CURRENT STATUS AND FUTURE PROJECTS OF THE ITHEMBA LABS CYCLOTRON FACILITIES

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Abstract

The cyclotron facilities at iThemba LABS have been utilized for isotope production, nuclear physics research, proton therapy and neutron therapy for nearly 25 years. The upgrading and replacing of redundant systems is essential, in order to keep the interruptions due to equipment failure to a minimum. The computer control system will be replaced by an Experimental Physics and Industrial Control System (EPICS) and the analogue low-level RF control systems will be replaced with digital systems. The Minimafios ECR ion source is being replaced with an ECR source that was used at the former Hahn Meitner Institute. Another source, based on the design of the Grenoble test source, will be commissioned later this year. To increase the production of radioisotopes, the 66 MeV proton beam is split with an electrostatic channel to deliver two beams simultaneously. The first results with the beam splitter will be reported. A phase measuring system for the separated-sector cyclotron, comprising 21 fixed probes, has been installed. The progress of these projects and the status of the facilities will be presented. Plans for new facilities for proton therapy and radioactive beams will also be discussed.

EPICS CONTROL SYSTEM

During the past 2 years iThemba LABS has been developing an EPICS-based control system, which will eventually replace the current control system that was developed during the 1980's. The current system is based on a LAN of PCs with an in-house developed distributed database, in which portions of the database reside on PC nodes close to the equipment. This is very much the philosophy of EPICS with the EPICS process variables (PVs) implemented in Input/Output Controllers (IOCs) constituting a distributed database. Our I/O structure is defined by a series of crates and I/O cards. The various types of cards allow a range of controls, including analogue and digital signals, power supply, stepper motor and actuator control. There are approximately 25000 variables connected in this way. EPICS driver software has been developed to connect to this I/O structure.

So far EPICS has been installed on a rotating wire scanner, the beam splitter devices, slits, pneumatic actuators and vacuum system components and also constitutes 90% of the controls of the tandem Van de Graaff at iThemba LABS Gauteng.

During the transition phase when both the old and the new control systems have to run concurrently, it was necessary to develop bridging programs that allow operator screens to access both systems. So far the IOCs which are running on standard PCs with Ubuntu Linux ver. 10.04 have proved to be very stable.

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RF CONTROL SYSTEM

A prototype of a digital low-level RF control system has been successfully developed at iThemba LABS. The system as illustrated in Fig. 1 utilizes a Xilinx Virtex 5 FPGA that is interfaced with high speed 16 bit 500MHz DACs from Analog Devices to synthesize the RF signals. Amplitude and phase information is extracted from the feedback signals using quadrature demodulation. A closed loop controller within the FPGA is utilized to keep the phase and amplitude at an operating point and to reject system disturbances. Amplitude and phase information as well as system parameters can be streamed to a LabVIEW client via Ethernet allowing monitoring and diagnostics of the RF signal to be performed in real time. The system has the capability to generate, under closed loop conditions, an RF signal with an intrinsic amplitude and phase accuracy of 0.006% and 0.005 degrees respectively.

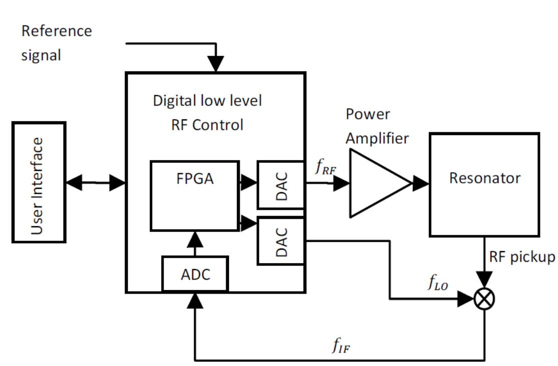

Figure 1: New prototype digital low-level RF control system

ELECTRON CYCLOTRON RESONANCE ION SOURCES (ECRIS)

Grenoble Test Source 2 (GTS2)

iThemba LABS is in the process of assembling an ECRIS (GTS2) that was originally designed by CEA Grenoble in France [2] which is based on the same design as the heavy-ion ECRIS in use at the Large Hadron Collider (LHC) facility at The European Organization for Nuclear Research (CERN) facility in Europe. Consequently a collaboration was proposed by CERN and a Letter of Intent was signed between iThemba LABS and CERN that outlines the terms and conditions of the collaboration agreement. It involves the initial commissioning of the GTS2 ECRIS at iThemba LABS, followed by the study of specific heavy-ion beams as requested by the fixed target experiment group (NA61) of CERN. Construction of the source is on schedule for completion by the end of 2010. Fig. 2 shows the partially assembled source.

