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EXPERIMENTS OF INJECTION AND EXTRACTION DEVICES OF ELECTRON beam

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ABSTRACT

Inflector and deflector, electron injection and extraction devices, have been developed and tested. Some characteristics of these devices and results of the performance using electron beam are presented.

INTRODUCTION

For the injection or extraction of the electron beam, pulsed beam deflection devices are used. some types of pulse devices, electrostatic inflector for the injection of 20MeV electron beam into synchrotron and deflector for the extraction of 800MeV electron beam from the synchrotron, were also developed. The characteristics and the performance of the devices are presented in this paper.

Other type of device, fast kicker magnet, had been tested and the results were presented before.[1]

INFLECTOR

The inflector, an electro-static type, is designed to deflect the 20MeV electron beam for 12.0 degree. The configuration of the inflector is shown in Fig.1. To increase the electron capture efficency into the acceptance of synchrotron in the case of multi turn injection, the thickness of the septum electrode should be thinn. In our case the thickness is 0.3mm. To obtain the mechanical strength and to insure the large phase-space acceptance of synchrotron at injection, the thin electrode is supported by the cupper brock as shown in Fig.1. To obtain the best gap width between two electrodes, the high-voltage electrode is mounted on a slide stage and the gap width could be changed by moving the slide stage in holizontal direction by moter.

The pulse voltage, pulse length is about 3 uS, is used to suppress the electric breakdown at the high voltage current feeder for example. The voltage of the electrode, about 80 kV, is supplied from the pulse forming network (P.F.N.) and pulse transformer. The P.F.N. is made of 16-section of capacitance (2000pF) and inductance (20uH) and the tyratron is used for swiching element. The voltage of the P.F.N. is 15 kV max. and is supplied by the stable DC power supply. The rising ratio of the pulse transformer is 7 and it has constant frequency responce to several hundred kHz.

The specification of the inflector is listed in Table 1.

Electron energy	20	MeV
bending angle	12	deg
designed field	66.6	kV/cm
length of electrode	700	mm
gap hight	25	mm
gap width	0~13	mm
septum width	0.3	mm
suplly voltage	80	kV
pulse length	3	us
repetition rate	<3	Hz

Table 1. Specificatin of the inflector

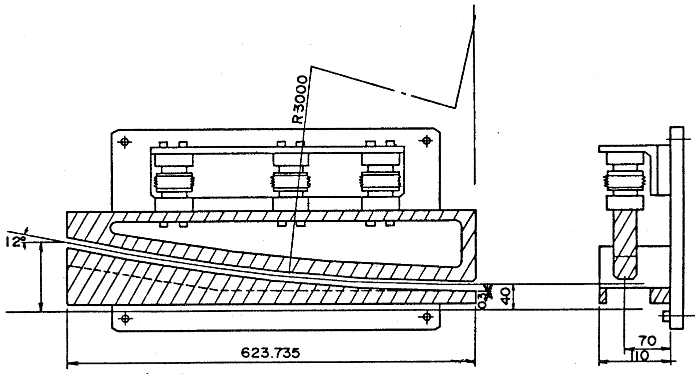


Fig.1 Configuration of inflector

DEFLECTOR

The deflector is a septum type magnet and is designed to deflect the 800MeV electron beam for 21.5 degree. In the case of the compact synchrotron the septum magnet should be smaller and the magnetic field become higher. To obtain the higher magnetic field, some cooling system of the septum coil is needed. In our device, the calculation using TRIM code showed that the current should be more than 11000A to obtain 1.33 T.

Therefore the septum coil should be cooled by some methodes. There are several kinds of septum cooling system, using water flow for example. In this septum magnet, heat of the septum coil is designed to flow through the cooling fins to the cupper heat sink. The cross section of the cooling fin is 2mm in thickness, in 10mm width and 100mm in length. This fins are connected to the septum coil by welding and are contacted to the heat sink through capton tape of 50um in thickness for the electric insulation. The fins are placed each 30mm. A simple estimation indicated that the rising of the temperature will be supressed to 20 degree when the magnet is operated at 2Hz of 12000 A.

