LA-UR- 04-4437

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Submitted to: EUROPEAN PARTICLE ACCELERATOR CONFERENCE (EPAC)
LUCERENE, SWITZERLAND
JULY 5-9, 2004

Los Alamos
NATIONAL LABORATORY

DESIGN, CONSTRUCTION, AND INITIAL OPERATION OF THE SNS MEBT CHOPPER SYSTEM *

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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 (LEBT) and a faster chopper in the medium-energy beam transport (MEBT). We report here on the final design, fabrication, installation, and first beam tests of the MEBT chopper. The traveling-wave deflector is a meander-line design that matches the propagation of the deflecting pulse with the velocity of the beam at 2.5 MeV, after the radio-frequency quadrupole (RFQ) acceleration stage. The pulser uses a series of fast-risetime MOSFET transistors to generate the deflecting pulses of +- 2.5 kV with rise and fall times of 10 ns. We describe the design and fabrication of the meander line and pulsers and report on the first operation during initial beam tests at SNS.

INTRODUCTION

The SNS linac will accelerate a 1-2 mA (average) H^- beam to 1 GeV for injection into an accumulator ring for bunch compression. Beam chopping is required to provide a gap in the beam, which is maintained during the accumulation process and allows extraction from the ring with minimal losses. A beam chopper in the low-energy beam transport (LEBT) between the ion source and the RFQ pre-chops the beam [1], and a fast traveling-wave chopper in the medium-energy beam transport (MEBT) provides the final clean up of the chopping gap [2]. The key parameters are listed in Table 1..

Table 1. MEBT Chopper Parameters

Parameter	Value	Comments
Beam energy	2.5 MeV	ß=0.073
Length	35 cm	
Gap	1.8 cm	Adjustable
Pulser voltage	±2350 V	Max. ±2500 V
Deflection angle	18 mrad	
Chopping period	945 ns	
Duty factor	32 %	68 % beam on
Structure rise/fall time	1.5 ns	
Puler rise / fall time	10 ns	2-98 %

The MEBT chopper matches the electric wave velocity along the beam axis to the beam particle velocity, thus providing a rise and fall time determined mainly by the rise and fall times of the electric pulse. The SNS chopper uses the same principle as the strip-coax helical structure successfully used in LANSCE/PSR for many years [3].

DESIGN CALCULATIONS

Electromagnetic calculations of various meander-line structures were carried out several years ago to determine the optimal design [4-7]. An example of these calculations is shown in Fig. 1. Based on the calculations, a "notched" meander line (see Fig. 2) was developed to concentrate the fields along the axis and thus reduce cross talk.

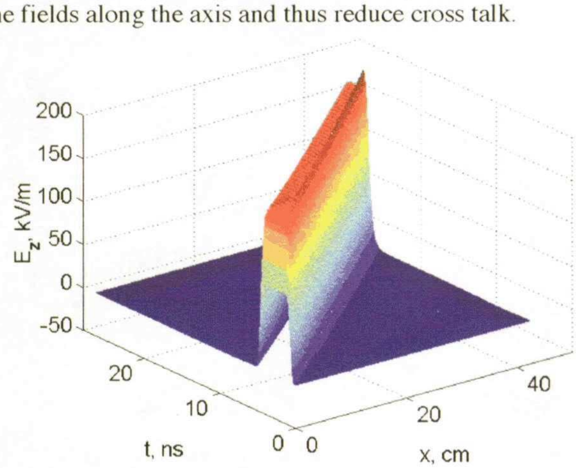
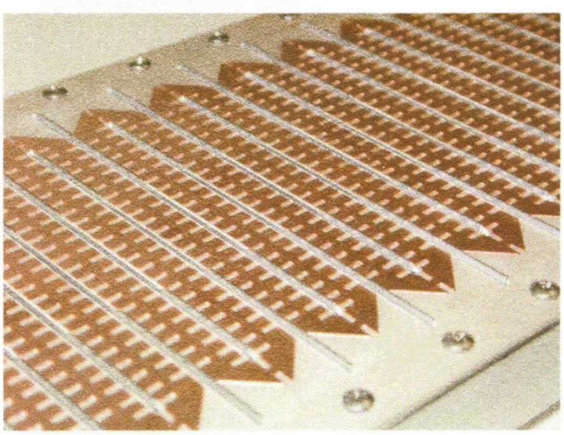


Figure 1: Deflecting field on the beam path versus time and position in the notched-strip meander structure.

DEFLECTING STRUCTURE

The design of the deflecting structure has been described previously [4-7].



* Work supported by the Office of Basic Energy Science, Office of Science of the US Dept. of Energy

Figure 2: The meander-line current structure with notches.

