Design, Construction, and Initial Operation of the SNS MEBT Chopper System

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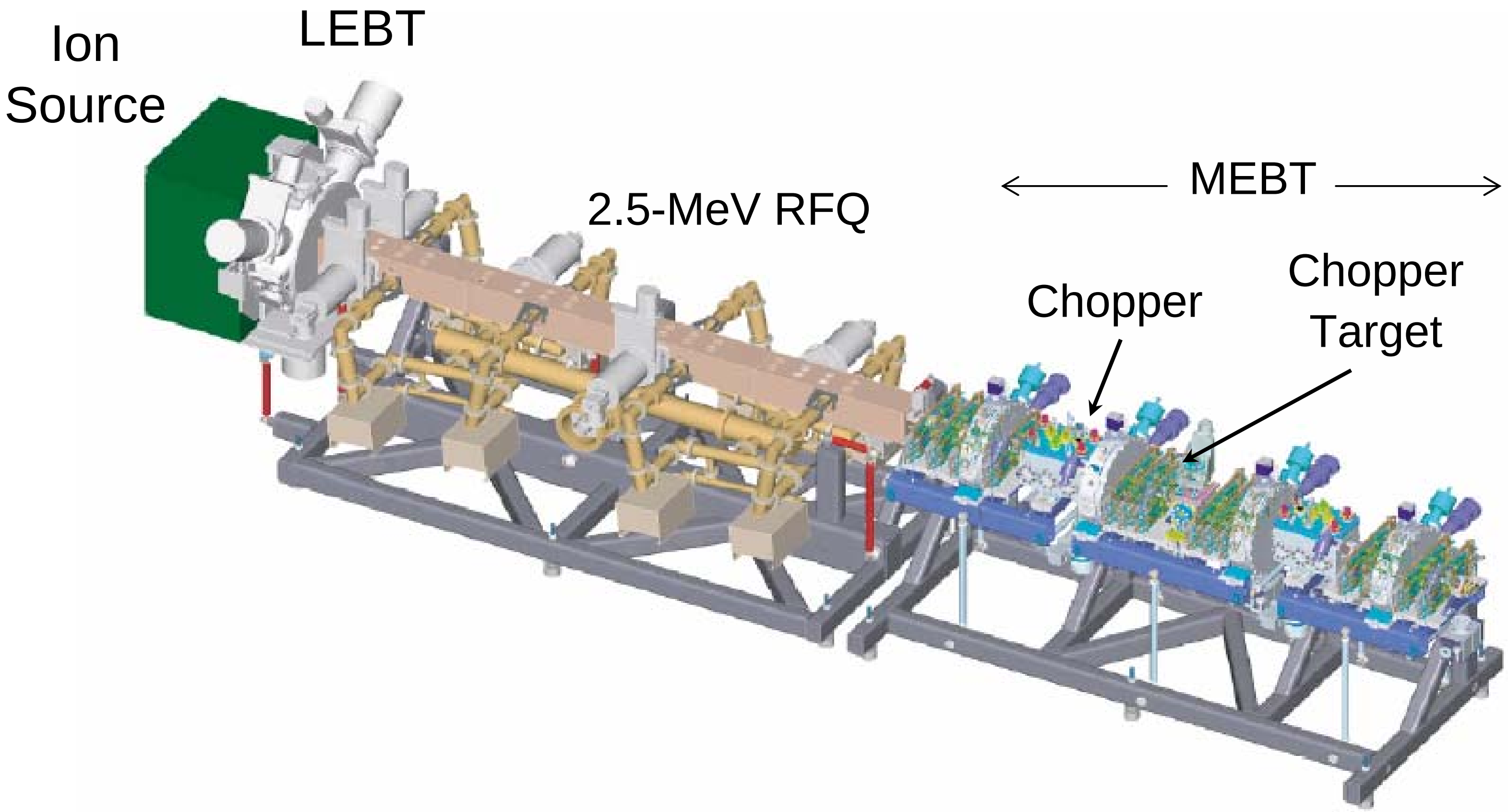
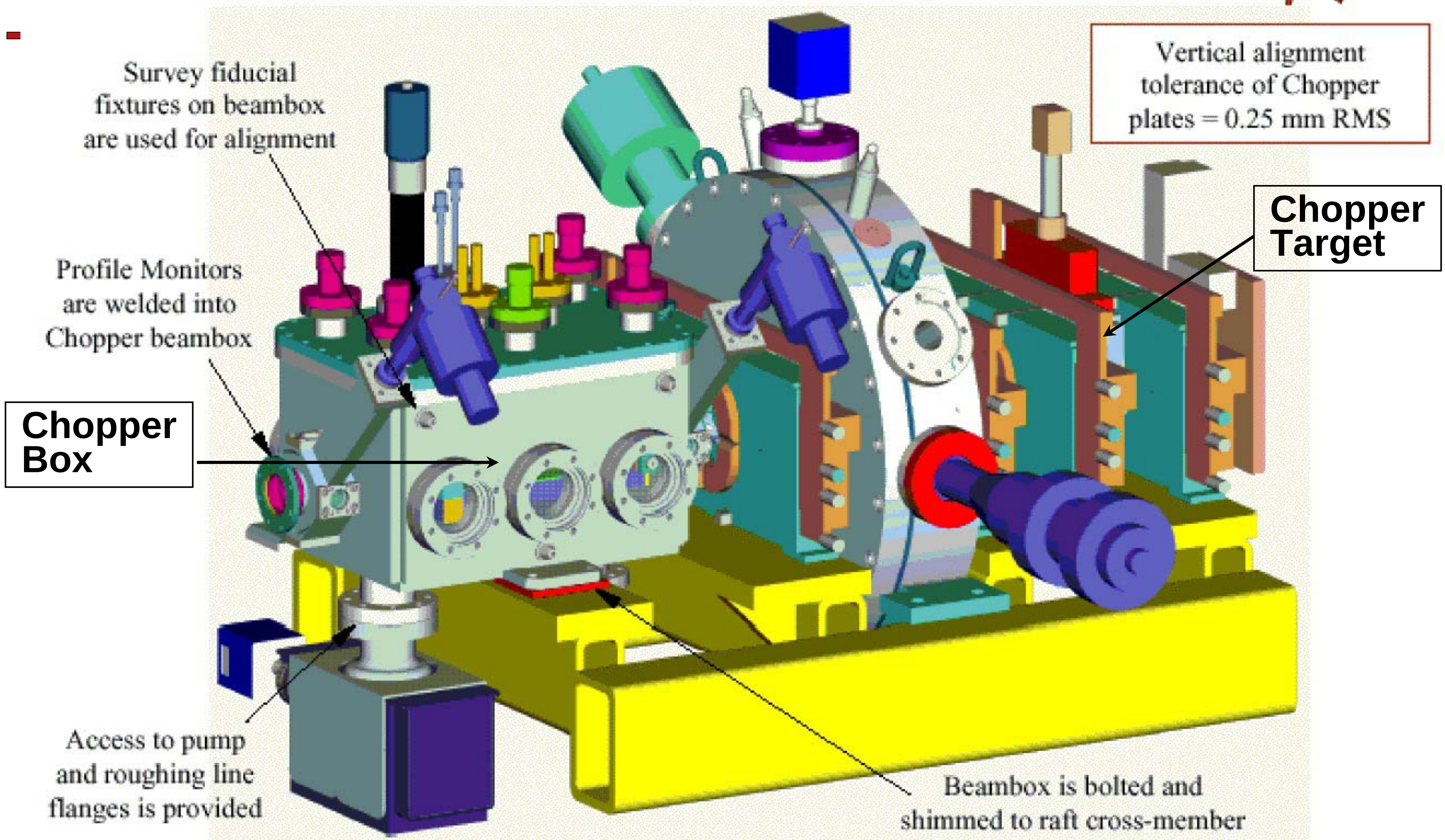
Introduction

