Development of VECC Cryogenic Penning Ion Trap: A Report

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Introduction

VECC Cryogenic Penning Ion trap is in advanced stage of fabrication and commissioning. The Magnet-Cryostat of VECC Penning Ion Trap [1, 2] has been cooled to liquid helium temperature (4K). The liquid helium evaporation rate is less than 100 ml/hr. A double walled evacuated scan tube has been fabricated for inserting in the liquid helium filled bore of the magnet. The scan tube has been so designed that the inside of the tube will be at room temperature, even when the outside temperature will be 4K. It is required for precise magnetic field measurement. The NMR probe used for field mapping operates at about room temperature. Therefore, a scan tube is fabricated to facilitate the NMR probe entry into the liquid helium space maintaining the temperate of probe at around room temperature

Electrode assembly design and fabrication

The trap electrode assembly having an electron source, a creation trap, a reflector arrangement and two trapping zones for analysis and precision measurement will be placed in a vacuum chamber as shown in Fig 1. Special mechanical arrangements have been designed for placing the trap precisely in the small highly homogeneous region of the magnetic field. It is also required that the axis of the trap is along the B-field, so special arrangements for alignment has been designed as shown in Fig 1. The whole assembly placed within a vacuum chamber would be lowered down by about 100 cm in the liquid helium filled bore (diameter = 10 cm) of the magnet. The vacuum chamber having indium

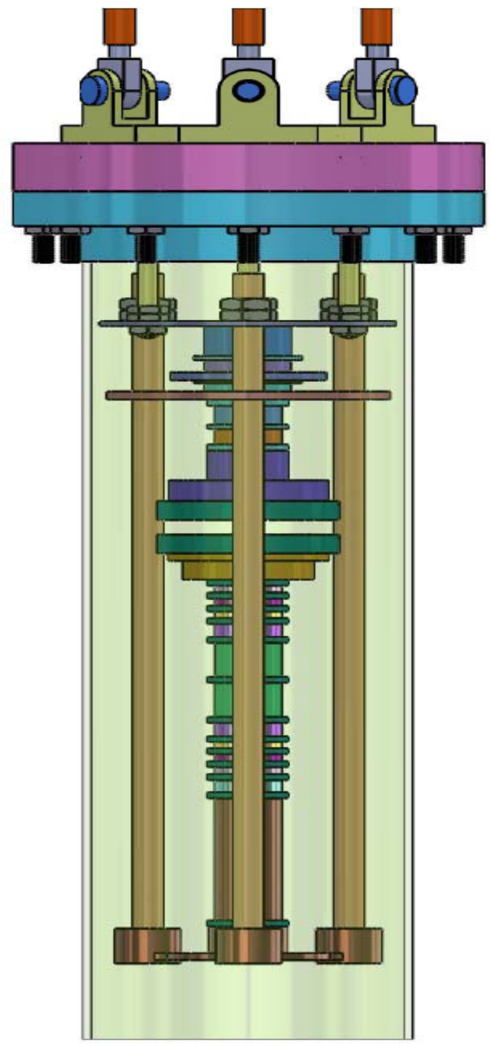

Fig 1: TRAP Electrode assembly within an evacuated chamber with axial alignment arrangement

Fig 2: Electrode assembly of trapping zone with MACOR spacers machined at VECC.

sealing for cryogenic operation has been fabricated and tested. The electrodes of the cylindrical trap separated by the MACOR spacers were machined successfully and a prototype of the trapping zone electrode assembly has been fabricated in our workshop as shown in Fig 2

Ion trapping and detection

A five electrode assembly will provide the required weak quadrupolar electro-static potential of the Penning Ion trap system for trapping ions. Detailed engineering drawing, (Fig 3) shows the dimensions of the trap with ±10 micron tolerance.

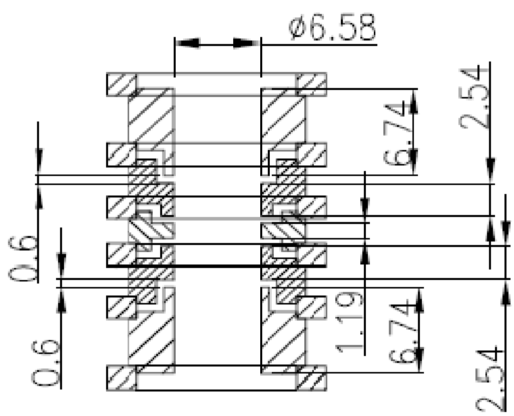

Fig 3: Engineering drawing of five electrode assembly proving quadrupolar field

Trapping potential would be applied between the central electrode called the ring electrode and the two end electrodes called end-caps. There is a pair of compensating electrodes for minimizing higher order contribution to the desired harmonic potential between the ring electrode and end caps. The dimension (*d*) of the trap is given by

$$d^2 = \frac{1}{2}(z_o{}^2 + \frac{r_o^2}{2})$$

where $(2r_0)$and $(2z_o)$ are the diameter of the inner ring electrode and closest distance between the end-caps respectively. The axial oscillation frequency of the trapped ions due to a trapping potential V_0 in a trap of dimension *d* is

$$\omega_z = \sqrt{\frac{qV_o}{md^2}}$$

The frequency variations considering a 100 micron tolerance in fabrication and applying V_0=10V as trapping voltage for some of the ions we are planning to trap are given in Table 1. Trapped Ions will be detected by measuring the induced image current on the end caps using a LCR resonant circuit cooled to 4K. The cryogenic resonant circuit for detection is being developed.

Table 1: Axial Frequency variation of ions

Ion	f_z+	f_z-
^{7}Be	537.15 kHz	534.51 kHz
^{9}Be	473.72 kHz	471.40 kHz
^{4}He (alpha)	1.0049 MHz	999.98 MHz
electron	60.661 MHz	60.363 MHz
^{12}C	410.26 kHz	408.24 kHz

References

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