THE MIT-BATES SOUTH HALL RING: A UNIQUE INSTRUMENT FOR STUDYING POLARIZATION *

W. A. FRANKLIN for the BLAST COLLABORATION

MIT-Bates Linear Accelerator Center,
P.O. Box 846,
Middleton, MA 01949, USA
E-mail: wafrankl@mit.edu

The MIT-Bates South Hall Ring (SHR) is a unique facility for carrying out experiments with polarized electron beams and polarized internal targets at energies up to 1 GeV. In its storage mode, the SHR delivers one of the most intense polarized electron beams in the world. This paper describes the characteristics of the SHR electron beam during experiments with the BLAST Spectrometer. Preliminary measurements of the beam polarization are shown and discussed.

The MIT-Bates Linear Accelerator Center is a facility which delivers intense polarized electron beams for a diverse set of experiments. The accelerator can operate in several distinct modes. In the standard mode, polarized electrons are accelerated from a polarized source through a 500 MeV linac at repetition rates as high as 600 Hz. The beam may be recirculated to reach energies of up to 1 GeV. This mode has been used for fixed target experiments such as SAMPLE[1].

Electron pulses from the accelerator may also be injected into the South Hall Ring (SHR) to achieve beams of high duty cycle. The South Hall Ring has a racetrack design with two long straight sections and a 190 m circumference. It contains 16 dipoles and a single RF cavity operating at 2.856 GHz. The SHR can operate in a pulse stretcher mode in which beams circulate for a limited number of turns while being slowly extracted for external target experiments. More often, the SHR is operated in its storage mode, in which electron pulses are gradually stacked in the ring to yield a long-lived continuous-wave beam. The beam usually circulates for

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several minutes and passes through a thin internal target on each turn.

Since 2002, the SHR has been used almost exclusively to deliver stored beam to experiments with the Bates Large Acceptance Spectrometer Toroid (BLAST). Properties of the beam in storage mode are therefore tailored to meet the needs of the BLAST experimental program, which requires a beam with high average intensity and high duty cycle. BLAST experiments utilize a spectrometer with an open configuration, a sensitive set of detectors, and a narrow internal target storage cell with a very delicate coating. This combination imposes strict limits on the tolerable levels of beam halo and experimental background. Finally, the experiments demand a high degree of longitudinal polarization at the target. Typical operating conditions for BLAST experiments at 850 MeV feature peak currents of 175 mA and 65% polarization, making the SHR polarized electron beam among the most intense in the world.

Stored beam in the SHR is achieved through a highly automated filling cycle based on the EPICS Control System. Pulses, of typical duration 2.3 μs and peak intensity 2 mA, are injected into the SHR at a rate of 10 Hz to allow for the ring's damping time. The filling cycle is linked with the BLAST high voltage control software, allowing detectors to be gated off during injection. The entire filling cycle typically requires about 90 seconds, whereas stored beams usually circulate for a period of at least 15 minutes. Beam lifetime is governed by the internal target thickness, but can exceed 40 minutes in the absence of a target.

To achieve the very high beam quality required for BLAST experiments, the SHR is outfitted with a comprehensive set of diagnostics, includng 32 sets of beam position monitors and a synchrotron light monitor which yields information on the beam profile. A tune sweeper permits measurements of dynamic properties of the beam at the outset and conclusion of a filling cycle. These elements are essential for steering the beam through the target cell, which forms an aperture 15 mm in diameter and 60 cm in length, and the 10-mm diameter tungsten collimator which shields it. To achieve best performance, slightly different orbits are used for injection and storage, with the SHR steering correctors ramped to make a smooth transition between the two. A set of plastic scintillators located in close proximity to the beamline provides rapid feedback on the level of beam halo and to regulate the position of a set of halo slits used to minimize background.

Several devices work in conjunction to produce high longitudinal polarization at the BLAST internal target. Longitudinal polarization at injection into the SHR can be dialed in using a Wien filter in the Bates polarized source. Because the beam polarization precesses as it traverses the ring, a full Siberian Snake is required to restore longitudinal polarization at the BLAST target. The beam polarization is measured continuously by a Compton polarimeter[2] located upstream of the BLAST target. An RF dipole[3] is located downstream of the target, which can be used to adiabatically reverse the polarization direction of the stored beam with high efficiency. The frequency at which the RF dipole induces a spin flip provides a very sensitive measurement of the SHR spin tune and was used establish a calibration of the fractional snake strength with accuracy better than 0.1%.