- ***Purpose:*** provide a gap in the beam for clean extraction from the accumulator ring.
- ***Approach:*** a pre-chopper in the low-energy beam transport (LEBT) and a faster chopper in the medium-energy beam transport (MEBT)..
- ***MEBT Chopper:*** traveling-wave chopper with meander-line to match propagation of the deflecting pulse with velocity of the beam.
- ***Pulse Generator:*** uses a series of fast-risetime MOSFET transistors to generate deflecting pulses of ± 2.5 kV with rise/fall times of 10 ns.
- ***Status:*** design and fabrication complete; system operated during initial beam tests at SNS.

SNS Front-End Built by LBNL



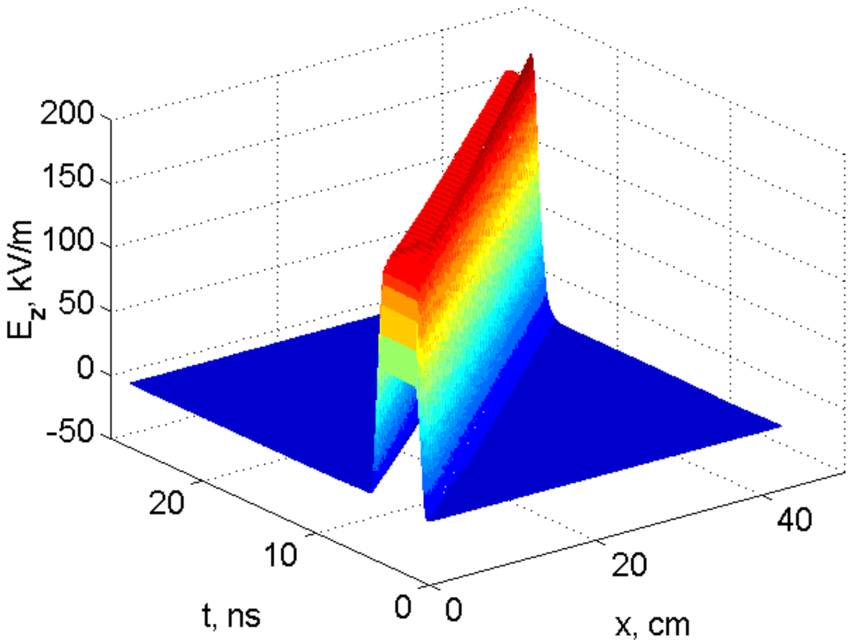
Chopper on MEBT Raft



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	645-ns pulse w 300-ns gap
Duty factor	32 %	68 % beam on
Structure rise/fall time	1.5 ns	
Pulser rise/fall time	10 ns	2% - 98 %

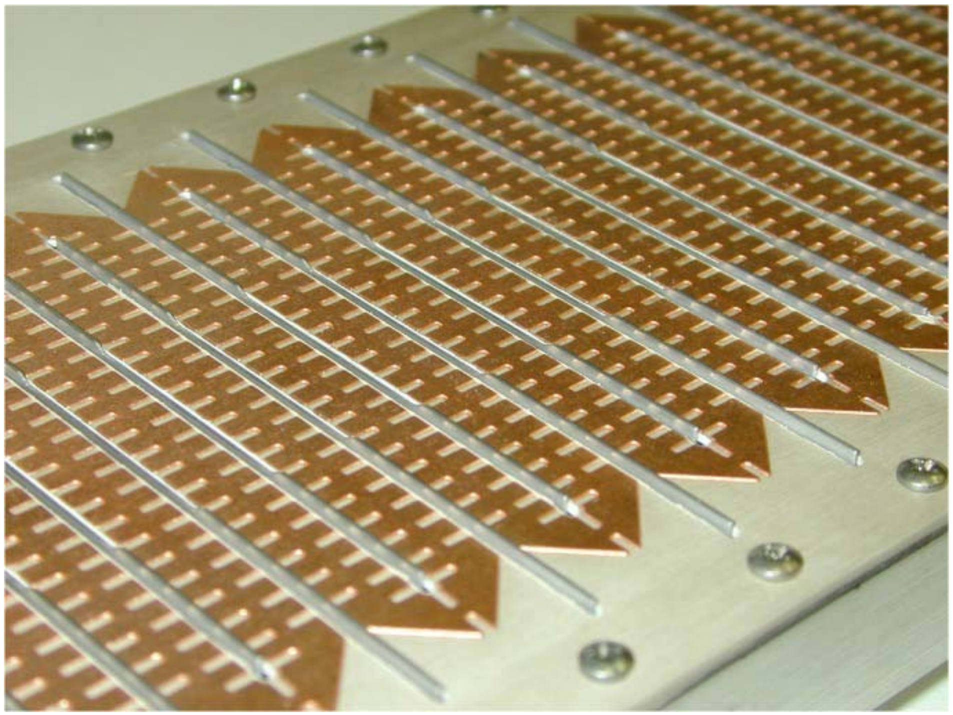
Electromagnetic Studies



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

- Electromagnetic calculations were carried out several years ago to determine the optimal design.
- We chose a “notched” meander line with grounded separators to optimize field and reduce coupling.
- The notched meander line provides the proper wave phase velocity (β=0.073) along the beam path with characteristic impedance of the line equal to 50 Ω.

