

# PERFORMANCE OF THE SARAF ION SOURCE

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## Abstract

Since October 2006 an ECR ion source is under operation at SOREQ. The source will be used to generate protons and deuterons in a current range from 0.04 to 5 mA. The paper will present operation results as current, emittance and stability measurements. Further the influence of variables as solenoid fields, RF power and gas flow will be described. A short description of the attached beam transport system and beam diagnostic system will be given as well.

## ECR ION SOURCE

The design of the ECR ion source based on a AECL design is described in [1] and consists of following sub-components:

- plasma chamber with acceleration/deceleration-electrodes
- gas flow system including dosing valve
- magnetron providing required RF power at 2.45 GHz
- two HV power supplies providing accelerating and decelerating voltage
- two solenoid magnets defining the ECR zone
- LEBT including vacuum pumping, focussing, bending magnet and beam diagnostics

Parameter	Unit	Value
Particles		H <sup>+</sup> , H <sub>2</sub> <sup>+</sup> , D <sup>+</sup>
Beam energy	keV/u	20
Beam current	mA	0.040 to 5
Emittance (rms, normalized, 100%)	π mm mrad	0.2

Table 1: ECR Ion Source Specifications

Several changes has been made by ACCEL regarding to the original design of AECL. The extraction geometry was adjusted to the required maximum current of 5mA, the RF-vacuum-window in the RF-waveguide was moved in front of a 90° bent to avoid damages by electrons, a solid boron nitride plate has been installed between wave guide and plasma chamber to prevent the plasma from entering the wave guide. Furthermore the wave guide is pumped by an additional bypass.

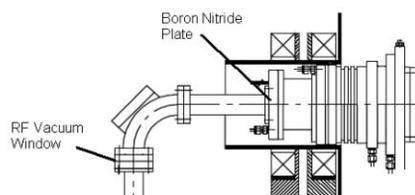


Figure 1: Scheme of the ECR ion source



Figure 2: ECR Ion Source (covered by RF cage) with LEBT at SOREQ

The source was operated with Hydrogen, Deuterium and for test reasons with Helium.

## OPERATING THE SOURCE

To get a stable and sufficient proton beam the Hydrogen gas flow must be set to a certain value with small range. The gas flow depends on the pumping capacity at the plasma chamber and effects the medium free length of path. At the SARAF source the optimal gas flow is 0.4 sccm. The gas flow is stabilized by software regulation loop and controlled by a dosing valve.

The magnetic field within the plasma chamber is created by two solenoids. Their field defines the ECR zones and the shape of the plasma. The beam current is very sensitive to the magnetic field. If the field is too low the electrons in the plasma are not kept long enough to ionise other atoms effectively. If the magnetic field is too high it is possible to create a plasma between the extraction electrodes creating a shortcut.

With the RF power of the magnetron the rate of ionisation can be adjusted. It is necessary to tune the magnetic field to the new RF setting because the frequency of the magnetron is changing slightly at different power.

## LOW ENERGY BEAM TRANSPORT

The ECR ion source is connected to the low energy beam transport (LEBT). This includes three focussing solenoids, one 90° dipole magnet, four x/y steering magnets, an adjustable aperture and beam diagnostics.

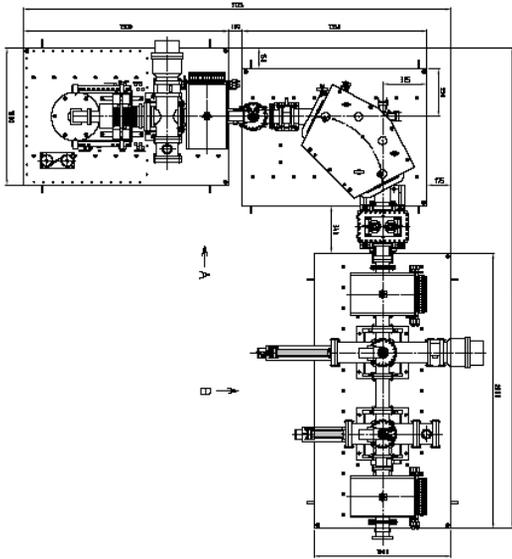


Figure 3: EIS with Low Energy Beam Transport

All diagnostics in the LEBT are beam intercepting including a biased faraday cup, slits in x- and y-plane and wires in x- and y-plane. With these devices it is possible to measure the beam current, the beam profile and the emittance of the beam. The adjustable aperture cuts away unwanted outer particles and decrease the beam current continuously to any desired value.

