BEAM DIAGNOSTICS OF HIGH INTENSE ION BEAMS ON THE HEIDELBERG HIGH CURRENT INJECTOR

R. Cee, Technische Universität Darmstadt, Germany
M. Grieser, R. von Hahn, R. Repnow, H. Schneider, O. Koschorreck, D.Schwalm,
MPI für Kernphysik, Heidelberg, Germany
S. Papureanu, Forschungszentrum Jülich GmbH, Germany

Abstract

The new High Current Injector at the Max-Planck-Institut für Kernphysik in Heidelberg provides ion beams with intensities up to several mA. Compared to the old injector that implies an increase of the ion current by two orders of magnitude. As a consequence, the diagnostic systems employed on the old part of the facility are not applicable anymore. It was hence necessary to develop a beam diagnostics that can be used under the conditions of the High Current Injector. On this purpose a profile grid system for profile and position measurements of beams with intermediate currents ($\approx$10 μA, DC) was set up. This part of the work mainly concerned the development of a new readout electronics matching to the personal computer control. For higher ion currents a beam profile monitor based on the projection of the residual gas particles ionized by the interaction with the beam was developed. Calculations and simulations of the projection process showed that the imaging defect of this device, estimated to be $\lesssim$ 170 μm, is small compared to the intrinsic resolution of the detector in use, which amounts to 800 μm. The profile measurements successfully carried out during beam times proved the functionality of the new diagnostic devices.

1 INTRODUCTION

Since 1997 the High Current Injector (HCI) produces high intense ion beams with a minimum charge-to-mass ratio of $q/A = 1/9$ within an energy range of 0.5–1.9 MeV/u [1]. The sources used at the HCI in its first phase are well suited for the production of ^{6,7}Li, ^{9}Be and ^{24}Mg ions, which are especially interesting for the laser cooling experiments [2, 3] performed at the Test-Storage-Ring (TSR) [4], as they possess resonance lines that can be covered with commercial narrow-band lasers. Even molecular ions such as H_2^+, H_3^+ or $^4HeH^+$ utilized by the Coulomb explosion imaging experiment [5] can be delivered by the HCI.

In the first phase of operation, the ion source section of the High Current Injector (Fig. 1) consists of two CHORDIS, each assembled in an angle of 60° with respect to the beam-line. The installation of the ECR source and the stripper with the charge state selector for the production of highly charged heavy ions are planned for the end of the year 2000. The ions extracted from the source are deflected into two directly coupled RFQ resonators with a total length of 6 m [6] and accelerated up to an energy of 480 keV/u. Several quadrupoles and a 4% rebuncher focus the beam into the first of eight seven-gap-resonators, that are arranged in four modules [7]. A compensation of the defocusing influence of the resonators is achieved by quadrupole doublets mounted between the modules. After passing another two magnetic lenses and the last component of the injector, a 6% rebuncher, the beam is injected with a maximum energy of 1.9 MeV/u into the post-accelerator, which offers the possibility to enhance the beam energy with an additional total accelerating voltage of 25 MV.

2 BEAM DIAGNOSTICS

When operating an accelerator machine, the knowledge of the beam position and profile is of major interest during the setting of the dipole and quadrupole magnets and the accelerating components. At beam currents in the μA range three profile wire grids with a spatial resolution of 1 mm have been proven to be reliable devices for the observation of the beam. At higher beam currents the power transferred to the grid wires exceeds a critical limit and leads to their destruction by melting. In this case a direct monitoring of the beam profile is not possible anymore. To expand the measurements to the high intensity region, the detection of the ionized residual gas ions represents an excellent alternative.

2.1 The profile grid system

A profile grid – also called ”harp” – consists of two planes of 16 thin tungsten wires fixed on an insulating ceramic frame. One end of the wires is equipped with a loop and can thus be suspended into a spring. This guarantees the stretching of the wire when heated up during operation. The ceramic frame is surrounded by a tantalum aperture with a hole size of 16$\times$16 mm^2. The grid is mounted on a compressed air activated feedthrough. When inserted in the ion beam some of the ions hit the wires and are stopped if the beam energie is < 2.0 MeV/u. The collected charge results in an electrical current that is proportional to the beam intensity at the position of the wire. With the knowledge of the wire currents a beam profile can be calculated and displayed. A compilation of the most important parameters of the profile grid measuring system is given in Tab. 1.