Meander-Line Design and Fabrication



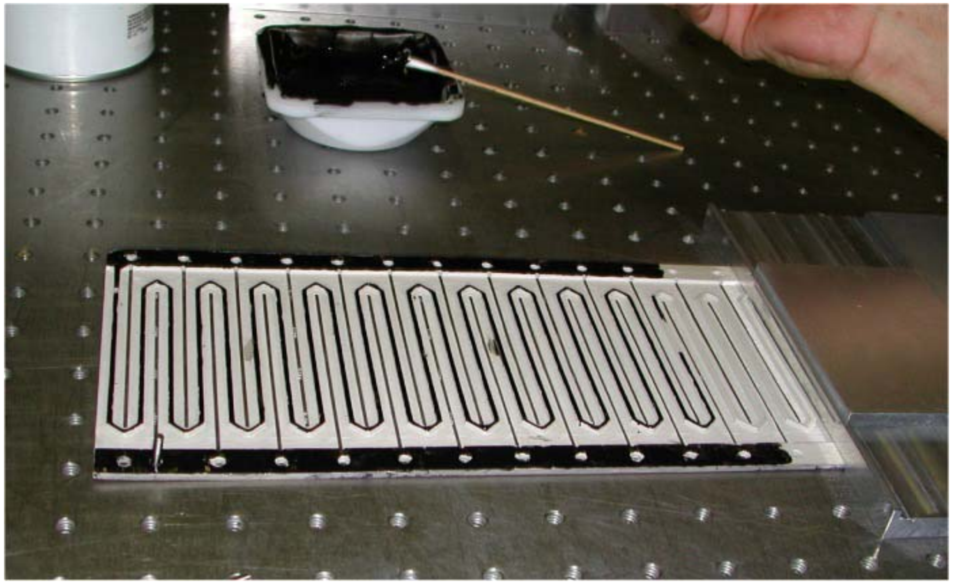
Meander-line current structure with notches and grounded separators.

- 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.

Electromagnetic Performance of Meander Line

- Agreed with calculations
- Matches velocity for beam energy of 2.5 MeV (ß=0.073)
- Structure has 1.5-ns risetime
- 50-ohm impedance

