SMALL ISOCHRONOUS RING PROJECT AT NSCL

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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 main objective of the project is the experimental study of space charge effects in the isochronous regime. The ring is a small-scale experiment that requires low beam intensities to simulate the dynamics of intense beams in large-scale accelerators. The important issues to be addressed by the ring are the space charge induced vortex motion specific to the isochronous regime, the longitudinal break-up of long bunches, formation of the self-consistent stable charge distribution by short bunches, and formation of weak beam tails and beam halo. This paper reports the status of the project and describes the design of major ring systems.

1 INTRODUCTION

The Small Isochronous Ring (SIR) [1], whose main objective is experimental study of space charge effects in the isochronous regime, is under development at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU). The ring will provide the unique opportunity to perform precise experiments on the space charge that are difficult to conduct in large-scale accelerator because of power and timing limitations imposed on beam diagnostics. The results of the experiments will have applications to high-current isochronous cyclotrons and synchrotrons at the transition gamma. A possibility of accurate measurement of beam parameters will also allow SIR to be used as a convenient tool for validation of multi-particle codes used for space charge simulations.

2 SIR DESIGN

2.1 SIR Lattice and Main Parameters of the Ring

Figure 1 shows a schematic view of SIR and its injection and extraction lines. Table 1 summarizes the ring main parameters. Results of detailed computer simulations of the beam dynamics, both single- and multi-particle, in SIR are presented in [2].

2.2 Ion Source and Injection Line

A multi-cusp ion source, that can be biased up to a potential of 30 kV, is used for production of accelerated hydrogen or deuteron beams. An ion source setup has been assembled and successfully tested the latter part of 2001. The maximum total extracted current of the 20 keV hydrogen beam exceeded 500 μA. The measured total emittance of the beam was less than 50 π·mm·mrad, approximately 15 times smaller than the ring acceptance.

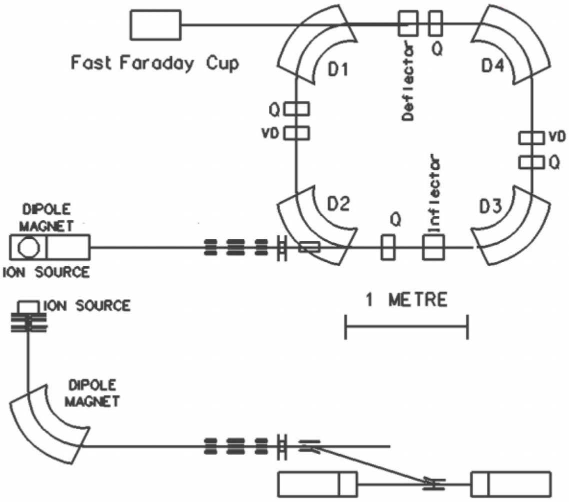

Figure 1: Plan and side view of the Small Isochronous Ring.

Table 1: Main beam and machine parameters

Particles	H^+, H_2^+ or deuterons
Max. Energy	30 keV
Circumference	6.57 m
Bare betatron tunes ν_x, ν_y	1.14, 1.11
Momentum compaction α_p	1.0

The injection line, schematically shown in Figure 1, consists of an Einzel lens placed next to the ion source, a dipole magnet that serves as a charge-state separator, electrostatic beam steering electrodes, and a triplet of electrostatic quadrupole lenses responsible for beam matching to the ring. It also includes an emittance measurement system that follows the dipole magnet. A detailed description of the injection line can be found in [3].

2.3 Magnets

Figure 2 shows a 3D drawing of the SIR dipole magnet with a partly removed yoke. Table 2 lists the main magnet parameters.

