BEAM CHOPPER FOR GEMINI

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Abstract

We investigate a traveling-wave beam chopper, which aims at the reduction of the beam loss in a high-intensity synchrotron. A model deflector is constructed and inspected. Positive and negative 500 V pulses with rise-time less than 25 ns can be generated to drive the deflector of 50 Ω characteristic impedance with Power MOS FET.

Introduction

A rapid-cycling synchrotron which is called GEMINI is designed for the intense pulsed neutron and meson sources at KEK[1]. In GEMINI using the H^- charge-exchange injection scheme, the most likely beam loss at around injection will result from the inefficiency of beam trapping in the longitudinal phase space. RF capture efficiency in ordinary methods will be at most 80 % with reasonable parameters. Particularly in a high intensity machine such as GEMINI, therefore, the beam loss at RF capture should be significantly reduced. A beam chopper will be introduced into the beam line following the preaccelerator. Computer simulation showed that the inefficiency of adiabatic trapping process is less than 1 % in the synchronous injection of a 20 % chopped beam into RF bucket[1]. Fig. 1 shows the RF bucket and the injected beam in a longitudinal phase space.

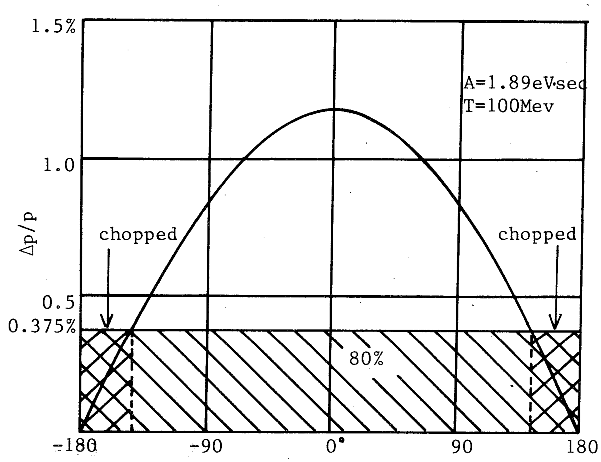


Fig. 1 Stationary bucket and coasting beam

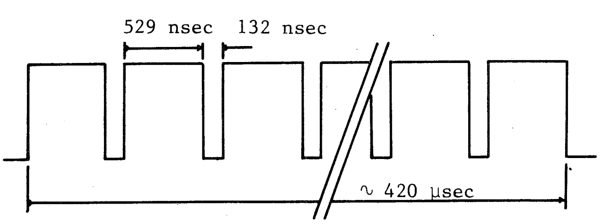


Fig. 2 H^- Injection Beam

The beam chopper will be placed between 1 MeV RFQ and 100 MeV Alvarez linac. H^- ion beam from the 1 MeV RFQ is about 420 μs in pulse length at the repetition rate of 50 Hz. The beam chopper shapes it into a pulse train, as shown in Fig. 2. We will conceive how much of the deflection angle is required in our case. Linac has 1 cm aperture[1]. We assume that there is a straight section of about 1 m. The 1 m long deflector is needed to kick the beam by about 10 mrad. with the voltage less than 1 kV. The 1 MeV H^- ion takes about 70 ns to traverse this distance with the velocity of 1.4 cm/ns. Therefore, a traveling-wave principle is used, in which the longitudinal velocity of the deflecting pulse is matched to the beam velocity. Required parameters of beam chopper for the 1 MeV H^- ion beam is listed in table 1.

Table 1
Required parameters of beam chopper for 1 MeV H^- ion beam

Length of deflector	1 m
Aperture of deflector	25 mm
Width of deflector	100 mm
Kick angle of deflector	10 mrad
Longitudinal velocity of deflecting pulse	14 mm/ns

Traveling wave deflector

We select two types of deflectors; one is a meander type with the propagation mode of odd, the other is a coax-plate type with even mode, as shown in Fig.3.

