COMMISSIONING THE MIT-BATES SOUTH HALL RING *

K. Jacobs, R. Averill, S. Bradley, A. Carter, G. Dodson, K. Dow, M. Farkhondeh,
E. Ihloff, S. Kowalski, B. McAllister, W. Sapp, C. Sibley, S. Sobczynski, D. Tieger, C. Tschalaer,
E. Tsentalovich, W. Turchinetz, A. Zolfaghari,
MIT-Bates Linear Accelerator Center,

and
T. Zwart,
Boston University

Abstract

The South Hall Ring at the MIT-Bates Linear Accelerator Center is a 1 GeV electron ring for nuclear physics experiments. It is designed to operate in two modes: as a pulse stretcher to deliver high duty factor beams to external targets, and as a storage ring for internal target experiments. To date we have injected beam into the ring using one and two-turn injection, stored beam with a lifetime of several minutes, and achieved early results performing half-integer resonant extraction from the ring in pulse stretcher mode. Experience in commissioning the ring is presented. Future plans for extraction, improved storage and backgrounds, and spin control and measurement in the ring, are also discussed.

I. INTRODUCTION

The South Hall Ring (SHR) at the MIT-Bates Linear Accelerator Center is now being commissioned. It is an electron stretcher/storage ring designed to serve nuclear physics experiments in two ways: as a pulse stretcher ring, converting the 1 % duty factor beam from the Bates linac into a high duty factor beam, and as a storage ring, providing high average current beams for internal target experiments. Coupled with the existing linac and recirculator, the polarized electron source, and various large spectrometers, as well as the planned large acceptance spectrometer, the SHR provides unique opportunities in medium energy nuclear physics.

The layout of the ring and its associated beamlines is shown in Fig. 1. The ring circumference is half the linac-recirculator circumference, providing for two-turn injection. Each $180°$ ring bend section is a symmetry corrected second order achromat. The injection straight section has flat beta at the injection point, and low betas at the internal target location. This will help in maintaining good beam lifetimes and low backgrounds with the gas-cell targets we anticipate using. The extraction straight section has a large beta at the extraction electrostatic septum to facilitate extraction. Table 1 gives a summary of ring and beam parameters.

II. COMMISSIONING EXPERIENCE

Commissioning started in early 1993. A staged approach was adopted, with commissioning of the injection line first, followed by storage in the ring, extraction from the ring, commissioning

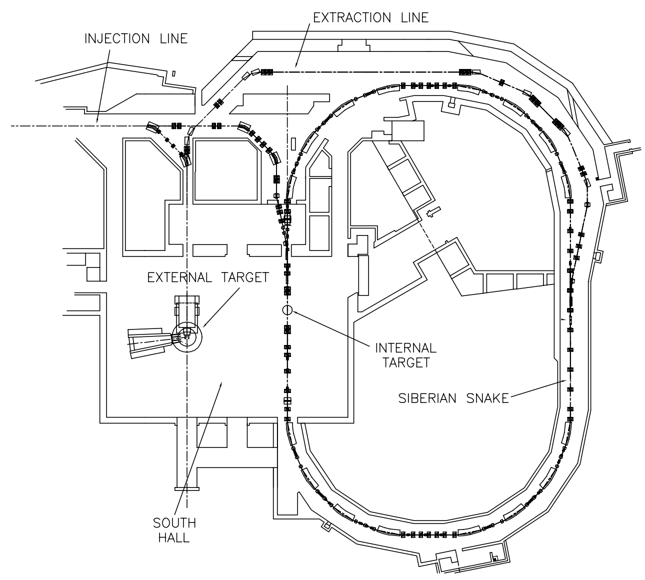

Figure 1. Layout of the South Hall Ring.

the extraction line, and finally spin control in the ring. Ring diagnostics, when fully implemented, will include 31 BPMs (x, y, and I), 12 retractable flourescent screens, a fast current monitor and a DCCT, loss monitors, and synchrotron light monitors.

A. Storage

Initial commissioning of the ring was done using a single injection kicker and one-turn injection. Figure 2 shows the turn-by-turn current in the ring for the first several turns, demonstrating good capture efficiency. The one-turn injection goal of 40 mA current has been achieved. Using two kickers, we have also demonstrated two-turn injection.

Initially the ring was operated with no RF. In that case, energy loss due to synchrotron radiation gives a short lifetime. Figure 3 shows the beam current measured by a DCCT, for the case of no ring RF. The flat part of the current occurs as the beam is still contained within the beam-pipe, but is moving toward the inner wall of the bend sections as its energy drops. After several milliseconds, the beams starts to be lost on the wall, and the stored current drops.

