than plasma heating. Thus interpreting the loop signal as due to plasma heating is not correct in the rotating electron beam-plasma interaction experiments.

7. The observed spatial and temporal variations of the azimuthal return currents have shown that the return current layer is trapped in the magnetic mirror. After the beam passage, the finite azimuthal return currents are localised in a region about 50.0 cm within the mirror and symmetric around the mirror centre.
8. At the mirror centre, the diamagnetic loop signal decays rapidly in absence of the mirror field. The non-occurrence of the long azimuthal return current decay without the mirror shows that the magnetic mirror field plays an important role in the formation of the trapped return current layer.

9. The observed azimuthal return current decays at a rate much faster than what the classical decay should be but is slow as compared to the rate estimated from ion acoustic or Buneman turbulence.

10. Numerical results of a magnetic diffusion model for the response of the plasma to the rotating electron beam, are in general agreement with the experimental observations.

5.1 SCOPE FOR FUTURE RESEARCH

The experimental results of the present investigation provides the basis to carry out further detailed experimental and theoretical work, in order to acquire a more complete and thorough understanding of the interaction of the rotating relativistic electron beam with plasma and the beam propagation through the cusp magnetic field. The research work need to be carried out in the future are enumerated as follows:
(1) Injection of intense electron beam into a cusp magnetic field in the presence of a dielectric drift tube have shown a significant increase in the beam transmission through the cusp. The observed phenomena is interpreted as due to the presence of a background plasma, created by the electrical breakdown at the tube surface. To determine whether the above predicted physical process is responsible or not for the observed enhancement, a more systematic experimental investigation is being planned to be carried out.

(2) Theoretical models have revealed that the collision frequency plays a crucial role in determining the response of the plasma to the rotating electron beam. When collision frequency is large enough, magnetic diffusion is the dominant process whereas the rotating electron beam excites magnetosonic modes in a collisionless plasma. In the experiments reported so far, no measurements on the collision frequency are available. Nor is it known how response of the plasma to the rotating electron beam depends upon the collision frequency.

(3) Another aspect which would be interesting topic for future research work is the physical mechanism
responsible for the azimuthal return current generation. The present experiment indicates that the driving mechanism responsible for the generation of the azimuthal return currents is azimuthal electric field, however more experimental work needs to be done to identify the exact process.

(4) A rise in the interaction strength of the rotating electron beam with plasma is observed with an increase in the plasma density, in the regime $10^{11}-10^{13}$ cm$^{-3}$. The question arises as to how the rotation of the electron beam results in an increase in the energy transfer efficiency from the beam to the plasma at higher plasma to beam density ratios, in contrast to the case of a linear beam - plasma interaction. Experimental investigation needs to be carried out in a wider plasma density range to establish the scaling for energy transfer efficiency from the rotating electron beam to the plasma.

(5) As has been concluded from the present experiment that the diamagnetic loop signal is dominantly caused by the azimuthal return currents, indicating that the above diagnostic is not reliable for plasma energy measurements in the rotating electron beam - plasma interaction experiments. Therefore the plasma energy
needs to be determined by more sophisticated diagnostics such as Thomson scattering and charge exchange analyser. These diagnostics will also be of help to determine the distribution of the beam energy to ion and electron components of the plasma.

(6) The observed decay of the azimuthal return current could not be explained by either classical analysis or by ion acoustic or Buneman turbulent process, thus indicating the necessity of a new theoretical model on return current decay.

(7) In the magnetic diffusion model used for numerical simulation, the beam is regarded as a specific current source, immersed in the plasma and the interaction is turned on at $t = 0$. Such a model neglects the details of the diode and the cusp field regions, the entry of the beam into the plasma and the effect of the conducting boundary. Determination of the plasma response to the rotating electron beam using a more realistic model would be an added justification for comparing numerical results with experimental observations.