STATUS OF THE SUPERCONDUCTING CYCLOTRON PROJECT AT KOLKATA

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Abstract

The superconducting cyclotron under construction at this Centre has K_{bend}=520 and K_{foc}=160. Fully stripped ions can be accelerated up to about 80 MeV/nucleon energy. All parts of the main magnet frame have already been machined. They are undergoing inspection tests at the vendor's site. Trial windings on a full-scale dummy bobbin have recently been completed to get hands on experience on the winding techniques, using an elaborate superconducting coil winding set up at VECC. Fabrication of the RF resonators is going on. The He liquefier/refrigerator has been operating on site for over a year now. Fabrication contract for the cryostat and related accessories has recently been awarded. The cryogenic transfer lines are in the process of finalization for awarding the contract. Several other sophisticated components and parts are being fabricated in-house. Construction of the building and support services is going on full swing. The experimentalists are planning for large-scale experimental facilities and are in the process of obtaining funds for the same.

1 INTRODUCTION

The K=130 room temperature cyclotron (VEC), operating at this Centre for the past two decades for light ions, has recently started accelerating light heavy ion beams from a 6.4 GHz ECR source[1]. In order to extend the heavy ion acceleration capability of the VEC, a more powerful and versatile ECR source operating at 14.4 GHz RF frequency has been commissioned at the Centre. This source, supplied by M/s PANTECHNIK, can also produce highly stripped solid ions. The source has been tested to produce intense heavy ion beams such as 20 μA of O^{8+}, 18 μA of Ar^{14+}, 2 μA of Xe^{30+}, 1 μA of Pb^{36+} and 2 μA of Ta^{32+} at 20 kV. Injection from the new source into VEC will be done towards the end of 2001. Figure 1 shows injection schemes from two sources. A low to medium-energy heavy ion facility will thus soon be available to the experimentalists at Kolkata (Calcutta). In order to extend the scope of research with heavy ion beams at VECC, we decided after extensive deliberations, in the early 90s, to construct a superconducting cyclotron operating in stand-alone mode. Design of the K500 cyclotrons operating at the NSCL, East Lansing[2] and the Cyclotron Institute, College Station[3] was adopted. It will be the largest nuclear physics facility available in India during the next one decade or more. Eventually, one or both the ECR sources will be moved to the superconducting cyclotron laboratory in the same campus. The VEC will then operate as the primary beam source for a low energy Radioactive Ion Beam (RIB) facility that also is under construction.

Construction of the superconducting cyclotron[4] has been going on steadily but with a bit slower than desired pace. This is due to the complexity in fabrication of several components and the reluctance of the industry to take up such jobs. Further delays were introduced by difficulty in availability of certain crucial items. Situation has however, improved recently. We hope to start the beam commissioning trials around the beginning of 2005. Figure 2 shows layout of the accelerator and the beam lines.

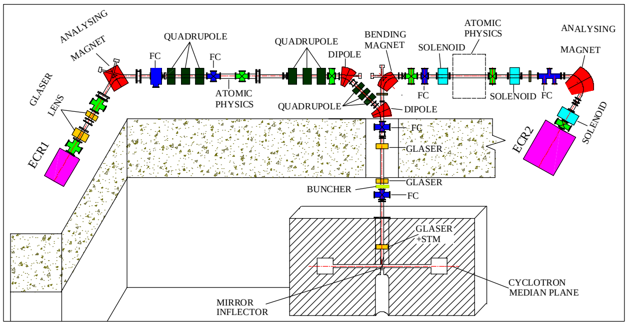

Figure 1 : ECR beam injection lines for VEC

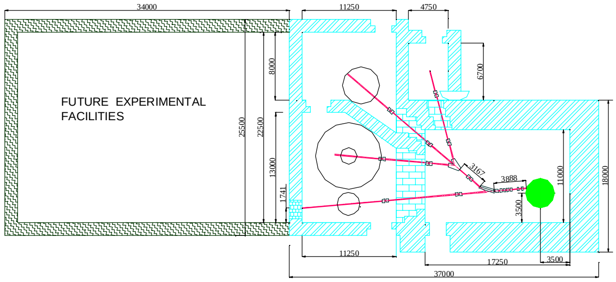

Figure 2 : Beam line layout for the K500 superconducting cyclotron under construction at Kolkata.