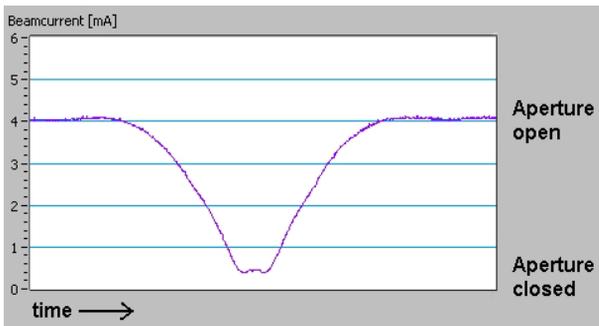


Figure 4: Adjustment of beam current by aperture

By changing some parameters at the source settings and using the aperture the low beam current value of 0.04 mA can be reached easily.

**PERFORMANCE MEASUREMENTS**

The measurement equipment is placed behind the bending magnet. So, all measurements are related to a specific desired beam fraction. A biased faraday cup and a slit/wire system was used to measure the beam current and the emittance. The beam stability was measured with a biased faraday cup as well. The specified beam stability of the source is 5% peak-peak at the high current mode. The stability of the source was tested at a beam current of at least 5 mA. During the testing time of one hour the source was operated with constant settings.

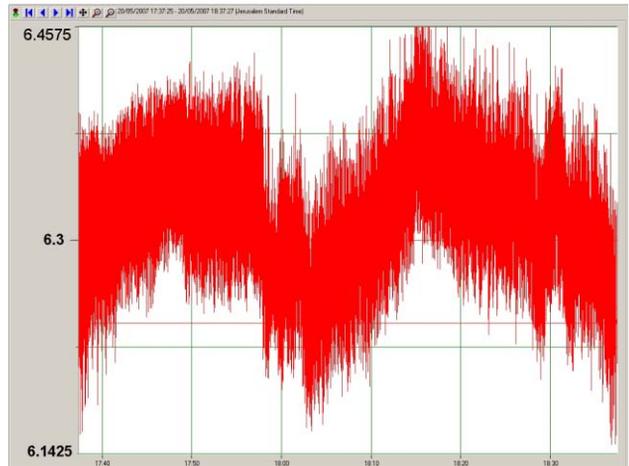


Figure 5: Beam stability over one hour (+-2.5% at 6.3 mA proton beam)

The source is running very stable in proton and deuteron mode after a short warm up time of approximately half an hour. The proton beam has already been used in pulsed mode to commission the RFQ [2].

As it is shown in Fig.2 the maximum proton beam current is up to 20% higher than the specified value. Without using the aperture the beam emittance is about  $0.2 \pi$  mm mrad. If the aperture is used to decrease the current the outermost particles are cut away and the emittance improves.

In the following the results of emittance measurements of proton and deuteron are shown.

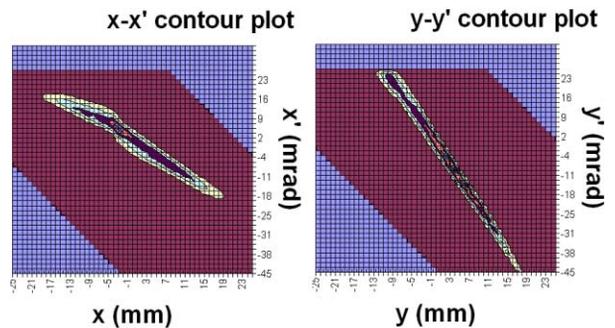


Figure 6: Beam emittance measurement for 5mA proton beam ( $\epsilon_{norm,rms,100\%} = 0.18 \pi$  mm mrad )

Table 2: Results of emittance measurement

Particle	Beam current [mA]	Emittance [ $\pi$ mm mrad]
Proton	5.0	0.18
	0.04	0.14
Deuteron	5.0	0.15

## CONCLUSION AND OUTLOOK

The ion source is running in proton operation reliable since March 2007 and is used routinely during commissioning of the RFQ accelerator.

During this summer ACCEL is going to perform further measurements and the final acceptance tests of the SARAF ion source.

## REFERENCES

- [1] C.Piel et al. "Development and performance of a proton and deuteron ion source", PAC'05, Knoxville, 2005
- [2] C.Piel et al. "Beam operation of the SARAF light ion injector", PAC'07, Albuquerque, 2007