STATUS OF THE SUPERCONDUCTING CYCLOTRON PROJECT AT VECC

Bikash Sinha and R. K. Bhandari
Variable Energy Cyclotron Centre, Department of Atomic Energy, Kolkata 700 064, India

Abstract

A superconducting cyclotron with K_{bend}=520 and K_{foc}=160 is under construction at this centre. Heavy-ion beams of 80 MeV/nucleon energy will be available from this cyclotron. Fabrication and development of most of the major systems have advanced significantly. The 80 tonne main magnet iron structure has been successfully fabricated and is being installed in the new cyclotron building at VECC campus. The superconducting coil was wound on the cryostat bobbin late last year using a specially developed winding set up. The liquid helium chamber housing the coil has been welded shut. The cryostat containing the superconducting coil is being assembled. The cryogenic delivery system both for LHe and LN2 for the main magnet cryostat is also being fabricated. The 200W (at 4.5K) helium liquefier / refrigerator is being relocated and re-commissioned in the main accelerator building complex. Main magnet power supply along with dump resistors and control logistics has been installed and tested in position. Trim coil power supplies are also being commissioned. We expect to begin the energization trials of the superconducting coil (stored energy about 22 MJ at full excitation) in the third quarter of 2004. Development of the elaborate magnetic field measurement set up is also near completion. Extensive measurement of magnetic field and its harmonics has been planned to evaluate the beam dynamics. Work is also proceeding on fabrication of the intricate RF cavities that will operate at room temperature. Various groups are engaged in the development of other systems such as RF amplifiers, LHe cooled cryopanels, ECR ion source and injection, extraction, diagnostics, controls, beamlines etc. Funding has recently been approved by the government for development of elaborate experimental facilities to utilize effectively the cyclotron beams. They include a large scattering chamber, charge particle detector array, ion trap and irradiation facilities. The superconducting cyclotron will become a national facility for various universities and institutes. It will also be open to the international experimental physics community.

INTRODUCTION

The K=130 room temperature variable energy cyclotron (VEC) has been accelerating light heavy ions (oxygen, neon, sulphur, argon etc.) over the years [1]. The cyclotron is equipped with two ECR ion sources, an indigenously developed 6.4 GHz ECR source and a 14 GHz ECR source supplied by M/s PANTECHNIK, the later one is able to produce also metal ions for injection into the VEC. Thus, VEC provides low to medium energy heavy ion beams to the experimentalists. In order to extend the scope of the research with heavy ion beams at VECC, the superconducting cyclotron project was conceived in the early 90s. The design is similar to the cyclotrons operating at National Superconducting Cyclotron Laboratory (NSCL), East Lansing [2] and the Cyclotron Institute, College Station [3]. After some initial delay in progress due to various unavoidable reasons [4], the superconducting cyclotron project is now smoothly and rapidly moving towards the commissioning phase. Figure 1 shows the beamlines layout for the superconducting cyclotron facility.