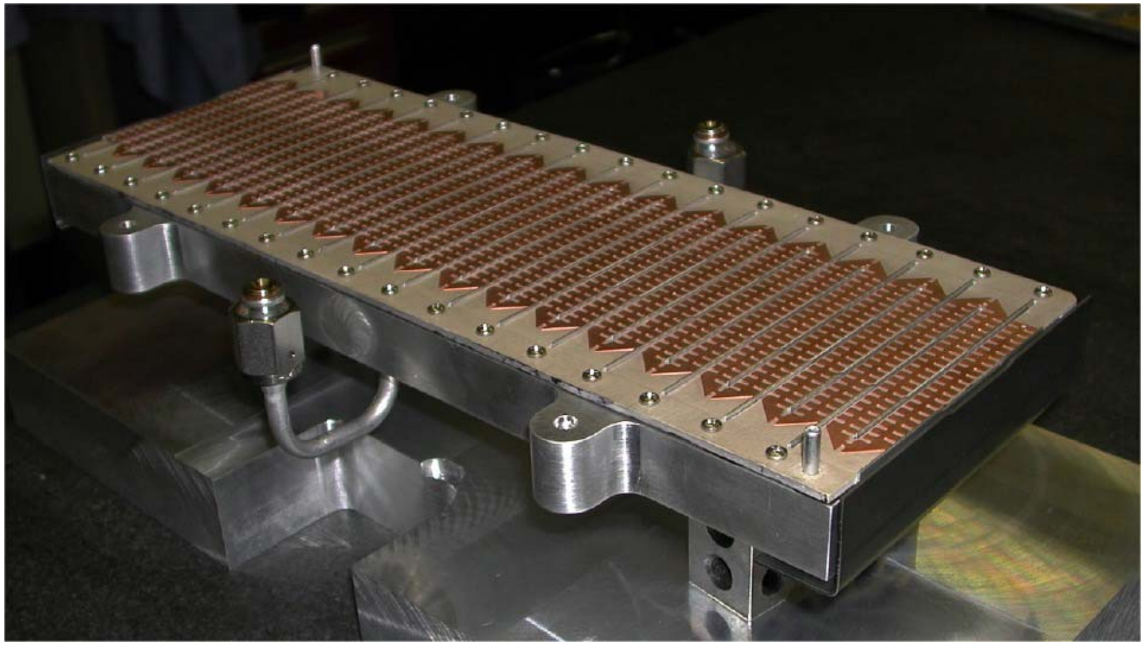
Structure Fabrication Techniques



Epoxy being applied to substrate

Chopper unit curing under weight

Finished Deflection Structure



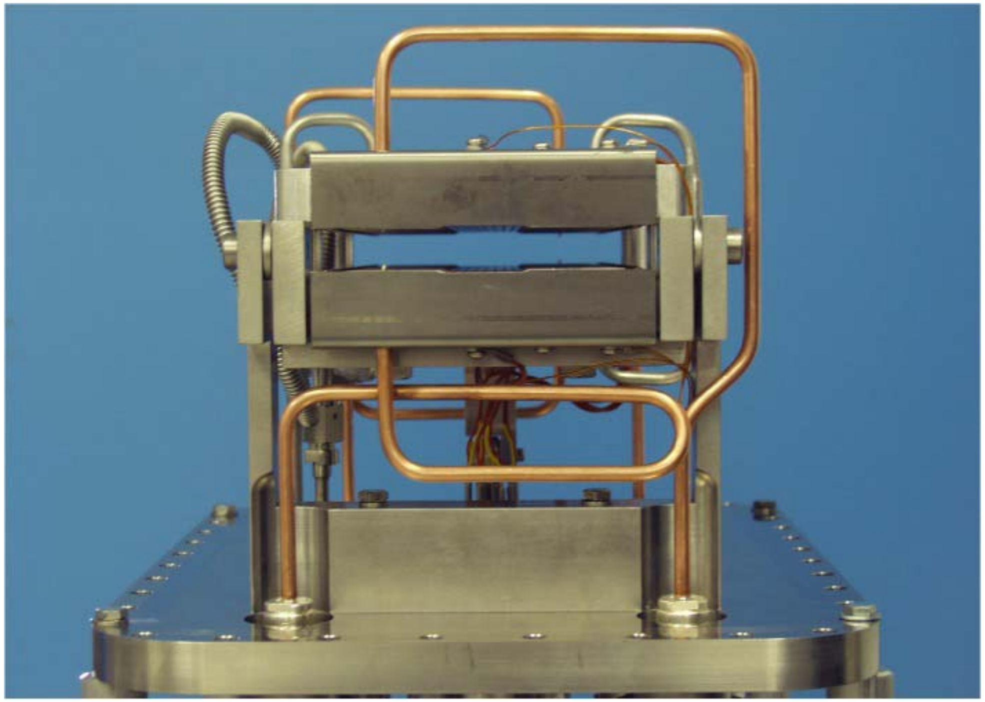
- 35-cm long
- 13-cm wide
- HV connections to meander line
- Water cooling through mounting structure

Chopper Assembly on Mounting Lid

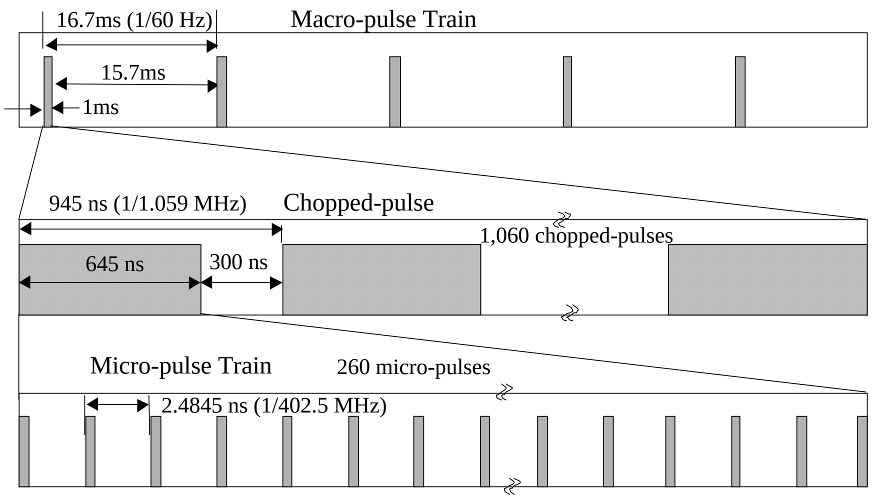
- All electrical and cooling connections made through vacuum-box lid.
- Mounting provides for vertical adjustment of deflection plates.

