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ELECTROMAGNETIC SIMULATION OF LANSCE CHOPPER STRUCTURE

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Abstract

Particle accelerators are complex systems that require precise control of beam pulse structure to achieve desired beam properties. At the Los Alamos Neutron Science Center (LANSCE), a charged particle beam of H minus is created by an ion source and accelerated to 750 KeV energy by Cockcroft-Walton (CW) column. Particle beams gain high energies further by utilizing a progression of radio frequency (RF) cavities. The beam is then moved through a series of transport beamlines to the experimental areas, where it is utilized for different scientific and engineering experiments. To control the time structure of the particle beam in LANSCE, A chopper is placed in low-energy beam transport (LEBT) after the CW column. This chopper is designed for a 750 keV charged particle beam. A good chopper must provide a clear gap in the beam and a fast transition from the gap to full current [1].

INTRODUCTION

High-energy particle accelerators provide beams to multiple users for research related to nuclear physics, medical science, and material science. Intensity and time structure requirements for different research areas might vary. For example, the LANSCE particle accelerator provides a beam to 5 different user areas such as the Proton Storage Ring (PSR), Weapons Neutron Research Facility (WNR), Proton Radiography (pRad), Ultracold Neutron Facility (UCN) and Isotope Production Facility (IPF) and all of them use different time structure of the beam.

During LANSCE operations, PSR receives 20 Hz while WNR receives 100 Hz. UCN and pRad steal a few pulses from the WNR pulse when they require the beam. pRad has an 80 ns pulse with a 1 microsecond gap while stealing 1 pulse from 100 Hz of WNR pulse. IPF which shares the DTL portion of LINAC uses an H plus ion beam line. IPF does not use a chopper as currently there is no chopper for the H plus beamline. LANSCE provides a total of 120 Hz repetition frequency of the 625-microsecond pulse. The Proton storage ring which has a revolution time of 358 ns requires a clean gap of 70 ns for beam extraction and injection. This requirement is fulfilled by chopping every 70 ns of the beam from 358 ns of the beam.

The WNR beam pulse is in a 201.25 MHz bucket separated by 1.8 microseconds. Though this WNR bunch is created by a 30-36 ns chopped beam pulse passed through a low frequency buncher (LFB), pre buncher, and main buncher. Low frequency buncher converts approximately 20 ns of this 36 ns time structure pulse into a 201.25 MHz bunched beam.

For PSR and WNR beam pulse structure see Fig. 1. These well-defined time structures are achieved with the help of choppers. These are devices that selectively block or regulate the beam, permitting researchers to control the beam timing. In general, there are two main categories of choppers: electrostatic and electromagnetic. The existing chopper at Spallation Neutron Source (SNS) in Oakridge National Lab (ORNL) is an electrostatic kind of chopper while the chopper in the LANSCE accelerator is an electromagnetic structure. For SNS a chopper was developed for its MEBT sections with 1 ns rise and fall time, though this chopper is currently not in operation [3]. There are other kinds of chopper also for example chopper at JPARC is a two-gap TMRF cavity deflector with a quality factor Q of 10.

The current chopper is a traveling wave chopper that kicks the beam in the vertical direction which goes to a target. When the chopper is on no beam goes through the beamline and when the chopper is off all the beam goes through the accelerator. The rise and fall time of this chopper is close to 10 ns. In these kinds of slow wave chopper, the beam and electromagnetic field (produced across the beam-facing strip lines) moves along the structure at the same speed. The LANSCE chopper placed in the beamline is shown in Fig. 2. The major issue of fast choppers is the restrictive power requirements from the voltage pulses [4].

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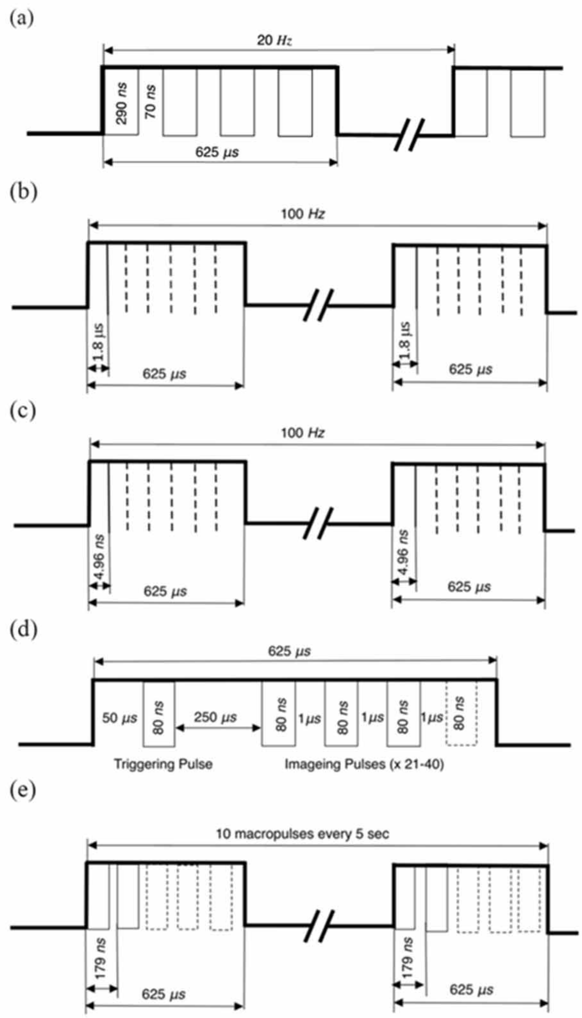

Figure 1: Schematic showing the various beam pattern signals for the LANSCE user facilities. (a) Lujan, (b) WNR (c) IPF, (d) pRAD, (e) UCN. Figure copied from [2].

