

VEC, CALCUTTA - DEVELOPMENTS AND STATUS

A.S. Divatia, Santimay Chatterjee, S.S. Ramamurthi and N.K. Ganguly  
Variable Energy Cyclotron Centre, Bhabha Atomic Research Centre  
Calcutta-700 064, India

VEC is now operating regularly for experiments with alpha beams with energies between 26 to 85 MeV. This national facility is being utilized by various user groups for basic and applied research in nuclear physics, solid state physics, radiochemistry, biomedicine and radioisotope production. A new driven radiofrequency system based on the RCA 4648 tube has been incorporated. The performance of the beam transport system has been greatly improved. Narrow pulses of 4 ns ( $10^0$  RF) width could be obtained without the use of internal slits. High resolution beam lines are being designed. Fabrication and development work on a QSD magnetic spectrometer is progressing rapidly. A powerful new data acquisition system is to be installed shortly to meet the nuclear physics users' requirements. First design of an external injection system for an ECR source has been developed.

Introduction

The Variable Energy Cyclotron (VEC) at Calcutta has a K value of 140. Its design is similar to the 88 inch cyclotrons at LBL, Berkeley and Texas A&M University. The machine has, however, been completely built in India. At the last cyclotron conference we had reported the commissioning of VEC for utilization with 30 MeV alphas. Uninterrupted grid power is now available for the operation of the cyclotron which was previously limited by the available power from the 2 MVA diesel generator captive plant. Alpha beams with 26 to 85 MeV energy have been extracted and transported to the experimental area. The machine operates for most of the time for the experiments. Improvements and modifications on the cyclotron and its systems are being carried out for reliable and trouble-free operation simultaneously with the utilization. A major effort has been put in improving and streamlining the radiofrequency and beam transport systems and for obtaining the higher energy beams. Fig.1 shows a view of VEC with 3 high intensity beam lines.

Cyclotron Systems

Radiofrequency system

This system was originally self excited based on the RCA 6949 tube which is a triode. This tube is expensive and not readily available. The new system is driven type, incorporating less expensive RCA 4648 tetrode. Fig.2 shows the block diagram of the new system. The master oscillator is a frequency synthesizer delivering highly stable ( $1 \text{ part in } 10^7$ ) signal in the required frequency range. Its output is fed to a voltage controlled rf

attenuator which in turn feeds to a 10 W wide band amplifier followed by a 1 kW wide band distributed amplifier. The output of the power distributed amplifier is coupled to the grid of the final power amplifier using RCA 4648 through suitable matching network. The entire drive system upto the grid of the power tube has a band width which is larger than the operating frequency range of the cyclotron.

The coarse tuning arrangement remains the same in the new configuration while the fine tuning signal is obtained by using a phase comparator which finally drives a servo amplifier coupled to the trimmer motor. The dee voltage is capacitively picked up at the dee edge and compared to the set value. The output of the comparator adjusts the drive and keeps the dee voltage within 0.2% of the set value. Whenever there is sparking or ion loading inside the resonator the recycler makes the output pulsating and helps in overcoming this situation faster. There are special crowbar circuits both in the plate as well as screen power supplies to protect the power tube in case of adverse load conditions.

The performance of the new radiofrequency system has been tested to be satisfactory upto frequency of 12 MHz and 50 kV dee voltage. However, it has been used with the beam upto 11 MHz, 45 kV.

Vacuum System

In order to obtain better and clean vacuum in the dee tank a 6000 l/s turbomolecular pump is being installed near the deflector exit. This will replace the present 3000 l/s oil diffusion pump which throws too much oil in the tank when operated. Special shielding for about 1 kG of magnetic field will be provided by the manufacturer for the turbomolecular pump. Installation of this pump and the cryopanel close to it are the first steps towards improving the cyclotron vacuum for our heavy ion acceleration programme.

