HIGH DUTY FACTOR BEAMS EXTRACTED FROM THE MIT-BATES SOUTH HALL RING*

K. Jacobs, R. Averill, S. Bradley, G. Dodson, K. Dow, M. Farkhondeh, S. Kowalski, B. McAllister, D. Tieger, C. Tschalaer, E. Tsentalovich, W. Turchinetz, F. Wang, A. Zolfaghari, and T. Zwart
MIT-Bates Linear Accelerator Center

Abstract

The South Hall Ring at the MIT-Bates Linear Accelerator Center is a combination of pulse stretcher ring to produce high duty factor extracted beams and storage ring for use with internal targets. It is designed to operate at energies from 300 MeV to 1 GeV for nuclear physics experiments. In pulse stretching mode, half-integer resonant extraction is used to convert the <1% duty factor beam from the linac into near CW beam. To date, we have extracted beams with duty factors in excess of 50%, and high throughput efficiencies. The first nuclear physics experiments using extracted beam are planned for the near future. Details of commissioning the ring for extracted beam operation are presented.

1 INTRODUCTION

The MIT-Bates Linear Accelerator Center operates a 1 GeV S-band linac/recirculator used for basic research in nuclear physics. The linac has a maximum duty factor of 1%, with average currents up to 50 µA. With the present interest in coincidence experiments, it is desirable to have a much higher duty factor while maintaining the same average current. To achieve this, we have constructed the South Hall Ring (SHR) at Bates. Operated in pulse stretcher mode, it is designed to convert the pulsed beam from the linac to near CW beam using half-integer resonant extraction. The extracted beam is delivered to the existing external target set-up in the South Hall for use in experiments.

This paper describes the design of the ring and the results of resonant extraction to date.

In addition to operating as a pulse stretcher, the ring can also be operated in a storage mode to provide high average current beam to internal target experiments.

2 DESCRIPTION

Figure 1 shows the layout of the Bates facility, including the ring and the south experimental hall. The ring is 190.204 m in circumference, with a 9.144 m bend

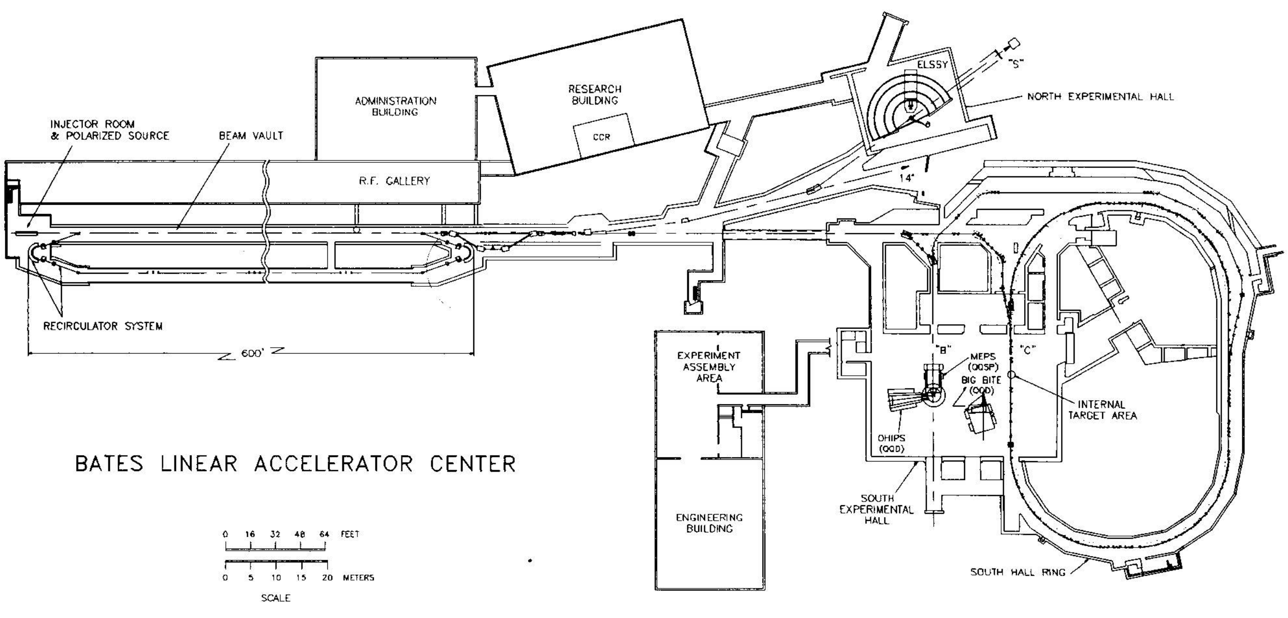

Fig. 1 Layout of the Bates facility, including the South Hall Ring and associated beamlines

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

0-7803-4376-X/98/$10.00 © 1998 IEEE

radius. It is designed for two-turn injection of 40 mA from the linac, giving 80 mA stored current, operating at a fixed electron energy between 0.3 and 1 GeV. With an injection frequency of 1 kHz and a 1 ms extraction time, the average current delivered to an experiment is designed to be 50 µA. The ring RF frequency is 2.856 GHz, the same as the linac frequency, giving a harmonic number of 1812. Every RF bucket contains charge. An energy compression system located after the linac gives an injected energy spread into the ring of 0.04%.

In extraction mode, the horizontal tune is 7.460. Octupoles are used to divide the horizontal phase space into stable and unstable regions. The beam is injected into the stable region near the separatrix. A ferrite-core ramped quad is then used to move the tune closer to the half-integer resonance. This causes the stable area to gradually shrink resulting in some of the electrons becoming unstable. As an unstable electron's betatron oscillation amplitude increases, it will eventually enter the field of the extraction electrostatic septum and be deflected down the extraction line to the fixed target in the South Hall.

