INITIAL EXPERIMENTAL RESULTS OF THE SMALL ISOCHRONOUS RING (SIR)*

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Abstract

The Small Isochronous Ring (SIR) is under development at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU). The ring is a small-scale experiment that simulates the dynamics of intense beams in large-scale accelerators. Its main purpose is the study of longitudinal space charge effects in the isochronous regime. A 20 to 30 keV bunch of hydrogen or deuterium ions is injected in the ring. After a variable number of turns (~ 20-30), the bunch is extracted and its longitudinal profile is studied. This paper describes the hardware already designed, manufactured and installed as well as the first preliminary experimental results.

1 INTRODUCTION

The main goal of the project is to study experimentally the effects of space charge in the isochronous regime. Using low energy, low intensity hydrogen or deuterium beams, we intend to simulate the beam dynamics of high current machines. Papers [1], [2] and [3] provide additional details on the project. Results of simulations of the beam dynamics in the injection line and in the ring can be found in [4] and [5] respectively.

The injection line of SIR and the four magnets of the ring have been manufactured and installed. Beam has been extracted, injected in the ring and detected with a Faraday Cup after ¼ of a revolution. No systematic experiments have been performed yet since the assembly finished at the end of April 2003. Figure 1 shows a picture of room where SIR is being built. Beam has been transported through the colored segments.

2 ION PRODUCTION AND SEPARATION

A multicusp ion source is used to produce a beam composed of H^+, H_2^+ and H_3^+ ions. Experiments with deuterium will also be performed. In this case, the ultimate pressure in the ring will be lower since its higher mass will increase the effective pumping speed giving a longer life-time of the bunches in the ring.

Biasing the source (up to 30 kV) defines the extraction energy of the beam. The puller of the ion source also acts as the first ground electrode of the Einzel lens that immediately follows. Focusing as close to extraction as possible is required due to the large angle dispersion of the extracted beam. Typically, a voltage in the Einzel lens of ~ ⅔ of the extraction voltage provides a focusing length ~10 cm. Some non-linear effects have been observed. Simulations indicate that they are mainly

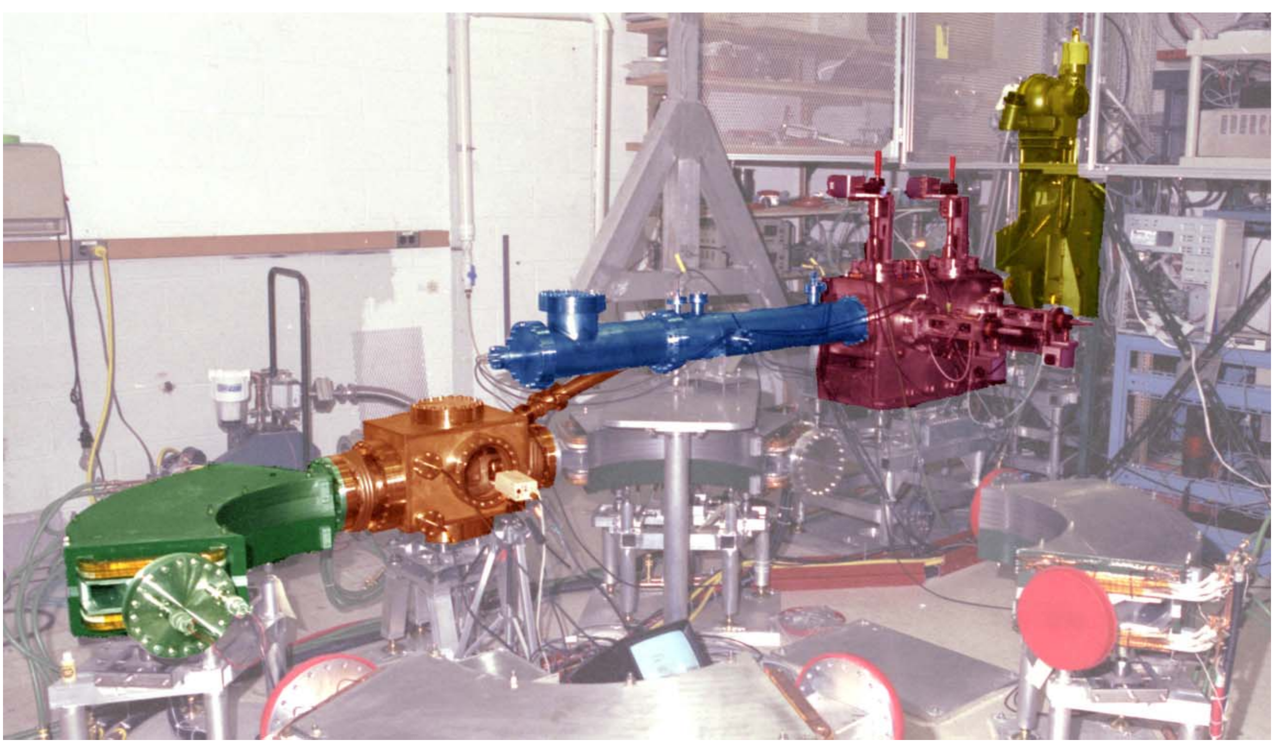

Figure 1: Room where SIR is being built.