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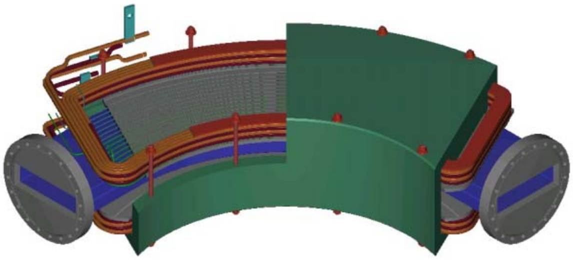

Figure 2: SIR magnet

Table 2: Magnet parameters

Gap	71.4 mm
Bending angle	90°
Bending radius	0.45 m
Magnetic field	800 Gauss
# of coil turns	32
Current	135 A
Weight of a magnet	130 kg
Total power consumption	4 kW

SIR magnets were designed to accommodate the beam with a large radial size. Facets provided on both sides of the 19 cm wide pole tips increase the flat field region ($\Delta B/B \leq 5 \cdot 10^{-4}$) to ±5 cm. Both entrance and exit pole faces of each dipole are rotated 26°. The edge focusing provides both vertical focusing and isochronism in the ring.

2.4 Quadrupole Correctors and Steering

The betatron tunes and isochronism in SIR can be controlled, if required, by means of four electrostatic quadrupoles installed between the magnets (see Figure 1) and four quadrupole correctors situated in the magnets. The later consist of aluminum grooved plates with single-layer quadrupole coils placed in the grooves. These correctors induce a field gradient in the dipoles. One of these plates can be seen in Figure 2 between the main coil and the vacuum chamber.

The dipole magnets also include small steering coils that allow us to trim the field in each magnet independently. Powered from small, independent power supplies, the coils are capable of producing a magnetic field as strong as ±16 Gauss. This field variation is strong enough to correct 10 cm horizontal errors of the closed orbit at the maximum field level. To control the vertical position of the beam in SIR we plan to install electrostatic vertical deflectors in the drifts between the magnets.

2.5 Vacuum System

The vacuum chamber in the dipole magnets will be made of aluminum to avoid complications arising from residual or induced variation of the μ for stainless steel. The vacuum chamber between the magnets, where the magnetic field is weak, will be made of regular 304 stainless steel.

The vacuum system will be equipped with three 500 l/s turbo-pumps. One of the pumps will be installed next to the ion source. The other two will be installed in the ring: one close to the inflector and and the other one in the deflector drift.

Two main sources of residual gas in the ring are outgasing from the walls of the vacuum chamber, which can be reduced by means of baking, and the gas flux from the ions source linearly depending on pressure in the ion source chamber. Vacuum calculations and model experiments with the injection line substituted by an orifice of an equivalent conductance show that pressure in the ring will be at a level of 10^{-7} Torr if the ion source pressure is kept below 1.0 mTorr. The expected beam life which is mostly determined by electron capture at this pressure is approximately 100 turns.

2.6 Injection-Extraction System

Single-turn vertical injection will be performed by means of a fast pulsed electrostatic inflector. The voltage on the inflector is regulated by the fast semiconductor switch PVX-4140 commercially available from Directed Energy Inc. The output of the switch is matched to the capacitive load of the inflector. Table 3 gives the main parameters of the injection system.

Table 3: Parameters of the injection-extraction system

Injection angle	17.5°
Length of the plates	16 cm
Gap between the plates	7 cm
Max. Voltage	±3500 V
Rise-decay time	30 nsec
Pulse width	0 to ∞
Pulse amplitude stability	1%
Repetition rate	100 Hz

The extraction system, which sends the beam to a Fast Faraday cup, is identical to that used for injection.

2.7 Diagnostics

The diagnostics in the ring will consist of a retractable phosphor screen placed at the injection point and three retractable four-sectored Faraday cups positioned in the drifts between the magnets. The diagnostics will also include a Fast Faraday cup with a movable vertical slit in a front of the Faraday cup. This setup will be used for accurate measurements of the longitudinal-radial beam profile, will be situated at the end of the extraction line. The Fast Faraday cup can be of either the coaxial or the strip-line kind. Both designs have a time resolution less than 1 nanosecond, equivalent to spatial resolution of 1.4 mm for a 20 keV deuteron beam.

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