The etched copper structures were bonded to the cooled support structure using a thermally cured adhesive. Fabrication details are described in [2]. A finished structure assembly is shown in Fig. 3.

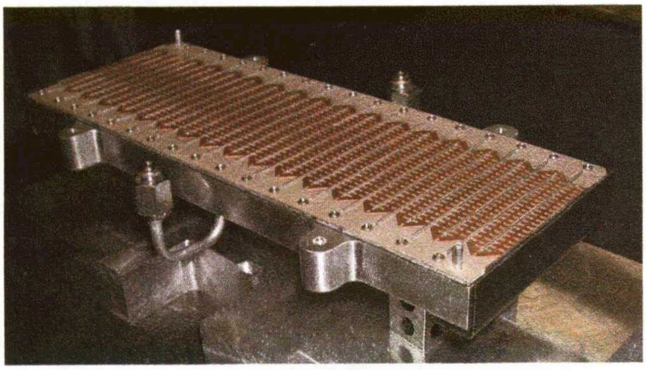


Figure 3. Finished circuit board glued to ground plane

The electrical risetime of a complete assembly was measured to be 1.5 ns, including the interconnections and vacuum feedthrough connectors. The chopper is suspended from the lid of a vacuum box located just downstream of the RFQ (see Fig. 4).

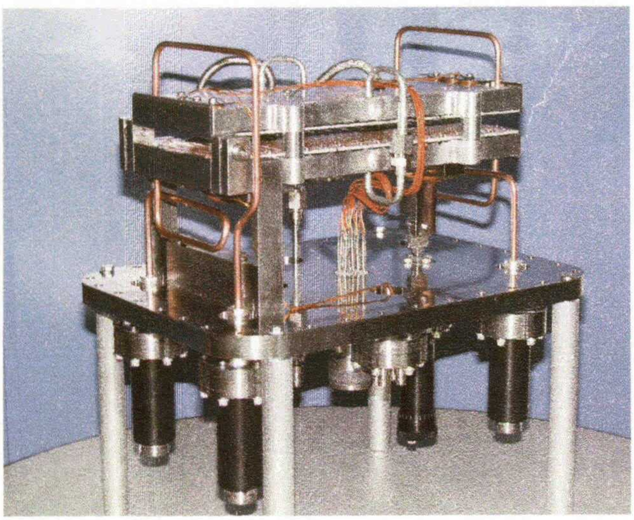


Figure 4. Completed MEBT-chopper structure assembly.

CHOPPER SYNCHRONIZATION

A recent paper [8] analyzed the synchronization between the LEBT and MEBT choppers, as shown in Fig. 5. The left-hand column shows the relative timing and the voltage ramps of the two choppers, the LEBT chopper in red and the faster MEBT chopper in blue. The middle column shows the corresponding current in individual micropulses at the entrance to the DTL. The right-hand column shows the current intercepted on the MEBT-chopper target during the turn-on transient. In option 1, the MEBT chopper turns on first to minimize stray beam entering the linac. However, this scenario results in the maximum power dissipation on the chopper target. In option 2, the LEBT chopper turns on first so that no beam ever gets deflected onto the MEBT target. This option results in no power deposited in the chopper target but maximizes the amount of beam lost in the linac. In option 3, the voltage ramps start together while in option 4, ramps end at the same time. The results of this study lead us to prefer option 3, which minimizes the partially chopped beam entering the linac while producing acceptable beam power on the chopper target..

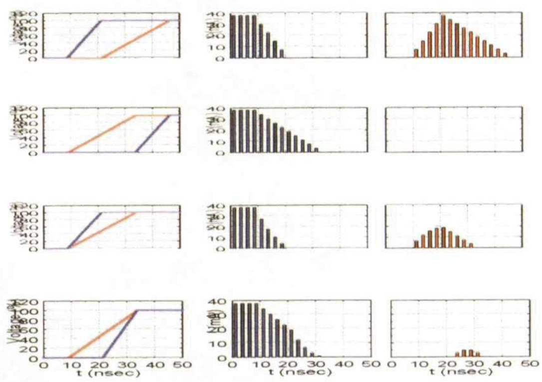


Figure 5. Chopper timing options showing LEBT and MEBT voltage ramps, pulse current in the falling edge of the chopper gap and pulse current on the chopper target.

PULSE GENERATOR

Both the fast power MOSFET transistors and the 50-ohm pulse generator were designed and built by Directed Energy, Inc. (DEI). The two pulsers drive the top and bottom meander lines at ± 2500 V with 10-ns (2 to 98%) risetime. The pulser layout is shown in Fig. 6, and the operational characteristics are given in [2].