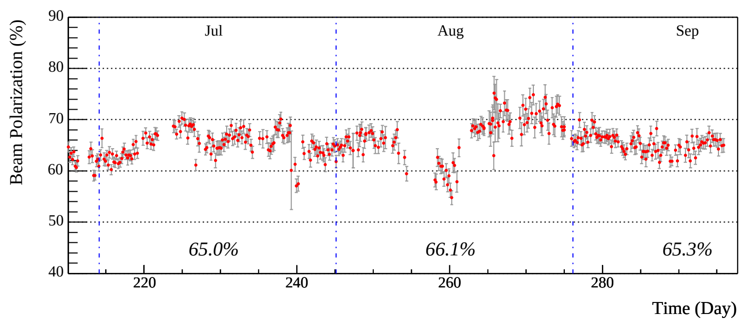

Figure 1. Preliminary polarization measurements during SHR operation in 2004.

The polarization in the South Hall Ring has averaged 0.66±0.04 (systematic) in 2004 and is generally stable as a function of time to within a few percent. This figure is consistent with measurements at low energy in the polarized source. Preliminary measurements of the SHR longitudinal polarization during a portion of the 2004 run are shown in Figure 1. During the early stages of beam development, substantial losses of polarization were observed for certain ring parameters. Such effects were most pronounced for high intensity beams and were correlated with tune spreading in the electron beam. Although, this study was too limited in scope to produce a detailed resonance map, it led to restrict of the betatron tunes used for ring operation during BLAST experiments ($\nu_x = .38 \pm .02$,$\nu_y = .17 \pm .01$). Similar issues will need to be addressed by future high intensity devices based on storage rings, such as a proposed electron-ion collider.

The SHR polarization lifetime is very long compared to the beam lifetime. Measurements were carried out in which beams were injected into

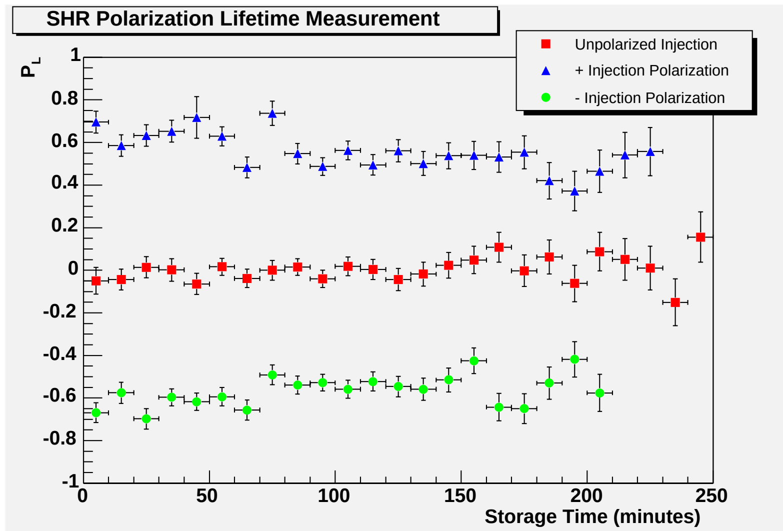

Figure 2. Preliminary polarization measurements vs. storage time in the SHR.

the Ring at 190 mA and allowed to circulate for several hours. Preliminary polarization data taken for these conditions are in Fig. 2. For very large storage times, the beam current decays to the point that it is no longer possible to obtain a statistically accurate measurement. Measurements were perforemed with two different initial electron polarization directions and with initially unpolarized beams. From these data a mean polarization lifetime of 810 ± 190 minutes was extracted, a number which is slightly shorter than predictions of 1100 minutes. No conclusive evidence of radiative polarization of the beam was observed.

In summary, operation of an intense polarized electron beam in the SHR is now routine for polarized internal target experiments. Integrated charge is accounted for on a daily basis with more than 10 kiloCoulombs of charge typically delivered to the BLAST internal target. This beam has enabled the success of a frontier experimental program using the BLAST Spectrometer[4].

References

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