The configuration of the magnet is shown in Fig.2. In order not to reduce the acceptance at the injection stage, the cooling fin is connected to the coil as shown in Fig.2.

The current of maximum 15kA is supplied from the slow condencer bank. The current is limited by the capacity of the DC power supply to the slow condencer bank. The capacity of the bank is 60 mF and the thyrister is used for the swiching element. The voltage of the generator is about 100 V. By using this low voltage, there are no difficulty to the electric insuration,the capton tape of 50um in thickness is enough for insulation.

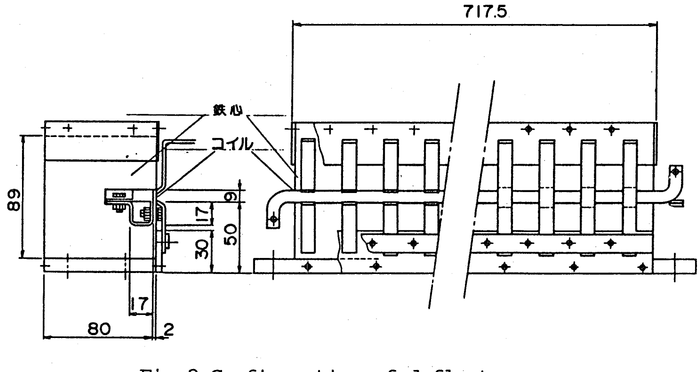


Fig.2 Configuration of deflector

The specification of the deflector is listed in Table 2.

electron energy	800	MeV
bending angle	21.5	deg
designed field	1.33	T
	1.5	T (Max)
core length	717.5	mm
gap hight	9	mm
gap width	15	mm
septum width	2	mm
number of turn	1	turn
inductance	2.09	uH
peak current	11000	A
	15000	A (max)
pulse length	1.2	ms
repetition rate	2	Hz

Table 2. Specification of the deflector

The 20 MeV electron beam was used to study the performance of these devices.

EXPERIMENTAL RESULTS

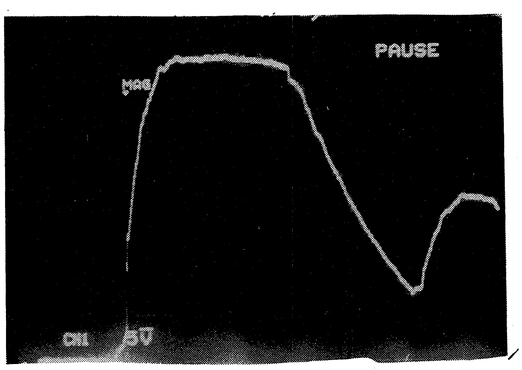
INFLECTOR

The voltage wave form of the inflector at 35kV is measured by high-voltage probe and is shown in Fig.3. This shows the voltage has a good flat top duration for the electron beam of 2us pulse length,

The schematic diagram of the experiment is illastrated in Fig.4. The beam current and beam size before and after the inflector were measured by current transformers (CT11 and CT12) and wire-grid monitors (WG12 and WG13). By using the results of the wire-grid monitors, the full beam size of the electron at the entrance of the inflector was calculated to be about 4.12 mm in holizontal and 1.76mm in vertical.

Fig.5 shows the beam current wave from measured by CTs. The gap width of the inflector was 4.55mm in this case. This shows that about 93% of the electron went through the inflector. The difference of the trace after the beam in Fig. 5 was caused by the noise of the thyratron of the P.F.N. pulse generator.

Fig.6 shows the relation between the gap width of the inflector and the fraction of the electron current went through the inflector. This shows that the current is reduced rappidly if the gap becomes smaller than 3 mm.