2 STATUS OF VARIOUS SYSTEMS

2.1 Main Magnet Frame

All parts of the frame are made of low carbon steel forgings. Rigorous chemical and ultrasonic tests were performed on the forgings prior to machining. All except one, i.e., the upper pole cap forgings were accepted in the first instance. A large cylindrical forging for the upper pole cap, weighing about 60 tonnes, was rejected because an unacceptably large void/inclusion was noticed at its edge during the ultrasonic tests. Magnetic field analysis showed that this defect would give rise to a first harmonic with amplitude ~1.6 gauss at the extraction radius for a void/inclusion thickness of ~3 mm. New forging was, eventually, made with acceptable quality. All parts of the frame have been machined, generally, within acceptable tolerance utilising a number of jigs and fixtures specially made for the purpose. However, during the assembly tests several deviations are being seen and analysed for correction. Drilling of numerous holes posed considerable problem, as the material is very soft. Figure 3 shows the pole tip family components assembled on the pole base for dimensional checks. Figure 4 shows the machining operation on the central return path ring. It allows several insertions into the acceleration chamber.

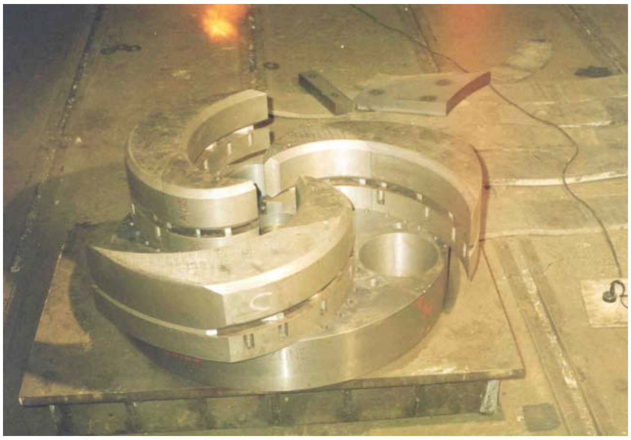

Figure 3 : Pole tips assembled on the pole base for inspection at the fabrication site.

Figure 4 : Machining of the central return path ring for the main magnet frame.

2.2 Superconducting Coil

The elaborate set up for winding the superconducting coil has been used to wind dummy coil on a full-scale dummy bobbin to get a feel of the actual job as well as to train the coil winding team. Several layers were wound utilizing NEMA G-10CR spacers that will be used for the actual coil. This set up, shown in figure 5, has been fabricated and installed by a private firm as per our requirements. It consists of several stations for various operations and checks during winding process. Figure 6 shows a picture of the dummy bobbin and coil. Actual winding starts in the late 2002. By this time the manufacturer will have supplied the SS bobbin that will, eventually, become part of the cryostat. Reference 2 gives more details of the superconducting coil winding process. A 1/5th scale

Figure 5 : Superconducting coil winding setup at VECC.

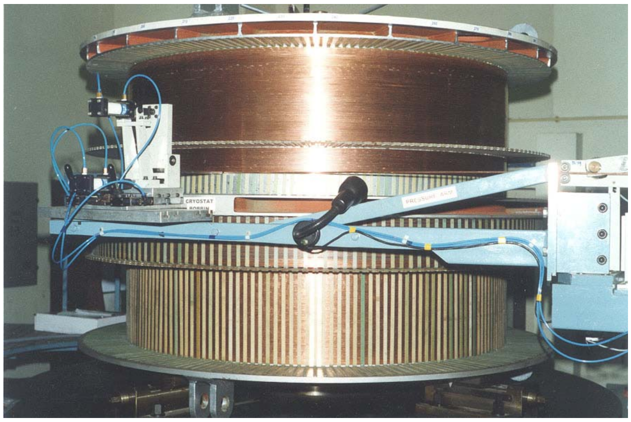

Figure 6 : Dummy bobbin and coil.

model of the superconducting coil is being wound with minor modifications in the set up. This coil will be tested in a set up involving an SMD20 dewar from M/s Oxford Instruments. This facility is coming up fast and will also be used to characterise the superconducting cable.

2.3 Cryostat

This part of the superconducting cyclotron is, possibly, the most intricate and complex in construction due to its 'combined function' role. It houses the coil at 4.5K and also provides positioning/driving access for several extraction and diagnostic components inside the acceleration chamber. The main magnet frame encloses the cryostat assembly. We have faced several problems in getting it fabricated. Most fabricators are, in the first instance, reluctant to take up the job being one of its kinds. The machining and assembly tolerances are rather tight. Further, the fabrication and assembly has to be done interactively with the coil winding. All these factors and our official procedures considerably delayed placement of the fabrication contract. However, it is now in place. The manufacturer will do the final assembly in the cyclotron vault after the coil winding has been completed. In the mean time, we have been simulating the entire assembly on computer (figure 7) to check accuracy of the drawings and work out the sequence of operations. Heat load calculations for the entire assembly have been done[5].