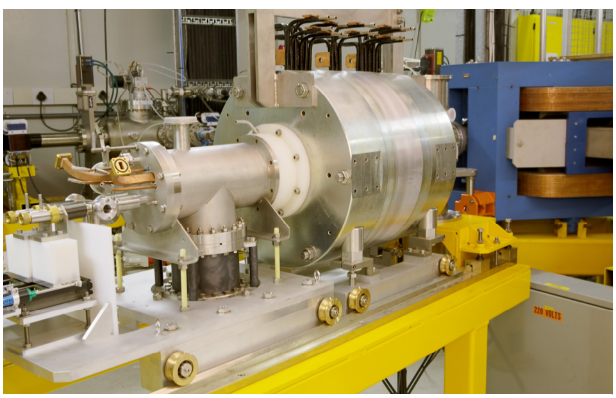

Figure 2: Partially assembled GTS2 ECRIS.

Hahn Meitner Institute (HMI) ECR Ion Source

The HMI ECRIS, donated by the Hahn Meitner Institute, was fully commissioned and put into service during 2009. Since then the source has been used to deliver beams of various ion species for nuclear physics experiments. The beams are very stable and with higher charged states and intensities than can be achieved with the Minimafios ECRIS. The Minimafios source will be decommissioned by end of September 2010, after more than 20 years of operation.

BEAM SPLITTER

The beam splitter system [1] was commissioned during the course of the year. To allow simultaneous irradiation of two targets for isotope production, an electrostatic channel (EC) and a magnetic channel (MC), similar to those at the Paul Scherrer Institute, are used to obtain two separate beams. During the beam development phase some components in the beam line section between the EC and MC had to be rearranged and after careful optimization of the beam optics, beam was delivered to both the vertical and the horizontal beam line targets simultaneously. The beam profiles in front and behind the electrostatic channel are shown in Fig. 3. Beam transport parameters were fine-tuned while the intensity of the split beam was increased, and so far 80 µA has been split and delivered to the horizontal line while 140 µA has been delivered to the vertical beam line, with negligible beam loss. Additional precautionary modifications have been implemented, e.g. in the beam line section between the EC and MC, quadrupole magnets with larger apertures and a beam pipe with a larger diameter were installed in order to reduce the setup time of the beam splitter and to practically eliminate all beam losses. Full radionuclide production with the beam splitter will start in September 2010.

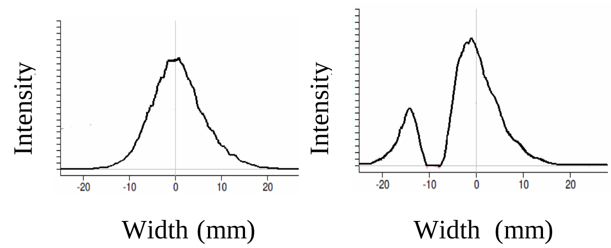

Figure 3: The beam profile in the horizontal plane in front of the electrostatic channel (left) and 100 mm behind the electrostatic channel (right), showing clear separation between the deflected part and the main beam.