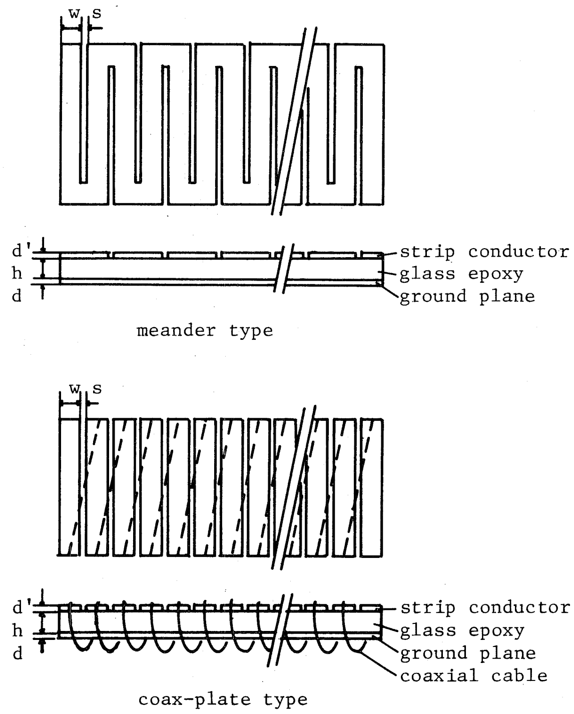


Fig. 3 Schematic diagram of two type deflectors (w >> h >> s >> d,d')

We use copper plated 1.5 mm-thick glass epoxy. One side of the plate is ground plane, the other is strip conductors. In order to estimate the characteristic impedance of those deflectors,we consider firstly a microstrip transmission line as a simple case. The microstrip transmission line consists of a conductor ribbon attached to a dielectric sheet with a conducting backing, as shown in Fig. 4.

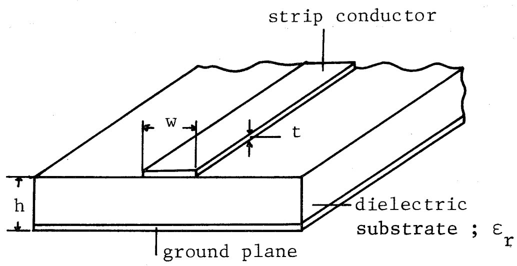


Fig. 4 Schematic diagram of a microstrip transmission line

The characteristic impedance for a wide microstrip transmission line was derived by Assadourian et al.[2)], and it is expressed by;

$$Z_o = (h/w)\cdot\sqrt{\mu/\varepsilon} = (377/\sqrt{\varepsilon_r})\cdot(h/w) \quad \text{for } w \gg h \quad (1)$$

As well known, one can simply write the characteristic impedance Zo of the transmission line and the phase velocity v respectively as follows;

$$Z_o = \sqrt{L/C} \quad (2)$$

$$v = 1/\sqrt{L\cdot C} \quad (3)$$

where C is the capacitance per unit length and L is the inductance per unit length. Impedance measurement of the meander and coax-plate type is done by TDR-measuring method. Fig. 5 shows the measured characteristic impedance of two types of deflection in comparison with the calculated one of the microstrip transmission line.

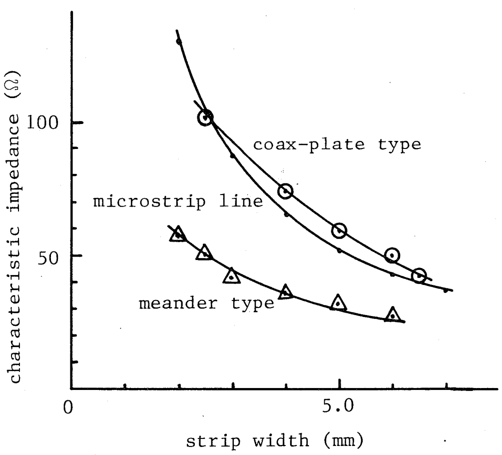


Fig. 5 The characteristic impedances of a microstrip transmission line and each types of deflector (For coax-plate type, the effect of coaxial cable is not taken into account.)

The difference of characteristic impedance is caused by line-to-line coupling. The odd-mode capacitance per unit length is higher than the even-mode capacitance per unit length[3)]. Fig. 6 shows the longitudinal velocity of deflecting pulse.

