Beam experiments with the Grenoble Test

Electron Cyclotron Resonance Ion Source at iThemba LABS

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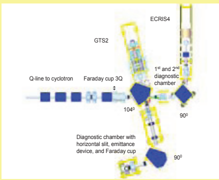
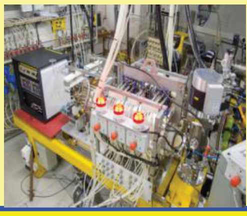
ABSTRACT

At iThemba Laboratory for Accelerator Based Sciences (iThemba LABS) a new electron cyclotron ion source (ECRIS) was installed and commissioned. This source is a copy of the Grenoble Test Source (GTS) for the production of highly charged ions. The source is similar to the GTS-LHC at CERN and named GTS2. A collaboration between the Accelerators and Beam Physics Group of CERN and the Accelerator and Engineering Department of iThemba LABS was proposed in which the development of high intensity Argon and Xenon beams is envisaged. In this paper we present beam experiments with the GTS2 at iThemba LABS, in which the results of CW and afterglow operation for Helium and Oxygen as supporting gases are presented.

INTRODUCTION

iThemba LABS provides accelerator and ancillary facilities for research and training in physical, biomedical and material sciences. At the heart of the iThemba LABS accelerator complex is the variable-energy, separated-sector cyclotron. A high-intensity 66MeV proton beam, pre-accelerated in the first solid-pole injector cyclotron is used for therapy and radioisotope production, while a low-intensity 200MeV beam is used for proton therapy. The second solid-pole injector cyclotron is used for pre-acceleration of light and heavy ions as well as polarized protons from the three external sources [1]. In 2006 the decision was made that, due to the requirements of nuclear physics for new ion species and higher particle energies, a new ECRIS should be procured. A source, based on the design of the Grenoble Test Source (GTS) [2], which is similar to the GTS-LHC at CERN, has been constructed and installed. At the same time a 14.5GHz ECRIS4 that was designed and constructed by Grand Accelerator National d'Ions Lourds (GANIL) [3] and originally built for the Hahn-Meitner-Institute (HMI) in Berlin [4] was donated to iThemba LABS and is in operation since 2009.





BEAM LINE SET-UP

The set up of the beam lines in the ECRIS vault with the new diagnostic beam line for the GTS2 allows for simultaneously operation, i.e. the required beam for cyclotron acceleration will be delivered from one source, while the second source can be used for beam development. The diagnostic beam line of the GTS2 has an einzellens which focuses the beam on the double-focusing distance in front of the 90^0 magnet. Behind the magnet a horizontal slit is installed on the double-focusing distance to ensure sufficient mass resolution. The diagnostic line is completed with a chamber containing a slit-harp emittance device for both transversal planes and a Faraday cup.

GTS2 ECRIS

The coils, the permanent magnet assembly, the plasma chamber and all mechanical parts of the GTS2 were manufactured by different companies in Europe, which were also involved in manufacturing the GTS-LHC. For the vacuum system of the source three 700l/s turbo pumps (one at injection and two at extraction), one 70l/s turbo pump for the oven system and two dry roughing pumps are used. The longitudinal magnetic field is produced by three coils, namely the injection-, centre-, and extraction coil. The power supplies for the injection- and extraction coil can deliver 1300A at 60V leading to a maximum B-field of 1.6T. A 600A bipolar power supply is connected to the centre coil. The permanent magnet array in the Halbach configuration produces 1.27T at the plasma wall surface [5]. Two 2.3kW micro wave generators operating at 14.5 and 18GHz are connected to the source via WR62 wave guides. The active plasma chamber volume which is manufactured from Aluminium is 1430cm^3 at an active length of 30cm and a diameter of 7.8cm. The triode extraction system consists of a plasma electrode which is positioned at the end of the permanent magnet array in the plasma chamber, an intermediate electrode at a distance of 30mm to the plasma electrode, and a ground electrode at 8mm distance to the intermediate electrode. The aperture diameters of the electrodes are 12, 17, and 17mm, respectively. The source can be operated with two resistive ovens which were not installed during the experiments. The bias disc (BD) has a surface of approximately 12cm^2 and is positioned at 189mm distance from the injection chamber exit flange which roughly corresponds to a position at the beginning of the permanent magnet array in the plasma chamber.