2 us/div
5kV/div

Fig. 3 Voltage wave form of inflector

DEFLECTOR

The wave form of the current is shown in Fig.7. The pulse length is enough to insure the flat top duration for the fast extracted electrons from syncrotron, electron pulse length would be several tens of nsec.

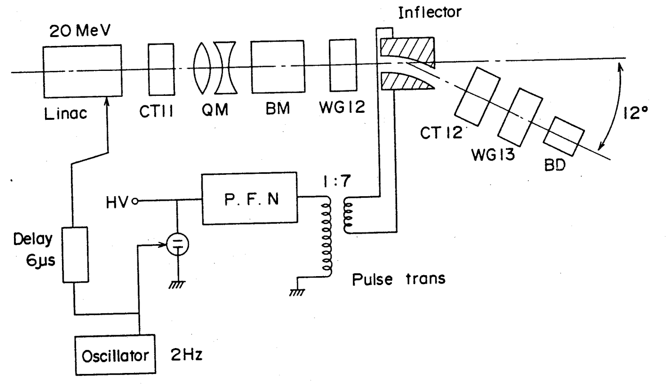


Fig.4 Experimental set-up of inflector

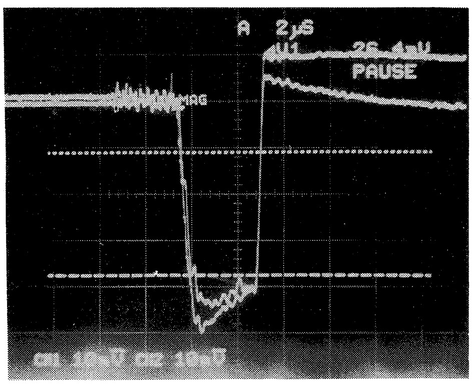


Fig.5 Electron beam current befor(lower trace) and after(upper trace) the inflector

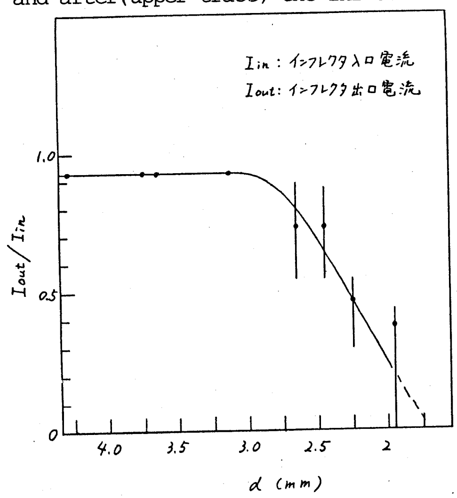
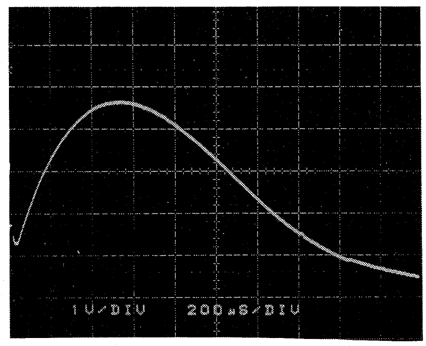