End View of Chopper

- Nominal 1.8-cm gap between upper and lower structure (adjustable).
- Insulated tantalum plates on ends protect structures from stray beam or backstreaming electrons.



SNS Chopped Beam Structure

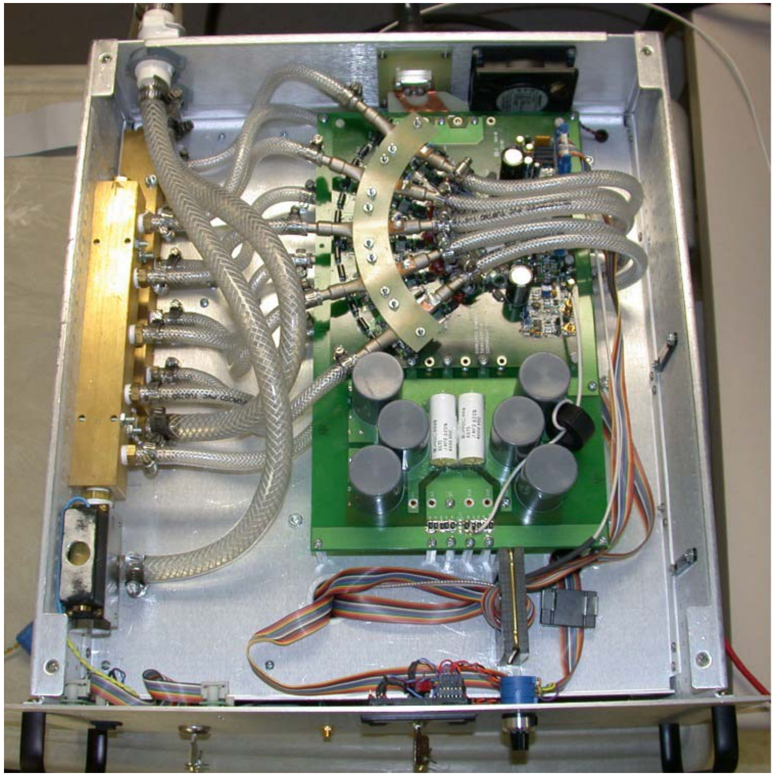


- Macro-pulses are about 1-ms long at up to 60 Hz.
- Macro-pulses are chopped into mini-pulses about 645-ns long.
- A 300-ns gap between mini-pulses allows for lossless extraction from ring.
- There are nominally 1060 mini-pulses in a macro-pulse.
- Each mini-pulse has about 280 micro-pulses (from lthe 402.5-MHz frequency of the linac).

Pulser Uses New MOSFETs Developed by DEI for LANL

- MOSFETs were developed by Directed Energy, Inc. of Boulder, CO under LANL R&D contract.
- Each MOSFET has risetime of 1 ns at 1000 V.
- The PVX-3125 pulse generator, uses five power MOSFET transistors in each leg of the bridge, configured in a series transmission line format.

