IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

VERSATILE H^+ BEAM CHOPPER SYSTEM AT LAMPF*

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Abstract

The H^+ chopper system at LAMPF provides two modes (A and B) of beam chopping. Mode A provides single micropulses separated by 1 μs or more. Mode B provides a single pulse 50 ns to 10 μs long at the LAMPF repetition rate of 120 Hz. The mode of operation is selected with coaxial relays which can switch during the dead time between LAMPF macropulses. The chopper consists of 1-m-long push-pull helical-wound slow-wave deflecting structures having an axial pulse velocity of 0.04c, which matches the velocity of the proton beam. The helix ground-planes are biased by a pulser providing push-pull 500-V pulses to deflect the H^+ beam from the injection channel. In chopping mode A, the helical windings are driven by push-pull, 1000-V, 5-ns pulses delivered by a circuit utilizing avalanche transistors and planar triodes. In mode B, the helical windings are driven by push-pull, 1000-V, 50-ns to 10-μs long pulses, produced by a circuit utilizing beam-power tetrodes and fast SCRs. In both modes, these pulses cancel the ground-plane bias and permit beam pulses to be delivered to the linac.

Introduction

A chopper system[1] that can provide a wide variety of pulse structures has been developed and is presently in use in the 750-keV proton injection transport line of LAMPF. The primary purpose of the chopper is to generate proton pulses having lengths and repetition rates suitable for producing neutron bursts needed in time-of-flight measurements at the Weapons Neutron Research (WNR) Facility. The chopper system provides two distinct modes of pulse selection, which are illustrated in Fig. 1.

The first mode (A) can provide a train of single micropulses less than 1-ns long, spaced at intervals as short as 1 μs, throughout every tenth (500-μs-long) LAMPF macropulse. An important quantity for this mode is the chopping efficiency (the ratio of beam intensity transmitted in a given micropulse to the intensity initially available in that micropulse) obtained when the contamination level (ratio of intensity transmitted from adjacent micropulses to intensity transmitted in the desired micropulse) is reduced to an acceptable level. Figure 2 illustrates the relationships between transmission efficiency and contamination level. A transmission efficiency of ⩾50% has been obtained with a contamination level of ⩽1% using the present chopper system.

The second chopping mode (B) is used to provide variable length (50-ns to 10-μs) proton pulses at the end of each LAMPF macropulse and to provide an adjacent gap of 12-μs in the proton beam to allow a fast pulsed (kicker) magnet in the LAMPF switchyard to be energized without spilling beam. The kicker magnet directs the variable width pulses into the beam transport line leading to the WNR Facility.

The chopping system consists of push-pull, helically-wound 100-Ω traveling-wave deflecting structures and the electronics necessary to drive them. A block diagram of the main elements is shown in Fig. 3. The switches shown in Fig. 3 are coaxial relays that can switch in less than 6 ms. This switching speed allows the chopping mode to be changed during the interval between macropulses.

Deflecting Structures

The deflecting structures are located in the LAMPF injection transport line, where the proton beam energy is 750 keV (β = 0.04), which corresponds to a velocity of ≈1 cm/ns. The longitudinal velocity of the transverse electric field produced by push-pull pulses on the helical windings is matched to the proton beam velocity. The deflection structure thus has an intrinsically wide bandwidth. Construction details of the deflection structure are shown in Fig. 4. A complete discussion of the principles of operation of the traveling wave deflection system is given in Ref. 1.

The construction method used for the deflection structures involved a compromise between optimum electrical performance and adequate mechanical character-

*Work supported by U.S. Department of Energy.
New England Nuclear, Inc., Billerica, MA.

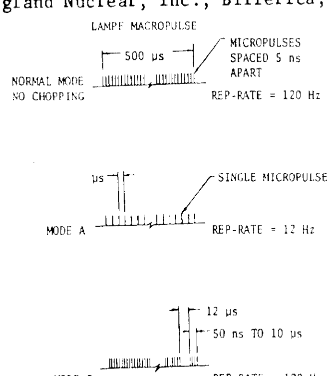

Fig. 1. Proton beam current waveforms in the normal mode and the two chopping modes of operation.

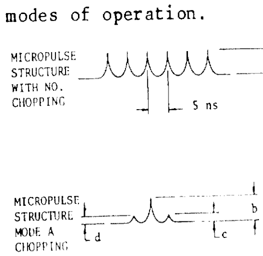

Fig. 2. Mode A chopping efficiency and contamination level.

