PROGRESS REPORT FOR THE CRYRING FACILITY

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Abstract

The present status and upgrades planned in the near future for CRYRING are described. The topics include new residual gas ionisation beam profile monitors, a current transformer, an ECR source, and an upgrade of the vacuum system.

1 OVERVIEW OF CRYRING

The CRYRING facility [1] has two ion sources, an EBIS source CRYSIS for highly charged ions [2] and an electron bombardment source MINIS for singly charged molecular and atomic ions. Both sources are placed on high voltage platforms (maximum 40 kV). If $q/m>0.24$ the ions are accelerated in an RFQ to 290 keV/u, otherwise they are only transported through the RFQ. The ring has 52 m circumference and maximum $B\rho$ is 1.44 Tm [3]. The electron cooler has recently been equipped with a superconducting gun solenoid [4] to reduce the transverse temperature to 1 meV. CRYSIS is also used for low energy collision experiments, surface physics and for the SMILE ion trap [5].

2 IONS STORED IN THE RING

2.1 Presently Used Ions

Three different groups of ions are used for experiments in the ring, highly charged ions, molecular ions, and heavy singly charged ions. So far around 60 different ions have been stored in the ring, and as examples those used hitherto this year are presented in table 1. Electron cooling has been used in all cases in the table except for Ca^+ and Sr^+.

2.2 Future Ion Programme

The ECR source will fill the gap between two other sources and produce ions with $q>1$ and $q/m<0.24$. We also plan to test a source for negative ions during the autumn.

3 DIAGNOSTICS

Besides the two devices described below, more news about diagnostics can be found in references [6] and [7].

Table 1. Ions stored in the ring during spring 1998.

Ion	Current µA	Energy MeV/u
D^+	20	24
F^{6+}	1	8
N^{4+}	2	6
Ar^{13+}	1	5.6
$Pb^{53+,54+}$	0.1	4.2
HD^+	5	0.3
CH_2^+		0.5
CN^+	0.4	0.14
HCN^+	2	0.13
Ca^+	5	0.001[2]
Sr^+	6[1]	0.0005[2]

[1] Limited by space charge tune shift.
[2] Neither accelerated nor electron cooled.

3.1 Beam Profile Monitors

One vertical and one horizontal beam profile monitor has been mounted in the ring [8]. The design is based on a detector developed by the atomic physics group [9].

The residual-gas ionisation beam profile monitors measure the horizontal and vertical profiles of stored ion beams with a spatial resolution of ±0.2-0.3 mm. Since the ion rates are relatively low a chevron assembly is used with a resistive anode as a detector head.

A high-voltage system, maximum ±3 kV, generates a homogenous electric field over the active volume.

Four charge sensitive pre-amplifiers integrate the charges at each corner of the resistive anode. A fifth preamplifier is used for the timing. After pulse shaping, amplification, and stretching the spatial co-ordinates are computed from the ratio of the charge amplitudes with analogue dividers.

The digitised position data are stored in a PC by a dedicated dual-port increment matrix memory card.

The beam profile monitor without detector is shown in figure 1, and an example of read-out from the beam profile monitor is shown in figure 2.

3.2 AC Current Transformer

To be able to measure low ion currents we have bought an AC current transformer from Bergoz [10]. Especially during experiments with molecules where the cross-sections are large we need to measure very low currents. A measurement of a 20 nA current is shown in figure 3. This detector has the disadvantage that the beam has to be bunched, and the phase of the transformer has to be precisely matched to the phase of the beam.

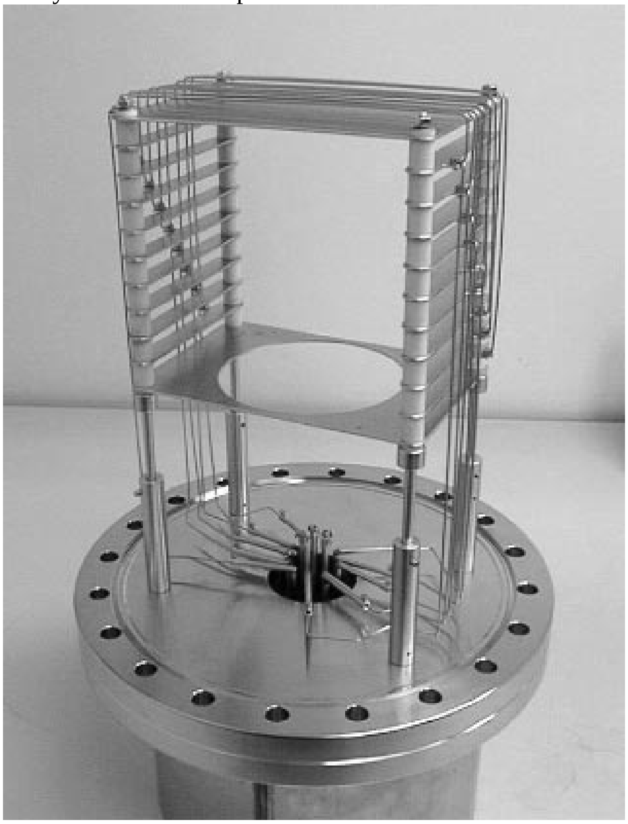

Fig 1. The beam profile monitor without detector. The gap is 100 mm.

4 CONTROL SYSTEM

A useful application program is the so called "Virtual operator". This Pascal program systematically varies beam line elements from a list and reads the beam signal from a strip detector, current measurement, or a spectrum analyser. Changes that sufficiently increase the signal are kept, others are discarded. The virtual operator in many cases does the boring routine optimisation faster than a human operator. (After an idea by V. Ziemann).