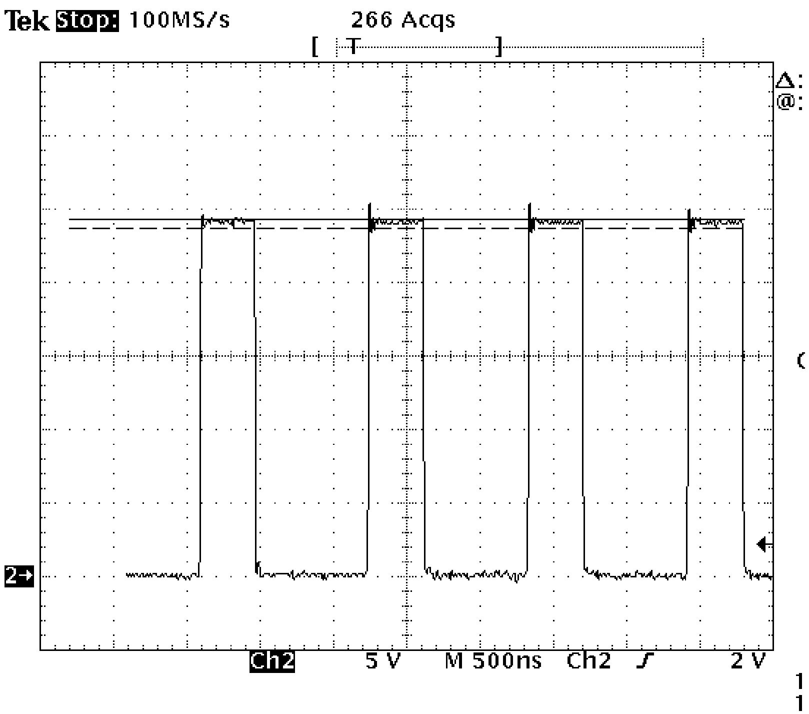
Pulser Layouts With Water Cooling

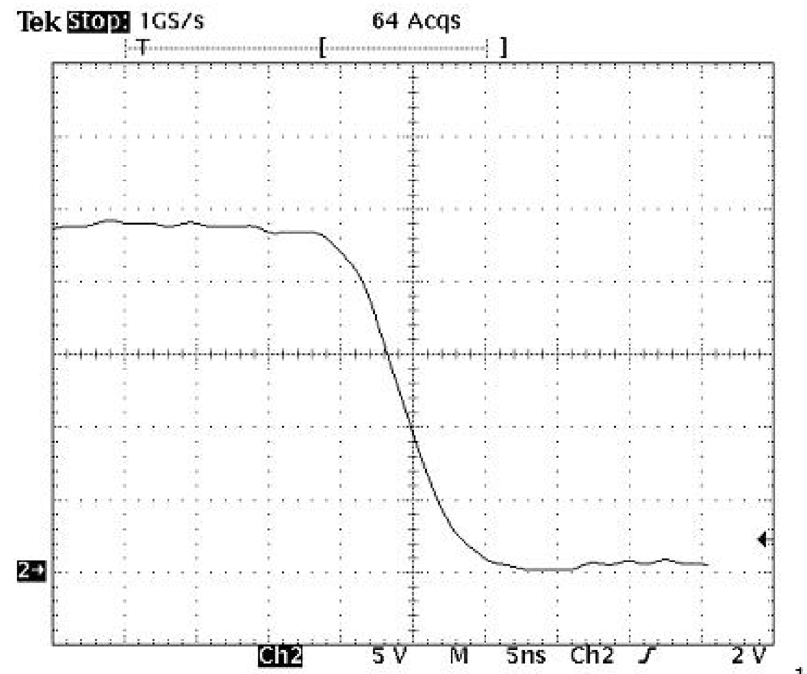


Chassis layout of the DEI positive polarity pulser

Bottom of chassis

Scope Traces of Pulser Performance

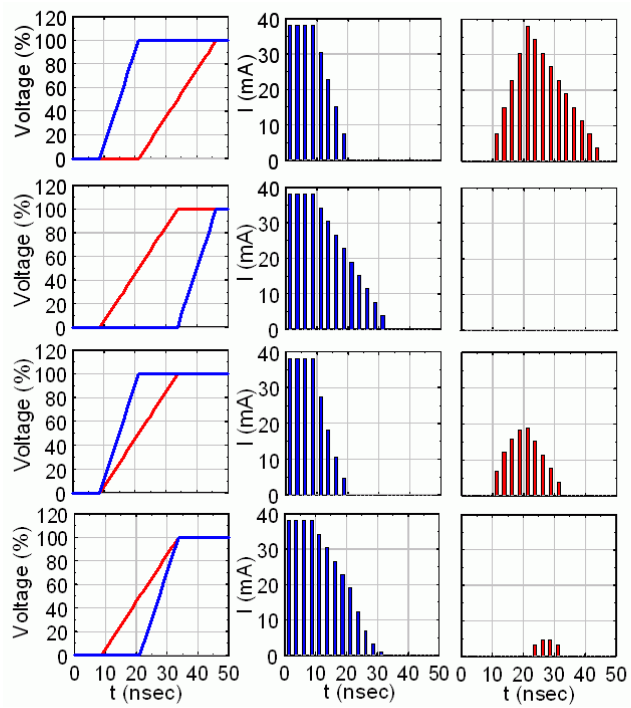




String of four pulses (out of ~1000 during a 1-ms SNS macropulse).

