Progress in VECC Cryogenic Penning Ion Trap Development

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Introduction

The development of the Cryogenic Penning Ion trap poses several challenges for its high precision fabrication and its operation at cryogenic temperature. The mechanical fabrications of all the components of the trap setup have been completed as per drawing and assembled. The electronics for the detection of the trapped electrons/ions in resonant mode are being developed indigenously. The development of cryo-electronics test setup, cryo-feed throughs, circuit details are discussed in this report.

Mechanical fabrication and assembly

The assembled Penning trap components are shown in Fig. 1. The 5-electrode trap assembly is hung from the bottom flange of the setup and enclosed in a vacuum-tight copper chamber. Indium sealing has been used to make the copper chamber vacuum-tight and it has been fabricated and tested down to 77K. The entire assembly would be placed in the liquid helium-filled bore of a superconducting 5 Tesla persistent mode magnet that was commissioned earlier [1]. The bottom flange of the assembly has been hung by three G10 rods and six radiation baffles are held on to the G10 rods by a special arrangement in order to reduce the radiation heat load. Special bellows have been provided to the top flange for placing the trap electrode assembly at a proper position within 1cm DSV inside the magnet bore.

Special feedthroughs are required for applying high voltages to Penning trap electrodes and for taking out electrical signals from the Penning trap electrodes placed in an ultrahigh vacuum chamber immersed in liquid helium. The development and installation of such special feedthroughs has always been a challenge.

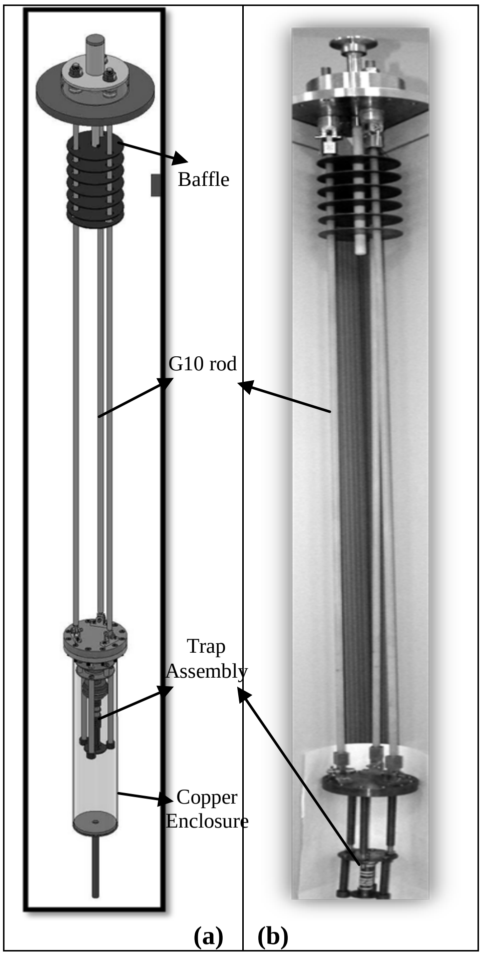

Fig. 1 (a) Trap assembly conceptual and (b) fabricated and assembled trap assembly

Recently, a simple, nonmagnetic multipin, electrical feedthrough system that can operate in cryogenic environment has been developed and tested down to 77K. This feedthrough system is based on indium sealing between an OFHC Copper (Oxygen Free High Thermal Conductivity Copper) plate and G10 block with conducting OFHC copper pins (through which voltages would be applied and signal taken out) screwed through the G10 block with the help of M6 copper screws sealed to the G10 block by indium sealing as shown in Fig. 2(a). Alternative feedthrough systems are also under investigation.

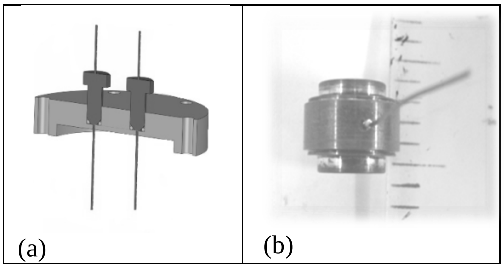

Fig. 2 (a) 3D drawing of cryogenic feedthrough (b) Laser welded copper pin on trap electrode

Another set of OFHC copper pins has been laser welded to the tiny (smallest one of diameter 2.12 mm) Penning trap electrodes using Nd:YAG laser beams of diameter 2 mm at RRCAT, Indore. A laser welded OFHC copper pin to an electrode has been shown in Fig. 2(b).

Two sets of trap electrodes and MACOR spacers were fabricated one set at VECC, workshop and another at MPIK, Germany with an average tolerance of 20 microns. Precision measurements of the fabricated electrodes were done using Coordinate measuring machine (CMM) and a set of five electrodes was chosen among the fabricated electrodes based on our simulation studies to minimize the anharmonic coefficients of the quadrupolar electrostatic potential created by the trap electrodes. Our simulation studies using SIMION 8 code [3] shows that the assembled electrodes should produce a nearly perfect orthogonally compensated quadupolar potential over a 3 mm region near the center of the trap.

Simulation studies

We have also designed a seven electrode orthogonalized trap with higher order compensation based on the works of Fei et al. [4] and Farrar et al.[5]. The details of the work are given in ref [6].

Development of cryogenic detection circuit in resonant mode

A resonant circuit with a high Q-value is being developed to detect trapped electrons/ions for precision studies. An essential requirement in this development is the determination of the trap capacitance at cryogenic temperature. A two stage cryogenic setup has been developed and the measurement of the trap capacitance has been done down to 94K. The data analysis is in progress. The setup details and measurement scheme has been discussed in ref [7].

References

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