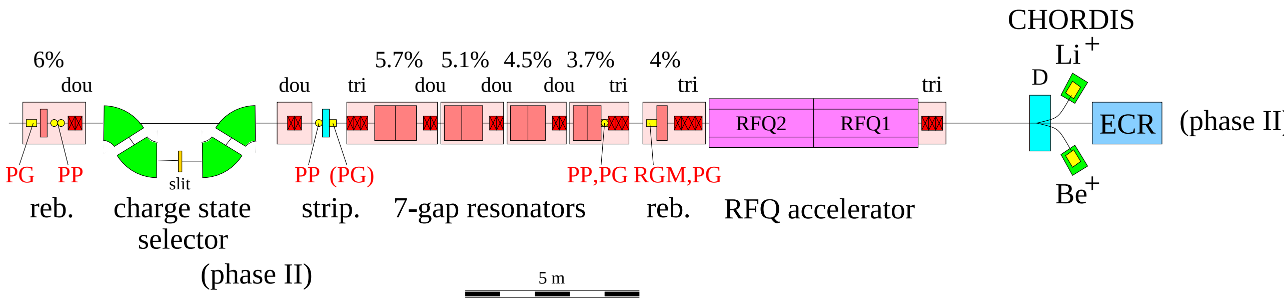

Figure 1: Setup of the Heidelberg High Current Injector with its main diagnostic instruments (PG: profile grid, RGM: residual gas monitor, PP: phase probe). The first phase of construction has been finished in 1997. After the second phase, an ECR source and a stripper with a charge state selector will complete the injector.

diameter of the wires	0.1 mm
spacing	1.0 mm
transparency	≈ 80%
length	20 mm
material	W-Re(3%) alloy
insulation (frame)	glass ceramics
aperture	Ta, 16×16 mm^2
number of wires	16
number of grids	4 (max. 8)
maximum power rate (dc)	0.25. . . 0.5 W/mm

Table 1: Important parameters of the profile grid measuring system.

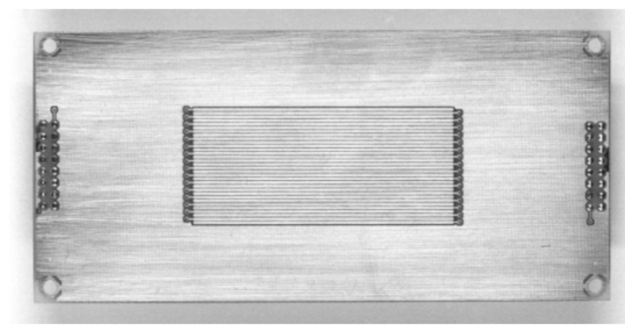

Figure 2: Imaging electrode of the residual gas monitor with a resolution of 800 μm.

2.2 *The residual gas ionization beam profile monitor*

The maximum power dissipation on the grid wires limits the applicable beam current to several μA, depending on the ion species and energy. To be able to measure the beam profile at higher currents, a prototype of a residual gas ionization beam profile monitor has been constructed. This device applies an electrical field perpendicular to the ion beam to accelerate the residual gas molecules ionized by the interaction with beam particles to an imaging electrode. In contrast to other residual gas monitors [8, 9]this electrode does not consists of a Multi-Channel-Plate with a resistive anode but of an arrangement of 32 collecting strips (width: 0.65 mm, length: 57 mm) made from copper etched from a copper plated PCB-board as shown in Fig. 2.

By plotting the strip currents versus the strip position the beam profile in one transverse direction can be visualized. To maintain both transverse profiles two identical devices with one of them just turned around by an angle of 90° with respect to the other are necessary. Three field shaping electrodes on each side of the monitor that are connected with voltage dividers (5 GΩ) improve the homogeneity of the electrical field and thus the accuracy of the imaging. A detailed description of the principles of operation is given in [10].