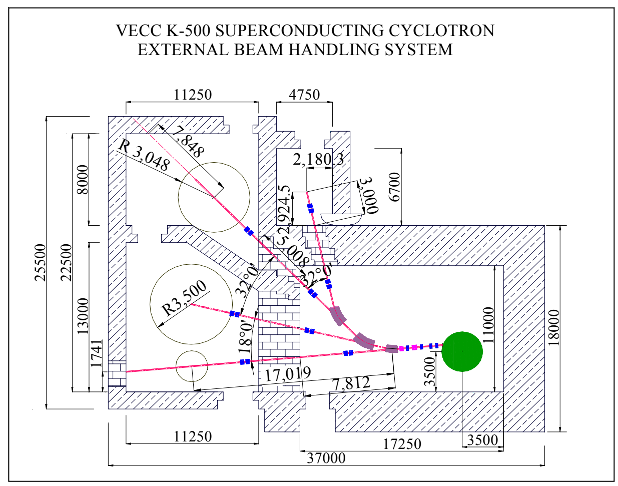

Figure 1: Beamlines layout for the superconducting cyclotron at Kolkata

STATUS OF VARIOUS SYSTEMS

Main Magnet Frame

M/s Heavy Engineering Corporation Ltd., Ranchi (about 400 km from Kolkata) have machined the main magnet iron frame in several parts. The composition of the magnet iron has been made from same heat of steel to get near uniformity of chemical composition, physical homogeneity and grain size. The achieved chemical composition is as follows: C 0.12 – 0.15%, Mn 0.21 – 0.25%, Si 0.1 – 0.18%, S 0.007 – 0.017% and P 0.005 – 0.010%. The magnet frame assembly is being installed in the new cyclotron building at VECC campus. Magnet pier supporting systems have been fabricated, installed and levelled within 800-micron accuracy. Then the pole base has been mounted on the pier supports. Figure 2 shows the lower pole cap mounted on the pier supports in the cyclotron building. Lower pole tips have been installed on the pole base and levelling achieved within specified tolerance (figure 3).

Figure 2: Main magnet pole base mounted on the pier support in the cyclotron building.

Figure 3: Pole tips installed on the pole base.

Superconducting Coil

Winding of the main superconducting coil on the bobbin made from SS316L was completed in September 2003 as per specifications. The coil winding was done in-house using an automatic winding setup developed based on our conceptual design by a reputed vendor (Figure 4). Strict quality control was enforced during coil winding. NbTi multifilamentary composite superconducting cable (I_c = 1030 A at 5.5 Tesla and 4.2 K), consisting of 500 filaments of 40 micron diameter embeded in copper matrix was used. The characteristic details of the coils are given in the table 1.

Table 1

α coil	No. of turns/coil	1084
	Total Length (km)	5.7
	ID and OD (mm)	1521and 1793
	Inductance (H)	13.8
β coil	No. of turns/coil	2234
	Length (km)	11.7
	ID and OD (mm)	1521 and 1793
	Inductance (H)	27.6

Figure 4: Superconducting coil winding in progress

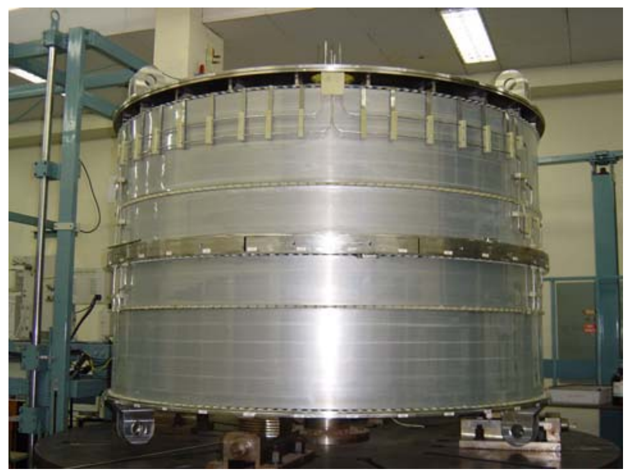

Figure 5: Superconducting coil for the cyclotron magnet

Cryostat

The cryostat is now in the final stage of assembling in the cyclotron building. Necessary cryogenic instrumentation such as LHe level sensors, temperature sensors, strain gauges etc. have been installed inside the LHe chamber. This chamber has been insulated with multilayer insulation and LN2 cooled radiation shield assembled around it. The current leads, refrigeration lines and vent lines have also been welded to the LHe chamber and insulated (Figure 6). Finally, the whole insulated assembly has been welded inside the iron vacuum chamber (so called Coil Tank, Figure 7). Median plane penetrations for several extraction and diagnostic elements are being positioned and welded. After the final assembly, helium leak test will be performed and then the cryostat assembly will be shifted to cyclotron vault and installed on the magnet frame.

Figure 6: Cryostat bobbin with multilayer insulation and LN- 2 cooled radiation shield. Support links are also shown.