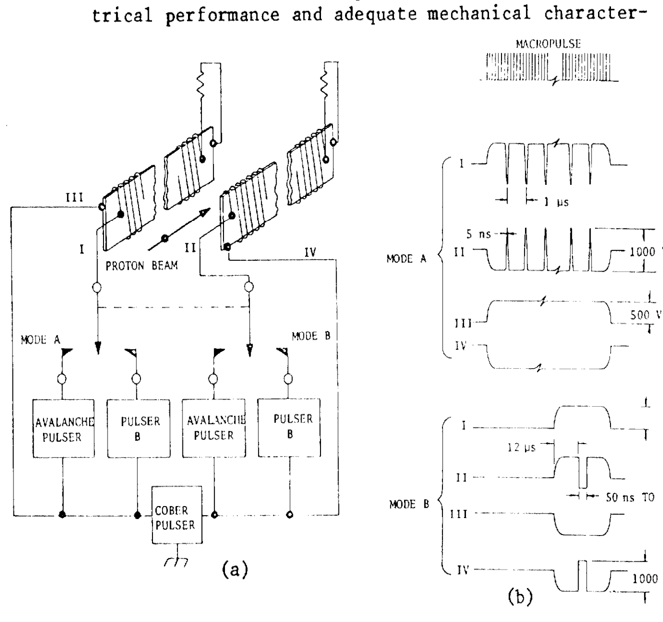

Fig. 3. Proton chopping system:
(a) Functional diagram (b) Pertinent waveform

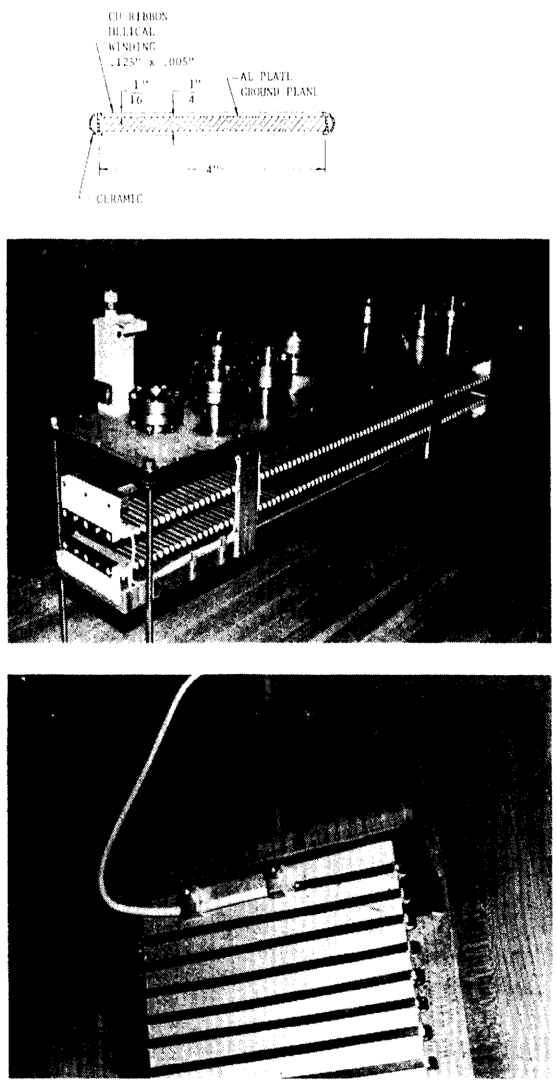

Fig. 4. Deflection structure construction.

istics. The shortest pulse risetime was obtained using Teflon corner insulators between the aluminum plate ground planes and the copper ribbon windings. Teflon causes several problems: it contaminates the vacuum if struck by the proton beam; it does not conduct enough heat from the windings if they are struck; and it is difficult to bond to other materials. Ceramic corner insulators were used even though their electrical performance is inferior to that of Teflon because their pulse performance is nevertheless quite adequate. The risetime of a step transmitted through the 80-ns-long deflection structure is no worse than 1.5 ns.

Bias Pulsers

Three pulser types are used to provide the pulses necessary for the two modes of chopping. A commercial (Cober) pulser is used to drive the aluminum plate ground planes with relatively slow push-pull pulses. The E-field generated by these pulses deflects the proton beam out of the beam channel. The pulse voltage required for adequate deflection in the present injection beam line configuration is approximately 500 V on each plate. The impedance of each plate circuit is approximately 1000-Ω resistance in parallel with a 1000-pF capacitance. The Cober pulser can easily deliver the necessary pulse lengths and repetition rates into this load.