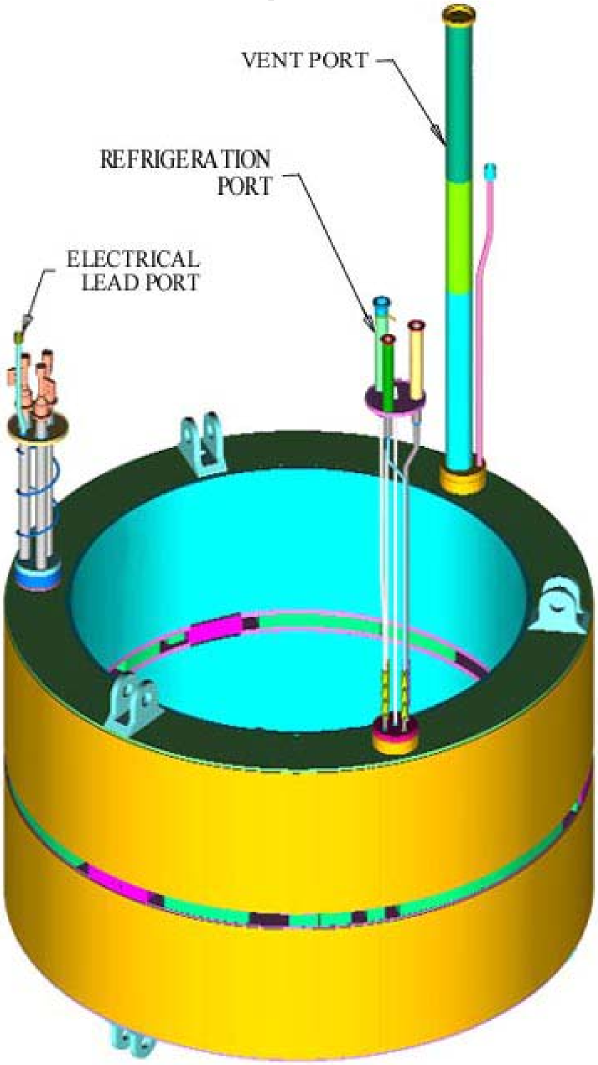

Figure 7 : Computer generated bobbin assembly.

2.4 Cryogenic Transfer Lines and Plants

General layout and specifications for the cryogenic delivery system have been finalized as per the design of our building. We are negotiating with the possible vendors for its fabrication and installation. Apart from supplying LHe to the cryostat, a major function of the transfer lines is to cool the cryopanels that are used to evacuate the acceleration chamber to high vacuum. The cryogens must be pumped up from below the cyclotron to the cryopanels through the RF resonators. Figure 8 shows the flow diagram of the LHe delivery system. A delivery system that eliminates the use of pumps for circulating the cryogens is also being investigated. Both LN2 jacketed as well as vacuum jacketed transfer lines will be used to transport LHe.

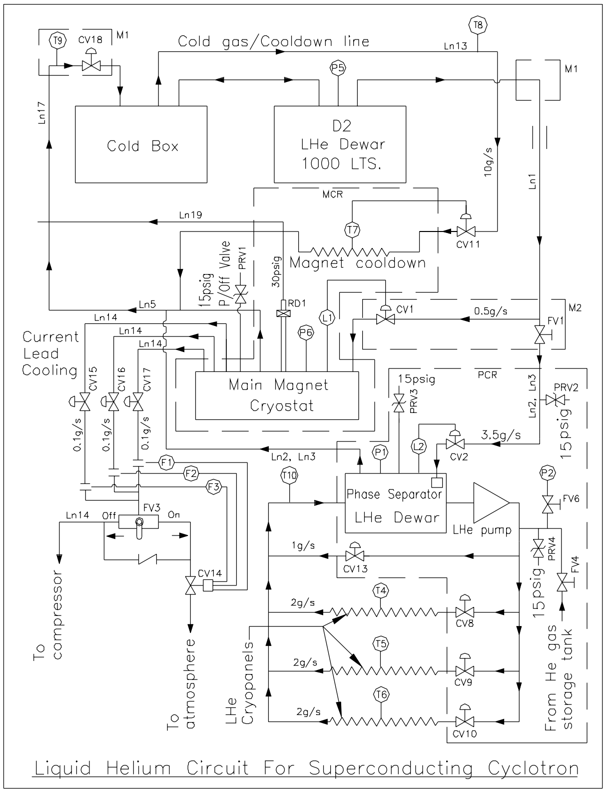

Figure 8 : Flow diagram of LHe Delivery System.