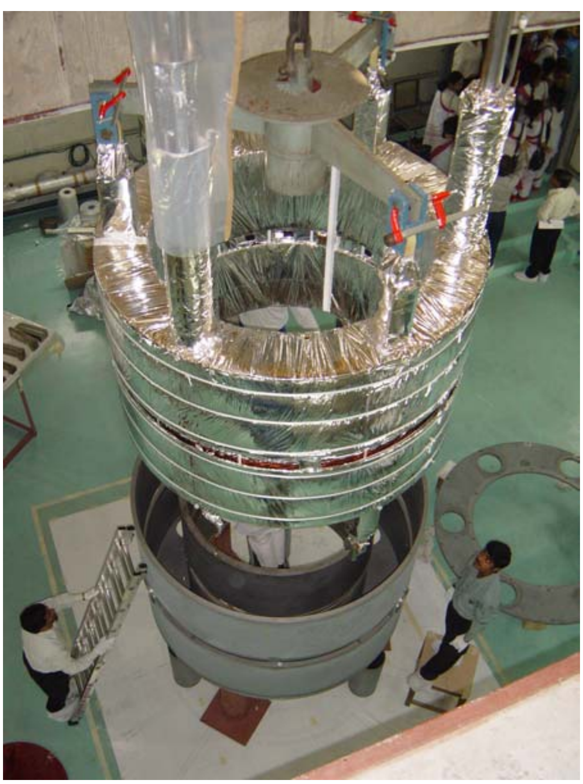

Figure 7: The insulated cryostat bobbin and LN2 shield assembly is being installed within the iron vacuum chamber (Coil Tank).

Figure 8: Final assembled cryostat without median plane inserts.

Cryogenic Delivery System

The cryogenic delivery system will supply cryogens, i.e., liquid helium and liquid nitrogen to the main magnet cryostat and the cryopanels used for evacuating the acceleration chamber. The design of the cryogenic delivery system has been finalized. The vacuum jacketed and liquid nitrogen shielded transfer lines have already been fabricated and tested successfully at manufacturers' site (Figure 9).

Figure 9: Vacuum jacketed and liquid nitrogen shielded cryogenic transfer lines under fabrication.

Other major components such as PLC control system, liquid helium and liquid nitrogen valves, instrumentation components etc. are being purchased. Various sensors for this cryogenic system, viz., temperature, level, pressure, strain, vacuum and their measuring units have already been tested thoroughly.

Radiofrequency System

The RF system has frequency range 9 to 27 MHz and the maximum dee voltage about 100 kV. Some of the RF cavity components such as panels, moving short, contact fingers, drive mechanisms etc. have already been fabricated/ purchased by the Centre for Design and Manufacture at BARC, Mumbai in consultation with VECC engineers. Other major components such as the inner and outer conductors, dee shells, liners etc. are currently on order. The electronics part of the RF system is being developed in-house at VECC. Most of the major components like power tubes, amplifiers, diagnostic equipment etc. are now available with RF group at VECC. The PCBs for various circuits have been designed and are in the process of getting fabricated.

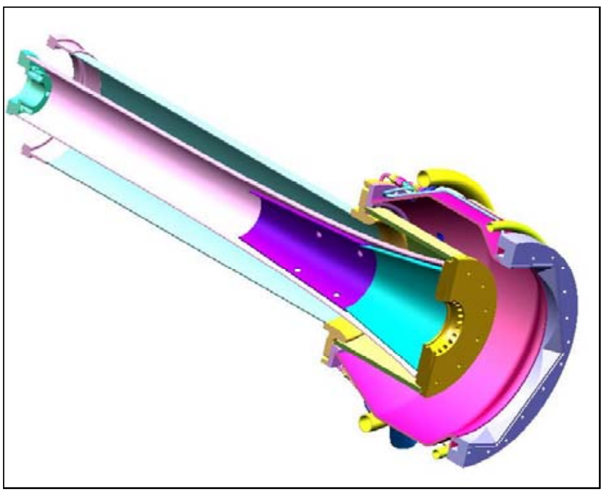

Figure 10: Computer generated model of inner and outer conductor of RF resonator with cooling lines.

