EXPERIMENTAL STUDY OF THE SNS MEBT CHOPPER PERFORMANCE

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Abstract

The chopper system for the Spallation Neutron Source (SNS) provides a gap in the beam for clean extraction from the accumulator ring. It consists of a pre-chopper in the low energy beam transport and a faster chopper in the medium energy beam transport (MEBT). It took several iterations to develop a working design with the required parameters. In this paper we describe the latest design of the MEBT chopper deflector and give results of the experimental verification of the chopper effectiveness, the gap cleanliness and the measured rise time. The effect on the losses is discussed as well

INTRODUCTION

One of the SNS Front End functions is to provide beam pulse time structure suitable for low loss single turn extraction from the accumulator ring. The 1-ms long H^- macro-pulses has to be chopped at the revolution frequency of the accumulator ring into mini-pulses of 645 ns duration with 300 ns gaps. Beam chopping is performed by two separate chopper systems located in the LEBT and MEBT. The LEBT chopper removes most of the beam charge during the mini-pulse gaps, and the traveling-wave MEBT chopper further cleans the gap to a level of 10^{-4} and reduces the rise and fall time of the mini-pulse to 10 ns. The MEBT chopper system consists of a fast transmission line deflector, a high voltage solid state pulse generator and a target. The main parameters of the chopper systems are given in Table 1.

Table 1. Main parameters of the original MEBT deflector.

Chopper	LEBT	MEBT
Ion energy	~25 kV	2.5 MeV
$\beta = v/c$	~ 0.0073	.073
Max Voltage	± 3 kV	± 2.5 kV
gap	~ 14 mm	18 mm
Effective length	~ 27 mm	~370 mm
Max deflection	240 mrad	18 mrad
Time of flight	~ 12 ns	~ 17 ns

It took several iterations to build a MEBT chopper deflector suitable for high power beam operation, as described in Refs. 1 and 2. The latest version of the deflector, utilizing a solid copper strip-line, was installed in summer 2009. The deflector assembly before installation in the vacuum chamber is shown in Fig. 1. The system has been in operation for a year with beam power up to 1MW and demonstrated the design performance parameters.

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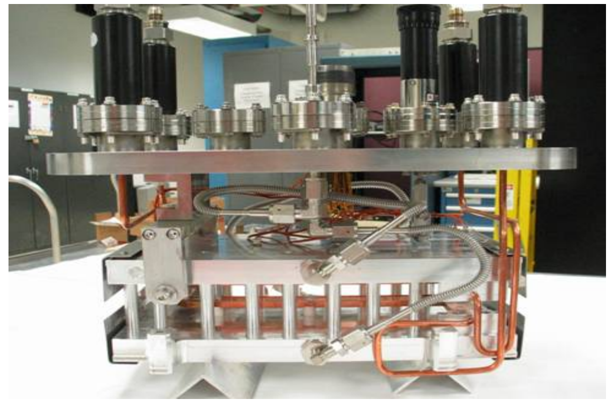

Figure 1: The new MEBT chopper deflector ready for installation.

CHOPPER PERFORMANCE EVALUATION

The major parameters of the chopper system are the extinction ratio (the ratio of the beam current with chopper ON to the beam current with chopper OFF) and the rise / fall time (the sharpness of the gap edges). Measuring both characteristics simultaneously is a difficult task because of required high dynamic range, of about 10^5, and large bandwidth, of about 100MHz. We measured these parameters separately and then used the effect on beam loss as the ultimate characteristic of the chopper performance.

Kick Strength Measurement

We measured the deflector kick strength by observing the transverse separation of chopped and un-chopped parts of the beam pulse close to the chopper target. The beam transverse profile measured by the wire scanner is shown in Fig.2. The separation of 12.7 mm exceeds the design requirement of 11 mm.

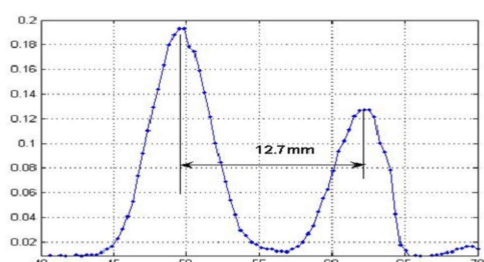

Figure 2: Transverse beam profile in front of the chopper target. The separation of chopped and un-chopped beamlets is proportional to the deflector kick strength.

Rise/Fall Ttime Measurement

The speed of rise and fall of the chopper depends on the high voltage power supply bandwidth and on the delay in the deflecting structure. The power supply loaded on an ideal 50 Ohm load has a rise time of 9 ns and a fall time of 14 ns, as illustrated by an oscilloscope snapshot in Fig.3.

