FABRICATION OF THE MEBT CHOPPER SYSTEM FOR THE SPALLATION NEUTRON SOURCE *

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Abstract

Los Alamos completed design, fabrication, procurement, and initial testing (without beam) of the SNS medium-energy beam-transport (MEBT) chopper, including the meander-line traveling-wave structure and the electrical-pulser system. This report reviews the design parameters and discusses the fabrication process for the chopper structures, including measurements of the impedance and rise time. (The MEBT vacuum system and chopper-target beam stop were developed at and reported by LBNL.) We discuss the specifications for the pulse generator and its fabrication and testing at Directed Energy, Inc. of Ft. Collins, CO. Experimental tests of the chopper system are currently being performed at the SNS site at ORNL and will be reported separately.

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, and a fast traveling-wave chopper in the medium-energy beam transport (MEBT) provides the final clean up of the chopping gap. The physics design of the MEBT chopper meander-line deflecting structure has been described previously [1,2]. It is a folded, notched stripline that 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.

Table 1. MEBT Chopper Specifications

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
Rise / fall time	10 ns	2-98 %

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Figure 1. One of two completed MEBT-chopper structure assemblies. The unit is upside down from the normal mounting position on the beamline.

The MEBT chopper is suspended from the lid of a vacuum box located just downstream of the RFQ [3]. There is space in the MEBT for an identical structure called the "antichopper" located downstream of the chopper beam stop. If required, the antichopper could restore partially deflected beam on the leading and trailing edges of the pulse to the MEBT axis prior to entering the DTL. Beam simulations of the chopper systems were reported at a previous conference [4].

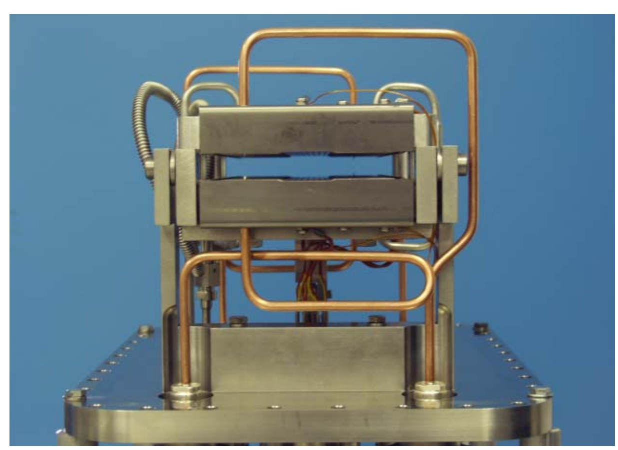

Figure 2. End view of the chopper structure

DEFLECTING STRUCTURE

The meander line required a material with high electrical conductivity on a substrate with a low dielectric constant. We chose a composite material commonly used in the manufacture of printed circuit boards, Rogers Corp. RT6002, which is 0.100-inch thick with a .020-inch thick copper back plate. The profile of the meander stripline was drawn in AutoCAD and translated to a machine that made a mask of the notched meander pattern. The vendor for the etched circuit boards was Multi-Plate Circuits, Inc. Although not extremely difficult, the entire process was tedious and time consuming. The first step was to fabricate sample pieces that could be used to measure critical dimensions. We determined that an "etch factor" was needed in the artwork to achieve our final specifications. The next step was to etch the raw material to the desired thickness. Then a photo-image resist was applied to the boards, and they were run through a developer. About 350 microns of tin/lead was applied to the boards, and they were then run through an ammonia etcher. The boards were measured on an optical comparator after each pass until desired dimensions were achieved. Finally, the tin/lead was stripped, the boards were run through a dryer, and then routed to the final dimensions (See Figure 3).