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produced by the Einzel lens [4].

A couple of orthogonal pairs of steering plates (9 cm long, 6 cm gap, ±1 kV voltage, up to 65 mrads kick to 30 keV H_2^+ beam) are the first mean to correct possible misalignments in the injection line.

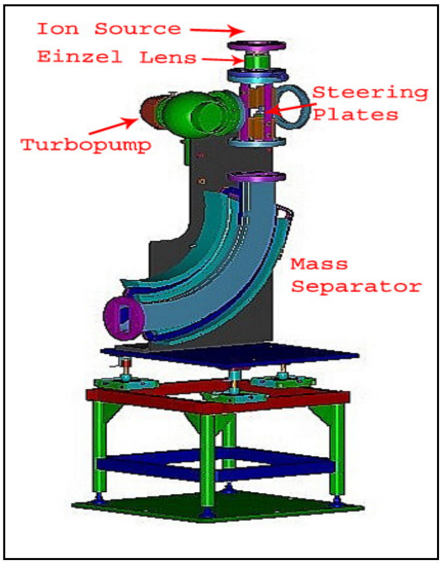

Figure 2: First section of injection line

The different mass states are separated by a dipole magnet identical to those used in the ring [2].

The first preliminary measurements show currents in the order of 10-100μA for different ions species. This is enough to cover the desired range of peak currents in the ring. Systematic experiments to characterize the extracted beam will be conducted in the following months.

3 EMITTANCE MEASUREMENT SYSTEM

A couple of orthogonal pairs of movable slits and Faraday Cups are used to characterize the transverse beam parameters. This information is used to recalculate the focusing lengths of the Einzel lens and electrical quadrupoles needed to match the injected beam to the close orbit solution in the ring.

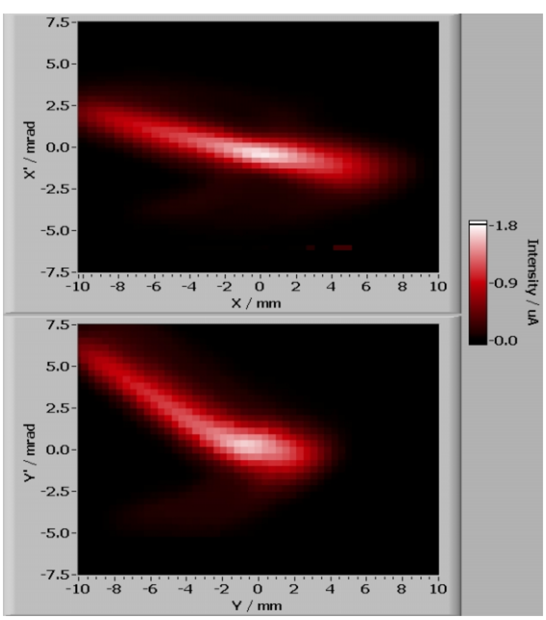

Figure 3: X-X' and Y-Y' maps (15keV H_2^+)

Figure 4 shows an X-X' (medium plane of the ring) and a Y-Y' map of a 15 keV H_2^+ beam from which an emittance $\varepsilon \simeq 10\pi \cdot mm \cdot mrad$ (unnormalized) can be estimated. Previously, other experiments were performed where the ion source had a 2 mm diameter aperture instead of a 1 mm one. In that case an emittance $\varepsilon \simeq 50\pi \cdot mm \cdot mrad$ was measured.

The distance between slits (0.5 mm gap) is 47.5 cm. Another couple of orthogonal pairs of steering plates (identical to the ones right after the ion source) are located between slits. These electrodes, together with the dipole magnet and the inflector plates can be adjusted to correct for possible misalignments or residual external fields.

A beam stopper will be added in this region in the coming months. It will be covered with phosphor to be used as a fast diagnostic tool.

4 MATCHING AND CHOPPING SECTION

A triplet of electrical quadrupoles, located right after the emittance measurement box, together with the Einzel lens and the quadrupole corrector coil in the mass separator provide flexibility to match the extracted beam to the close orbit solution in the ring. Refer to [4] for more details in the capabilities of the injection line to match different initial ensembles. The lengths of the quadrupoles are 10.5 cm, 14 cm and 6 cm. The distance between them is 9 cm and the gap between electrodes is 7 cm. The shape of the electrodes is not hyperbolic but circular. 3-D calculations do not show a significant deviation from ideal case.