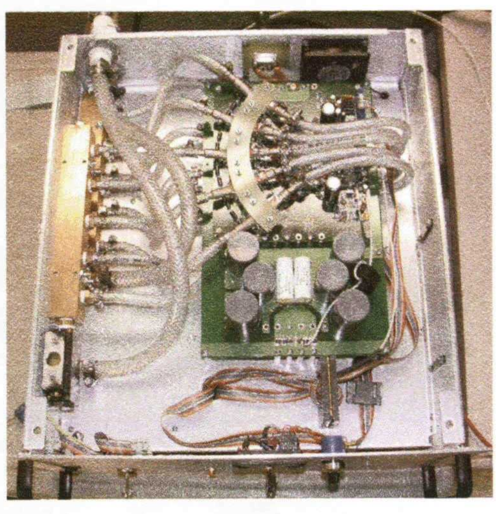


Figure 6. Chassis layout of the DEI PVX-3125 pulse generator

Fig. 7 shows an examples of the output from one of the pulse generators.

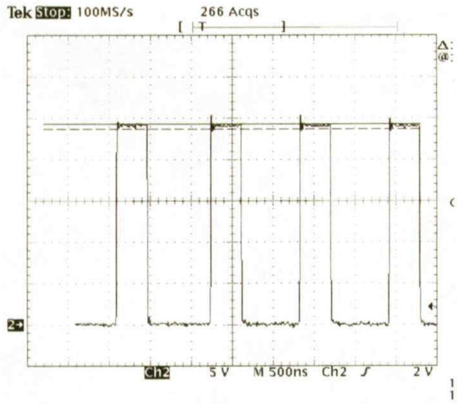


Figure 7. String of four pulses (out of ~1000 during a 1-ms SNS macropulse)

OPERATIONAL TESTS

The first tests of the MEBT chopper system took place during the DTL-1 commissioning in October 2003 when we tested the chopper with beam for the first time: We demonstrated the specified rise/fall times of both the LEBT and MEBT choppers separately, as shown in the following beam traces.

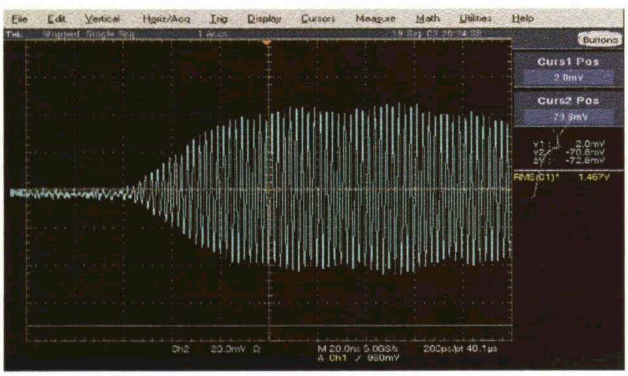


Figure 8. LEBT chopper gap measured past the chopper target in the MEBT; measured rise/fall time is below design value of 50 ns.

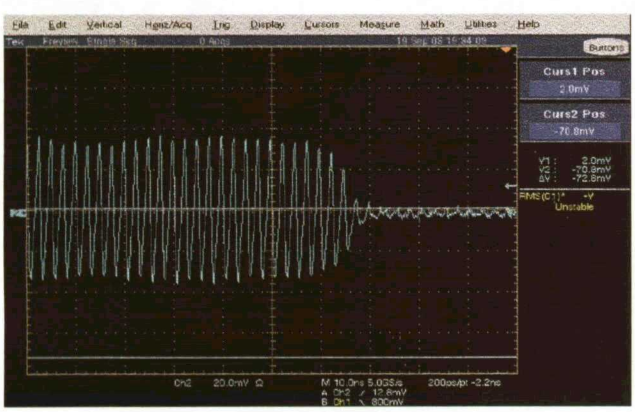


Figure 9. MEBT chopper gap measured past the chopper target in the MEBT; measured rise/fall time is close to design value of 10ns

The measurements show partial chopping of about three 2.5-ns micropulses, as expected. Simulations show that these partially deflected micropulses will transit the linac without additional beam loss. As a result, we cancelled an earlier plan to install an anti-chopper in the MEBT to return these partially deflected pulses to the beam axis

Additional tests with synchronization of the LEBT and MEBT choppers are planned for upcoming SNS linac commissioning.

ACKNOWLEDGEMENTS

The authors acknowledge the collaboration with LBNL personnel who designed and built the SNS Front-End system, in particular, D. Oshatz. We also acknowledge the contributions of T. Cote, D. Schrage, and R. Roybal of LANL for mechanical fabrication of the meander-line structures, and R. Sherwood and S. Collins of DEI, Inc. for design and fabrication of the pulse generators. Finally, several collaborators at ORNL helped with the setup and commissioning of the chopper systems, and we are thankful for their help.

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