When CW RF became available, we were no longer limited by synchrotron radiation losses. Lifetimes $(1/e)$ of several minutes have now been obtained, as shown in Fig. 4. In order to

*Work supported by the U.S. Department of Energy

Energy range	300–1000	MeV
Circumference	190.204	m
Revolution frequency	1.576	MHz
Bend radius	9.144	m
Stored current (2-turn inj.)	80	mA
Extracted current (average)	50	μA
Extracted duty factor	85	%
Injection frequency	1	kHz
RF frequency	2.856	GHz
Harmonic number	1812	
Momentum compaction	0.029	
Horizontal tune (extr. mode)	7.460	
Vertical tune (extr. mode)	7.798	
Synch. rad. losses (at 1 GeV)	9.8	keV/turn
Energy spread (with ECS)	0.04	%
Emittance (at 500 MeV)	0.01	mm·mr

Table I
SHR design parameters

achieve these longer lifetimes, it was necessary to make controlled bumps in the closed orbit, to move the beam away from apertures (most notably the injection septum). It is likely that further aperture studies will result in increased lifetimes; at this time we know of no other mechanism which should be limiting the beam lifetime. It is worth noting, however, that the lifetimes already achieved are sufficient for the planned experimental programs at Bates.

B. Extraction

Half-integer resonant extraction is used when the ring is operated in pulse stretcher mode. A ramped air-core quadrupole is used to drive the horizontal tune from 7.46 toward 7.50. DC octupoles separate the horizontal phase space into stable and unstable regions. At injection, all of the beam is in the stable region. As the quadrupole is ramped, some electrons become unstable, and eventually pass into the deflecting region of the extraction septa, where they are directed out of the ring and down the extraction beam-line.

To date, preliminary extraction results have been obtained. Figure 5 shows the current stored in the ring during the extraction process, as measured by a DCCT, and the current extracted from the ring. The extracted current was measured by a photomultiplier tube aimed at a fluorescent screen in the extraction beam-line. While this does not provide a quantitative measure of how much beam was transported down the extraction line, it does demonstrate successful half-integer resonant extraction. When the fluorescent screen was removed from the beam-line, the PMT signal dropped to noise levels. In addition, the beam spot observed on the screen was well defined.

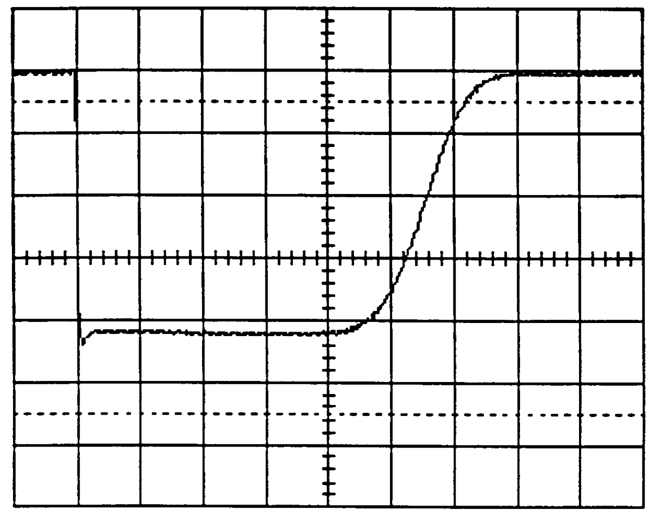

Figure 3. Stored current *vs.* time, without ring RF. The horizontal scale is 1 ms/div.

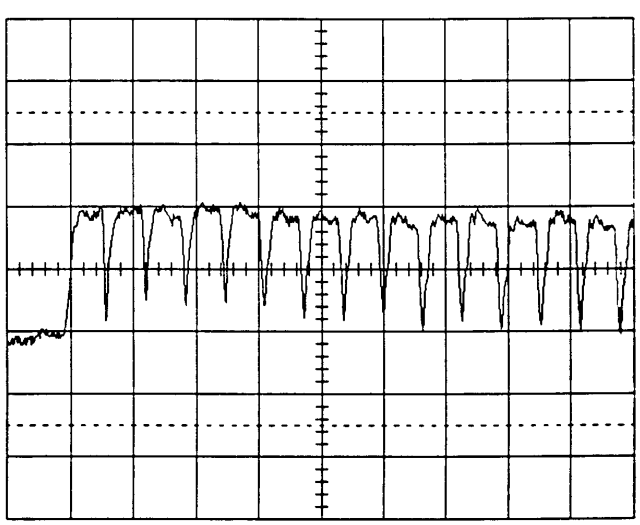

Figure 2. Current in the ring for the first several turns, using single-turn injection. The horizontal scale is $1\,\mu\mathrm{s/div}$.