In early 1982 we replaced the large gasket interfacing the dee tank and the resonator tank. This required moving the 20 tonne resonator tank with assemblies back by about 13 cm. A specially designed fixture incorporating rollers was used for this purpose. The tank was gently rolled back without having to lift it. The rollers will be useful in future for easy maintenance and development. Subsequently, in the end of 1983 the air leaks on the resonator tank door channels were plugged making the differential

pumping of these channels redundant. A quadrupole mass analyzer has been installed on the resonator tank for on-line detection of the type of leak. The resonator tank pressure is, typically  $3-5 \times 10^{-6}$  torr.

#### Beam Transport System

The third ( $35^{\circ}$ ) low resolution beam line, Fig.2, was made operational for sophisticated nuclear spectroscopy experiments requiring very low beam currents on the target but at the same time extremely low gamma and neutron back ground. Point to parallel mode of beam optics and cutting most of the beam in the vault itself has been found to be suitable. Additional quadrupole doublets have been installed in the second and third channels in the vault for point to point imaging in some cases. Beam transmission from cyclotron exit to the target in the caves, when no collimators are used, for all the channels, has been improved, typically to 80-100%.

The  $n = 0.5$  double focussing analyzing magnet has been installed in position along with its vacuum chamber and the coils. High vacuum has been obtained in the  $1.4 \text{ m}^3$  chamber. The second switching magnet with six ports for the high resolution beam lines is nearing completion. These beam lines are being designed using telescopic beam optical modes.

#### Cyclotron Operation

The cyclotron is operated for experiments and beam development 96 hours per week on round the clock basis. Vacuum system and services are, however, operated round the clock 7 days a week. At present the user's schedule is made twice per year and each utilization spell extends 4 to 5 months. The rest of the period is used for maintenance and development and improvement of systems. Table 1 shows the statistics of the cyclotron during the year 1983.

Table-1

Total time schedule for operation	3626 h (100%)
1. Beam available for experiments	1480 h (40.8%)
2. Beam development and tuning	620 h (17.1%)
3. On-line repairs including ion source filament changes	1298 h (35.8%)
4. Machine start-up and stop time	182 h ( 5.0%)
5. Grid power failure	46 h ( 1.3%)

The life time of the ion source filament has usually been 70-80 hours in most cases, however the filament was changed due to the thick shorting flakes which could not be burnt in situ.

#### Beam Development

##### Beam Tuning

Efforts have been made to obtain higher energies primarily for alphas due to users' demand. Initial settings of the magnetic field and rf parameters were obtained using the CYDE code <sup>2</sup> using the measured magnetic field of VEC. In some cases, however, the settings of the nearest available beam energy were used to begin with. The beam is tuned out using the dee and target area probes. With careful tuning of the trim coils nearly flat profile of the beam current vs. radius can be obtained beyond a radius of about 25 cm. A maximum of  $55 \mu\text{A}$  internal beam has been obtained so far. Beam extraction is optimized by tuning the deflector and central region parameters and the valley coil settings. The maximum extraction efficiency so far achievable is 35%. This, however is with a dee voltage of 40-45 kV. Using this procedure we have extracted alpha beams between 26 to 85 MeV energy. We have also been able to tune 100 MeV alpha beam upto the extraction radius with  $5 \mu\text{A}$  current. The extracted beam currents ranged from  $15 \mu\text{A}$  to  $1.5 \mu\text{A}$  as the energy is varied from 30 to 85 MeV. The ion source arc current is, typically, of the order of 1 A.

##### Phase Measurements and Trim Coil Corrections

Recently, a prompt gamma set-up has been installed near the north view port on the dee tank for internal beam phase measurements. The prompt gammas emitted by the target area probe are detected by a NE 111 plastic scintillator in conjunction with an RCA 8575 photomultiplier tube. Smith-Garren method is used to obtain the zero phase. In collaboration with JULIC, a programme has been developed to correct the trim coil settings on the basis of the measured phases.

##### Time Structure Studies

Using a similar prompt gamma set-up the effect of cyclotron central region parameters was studied on the external beam pulse width<sup>3</sup>. Prompt gammas emitted by a tantalum Faraday cup in the second ( $20^{\circ}$ ) channel were detected. Narrow pulses of 4 ns width were obtained. It was found that replacing the bevelled slit at the ion source by an unbevelled one brings down the pulse width by a factor of  $\sim 2$  to 8 ns. The width was further reduced by optimizing the dee voltage, narrowing down the slit width from 1.5 to 1 mm and optimizing the ion source and puller positions. Fig.3 shows an optimized time spectrum for 40 MeV alpha beam.