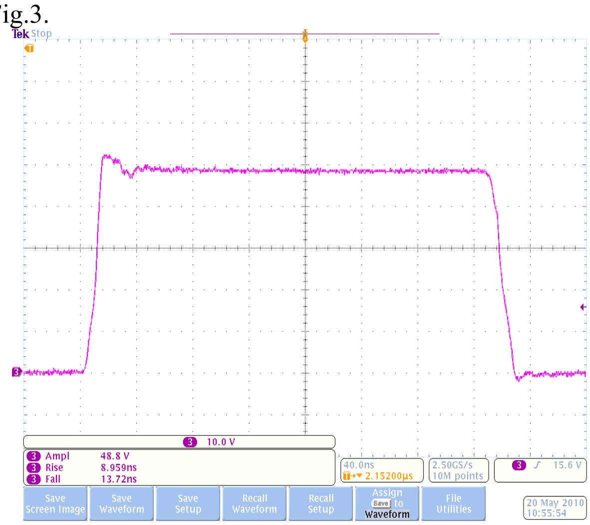

Figure 3: A high voltage pulse from the power supply measured on a 50 Ohm load.

We measured the actual rise and fall time of the beam gap by observing signal from the beam position monitor strip-line with an oscilloscope. The results of the measurements are shown in Figs. 4 and 5. The red trace shows gap edges created by the LEBT chopper alone, and the blue trace shows the effect of the MEBT chopper. It is interesting to note that the measured fall time of about 10 ns and rise time of about 15 ns are very close to the rise and fall times of the power supply. We do not see much of the rise/fall time increase due to the delay in the deflector structure.

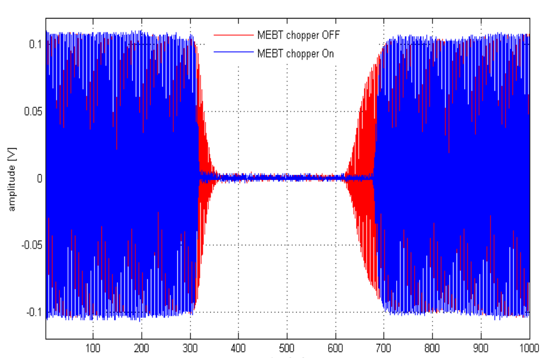

Figure 4: A gap in the beam created by the LEBT chopper (red) and cleared by the MEBT chopper (blue).

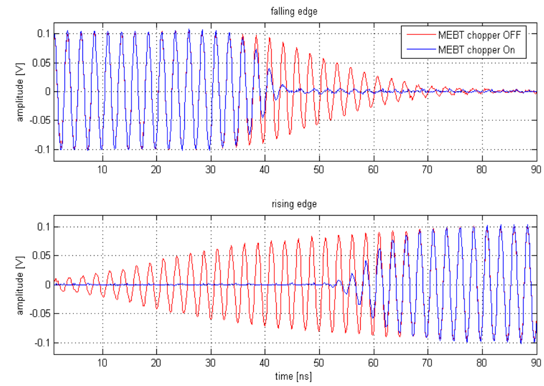

Figure 5: Zoom in of the beam gap edges from the Fig.4.

Extinction Ratio Measurement

We used a high dynamic range logarithmic amplifier to measure the extinction ratio of the MEBT chopper. The result is shown in Fig. 6. The upper trace was captured with the MEBT chopper off and the lower trace with the MEBT chopper on. In both cases the measured extinction ratio is better than the design level of 10^{-4}. It should be noted that the expected extinction ratio of the LEBT chopper was about 10^{-2}, therefore the MEBT chopper was added to the design to ensure that the specification of 10^{-4} is met.

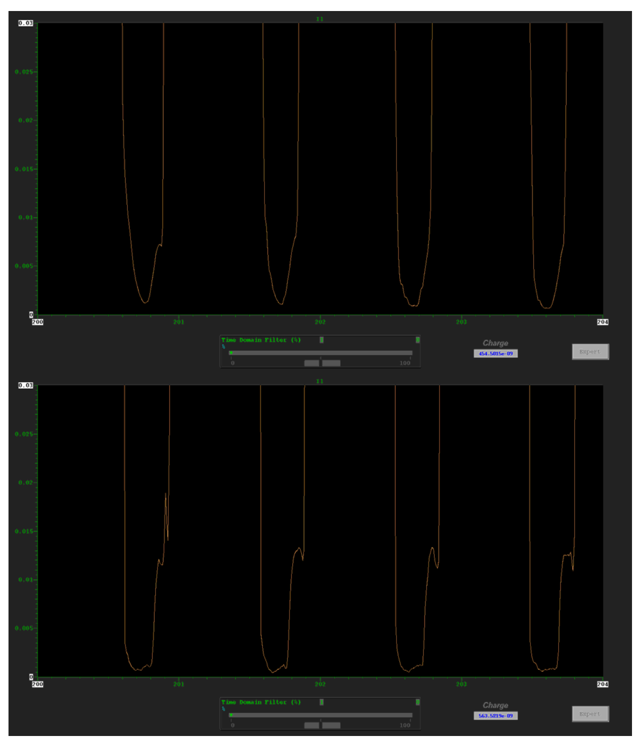

Figure 6: The beam gap depth measured using a logarithmic amplifier. The top snapshot is with the MEBT chopper off; the bottom snapshot is with the MEBT chopper on. Peak beam current is 40mA. The vertical scale is 5µA/div.