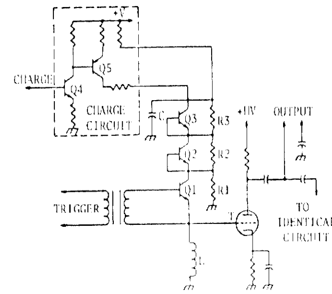

Fig. 5. Avalanche pulser simplified schematic.

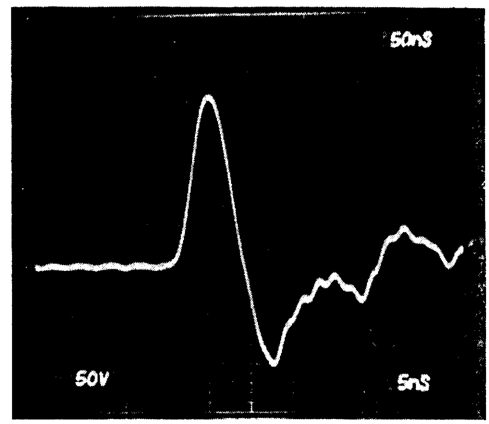

Fig. 6. Planar triode grid waveform
Horizontal: 5 ns/div; Vertical: 50 V/div

Pulser for Mode A

In chopping mode A the windings are driven with a LASL designed avalanche pulser, shown in Fig. 5. Transistors, Q1, Q2 and Q3, are 2N 3904s selected for avalanche characteristics. The voltage divider string, R1, R2 and R3, provides a small collector current (0.5 mA) through Q1, to improve triggering characteristics. When the avalanche transistor string is triggered, the capacitor (C) and inductor (L) form a resonant circuit that produces the waveform, shown in Fig. 6, at the planar triode grid. The avalanche pulser output waveform is shown in Fig. 7. An inverting transmission-line transformer obtains the positive output (also shown in Fig. 7) from an identical circuit. The charging circuit, shown in Fig. 6, recharges with a constant current after the avalanche transistor string has turned off.

Recharging C with a constant current allows faster recharging, without inadvertent triggering of the avalanche transistors, than can be obtained with resistive charging. With resistive recharging, the minimum time between output pulses is ~6-μs, whereas with constant-current recharging the minimum time between pulses is reduced to 1-μs. The voltage waveform across C is shown in Fig. 8.

Pulser for Mode B

In chopping mode B the helical windings are driven with LASL designed pulsers (B Pulser) that utilize fast SCRs and beam-power tetrodes (Fig. 9). The tetrode is self-biased near cutoff by cathode resistor R2. The "start" pulse triggers SCR3, which shorts the cathode to ground, and the tetrode conducts fairly heavily because the grid-to-cathode voltage difference is nearly zero. To end the output pulse, SCR2 is triggered. This drives the grid sufficiently negative through C1 to turn off the tetrode and SCR3. A resonant circuit (L1 and C2) speeds up turn-off of SCR2. When SCR1 is triggered, C1 is recharged through L2. A resonant circuit(L2 and C1) speeds up turn-off of

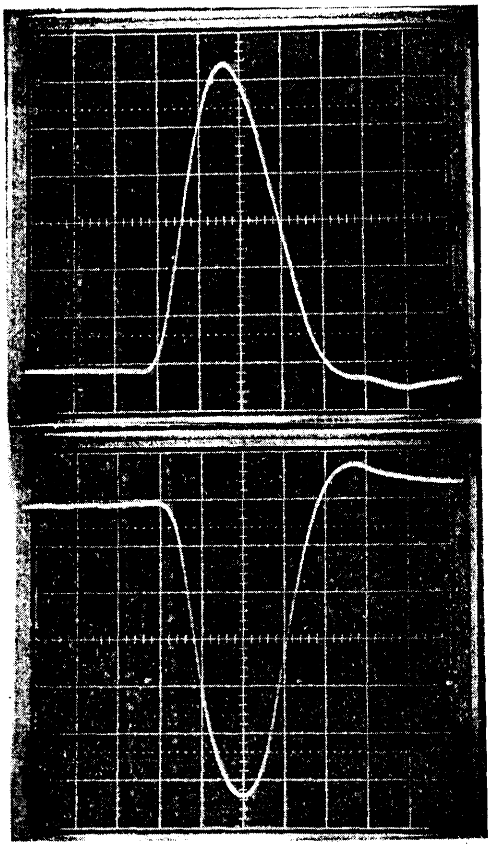

Fig. 7. Avalanche pulser output waveforms.
Horizontal: 2 ns/div; Vertical amplitude = 1000 V