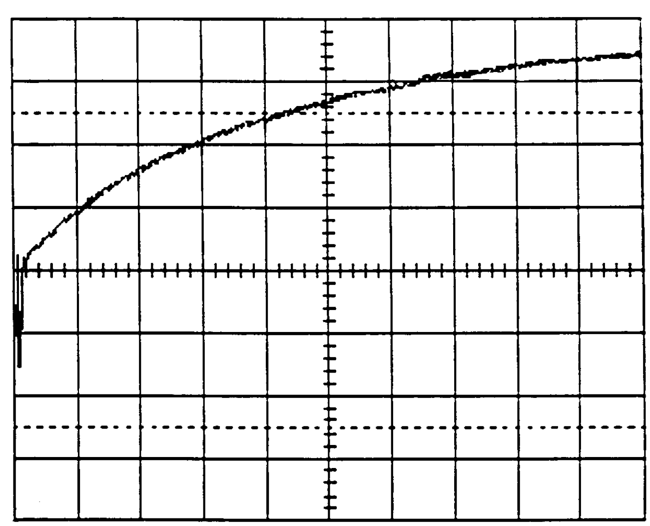

Figure 4. Stored current *vs.* time, with ring RF on. The horizontal scale is 50 s/div.

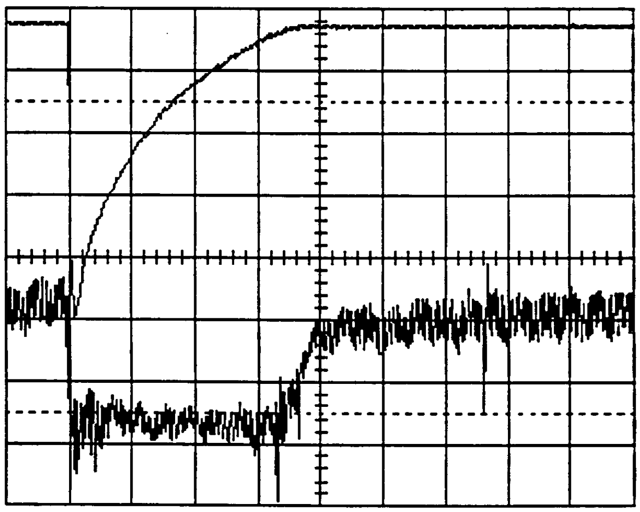

Figure 5. Preliminary results extracting from the ring. The upper trace shows the current stored in the ring, and the lower trace shows the signal from a photomultiplier tube looking at a fluorescent screen on the extraction line. The horizontal scale is 0.5 ms/div.

Beam was recently transported from the ring, through the entire extraction line, to the South Hall fixed target point, for the first time. This was not done with resonantly extracted beam, but rather with beam steered directly down the extraction line.

III. FUTURE PLANS

The work remaining to be done on the SHR falls into three categories: continuation of the work on resonant extraction, studies in storage mode to minimize backgrounds and increase lifetimes for internal target experiments, and the installation and commissioning of spin control and measurement components in the ring.

In the near future we expect to concentrate on further commissioning resonant extraction from the ring. This will include quantitative measurements of both the duty factor and efficiency of the extracted beam, with the ultimate goal being $50\,\mu$A of beam on target with good throughput and high ($\sim\ 85\,\%$) duty factor.

Although beam lifetimes are already sufficient for internal target usage, some work remains to be done to determine the sources of backgrounds, and their cures. This encompasses backgrounds associated with injecting beam into the ring ("injection flash"), as well as backgrounds from beam stored in the ring. It is likely that what reduces backgrounds, will also result in increased lifetimes.

Electrons from the Bates polarized source will be injected and stored in the ring with their spins oriented longitudinally. To compensate for $g-2$ spin precession at arbitrary electron energies, a superconducting solenoid (Siberian snake) will be installed on the straight section of the ring opposite the injection point. The location of this solenoid, indicated in Figure 1, is such that it will maintain longitudinal polarization both for internal targets and for fixed targets utilizing the extracted beam. The optics of the solenoid and its associated skew and normal quadrupoles has been designed such that the beam outside the snake region is not perturbed from unpolarized operation.[1] Installation and commissioning of the snake are expected to take place in late 1995.

We plan to measure the spin of stored electrons utilizing Compton backscattering. Design of the polarimeter is well underway at this time.

IV. SUMMARY

Commissioning of the MIT-Bates South Hall Ring is well underway. We have demonstrated one and two-turn injection, and have stored beam with lifetimes exceeding design goals. Good preliminary results have been obtained for resonant extraction, with more work to be done. Control of electron polarization in the ring is expected to be in place within a year.

References

[1] T. Zwart, P. Ivanov, Yu. Shatunov, R. Averill, K. Jacobs, S. Kowalski, W. Turchinetz, "A Spin Control System for the South Hall Ring at the Bates Linear Accelerator Center", these proceedings.