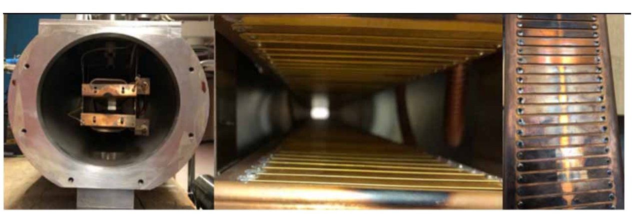

Figure 2: Image of a LANSCE chopper removed from beamline.

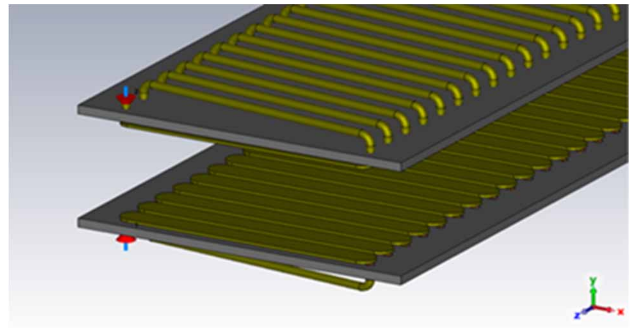

Figure 3: LANSCE Chopper Structure Model in CST Studio Suite.

There are 98 strips in the LANSCE chopper. Each strip has an 8 mm thickness and 8.3 cm of length. The spacing between the two strips is 2 mm. and the distance between the two plates is 3.5 cm as seen in Fig. 2. The voltage applied between these two plates is 650 volts each. It is designed in such a way that the coaxial cable provides most of the path length for the voltage pulse in the chopper, so deleterious effects from mismatches at the corners, as well as coupling between turns on the structure's back, are avoided [5]. The present chopper system at Los Alamos Neutron Science Center (LANSCE) is modeled in CST Microwave Studio. The model is shown in Fig. 3. The dimension and other parameters were kept the same. A time domain simulation was performed. The electric field profile obtained from this simulation is shown in Fig. 4.

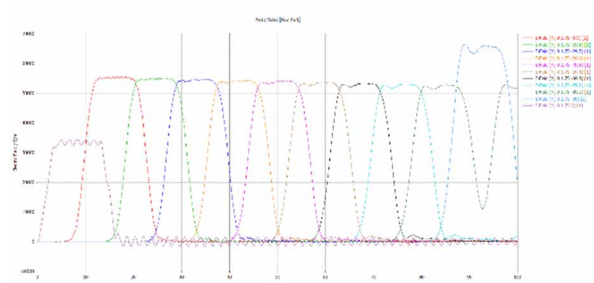

Figure 4: Electric field across the chopper at different time interval.

The distance between the two choppers is 3.5 cm. The expected field strength on the pulse top obtained through the computational simulation must be 1000V/1.75cm = 571.4 V/cm = 57140 V/m. This result was also verified through the simulation and shown in Fig. 4.

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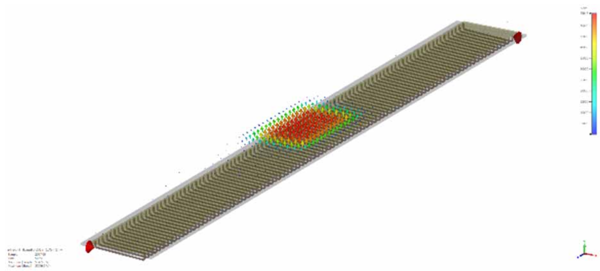

Figure 5: Electric Field Profile in Chopper at 50 nS.

In the slow wave chopper electric field and wave propagates with the same velocity. A voltage signal of 100 ns with a 10 ns pulse structure was injected through port 1 while port 2 was matched with 50-ohm impedance. An animated signal of electric field intensity and pulse with time variation was evaluated. The electric field magnitude and pulse at 50 ns are shown in Fig. 5. This shows the field moving through the chopper.

CONCLUSION

To provide different time structure to users in different beam areas of LANSCE particle accelerator facility an electromagnetic chopper is used. This chopper is designed for 750 keV H minus beam. The electromagnetic simulation of this chopper was performed through CST Microwave Studio. The actual mechanical dimensions were used and simulated. The results are shown in this proceeding. In order to manage the characteristics of particle beams in particle accelerators, the use of choppers is crucial. Further research to improve the design of choppers for LANSCE upgrade will be carried out in the future.

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