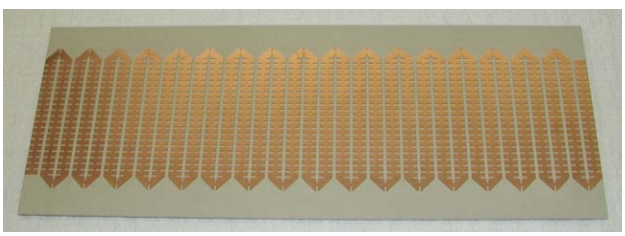

Figure 3. Etched circuit board prior to machining

After the machining of the substrate was complete, it was impossible to maintain the flatness tolerance on the copper surface because of the removal of the dielectric material on the underside of the substrate. A solution to this problem was to epoxy the substrate to the base plate. Eccobond 45 Catalyst 15 epoxy was used for this process. Several tests to determine the bonding strength of the epoxy were conducted prior to actually gluing the assembly together. A thin layer of epoxy (.003”-.004”) mixed with a “rigid” mix ratio yielded the best results. It was also determined that a “weighted” cure time of 48 hours with 100 lbs./sq. in. would be necessary. To ensure uniform weight distribution over the entire length of structure, a precision fixture was placed over the epoxied assembly. Approximately 2000 lbs. of weight were then placed over the entire assembly, and the epoxy was allowed to cure for over two days. As part of the manufacturing process we performed in-process testing to ensure that the glue joint had been properly made. Glue-joint specimens were fabricated simultaneously with the gluing of the meander line to the ground plane using the same procedure (epoxy from the same mixed batch, thickness of epoxy applied, joint loading, and cure time). The specimens were tested to affirm that the glue joint had achieved strength greater than that of the meander-line substrate material. The full strength of the epoxy is specified as 2.5X the ultimate strength of the substrate material. The strength test determined whether the glue joint would fail in the epoxy or in the meander-line assemblies.

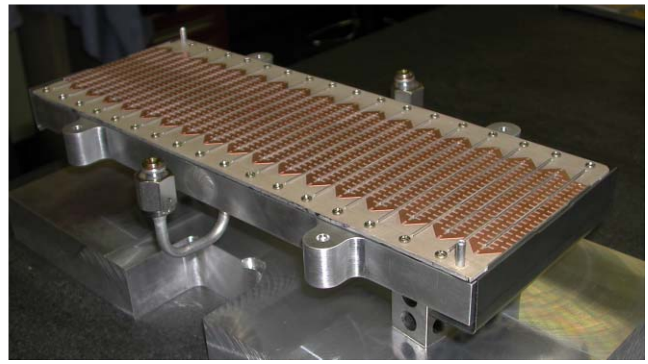

Figure 4. Finished circuit board glued to ground plane

Following fabrication, the structures were electrically tested and found to have an impedance of nominally 51±0.5 ohms. One could adjust the impedance to exactly 50 ohms with tuning tabs along the structure, but this was unnecessary in our case. The structures were hi-potted to 4.5 kV under vacuum, along with all of the high voltage cable assemblies. We measured the structure risetime to be 1.5 ns (see Fig. 5), substantially faster than that of the pulser (about 10 ns). The delay through the structures varies from 22.07 to 22.24 ns, including the 7-16 DIN to N to SMA adaptors required for the measurement.

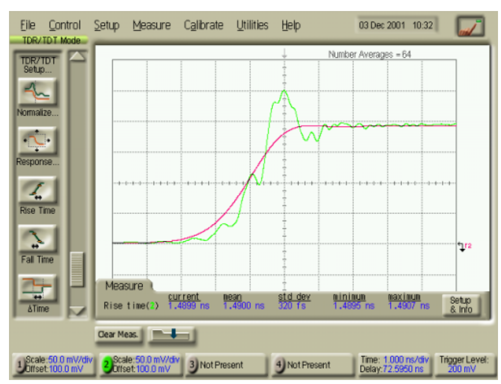

Figure 5. The risetime of a complete assembly is 1.5 ns, including the interconnections and vacuum feedthrough connectors. Data are in green, a 2-ns risetime filter in red.