The HELIAL 50 liquefier has been installed last year on a temporary site in the campus. It has been operating quite well. The liquefaction capacity with LN2 pre-cooling is 100 l/h while without pre-cooling it is 50 l/h.

Refrigeration capacity with LN2 pre-cooling is about 200W at 4.5K. A 1000 litre dewar has been provided as buffer. The plant will be moved to its permanent site near the cyclotron when the building is ready in 2002.

2.5 Radiofrequency System

The RF system has operational frequency range 9 to 27 MHz and the maximum dee voltage is expected to be 100 kV. Several parts of the RF resonators are under fabrication. The Central Workshops of BARC, Mumbai (Bombay) have taken up the job with our collaboration. Like in the case of the cryostat, we have faced problems with the vendors in view of sophisticated techniques involved in the fabrication. Moreover, the material for fabrication is OFHC copper for majority of the parts. Computer modelling of the dee shell and dee shell former was done. Scaled down prototypes have been fabricated to learn and perfect the techniques involved.

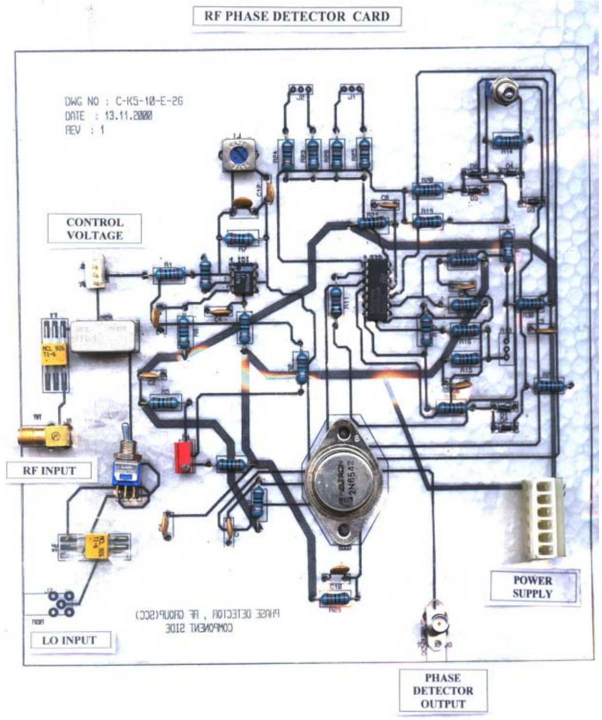

Figure 9: Dummy assembly of the RF Phase detector.

Eimac 4CW 150000E tetrode tube will be used for each of the 3 amplification stages. A variety of circuits are being fabricated in house. Several PCBs for the low power electronic circuits are being designed and developed. Figure 9 shows the dummy assembly of an RF phase detector circuit.

2.6 Trim Coils

Intricate jigs and fixtures have been fabricated for winding the trim coils. These are conventional coils. There are 13 sets of trim coils wound around the pole tips. OFHC copper conductor with 6.35 mm square cross section and central hole for water cooling will be used. Several coils have already been wound. The coils will be epoxy impregnated. Figure 10 shows a part of the trim coil winding set up.

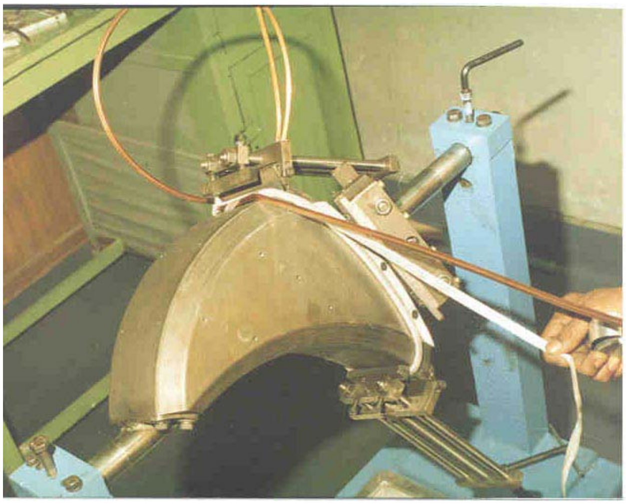

Figure 10 : Trim coil winding set up.

2.7 Magnetic Field Measurements

We plan to carry out elaborate magnetic field measurements to assess quality of the main magnet and to calculate the operational settings with best possible accuracy. A measurement set up based on the ones used at College Station and East Lansing is being developed in collaboration with a vendor. However, the data acquisition and control software as well as instrumentation are being developed at VECC.