A pair of 5 cm long plates are pulsed up to ±3.5 kV to provide the time structure of the bunches. Two grids next to the plates are used to limit the deflection region. Bunches as short as 30 ns are expected. At this time, no precise measurements of bunch lengths have been performed since a fast Faraday Cup has not been built yet. A regular Faraday Cup located at the end of the injection line has been used and pulses <5 μs have been observed.

A pair of 16.5 cm inflector plates (gap ≥7 cm), located right after the chopper, bend the trajectory of the beam

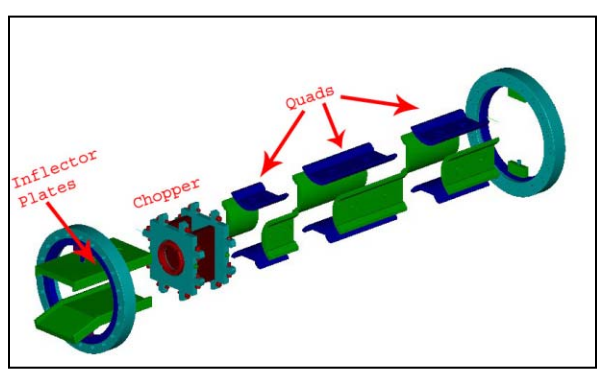

Figure 4: Quads, Chopper, Inflector Plates Section

17.5^o and a second pair located in between two of the magnets of the ring, position it in its medium plane. This second pair is pulsed to avoid deflection after completion of the first turn. The geometry of plates is optimized to maximize distance between deflected beam and plates and to avoid introducing non-linear effects in the beam.

5 RING INJECTION SECTION

Besides a pair of pulsed deflector plates responsible for bending the beam trajectory back to the medium plane of the ring, there is a movable three position phosphor screen. This allows interception of the beam both when it is injected and after the first turn. Figure 5 shows the beam being intercepted when injected.

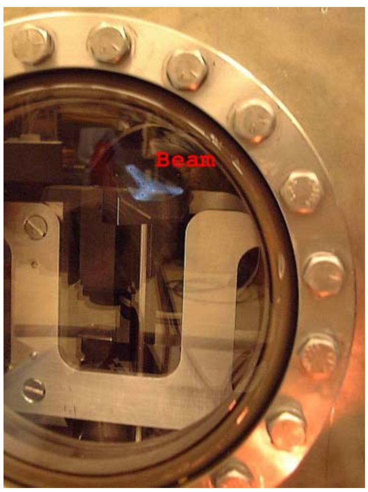

Figure 5: Beam intercepted in phosphor screen

A triangular shape in the beam can be observed. Although, no satisfactory explanation was found yet, it is believed that the ceramics holding the Einzel lens may be the cause. They may be charging up or the perturbation they introduce in the field distribution could be disturbing the beam close to their position.

Three 500 L/s turbopumps are used to reach a pressure of $2 \cdot 10^{-7}$ torr in the ring with a few mTorr pressure in the Ion Source. One of them is located right after the ion source, a second one in the emittance measurement box and a third one in the first straight section between magnets. A fourth one will be installed in one of the other sections of the ring.

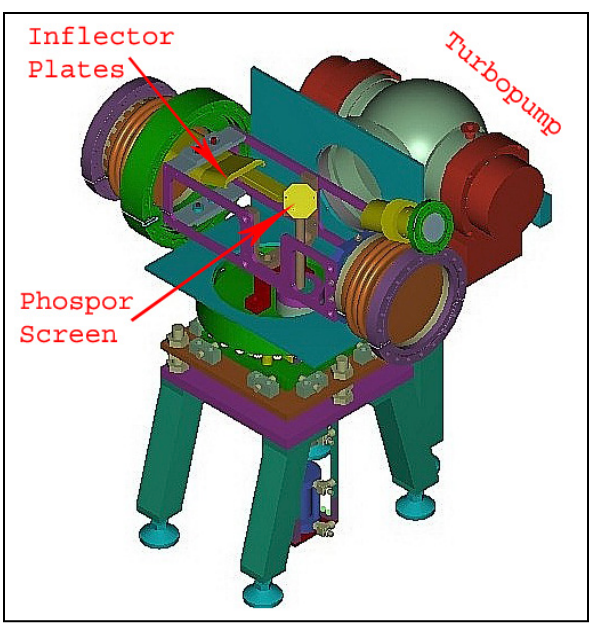

Figure 6: Straight section between magnets

6 CONCLUSION

The injection line and the four ring magnets have been manufactured and installed. Beam completed ¼ of a revolution in the ring at the end of April 2003.

In the next few months, the other three straight sections of the ring will be designed and manufactured. A Fast Faraday Cup will be developed and tested. The control system will be enhanced. The source of the triangular shape of the beam will be studied and corrected. Systematic experiments to characterize the ion source will also be performed.

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