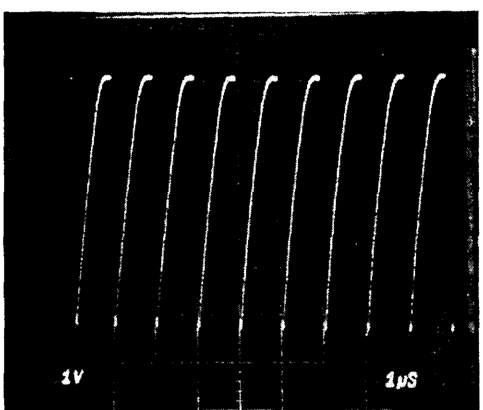

Fig. 8. Recharge voltage waveform across C in the avalanche pulser. Horizontal: 1 s/div

SCR1. The tetrodes are driven with SCRs because the necessary voltages and response times are easily attained with SCRs. The output pulse rise and fall times are ~20 ns (Fig. 10). The falltime is as fast as the risetime because the turn-off pulse delivered to the tetrode grid from SCR2 has sufficient amplitude to completely turn off the tetrode. The B pulser characteristics described above are adequate for mode B chopping. The B Pulser circuitry is con- structed on an electrically floating deck so that the outputs can be directly coupled to the deflection structures with either output polarity. Also, the Cober pulser can drive the deflection structure ground plates without disturbing the B Pulsers.

Future Chopper Requirements at LAMPF

The chopper system described in this paper is adequate for the neutron time-of-flight experiments pres-

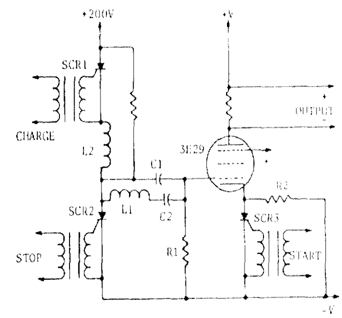

Fig. 9. Pulser B simplified schematic.

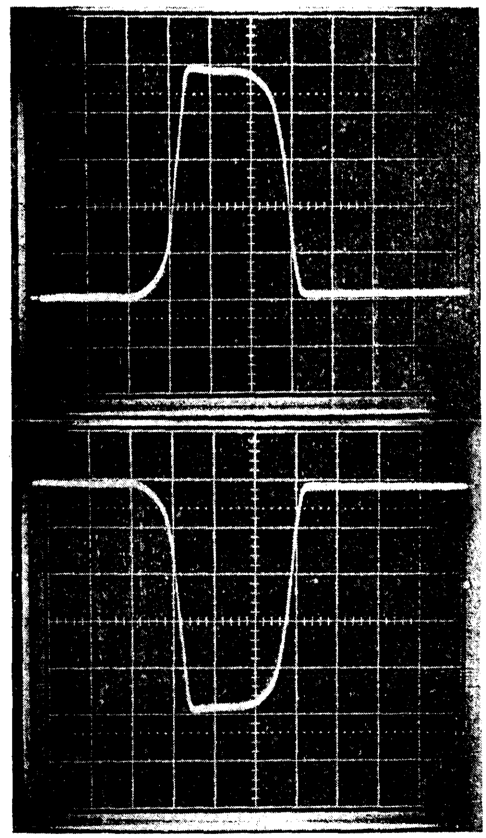

Fig. 10. Pulser B output waveforms.
Horizontal: 50 ns/div; Vertical: 200 V/div

ently in progress at the WNR Facility, but a Proton Storage Ring (PSR) is being designed as a major upgrade of this pulsed neutron source. The PSR will require an advanced chopper system in the H^- injection line. Mode A type operation will then require improved efficiency with less satellite pulse contamination, reduced time between micropulses, and probably a higher duty factor. Another mode of operation will require 90-ns pulses spaced 270 ns apart during a large percentage of the LAMPF macropulses. The present deflection structure is probably adequate for these applications, but the pulsers will have to be upgraded. A distributed amplifier is being designed, which looks promising as a replacement for the avalanche pulser and the B pulsers now being used and which could also satisfy the future PSR requirements.

Reference

1. R. F. Bentley, J. S. Lunsford, and G. P. Lawrence, IEEE Trans. Nucl. Sci. Vol. NS-22, No. 3, pp. 1526-1528 (1975).