Trim Coils

All the 78 trim coils, made of water-cooled copper conductor, have been wound successfully. Two trials of vacuum impregnation with epoxy resin for inner pole tip have been made. In order to improve on the shortcoming of impregnation process, it has been decided to make one more trial of vacuum impregnation with outer coil. Finally, after field measurements, the trim coils will be mounted on the pole tip and then vacuum impregnation will be done with epoxy resin and re-assembled.

Magnetic Field Measurement System

The entire set up for carrying out elaborate measurements of magnetic field and the harmonic components with high degree of accuracy is being developed, both in house and by M/s. Patel Analog and Digital Measurements Co. Pvt. Ltd., Pune. The measurement schemes have been prepared by the accelerator physicists and engineers involved in the project. We expect to start magnetic field measurements around the end of 2004 and complete by September 2005. Accelerator physicists are developing codes for processing and analysing the measured field data. To correct for the field imperfections, if any, and to find out the operational parameters of the cyclotron for efficient beam acceleration and extraction, the orbit tracking codes, developed at MSU and VECC, will be used

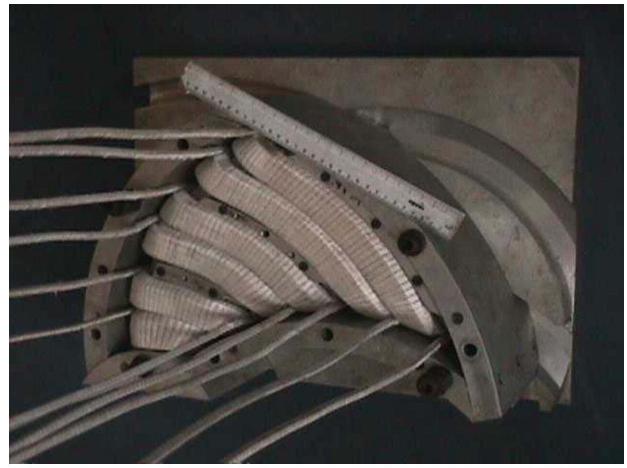

Figure 11: Trim coils wound on pole-tip.

ECR Ion Sources

In addition to the 14 GHz ECR ion source already operating at VECC, an indigenously designed source is being constructed. This source will also operate at 14 GHz microwave frequency. The axial mirror peak field is 12 kG on the injection side and 10.75 kG on extraction side.

Power Supplies

The 10 ppm class power supply for the main coil along with dump resistors has been installed in position after elaborate tests using a dummy load. The control logistics have been developed by our engineers and tested. Eighteen trim coil power supplies have also been tested and are awaiting installation in the cyclotron building basement area.

Extraction System

The extraction system consists of two electrostatic deflectors and nine magnetic channels. The M9 magnetic channel involves major design change as compared to the Texas K500 machine. We are going to make it active rather than a passive channel. Detailed calculations of the beam dynamics through the extraction system have been done.

Control System and Beam Diagnostics

All the technical systems of the cyclotron will be computer controlled. We are planning to have a distributed control system connected through ETHERNET LAN. Mostly PCs with Windows and UNIX based systems will be used. A number of single and multi-tasking applications have been developed. Those are being tested with the existing cyclotron. Developmental work in the area of capacitive as well as scintillation detector phase probes and image digitisation has been carried out.

Beamlines and Experimental Facilities

The layout of the experimental area is shown in the figure 1. Preliminary design calculations on the beam steering and phase space matching, immediately after the extraction of beam from cyclotron, have been carried out. The external beam transport system uses two bending magnets to reduce the dispersion coefficients to a certain extent. The ion optics beyond the second bending magnet is telescopic in nature.

Experimental facilities planned for the superconducting cyclotron include a large multipurpose scattering chamber, a 4π charged particle array, high energy gamma detector array etc. Several national groups are working on the development of these experimental facilities.

ACKNOWLEDGEMENTS

Construction of the superconducting cyclotron is a team work of several scientists, engineers and administrative staff of the centre. We are grateful to all of them for their contribution. Our special thanks are due to Mr. Malay Kanti Dey for the help in preparing this paper.

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