Fig.6 ratio of the electron beam after to before the inflector vs. gap width



3kA/div

Fig.7 Current wave form of deflector

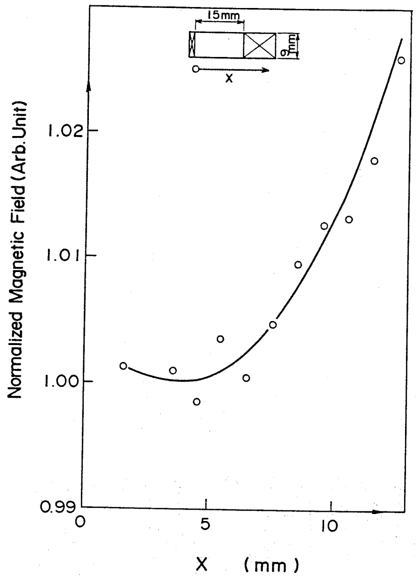


Fig.8 Magnetic filed distribution

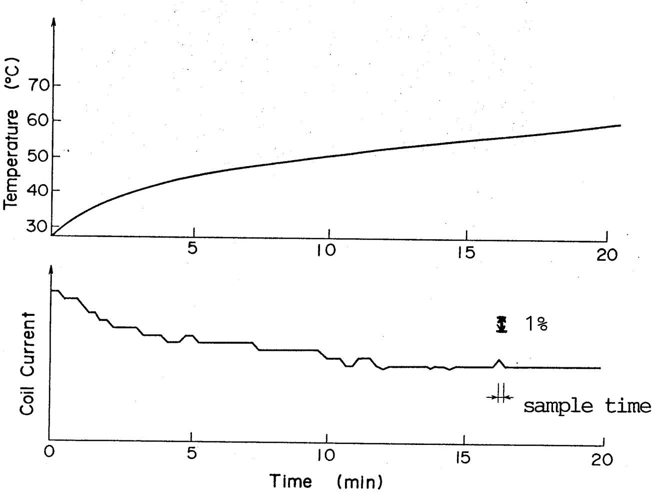


Fig. 9 Time dependence of temperature(upper) and current(lower)

The magnetic field distribution was measured by magnetic probe (1.2mm*12mm). The measurement point was limited near the entrance of the septum magnet and is shown in Fig.8. The good field region (the field homogeneity is less than 1%) is about 10 mm. On the other hand, the calculation of the field distribution by TRIM code shows that the field deviation is less than 0.1% over 15mm. The reason of the difference is thought to be the edge effect of the septum magnet.

The time dependence of the peak current at constant supplied voltage after 2Hz continueous operation was measured by shunt resister of 0.33 mOhm and also the dependence of the temperature at the middle of the septum coil were measured. The sampling time was about 10 sec. The results are shown in Fig.9. This figure shows that there is a strong relation between the current and the temperature. During the first 5 minutes, the current decreesed rapidly about 3% and the temperature rised to nearly 45 degree. However, after 10 minutes the current becomes very stable, the fluctuation of the peak current is shown to be less than 1%. The temperature rised to 60 degree.

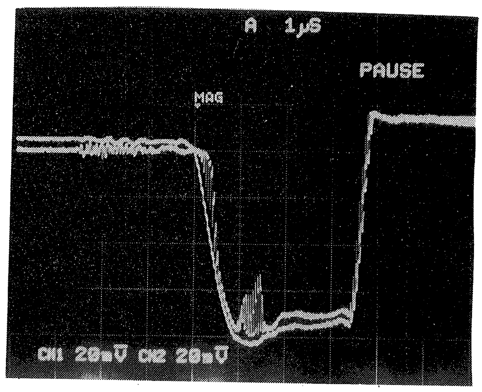


Fig.10 Electron beam current before (lower trace) and after (upper trace) the deflector

Fig.10 shows the beam current before and after the magnet. In this case the experimental set up was the same with the inflector. The beam size at the entrance of the magnet was calculated to be 5mm in holizontal and 7mm in vertical by the measurements of wire-grid monitors. The figure shows that about 90% of the electron was found to go through the magnet.

CONCLUSIONS

By this experiments, the following conclusion were found.

For inflector

1)About 93% of the electron beam of 4mm radius, can go through the inflector of 4mm gap width.

For deflector

1)The magnetic field of 1.5T max.,pulse duration of 1.2 msec, is produced at 14000 A.

2)The fluctuation of the peak current is less than 1%.

3)Homogeneity of the magnetic field is about 10 mm in the septum magnet.

5)About 90% of electron beam of 5mm*7mm cross section can go through the septum magnet.

ACKNOWLEDGEMENTS

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REFERENCE

1) S.NAKATA, Proceedings of the 1987 Particle Conference, Washington, D.C..