Diagnostics for use in extraction include a DCCT to monitor the current in the ring, another DCCT in the extraction line to measure extracted current, and a Faraday cup located after the South Hall target point, to quantify the extracted charge. The expected precision of the Faraday cup is ±0.1%[1]. A retractable secondary emission monitor (SEM) foil in the extraction line can be used for qualitative duty factor assessment, as well as a measure of the extraction efficiency. For more accurate duty factor measurements, we have implemented a system of particle detectors to monitor the singles and accidental coincidences counting rates[2].

3 RESULTS

We have successfully performed resonant extraction from the ring using both one-turn and two-turn injection. Figure 2 shows the extraction line SEM for extraction of a single, one-turn injection pulse. By integrating the SEM signal to determine the extracted charge, we calculate an extraction efficiency of 86%. A rough estimate of the duty factor, based on observing the SEM signal on different time scales, indicates a duty factor of a few tens of percent. The spike at the beginning of the extraction pulse is, in some cases, due to part of the injected beam lying outside the stable phase space area. In this situation, adjusting the injection trajectory into the ring can eliminate this spike, although this leads to a delay in the onset of resonant extraction with a corresponding reduction in the duty factor.

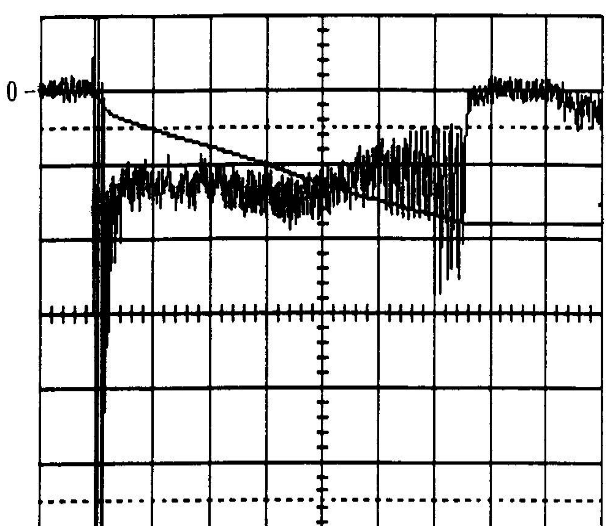

Fig. 2 Extraction of a single pulse from the ring. The vertical scale is 4.2 µa/div, and increasing current is down on the graph. The horizontal scale is 0.2 ms/div. Also shown is the integral of the extracted current.

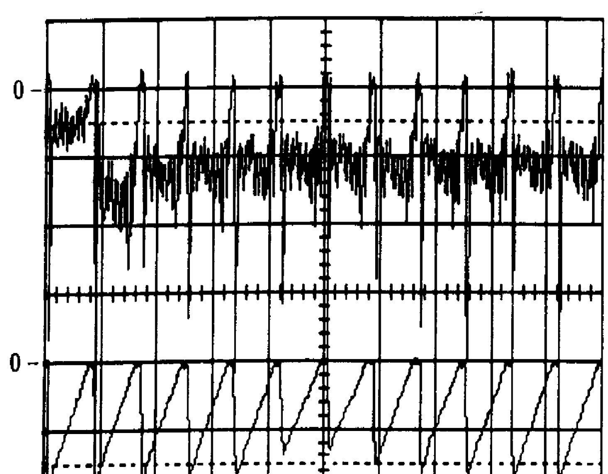

Fig.3 Extraction of a train of pulses injected into the ring at 600 Hz. The upper trace is the extracted current, and the lower trace is the current in the ring. For both traces, increasing current is down. The horizontal scale is 2 ms/div. The average extracted current is a few microamps.

In an effort to fully understand extraction from the ring, it has proven useful to study the ring in storage mode. With stored currents of up to 30 mA, we have achieved 1/e lifetimes of 7 minutes at 750 MeV. This has allowed us to make detailed investigations of various ring properties, including the closed orbit, tunes, and possible ion effects.

To date, extraction at high injection rates, as would be required by a nuclear physics experiment, has not been attempted for more than a brief period of time. Figure 3 shows an example of such extraction. The figure shows the extraction line SEM signal, and the current stored in the ring, for a series of injection pulses occurring at 600 Hz. This is a preliminary example of the sort of quasi-continuous beam we expect to be able to deliver in the near future.

Monochromatic extraction from the ring has also been performed. In this case, the ring RF is turned off, and the chromaticity is adjusted to be negative. (This is most easily accomplished by turning off the sextupoles, and using the natural chromaticity of the ring.) As the electrons lose energy due to synchrotron radiation, their tune gradually increases toward the half-integer resonance, and they are eventually extracted. This extraction technique lacks the flexibility of the extraction process described earlier because the duration of extraction is determined by the beam energy, the spread of electron energies in the beam, and the chromaticity. We do not anticipate using monochromatic extraction in general.

4 SUMMARY

We have demonstrated operation of the South Hall Ring in pulse stretcher mode using half-integer resonant extraction. Good throughput efficiency has been obtained, and rough estimates of the duty factor indicate extracted beams are close to being useable for experiments. More work is planned in both these areas. It is expected that after one more commissioning run, the ring will be ready to deliver extracted beam for use by experiments.

REFERENCES

[1] J. Shaw, R. Averill, S. Kowalski, S. Sarkar, C. Sibley, S. Sobczynski, and W. Turchinetz, "A High Power Faraday Cup to Measure Extracted Beam Current from the Bates South Hall Ring",presentation 8P73, these proceedings.

[2] J. M. Vogt, R. Florizone, "A Duty Factor Monitor for Usewith a Near CW Beam", *Nucl. Instr. and Meth. in Phys. Rev. A* **339**, 425 (1994).