VECC Cryogenic Penning Ion Trap: A status report

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Introduction

The Magnet-Cryostat of VECC Penning Ion Trap [1] that would house the Penning trap assembly was commissioned on 17/2/2012. The electrode assembly for loading, trapping and ion detection set up for this cryogenic trap facility is in an advanced stage and the progress made is reported here.

Commissioning of the magnet-cryostat system

The magnet-cryostat system had been kept at liquid helium temperature (4 K) for quite some time and cryostat stability was tested for any quenching effect before powering up the magnet. Only then it was powered up by inserting a detachable charging wand through the charging port of the system. In order to send current through the main superconducting coil, a superconducting persistent mode switch was at first heated up by sending 55mA current through a heater placed close to it. As the persistent switch became resistive, it allowed us to send current through the main solenoid coil. The current in the main solenoid coil was raised slowly from zero to 96.9 Amp (corresponding to 5 Tesla magnetic field). This is the maximum magnetic field that can be obtained from the system as per design specification. After attaining the maximum current, the heater of the persistent switch for the main coil was turned off and the switch was allowed to cool off to reach superconducting temperature. As soon as the persistent switch became superconducting again, 96.9 Amp current started flowing in a closed loop comprising the main solenoid magnet coil and the switch. At this stage, the current from the power supply was switched off and the system started running in the persistent mode.

Then seven superconducting shim coils were energized one by one. In order to do that, the persistent mode switch of each shim coil was first made resistive by sending 90 mA current through a heater placed close to it. As the switch became resistive, current was sent through the shim coil. The current through the shim coils varied from 0.67 Amp to 4.1 Amp as per requirement. As the current reached appropriate value, the heater was turned off and the switch was allowed to cool off and became superconducting again. Then the current started flowing in a closed loop comprising the shim coil and the switch, the external current was switched off and the shim coil was put in persistent mode.

After putting the main coil and all the seven shim coils in persistent mode, the external power supply was switched off and the power cables were disconnected from the magnet. The magnetic field remained as before. After running the system in persistent mode for 17-18 hours, we reconnected the power cables to the supply and measuring devices to measure currents through the solenoid main coil and shim coils. We found all the currents were exactly the same as before showing that the system was running in persistent mode perfectly well.

Design, Simulation, Fabrication and measurements of electrode assembly for electron trapping

Design of a five electrode cylindrical trap assembly that would provide the quadrupolar potential has been done taking into account realistic gap effects. Extensive simulation works have been done and a careful choice of electrode lengths, voltages applied to various electrodes have been done so that a high quality electrostatic quadrupole potential at the centre of the trap would be produced and the orthogonality condition making trapping potential depth independent of the anharmonicity tuning voltages applied to correction electrodes voltages would be satisfied. The parameters of this trap assembly orthogonalzied over 0.54 mm are given in Table 1.

Table 1: Trap Parameters

Dimensional (mm)		Potential parameter	
r_0	3.29	V_0	10 V
Z_0	3.04	V_c	4.9874 V
d	2.706 8	C_0	0.57463
L_{ring} (l_r)	0.92	C_2	0.65202
$L_{correction}$ (l_c)	1.38	C_4	1.17E-4
L_{endcap} (l_e)	10.00	C_6	0.0668
L_{gap} (l_g)	0.60	C_8	-0.00934

Trapped particles execute a motion which is a superposition of three oscillatory motions: an axial motion, at frequency ω_z which is along the magnetic field axis, a trap-modified cyclotron motion (ω_+), at a higher frequency and a magnetron motion (ω_-) at a much lower frequency [2]. The trajectories of electrons and beryllium in the above mentioned trap geometry have been studied using SIMOION8 code [3] and axial frequency extracted is in agreement with theoretically calculated values shown in Table 2.

Table 2: Simulation vs Calculation

ION	Axial Frequency(ω_z) in MHz	
	Calculated $\omega_z = \sqrt{\frac{qV_0}{md^2}C_2}$	Simulation (95% confidence level)
Electron	3.959×10^2	3.956×10^2
^{7}Be	3.508	3.501
^{9}Be	3.091	3.087

In order to determine the capacitance of the trap electrode assembly under cryogenic condition for the determination of the design value of the inductor required for resonant ion detection technique an oscillator circuit has been designed and is under testing.

The complete setup with Field Emission Point (FEP) holder and accelerating electrode for electron generation and trap assembly is shown in Fig 1. and it is under fabrication.

Results and Discussion

The magnet-cryostat of VECC Penning Ion Trap facility has been commissioned. The trap electrode assembly, insertion arrangement and detection setup are being fabricated. Simulation studies are being pursued with virtual assembly for understanding response of the trapped ions.

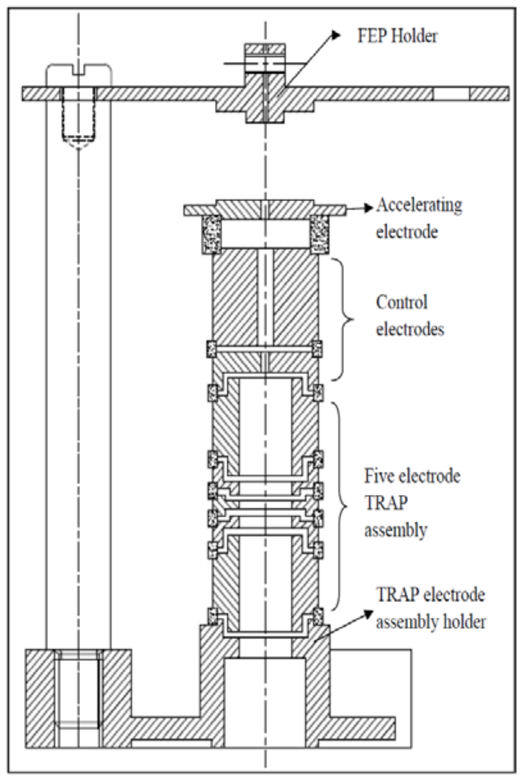

Fig. 1 TRAP assembly with electron source

References

[1] P. Das et al. Proc. Of the National Symp. On Nucl. Inst-2010, **33** (2010)
[2] K. Blaum, Phys. Rep. **425** (2006) 1
[3] SIMION 8.0 user manual