PHASE MEASURING SYSTEM FOR THE SSC

The radial moveable phase probe in the SSC injection valley vacuum chamber, which also contains the flat-topping resonator, a pulse selector and a beam stop, was recently replaced with 21 non-destructive fixed phase probes. They could not be installed on the centre line of the valley vacuum chamber and therefore have the shape of parallelograms instead of rectangles. Each probe consists of two double shielded electrodes, symmetrically arranged with respect to the median plane. Each electrode is connected to a semi-rigid cable through a coaxial, non-floating feedthrough mounted on a conflat flange. All the probes have the same radial and azimuthal width of 70 mm and 120 mm, respectively. Outside the vacuum chamber the semi-rigid cables are connected, via quarter-inch coaxial cables with solid outer conductors, to two multiplexers. Fig. 4 shows the phase probes and their support structure being installed into the vacuum chamber of the SSC.

Commercial multiplexers with suitable specifications could not be found. Consequently RF coaxial, terminated relays, with a specified life-time of ten million cycles were selected for the multiplexers. They are situated in the cyclotron vault below one of the sector magnets. Tests verified that the switches function satisfactorily in the low stray field of the magnet.

These multiplexers are connected, via half-inch coaxial cables with solid outer conductors and low-noise wideband amplifiers, to an oscilloscope in the control room to display signals. Initial measurements with these phase probes are very promising; the pulse shapes are exhibiting very limited reflections. When the signals from the upper and lower electrodes that comprise one phase probe are summed, the RF pick-up components from the resonators, being 180 degrees out of phase on the two electrodes, effectively cancel each other while the sum of the beam induced signal is doubled.

In the future the signals will also be routed through filters for phase measurement with a lock-in amplifier, controlled by LabVIEW software. It is possible to select various combinations of probes and operating modes for phase measurement.

Figure 4: The phase probe structure, supporting the 21 fixed probes, during installation in a vacuum chamber of the SSC.

BEAM STATISTICS

The cyclotron performance over the past 8 years is shown in Table 1. The improved statistics achieved during 2009 can be partially attributed to the excellent condition of the 4.4 MW uninterruptable power supply, resulting in zero interruptions due to power dips. Interruptions as a result of ageing equipment still remain a concern, but an ongoing program of replacing and upgrading obsolete equipment and the concerted effort of all operational and support staff generally ensured speedy recovery after break-downs.

Table 1: Operational statistics of the SSC for the past 8 years

Year	Beam supplied as:		% of scheduled beam time for:	
	% of total time	% of scheduled time	Energy changes	Inter-ruptions
2002	72.29	82.69	7.50	7.28
2003	70.93	82.79	6.87	8.08
2004	72.0	84.9	6.7	5.9
2005	71.3	83.6	5.5	6.4
2006	66.1	80.3	5.5	7.9
2007	67.1	79.28	5.4	10.4
2008	62.0	75.17	4.0	14.3
2009	70.5	83.7	6.9	7.9

FUTURE PROTON THERAPY AND RADIOACTIVE ION BEAM PROJECTS

Facilities for proton therapy, based on a 200 MeV cyclotron, with three new vaults, of which two will be equipped with gantries, were proposed in 2004 [3]. The third vault was envisaged for the implementation of the scattering method of treatment, with a horizontal beam line as well as a beam line at 30 degrees with respect to the vertical. A business plan has now been produced indicating the viability of this project. This project, if realized, will be in private partnership with iThemba LABS.

iThemba LABS is considering the establishment of a Radioactive Ion Beam (RIB) facility to provide additional beam time, which will meet the needs for human resource development, maintain and develop research at the international forefront, as well as increase radioisotope production.

It is proposed to divide the project into several phases. During the first phase a new cyclotron will be installed for isotope production and neutron therapy. This accelerator should be a H- machine capable of simultaneously supplying two proton beams in the energy range of 30 to 70 MeV and with a maximum current of about 400 μA for each of the two beams. These beams will fulfil future demand for isotope production and the creation of radioactive ion beams. Removing neutron therapy and isotope production from the SSC beam schedule will immediately double the beam time available for nuclear physics research with the advantage of a more stable beam.

The second phase is the development of radioactive beams using the new cyclotron as driver. The production target and ion-sources for radioactive beam production will be installed. These beams will have multidisciplinary applications, being used not only for nuclear physics but also astrophysics and material science research. A new injector and the existing SSC will be used to accelerate the radioactive beams to their final energy.

REFERENCES

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