Status and Commissioning of CRYRING

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Abstract

The status of the CRYRING project as of March 15, 1992 is reported. In particular the first year of beam operation in the ring is reviewed.

1 INTRODUCTION

CRYRING [1] is a facility for research in atomic, molecular and nuclear physics. An overview of the first phase, which is now close to completion, is shown in figure 2. It comprises a cryogenic electron beam ion source, CRYSIS, which produces very highly charged heavy ions. Via an RFQ linear accelerator the ions are injected into a synchrotron/storage ring where electron cooling can be applied. The beam from the ion source is also directed to different experimental set-ups in five beamlines. In one of these a Penning ion trap will be mounted.

An alternative injector (MINIS) has been constructed to be used primarily in machine tests. The ion source can produce singly charged ions of gases. It is placed on a 50 kV platform to give the correct injection energy for the RFQ.

2 CRYSIS SYSTEM

The ion source CRYSIS [2] has been remounted in the present position as part of the CRYRING project, see figure 2. After installation the first beam was delivered to experiments in the end of 1990. During the remounting many improvements have been made to reach higher charge states with more intensity. Replacements of some electronics and switch to full computer control are some of the changes made to gain in flexibility and reliability. A major reconstruction of the electron gun system has improved the electron current transmission to 99.97 % and raised the maximum electron energy to at least 50 keV. At 600 mA electron current a maximum of 1.5×10^{10} charges per pulse has been achieved. As shown in figure 1, ions of Xe^{48+} have been extracted from the ion source. The ion source system is placed on a 50 kV DC platform to give the ions proper energy, 10 keV/u, for injection into the RFQ. An injector isotope separator INIS has been installed close to CRYSIS to allow injection of singly charged ions into CRYSIS, which will give more ions of the chosen species as well as isotope selection and an increased variety of species. The pulsed operation of the injection has been preliminarily tested showing the need for minor modifications which have been performed but not yet tested. Ion beams from INIS have been used for atomic physics experiments since the end of 1989.

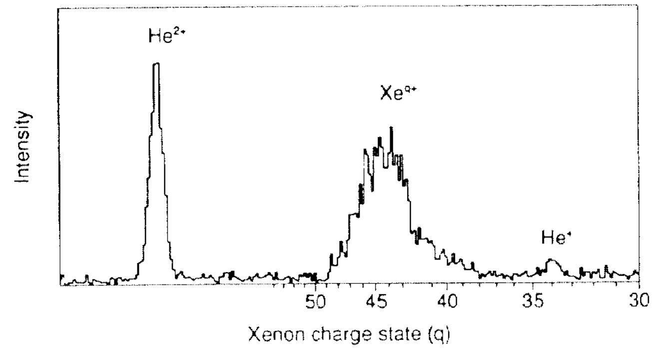

Figure 1: Spectrum of xenon ions from CRYSIS.

3 MINIS, RFQ AND INJECTION LINES

The test ion source MINIS can deliver singly charged ions of gases. It then covers the range of q/A from .25 to 1 for which the RFQ can accelerate the ions. The time structure of the injected beam is modified with a chopper. The number of turns injected can be varied from less than one to more than ten, the design value for multiturn injection. The RFQ [3] has been working since April 1990 for ions with $q/A > .3$. Lower q/A will need higher driving power. Extra amplifiers have been purchased and will be installed. After the acceleration in the RFQ to 300 keV/u the energy spread is about $\pm$ 1 %. It will be reduced by a factor of 2 in a debuncher.

The beamline from CRYSIS to the RFQ has been completed and tested. The beam is monitored with two-dimensional strip detectors.

The competition for CRYSIS beamtime is severe and several physics programs involve the use of low charge ions in the ring. An upgrade of MINIS including mass separation is therefore under way.