2.3 *Data acquisition*

The processing of the signal flow from the grid wires respectively collecting strips of the residual gas monitor to the display at the operating desk is shown in Fig. 3. The first step of the signal processing is an I/U-conversion. Several different conversion factors – 20, 2 and 0.2 μA – have been tested during beam times. The latter, corresponding to a feedback resistance of 50 kΩ, has been proven to be the most suitable one. With the following sample-and-hold module the signals can be stored until the readout process

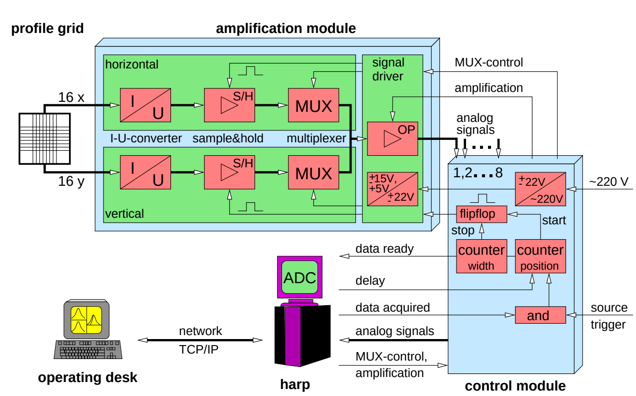

Figure 3: Block diagram of the data acquisition.

has been finished. Two analogue multiplexers are used to switch between the 32 channels during the readout. After a second amplification stage the signal is transferred through the control module to the A/D-converter located in the PC ”harp server”. In case of pulsed beams the control module generates a trigger pulse for the data sampling with adjustable beginning and duration. After transmitting the digitized signal to the operating desk, the beam profile can be visualized with a refreshing rate of 10 to 20 Hz. A compilation of the most important parameters of the acquisition electronics is displayed in Tab. 2.

Table 2: Important parameters of the acquisition electronics.

I/U-conversion	2 μA/V
post amplification	$\times$10, optional
trigger delay time	0–2.56 ms
trigger pulse width	0–2.56 ms
maximum output voltage	10 V

2.4 *Profile Measurements*

During several beam times the functionality of the profile grids and the residual gas monitor including the readout electronics could be demonstrated. In Fig.4 the horizontal beam profile of a $^4He^+$-beam with a peak current of 95 μA and an energy of 1.9 MeV measured with a residual gas monitor (a) and a profile grid (b)is plotted. To avoid the destruction of the grid wires the beam was pulsed with a pulse to period ratio of 1:10. It can be seen that the profiles are well described by the fitted Gaussian distribution. Taking the σ from the distribution function a horizontal beam width of 4σ = 4.0 mm resp. 3.6 mm can be derived. In addition, the profiles contain information about the beam position. Both measurements show a negative misalignment of approx. 0.5 mm. With the beam traveling in negative z-direction this corresponds to a beam positioned on the left hand side of the beam tube axis.

The combined operation of profile grids and residual gas monitors will allow the measurement of beam profiles from the lower edge up to the maximum intensities accessible to the High Current Injector.

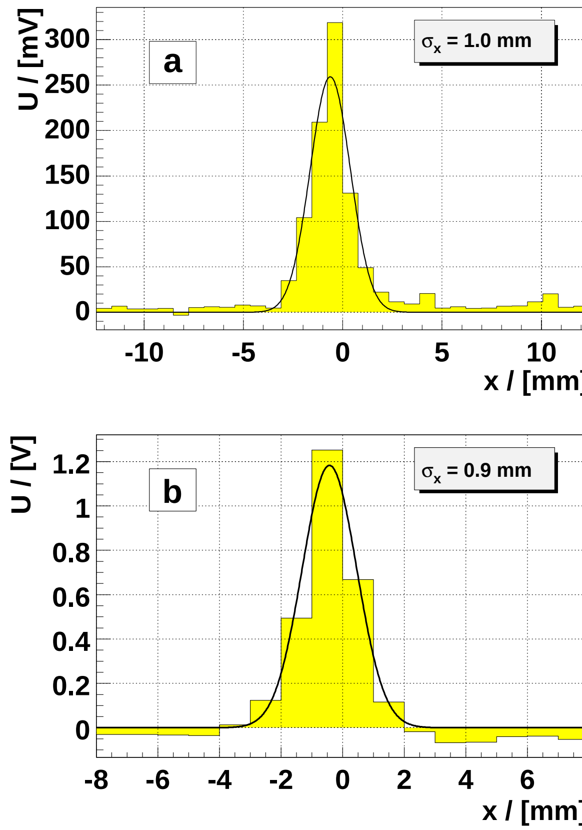

Figure 4: Comparison of a beam profile measured with the residual gas monitor (a) and a profile grid (b). The two measurements nearly result in the same beam width indicated in the frames.

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