Summary and Outlook

We have designed and fabricated a quadrupole Penning trap in order to trap a cloud of electrons at low magnetic fields. An electron source is designed and fabricated in the trap assembly for loading the electrons. We tested electrons from the heated filament by reading the farther end cap current with respect to filament bias voltage for different filament current with magnetic field turned on and off separately. We designed a detection circuit of high Q factor (30 – 50) and coupled it to the trap to detect confined electrons through their axial motion. The detection method here used is a non-destruction method. We determined the plasma parameters of the confined electron plasma. The plasma parameters such as Coulomb parameter, usually interpreted as Coulomb logarithm, $\Lambda \gg 1$ and the Coulomb correlation parameter, $\Gamma \ll 1$, shows that the confined non-neutral plasma are weakly-coupled with their thermal energy of the particles exceeds the mean electrostatic interaction energy. We measured the storage time of the confined electrons in our trap using LabVIEW controlled voltage system. The storage time of the confined electrons for B-field 0.05 T is found to be 80 ms in our trap.
We have determined the electron-electron collision time, $\tau_{ee}$ using Maxwellian velocity distribution and is found to be $\sim 10$ $\mu$s. This is the time for which the electrons entering the trap achieve thermal equilibrium. We did a measurement on energy distribution of the trapped electron. This work demonstrates the possibility of a direct measurement of the energy distribution function by monitoring the axial motion that is decoupled from the radial motion of the electrons, through electronic detection, under condition of LTE of the trapped electrons. The electron detection signal that is obtained, following a sequence of steps wherein the storage voltage is set to different values, varies as the storage voltage. This variation does depend on the range of electron energies determined by the filament bias voltage. The energy distribution shows a peak that corresponds to the energy of the electrons determined by the filament bias voltage. By varying the filament bias we can see a clear shift in this peak in the distribution function. This variation has no dependence on the applied magnetic field. The trapped electrons that form a non neutral, non thermal plasma are in Boltzmann equilibrium for an electron gas under low pressures.

We have designed and fabricated a linear Paul trap in order to trap and cool Ca$^+$ ions. We designed the necessary electrical connections to the trap and also designed a voltage amplification circuit for rf. Calcium atom source and Ca$^+$ ion generation source is designed for thermo ionization process. We also setup necessary lasers for photoionization process in order to generate Ca$^+$ ions. We did an effort towards laser cooling and trapping of Ca$^+$ ions in linear trap. Due to some of the probable reasons as listed in the Chapter 6, section 6.6 we were unable to see Ca$^+$ in the trap. Among them the most probable reason could be the source, which was near to the trap and might have increased the pressure at the center of the trap.

We have measured hyperfine constant, $A$ in the $D_1$ line (5 $P_{1/2}$ state) of the two isotopes of Rb. The measured values of the hyperfine constant, $A = 408.340 \pm 0.010$ MHz for $^{87}$Rb and $A = 120.510 \pm 0.026$ MHz for $^{85}$Rb. The measurement has been carried out using a
different technique. Here, the laser is not locked to the particular peak rather scanned around it. The interval between two hyperfine transitions are determined by an AOM in the path of the laser beam. The values obtained from the measurement after an analysis of possible systematic errors is consistent to earlier values. Through this measurement, we have corrected the earlier reported values.

8.0.1 Future direction

In Penning trap, for the study of confined plasma cloud size and their shifts in frequencies as a function of temperature, the detection system has to be more sensitive. For this, sensitivity of the detection circuit has to improved. so, the studies require a high Q factor detection circuit with high fidelity coils. The Penning traps are widely used in the field of precision mass spectrometry. For this one require a super conducting magnets. This set up can be used to measure precise mass of the confined ion. If the mass the ion is known the same device can be used to measure strong magnetic fields precisely. By monitoring the cyclotron motion of the reference ion in a miniature Penning trap, the device can be used as high-precision magnetometer.

By coupling rf to the static electric field and the magnetic field along the axial direction the trap can be modified as a Combined trap. Combined traps are widely used in the studies of dusty plasma. Collecting the scattered light from the confined dusty plasma yields the confined plasma cloud size.