EFFECT OF THE MEBT CHOOPER ON BEAM LOSSES IN THE ACCELERATOR

The ultimate performance characteristic of the MEBT chopper is its effect on the beam loss in the accelerator. The results of measuring beam losses with the MEBT chopper on and off in different parts of the SNS beam line are shown in Figs. 7,8,9,10, and 11. We observed a small loss change in the linac, slight decrease in the CCL and slight increase in the SCL, but both are very small and do not have any practical importance in reducing residual machine activation. There is a significant loss reduction of about 20% in the ring injection area, most probably due to sharpening the edges of the gap by the MEBT chopper. There is also a significant reduction of about 30% in the ring extraction and collimation area, most probably due to an additional cleaning of the gap by the MEBT chopper. It should be noted, that though relative reduction of beam loss in these areas is significant, the absolute beam loss is low even with the MEBT chopper off. High power beam operation with acceptable beam loss is possible even without the MEBT chopper due to the surprisingly good performance of the LEBT chopper.

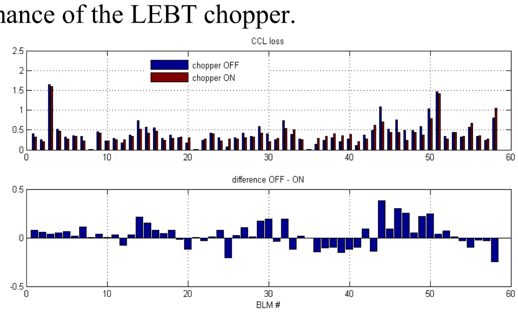

Figure 7: Effect of the MEBT chopper on beam loss in the CCL. An average loss reduction of ~2.5% is observed.

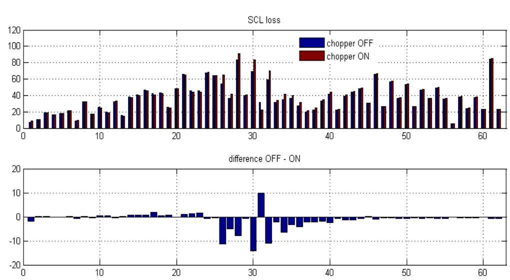

Figure 8: Effect of the MEBT chopper on beam loss in the SCL. An average loss increase of ~3% is observed.

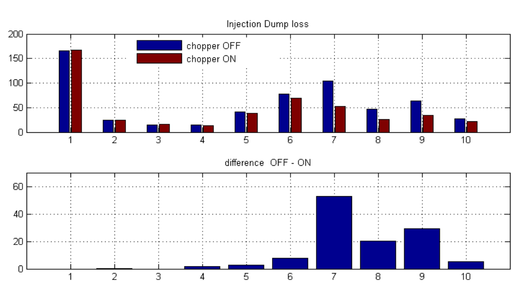

Figure 9: Effect of the MEBT chopper on beam loss in the ring injection . A loss reduction of ~20% is observed.

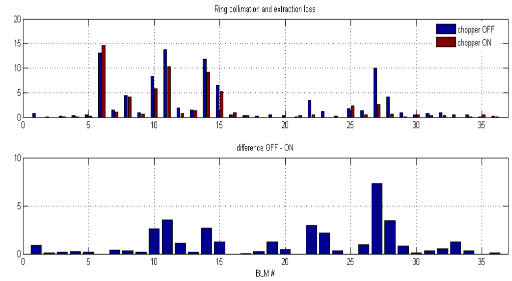

Figure 10: Effect of the MEBT chopper on beam loss in the extraction and collimation areas of the proton accumulator ring. An average loss reduction of ~35% is observed.

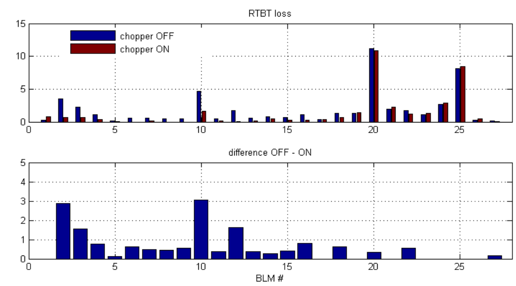

Figure 11: Effect of the MEBT chopper on beam loss in the RTBT. An average loss reduction of ~28% is observed.

CONCLUSION

The operational experience during the last year has demonstrated reliability of the latest MEBT chopper design in high power beam operation. Experimental measurements of the rise/fall time and of the extinction ratio confirmed that the MEBT chopper meets the design requirements. There is a significant loss reduction due to sharper beam gap edges and cleaner gap created by the MEBT chopper. However, better than expected performance of the LEBT chopper reduces practical importance of using the MEBT chopper, at least when operating with 1MW of beam power. We expect, however, the importance of the MEBT chopper to increase with increasing the beam power.

ACKNOWLEDGEMENT

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