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

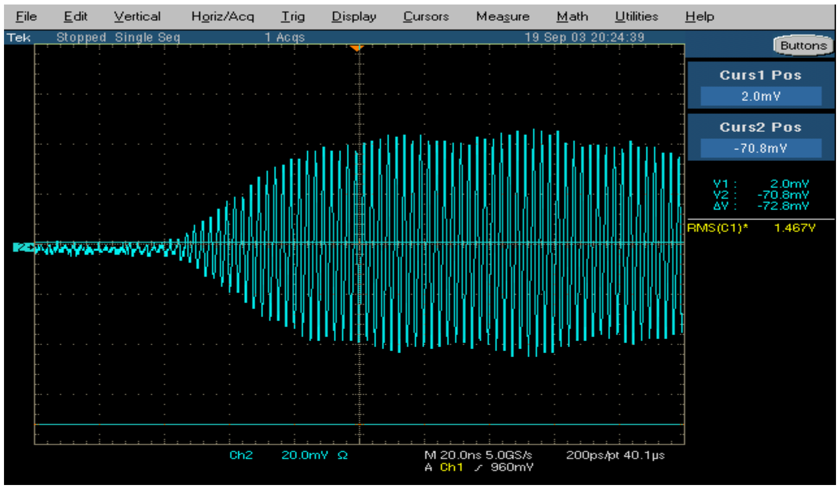
Synchronization of LEBT and MEBT Choppers



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.

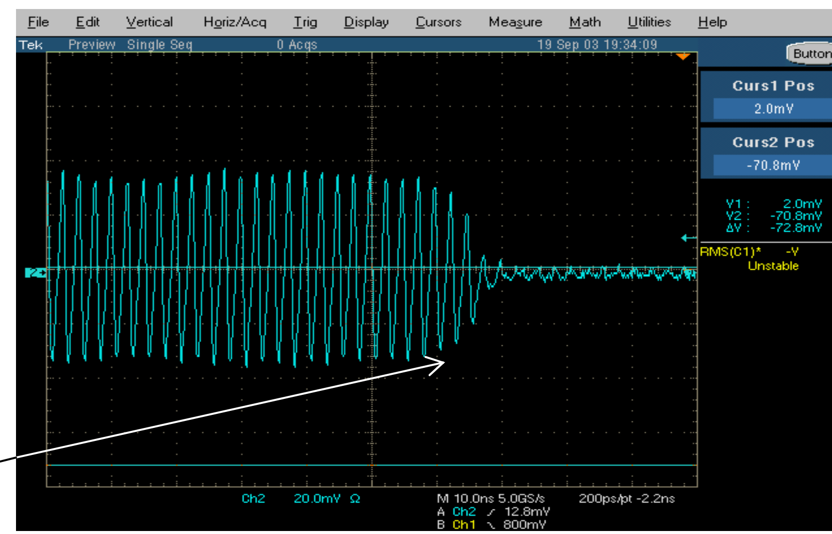
- In Option 1, the MEBT chopper turns on first, minimizing deflected beam entering the linac but with high power on the chopper target.
- In Option 2, the LEBT chopper turns on first, with no power on the chopper target but maximum deflected beam in the linac.
- In Option 3, the voltage ramps start together while in Option 4, the ramps end at the same time.
- We prefer Option 3, which minimizes partially chopped beam entering the linac while producing acceptable beam power on the chopper target.

Measured Beam Current at end of MEBT



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

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



Note three partially chopped 2.5-ns micropulses, as expected. (No beam loss is projected from these.)

Summary

- Meander-line deflecting structure was designed and fabricated with 1.5-ns risetime.
- Pulser was fabricated to LANL specifications by Directed Energy, Inc. with 10-ns risetime, ±2500V capability.
- Chopping system was installed and tested with beam on the SNS front end.
- Synchronization with the LEBT chopper required for full operational status.