##### Research Facilities & Utilization

For effective utilization of VEC suitable research facilities have been provided and more are being introduced. The existing facilities include a 915 mm scattering chamber, an on line data acquisition system, Canberra series 80 & 88, multichannel multiparameter analyzer systems, off-line computer IRIS-80 and in house laboratories for solid state detectors, targets and nuclear instrument modules and a solenoid spectrometer for

electron capture studies. A QSD magnetic spectrometer is being fabricated as a major facility on the high resolution beam lines. The machining of its dipole magnet is in progress at manufacturer's site and coil winding is being done at VECC. Focal plane detector is also being developed. A new and powerful data acquisition system, going to be installed shortly, is explained in Fig.5.

VEC being a national facility is utilized by almost all the major universities and research institutions in India.

#### Future outlook

Heavy ion acceleration is the future course for VEC which has been decided after careful studies and discussions. Development work on a PIG source is already under way. Installation of an ECR source is actively being considered. First design of the external

injection system has been worked out<sup>4</sup>. Possibilities of installing post accelerator on VEC have been considered.

#### References

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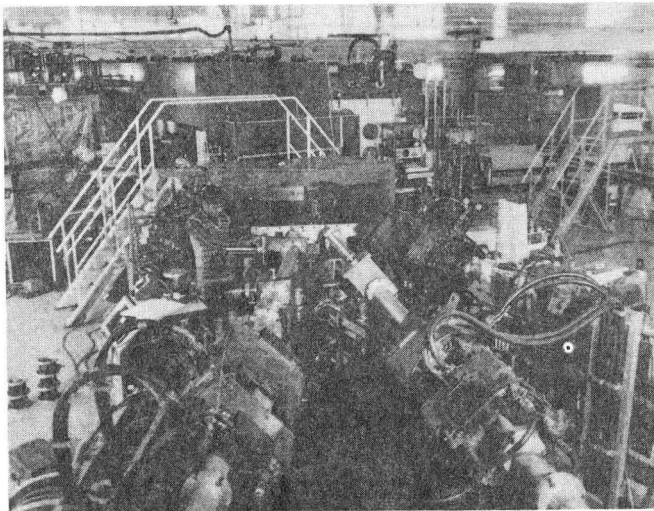


Fig.1. A view of VEC with three low resolution beam lines in the vault area. Cyclotron can be seen in the background.

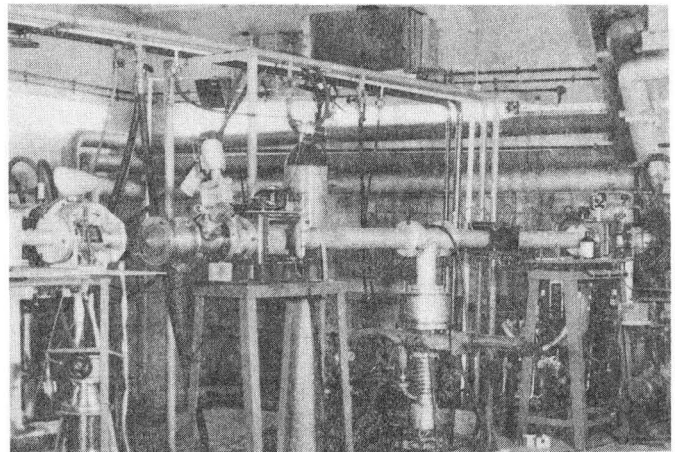


Fig.2. The third beam line inside the experimental cave. This line is used normally for the gamma spectroscopy experiment. A solenoid spectrometer for recoil - electron capture studies has been installed on this beam line.

