CHAPTER 6

Summary and scope of Future Work

Ion holes investigated in the linear unmagnetised plasma have shown several interesting characteristics of formation and propagation. We have observed asymmetric as well as symmetric holes. The asymmetric holes were obtained in the main ion acoustic pulse region, where they have shoulders of unequal amplitude. On the other hand, a train of fully developed symmetric holes were observed in the region behind ion acoustic pulse. These holes were launched by a fast (time scale $\sim \omega_{pi}^{-1}$) rarefactive density perturbation. The perturbation launched are of width $\sim 10\lambda_D$.

In our measurements the hole velocities were found to be same as the ion acoustic speed. Hole widths observed are of the order of $200\lambda_D$ and they are found to move till the end of the device, showing a stable configuration. Relative density associated with the hole varies up to 18%. In agreement with numerical calculations of Sakanaka (1972) the usual short wavelength Airy function type of oscillations were not seen. The width of the vortex was too large to confuse with Airy type oscillations. Sakanaka (1972) has given one example of a hole with width $100\lambda_D$, which is comparable with our experimental observations. Here the observed hole has a width of the order of $200\lambda_D$. The KdV equation was solved numerically for experimentally observed widths of the perturbations. These calculations show the presence of high frequency Airy function type of oscillations in the trailing edge of short pulses $\sim 5.0\lambda_D$. These solutions are in agreement with previous observations of Ikezi et al. (1973) and Okutsu and Nakamura (1979), but fail to explain behavior reported in present experiment. The validity of KdV in for such narrow perturbations is questionable.

Since large amplitude negative potential structures are under considerations, it would be more appropriate to solve the Vlasov Poisson system of equations numerically, as this would lead to a further understanding of the physical processes involved in this type of situations. The numerical calculations would provide more detailed understanding of ion velocity distributions. This would also provide a strong base for the understanding of role of vortex in phase space in the formation of double layers. It had been argued by several workers (Hasegawa and Sato, 1982 and Schamel, 1982), that the double layer formation takes place via a hole formation in the ion.
phase space and hence, similar measurements of ion velocity distribution should be made in a double layer formation.

In another experiment we have studied the basic properties of turbulence generated in a plasma from the free sources of energy available in the form of density gradients, curvature of magnetic field and the inhomogeneity in the confining magnetic fields and closed eddy structures resulting from this turbulence. The investigation shows that the plasma density and potentials are dominated by oscillations on them, the typical frequency at lower magnetic field are $\sim 9.0$ kHz. The spectral and correlation analysis shows that there are three different regions in the system, characterized by different spectral index and rms values of fluctuations. In the system these three regions are region I, which has a density gradient antiparallel to a effective g of the toroidal magnetic field, region II which is the region corresponding to very sharp density and potential gradients and region III is the innermost part of the system characterized by a weak density gradient and a good curvature of the toroidal field.

The spectral indices in these three regions were found to be $S(\omega) \propto \omega^{-6}$ to $\omega^{-7}$ in the region I, $S(\omega) \propto \omega^{-1.5}$ to $\omega^{-3}$ in region II, $S(\omega) \propto \omega^{-3}$ to $\omega^{-4}$ in the third region, showing different sources for the origin of these fluctuations active in the above mentioned regions.

The correlation analysis supports the above differences in the nature of oscillations in the three regions. The correlation times in these three regions are found to be different. The correlation analysis also reveals that the oscillations in the outer region is not correlated to the fluctuations in the inner side of the system. The contours plotted from correlation functions shows the formation of a large closed potential structure in the outer and central region of the device. The size of this structure is same as the system length in this region, i.e. the length over which density varies.

The plasma was found to be in a turbulent state at magnetic field $> 600$ Gauss, the turbulence was found to have a considerable non Gaussian distributions. The typical deviations from kurtosis of a Gaussian was found to be in the range of 0.02 to -1.4, and for skewness 2.0. The deviation was maximum in the central region (region II) of the plasma. The distributions were nearly Gaussian in the top and bottom edge of the plasma (kurtosis $= -0.02$ at $z = 12.0$, cm, $r = 1.0$ cm. Another remarkable feature was negative values of the kurtosis almost every where in the cross section, where measurements have been made. This essentially means a distribution flatter compared to a Gaussian. The probability distributions fall slowly for the negative potentials, and there exists a sharp cutoff in the positive values of
the potential fluctuations at about 60%.

The correlation analysis revealed the formation of coherent structures, but correlation functions are insensitive to sign of fluctuating field and therefore the technique of conditional averaging was used to find the coherent structures from the turbulent fluctuation. The conditional averages not only provide the information of amplitude and sign of the fluctuating field but also retains the phase information. The analysis showed the existence of large structure in the inner and central region of plasma. These structures get elongated in a direction perpendicular to the direction of density and potential gradient, over time scales $\sim 100\mu$s and then break into several smaller structures. These smaller structures move vertically down. During the evolution of these structures, eddies extending towards the radial outer locations. These are the open path for plasma particles to flow outward. Thus an enhanced transport should be observable.

In the experiments mentioned above the waves generated from the natural density gradients have been studied. The density and potential profiles were decided by the location of the cathode in the system. In the experiments reported here the cathode was placed in the center of the device and because of this we have obtained a profile as shown in chapter 5. This profile was found to be unstable to different instabilities in different regions. By changing the cathode locations either inwards or outward a monotonically decreasing density profile can be obtained. The experiment can be performed with such a profile and the origin of the resulting structures can then be identified unambiguously.

There can be another set of experiment performed with a different source of plasma e.g. a R.F. discharge to have flatter profiles. In this case the study of externally excited vortex structures can be undertaken. As a further extension of this, the convective cell type of perturbations can be launched and a study of their propagation behavior and their role in particle transport across the field lines can be made. The convective cell modes are zero frequency modes of plasma responsible for the anomalous transport of plasma density and energy. These modes are strongly modified by the nonuniformities in the magnetic field. These modifications theoretically are known to make the zero real frequency of convective cell mode to finite frequency. The toroidal geometry provides a very good system with this features. Thus a study of these modified convective cells can be made.