4 SYNCHROTRON/STORAGE RING

All the different subsystems of the ring except for the cooler are installed and tested. The vacuum system has

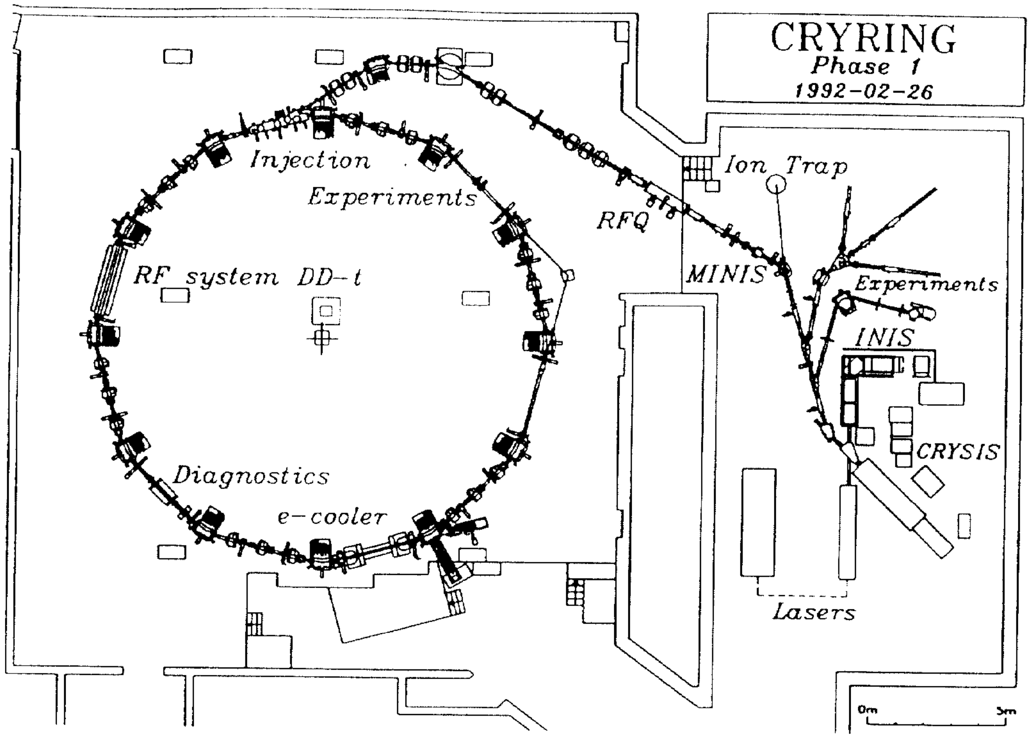

Figure 2: Layout of the CRYRING project, phase 1.

been completed with the exception of some baking equipment. It is described in another contribution to this conference [4]. Without any baking the vacuum in the ring is now 1-5 × 10^{-11} mbar.

The injection system [5], where both the inflection channel and the local orbit bumping system are electrostatic, works according to expectations both for singleturn and multiturn injection. The acceleration system [6] is of non-resonant type, a driven drift tube, with a very fast response. The operation has not been hampered by any significant problems except for a short lifetime of the water-cooled plate resistors. The effect of improved cooling-water purification is now being tested.

All ring magnets are installed except the two correcting dipoles around the cooler, which will be mounted on the cooler frame. The purchase of the sextupole power supplies had to be delayed until the total financing of the project could be settled. Fortunately it was found that the correcting dipoles were not needed with the modes of operation hitherto employed. The correcting dipole power supplies have therefore been used for the sextupoles. Ramped bipolar individual power supplies for all 12 sextupoles have been delivered and are now being installed.

Nine vertical and nine horizontal electrostatic pick-ups are mounted in the ring. The beam signals are read either as a trigged peak voltage [7] or as a synchronously rectified voltage [8]. The first method, which is now operational, means that the position of individual beam bunches can be observed. The signals can be fed to a VME-based system with an 8 bit flash-ADC were the positions of 256 successive turns can be registered. Together with an electrostatic kicker this system is used to make tune measurements. Four 1.35 m long plates surrounding the beam are used to pick up the Schottky noise. By making appropriate sums and differences of the amplified signals, the longitudinal and/or transversal beam properties have been studied. A commercial beam current transformer is used to measure the circulating current.

The control system [9] has now been in operation for almost three years and today most parameters in use are computer controlled.

The electron cooler [10] is moved to a place close to its position in the ring. All parts are manufactured. After testing it will be rolled into the ring. The field axis of the cooler solenoid has been tracked With two sets of correcting windings applied the deviation from a straight line can be reduced to less than 0.1 mrad. The final assembly is expected to be completed within a few weeks. A compensating solenoid has been installed.