5 ECR SOURCE

The ECR source [11] is presently in its commissioning state. Remaining is installation of the beamlines to the ring and low energy experiments, and in-house testing of the 315 kW motor generator. The source of the HYPER-NANOGAN type is from Pantechnik, with operating frequency 14.5 GHz and 2 kW maximum RF power. The source is equipped with three different injection systems, one for gases only, an oven for molten metals and a sputtering device for metals and compounds. Extraction voltages up to 30 kV are possible.

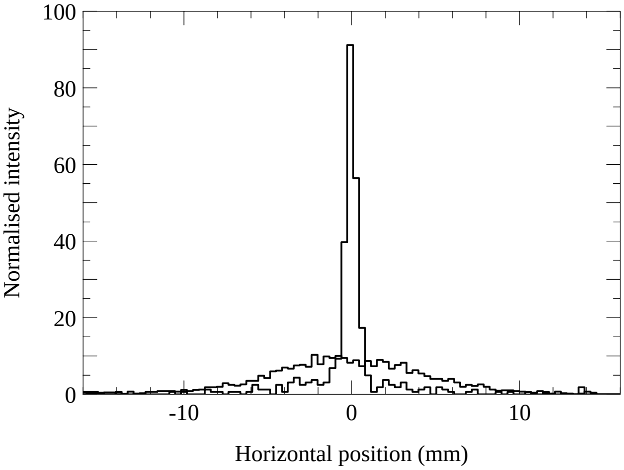

Fig 2. Beam profiles showing cooling of Pb^{54+}, from an experiment done in collaboration with CERN. The first profile shows the uncooled beam, and the second profile is measured 150-200 ms after the start of cooling.

The source is mounted on a 300 kV platform to get a reasonably high injection energy also for ions with q/m<0.24 (which cannot be accelerated in the RFQ), but the ion current stored in the ring will still in some cases be limited by space charge tune shift.

The source is enclosed with 60 cm air insulation and 100 cm porcelain insulators.

Table 2. Measured ion currents from the ECR source.

Ion	Current μA	Injection system
Ar^{8+}	300	gas
Ar^{11+}	125	gas
Ar^{14+}	8	gas
Pb^{25+}	30	oven
Ta^{24+}	24	sputter

6 VACUUM

The vacuum system in the ring is presently based on NEG (Non Evaporable Getter) pumps and ion pumps [12]. The pressure is 1×10^{-11} mbar, and the residual gas consists of 90 percent H_2. It is however mostly the remaining 10 percent that reduce beam lifetime and increase experimental background. Apart from ions from the beam the main components are CH_4, CO, CO_2, and Ar.

The system is upgraded to be able to reduce these heavy components in the residual gas approximately with a factor five, or even more with a gas load. Memory effects which follow with ion pumps become smaller.

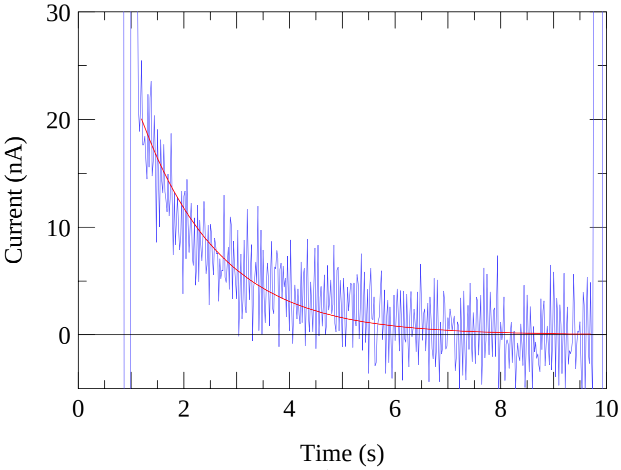

Fig 3. Decay of a 20 nA NH_4^+ beam with 1.5 s lifetime. 120 averages.

The most important part of the upgrade is to replace the ion pumps with eight high compression turbo pumps (the compression is 10^8 for helium). Two pumps will be situated around the new gas-jet target [13], one will be in the middle of the electron cooler section, and the others will be distributed around the ring so that each vacuum section of the ring is equipped with a turbo pump. To reduce H_2 outgassing a NEG pump is placed on the entrance to each turbo pump.

The high pressure end of the turbo pumps will be connected to a separate pre-vacuum system, a bakable stainless steel tube pumped with two or three turbo pumps down to 10^{-6}-10^{-7} mbar.

The ion pumps will still be mounted in the ring so it will be possible to activate them and thereby manipulate the composition of the residual gas.

Water cooling is installed in the dipole and electron cooler vacuum chambers in order to slow down the diffusion of hydrogen, and in that way decrease the outgassing of H_2 and CH_4.

7 CHARGE CHANGE DETECTION

To be able to detect charge changes of ions in the electron cooler the magnet section following the electron cooler is reconstructed. The apertures in the vacuum chambers are increased, and new ports are added to be able to mount detectors in several different positions. In order to get sufficient horizontal aperture one pick-up is removed and one vertical correction magnet is replaced with one with larger gap.

It is possible to detect any charge change that occur inside the electron cooler. Most important is single electron capture where four detector positions cover the full range of initial charge states in addition to the zero degree exit, but one can also study e.g. $D^+ + 2e^- \rightarrow D^-$ or molecular fragmentation where particles have much higher q/m than the original ion. In the last case a detector is inserted into the dipole chamber on a long arm.

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