DEFLECTING PULSER

The 50-ohm deflecting pulser was designed and built by Directed Energy, Inc. (DEI) to specifications provided by Los Alamos. The specification for two pulsers to drive the top and bottom meander lines is ± 2500 V with 10-ns (2 to 98%) risetime. Development of the 1-ns risetime, 1-kV MOSFET for this application was done by DEI under a separate R&D contract.

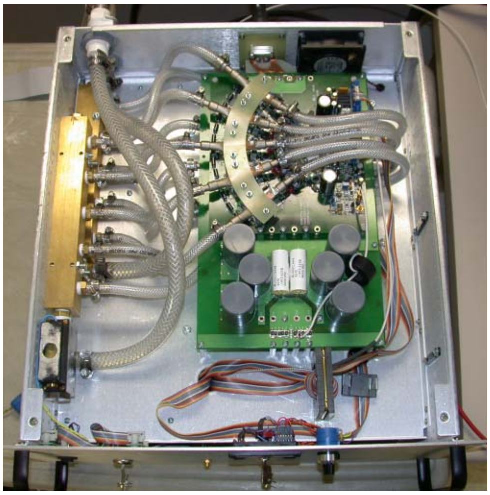

Figure 6. Chassis layout of the DEI positive polarity pulser

The PVX-3125 pulse generator is a half-bridge (totem pole) design, providing fast rise and fall times. It uses five of DEI's patented power MOSFET transistors in each leg of the bridge, configured in a series transmission line format, to provide the pulse generator's voltage and current requirements.

Figure 7. One-half of the MEBT chopper pulser output-switch assembly

The amplitude of the external DC power supply controls the output voltage. The efficiency of the pulse generator is about 90%; therefore a DC power supply setting of 3.3 kV yields an output voltage of about 3 kV. Two versions are required, a positive pulser and a negative pulser. A TTL input gate controls the output pulse width and frequency. Pulse width and frequency are constrained to preset limits suitable for our application. The maximum pulse width is 100 to 905 nanoseconds and the maximum frequency is 1.05 MHz.

This pulse generator features a high-speed overcurrent protection circuit. The main energy storage capacitor bank is isolated from the output stages by an IGBT switch assembly. A much smaller and faster capacitor is integral to the main switch assembly. If a peak over-current condition is detected, the IGBT is opened, the output pulse is truncated, and the output is tied to ground. This circuit protects the pulse generator, load and cabling from potential damage due to an arc or short in the cable or load. The following figures show examples of the output.

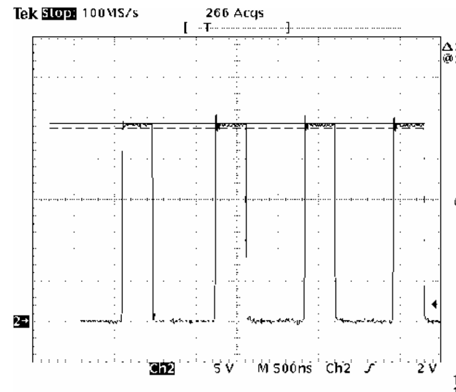

Figure 8. String of four pulses (out of ~1000 during a 1-ms SNS macropulse)

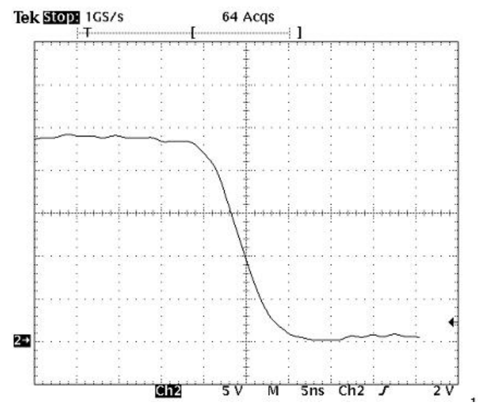

Figure 9. Expansion of trailing edge of typical output pulse showing fall-time of about 8 ns at 2350 volts

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