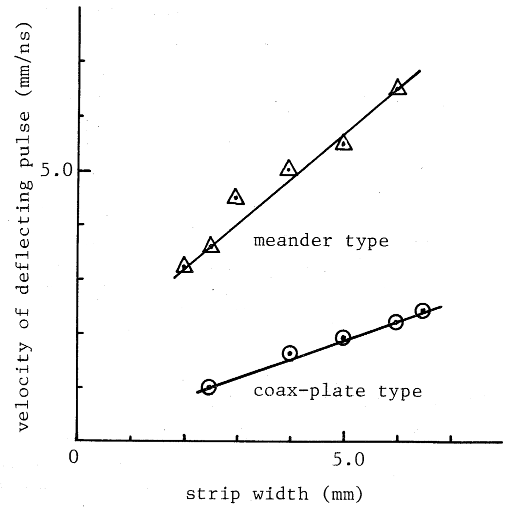


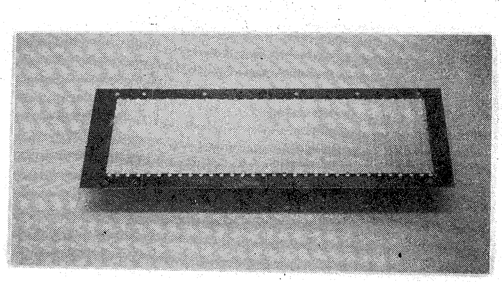
Fig. 6 The longitudinal velocity of deflecting pulse (For coax-plate type, length of coaxial cable is 1.3 times as long as strip conductor.)

A model deflector of coax-plate type, which is made of copper plated glass epoxy, is shown in Fig. 7.

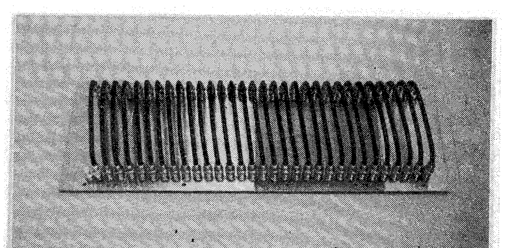
Characteristic impedance of the deflector is chosen 50 Ω for minimum perturbation at coaxial cable transmission line.

Table 2
Parameters of model deflector

	calculated	measured	unit
Length of deflector	0.5	0.5	m
Width of deflector	140	140	mm
Longitudinal velocity of Deflecting pulse	7.6	7.7	mm/ns
Characteristic impedance	50.0	49.1	Ω



strip conductor side



ground plane side

Fig. 7 Photograph of the deflector

Power amplifier for deflector

The characteristics of a power amplifier to drive the deflector are listed in Table 3.

Table 3
Required characteristics of a power amplifier

Rise and fall time	< 25 ns
Voltage output into 50 Ω	± 500 V
Pulse width	132 ns
Duty factor	< 1 %
Time jitter	< 5 ns

We have selected Power Mos FET to meet these requirements. Fig. 8 shows a simplified diagram of the model power amplifier and deflector. Fig. 9 shows the pulse response of the power amplifier.

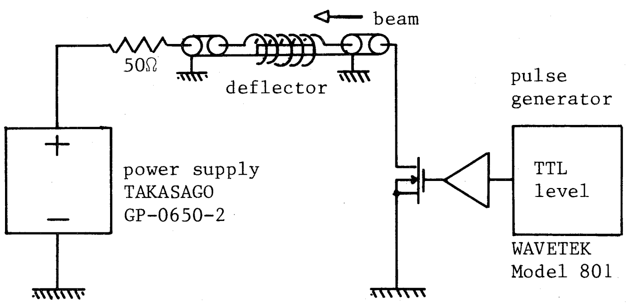
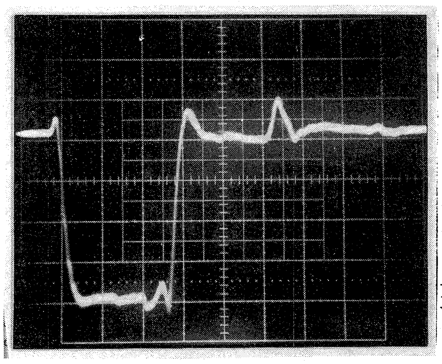


Fig. 8 Schematic diagram of a power amplifier and deflector



H (50 ns/div)
V (100 V/div)

Fig. 9 Photograph of pulse response of a power amplifier

The deflectors are driven by push-pull mode. One side of the deflector is driven by a power amplifier with positive 500 V output, the other is driven with negative 500 V output. We have following programs for the power amplifier.

(1) A number of Power MOS FET's are driven at the same time in parallel connection.
(2) A power amplifier is operated on isolated decks.
(3) Transmission line transformer, is used to feed a power, because the polarity of fast rise-time pulses can be inverted with small distortion.

Acknowledgment

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References

1) T. Adachi and Y. Masuda (Ed.), Proc. of the Meeting on BSF Future Prospects-II, KEK INT. 83-7
2) F. Assadourian and E. Rimai, Simplified Theory of Microstrip Transmission Systems. Proc. IRE, 40, 1651-1657 December 1952
3) T. G. Bryant and J. A. Weiss, Parameters of Microstrip Transmission Lines and of Coupled Pairs of Microstrip Lines. IEEE Trans. Microwave Theory and Techniques, Vol. MTT-16, No. 12 December 1968