5 RESULTS

In December 1990 a first beam of H_2^+ was transported around the ring. It was produced in the test injector MINIS which so far has been used for most of the machine development. The H_2^+ molecule was used as it had the best production rate in the ion source. However, the dissociation cross-section of the H_2^+ molecule is large. To gain in lifetime beams of deuterons have mainly been used despite the considerably lower output from the ion source.

As expected from the lattice calculations [5,11] there are few systematic resonances as well as a large stable region in the tune diagram which limits the losses due to the energy spread. The closed orbit measurements have shown that in most runs and at the present level of sophistication orbit corrections were not needed.

When powering the twelve sextupoles an increase in intensity and beam lifetime was achieved. During the early runs the lifetimes were measured as the decay of the sum signal of the electrostatic pick-ups, i.e. with rf on. As vacuum was improved and lifetimes became longer the influence of instabilities in the rf became obvious. A phase loop is therefore being constructed. The longer lifetimes are measured on a coasting beam with Schottky detector and current transformer.

The acceleration is made without feedback between magnetic fields and frequency of the accelerating system. The frequency ramp is adjusted to give the best performance. It was fairly easy to accelerate the beam to 5.2 MeV/u without major intensity losses. Maximum energy, 24 MeV/u at $q/A = 0.5$, was reached in October 1991 but with significant losses at regular frequency intervals. The reason was found to be 10 μs long disturbances on the frequency reference at times when many bits were changed. Due to the fast response of the driven drift-tube, the beam was affected as described. In figure 3 is shown the beam intensity during acceleration to 20 MeV/u after removal of the reference disturbance. The drop in intensity is caused by the measuring method, where the analyser frequency is varying linearly, not following the acceleration frequency. At the energy of 20 MeV/u and with the improved vacuum conditions, 1–5 $\times 10^{-11}$ mbar, the lifetime for the deuteron beam was estimated to several hours.

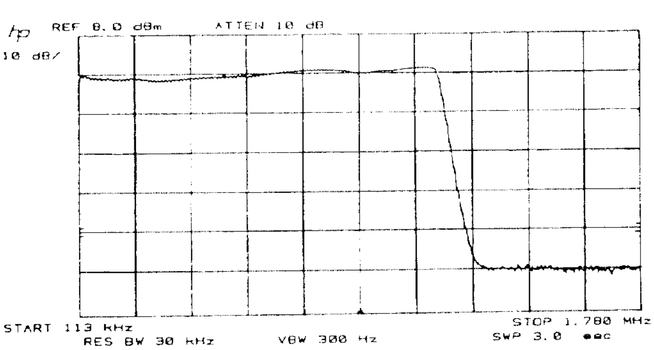

Figure 3: Intensity of a D^+-beam during acceleration 0.3-20 MeV/u. For drop see text.

Figure 4 shows the longitudinal Schottky spectrum for a 20 MeV/u deuteron beam at the beginning of flat top and about one hour later. No significant decrease in intensity can be seen. Typical values of the number of stored particles are 10^8 for deuterons and 10^9 for hydrogen molecules. The difference is mainly due to the difference in ion source output.

In November 1991 a first beam of He^{2+} ions, produced in CRYSIS, was transported to the RFQ, accelerated to 300 keV/u, injected into the ring, and stored with an apparent lifetime of 30 ms. Beams of N^{7+} have also been injected into the ring.

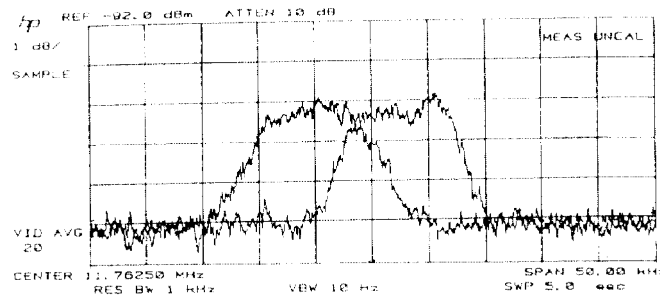

Figure 4: Longitudinal Schottky spectrum for deuterons at 20 MeV/u, right peak at beginning of flat top, and left 1 hour later, after 0.07% decrease of the momentum.

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