2.8 ECR Sources

In addition to the PANTECHNIK's 14.4 GHz ECR source, an indigenously designed source is also being

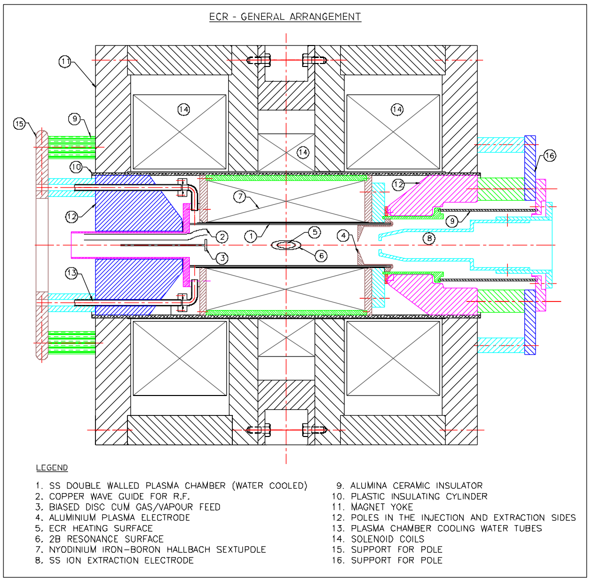

Figure 11 : Line diagram of the 14.4 GHz ECR source under construction .

constructed. This source will also operate at 14.4 GHz microwave frequency. Some parts of this source are already under fabrication. The axial mirror peak field on the injection side is 12 kG and on extraction side it is 10.75 kG. A 'halbach' type permanent magnet sextupole geometry with 11.24 kG field at the inside plasma wall will be used. Figure 11 shows the diagram of this source.

2.9 Power Supplies

Two 20V, 1000A power supplies for energising the α and β superconducting coils have been purchased from M/s DANFYSIK. They come along with the dump resistors and associated electronics. The supplies have now been put on a test bench for carrying out various operational studies. We shall also develop the standby power supplies at VECC. Several other power supplies such as those for the trim coils, RF system, extraction system, beam line magnets, ECR and injection line magnets etc. are being fabricated, largely, in house. This is a large activity involving fairly large amount of manpower. Elaborate fabrication and testing facilities have been set up.

2.10 Computer Control & Beam Diagnostics

The overall control mode has been planned to be open-loop control of accelerator operations and intelligent beam property regulation through various diagnostic devices. The NT & Linux work stations at console, Ethernet LAN for connectivity, Pentium PCs with Windows NT/CE and VXworks for front end and CAN, RS485, RS422, GPIB, Add-on modules for device interfacing are favoured at present. A number of single and multi-tasking application systems have been developed. They are being tried out with the existing cyclotron. Some developmental work in the area of capacitive as well as scintillation detector phase probes and image digitization has been carried out.

2.11 Beam Lines and Experimental Facilities

Layout of the first 3 experimental caves that are presently under construction is shown in the figure 2. Preliminary design calculations on the beam steering and phase space matching systems, immediately after extraction, have been carried out. Ion optics of the rest of the beam transport system utilises the two bending magnets to reduce the dispersion coefficients to a certain extent. The optics beyond the second magnet is telescopic in nature.

The experimental facilities that are being planned for these experimental caves include a large multipurpose scattering chamber, a 4π charged particle array, high energy γ-detector array, discrete γ-detector array etc. The undeflected beam line will take the beam to a large hall to be constructed soon for housing the facilities such as projectile fragment separator etc. Several national groups are working on finalisation of the first phase of experimental facilities. Facilities are also being planned to carry out experiments in the fields of material sciences, chemistry, radiochemistry etc.

Work on the construction of new building for the accelerator is coming up fast. We expect to occupy the building, along with limited services, for accelerator activities in the third quarter of 2002.

3 PROJECT SCHEDULE

We expect that all parts of the main magnet frame will be delivered to us by November 2001 after making a trial assembly of the frame for inspection at the manufacturer's site. The cryostat bobbin is likely to be available for the superconducting coil winding at VECC by April/May 2002. The coil winding may take about six months to be completed. The assembly of cryostat in the vault of the superconducting cyclotron building will begin early 2003. In the mean time, installation of the LHe plant and associated systems will be going on at its permanent site near the main building. The cryogenic delivery system will also be installed during this period. We expect to energise the main magnet sometime during the second quarter of 2003 and complete the magnetic field measurements early 2004. Assembly of the rest of the cyclotron systems will be carried out during 2004 to begin the commissioning trials sometime early 2005.

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