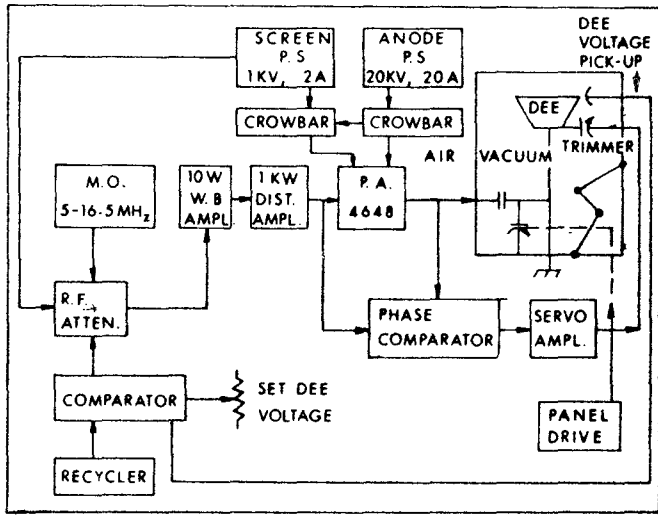


Fig.3. Block diagram of the newly incorporated RCA 4648 radiofrequency system.

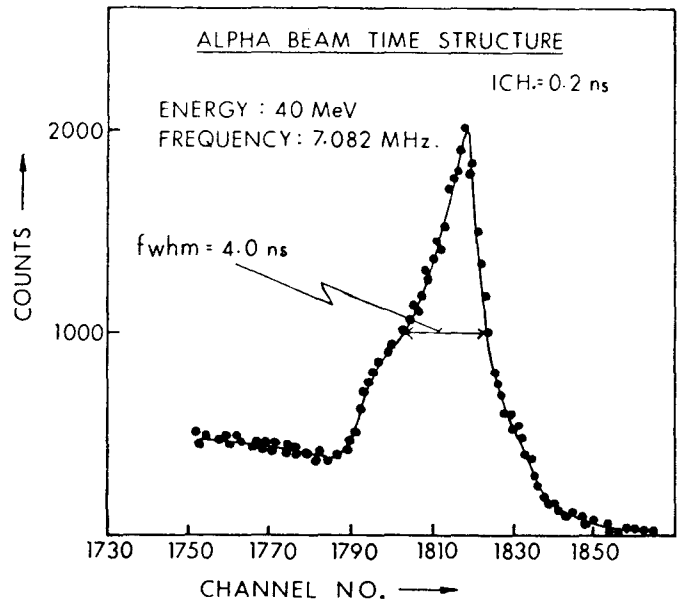


Fig.4. VEC alpha beam line structure.

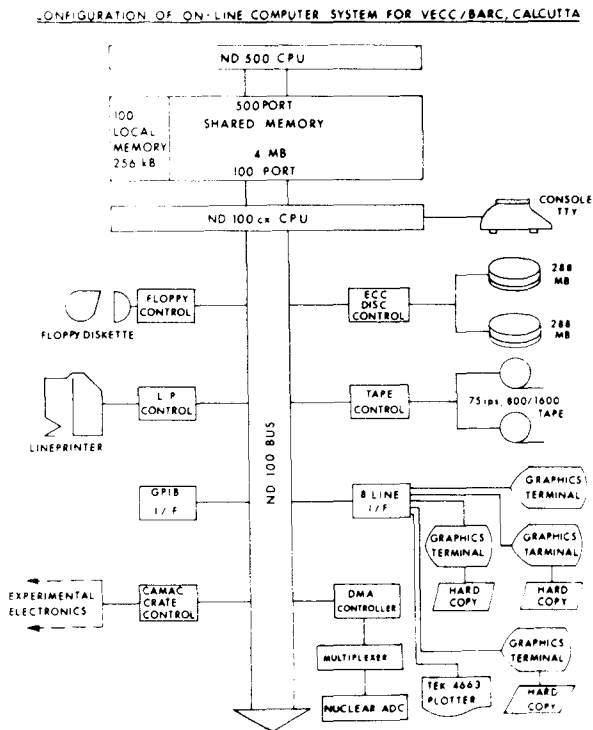


Fig.5. Block diagram of the new data acquisition system to be installed shortly at VECC.