References

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[3] P. Sortais, Nucl. Instr. and Meth. B98, 1995, p. 508.
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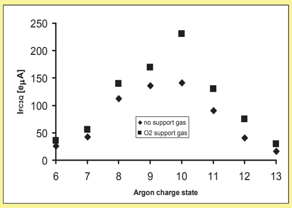
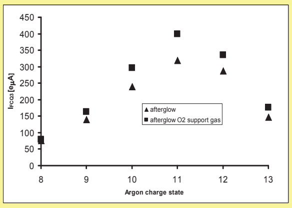
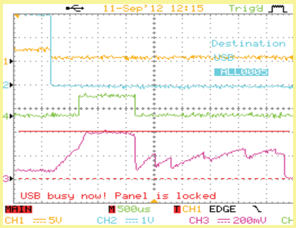


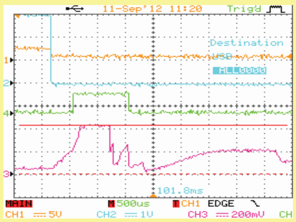
The Argon charge state distribution for CW operation with and without O_2 supporting gas. The source operation parameters are: No supporting gas: U_{ex}=9.6kV, U_{int}=-1.6kV, U_{BD}=-140V, I_{inj}=1100A, I_{cen}=340A, I_{ext}=1050A, F_{Ar}=1.2ml/h, p_{inj}=4*10^{-7}mbar, p_{ext}=4*10^{-7} mbar, P_{rf}=410W. O_2 supporting gas: U_{ex}=9.6kV, U_{int}=-2kV, U_{BD}=-180V I_{inj}=1130A, I_{cen}=290A, I_{ext}=1050A, F_{Ar}=1.1ml/h, F_{O2}=1.7ml/h, p_{inj}=2.0*10^{-7} mbar, p_{ext}=4.0*10^{-7} mbar, P_{rf}=460W.



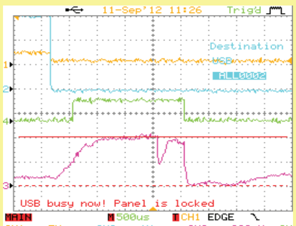
The Argon charge state distribution for after glow operation. Compared are the results without and with Oxygen as supporting gas. The source parameters are: No supporting gas: U_{ex}=9.6kV, U_{int}=-2kV, U_{BD}=-300V I_{inj}=1060A, I_{cen}=305A, I_{ext}=1030A, F_{Ar}=1ml/h, p_{inj}=1.8*10^{-7}mbar, p_{ext}=2.8*10^{-7}mbar, P_{rf}=650W. O_2 supporting gas: U_{ex}=9.6kV, U_{int}=-2kV, U_{BD}=-350V, I_{inj}=1120A, I_{cen}=281A, I_{ext}=1060A, F_{Ar}=1.0ml/h, F_{O2}=0.9ml/h, p_{inj}=1.8*10^{-7} mbar, p_{ext}=2.8*10^{-7} mbar, P_{rf}=720W.



The oscilloscope signal for afterglow operation. Trace 1 shows the end of the RF trigger pulse. Trace 2 is the read back of the RF generator (1V corresponds to 240W). Trace 4 shows the pulse for the bias disc switch (delay 0.5ms, pulse length 1ms) and trace 3 shows the Faraday cup signal measured across 1kΩ. Oxygen supporting gas.: U_{ex}=9.6kV, U_{int}=-2kV, U_{BD}=-350V, I_{inj}=1120A, I_{cen}=281A, I_{ext}=1060A, F_{Ar}=1.0ml/h, F_{O2}=0.9ml/h, p_{inj}=1.8*10^{-7} mbar, p_{ext}=2.8*10^{-7} mbar, P_{rf}=720W.



The oscilloscope signal for afterglow operation. Trace 1 shows the end of the RF trigger pulse. Trace 2 is the read back of the RF generator (1V corresponds to 240W). Trace 4 shows the pulse for the bias disc switch (delay 0.4ms, pulse length 1ms) and trace 3 shows the Faraday cup signal measured across 1kΩ. He supporting gas : U_{ex}=9.6kV, U_{int}=-2kV, U_{BD}=-340V, I_{inj}=1120A, I_{cen}=281A, I_{ext}=1060A, F_{Ar}=1.0ml/h, F_{He}=2.0ml/h, p_{inj}=2.0*10^{-7} mbar, p_{ext}=2.8*10^{-7} mbar, P_{rf}=720W.



The oscilloscope signal for afterglow operation. Trace 1 shows the end of the RF trigger pulse. Trace 2 is the read back of the RF generator (1V corresponds to 240W). Trace 4 shows the pulse for the bias disc switch (delay 0.4ms, pulse length 2ms) and trace 3 shows the Faraday cup signal measured across 1kΩ. He supporting gas : U_{ex}=9.6kV, U_{int}=-2kV, U_{BD}=-350V, I_{inj}=1120A, I_{cen}=300A, I_{ext}=1040A, F_{Ar}=1.0ml/h, F_{He}=2.0ml/h, p_{inj}=1.8*10^{-7} mbar, p_{ext}=3.1*10^{-7} mbar, P_{rf}=720W.