INJECTION AND EXTRACTION EXPERIMENTS OF A SMALL SYNCHROTRON

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Abstract

The experimental results of the injection and the extraction of a constructed small synchrotorn is reported. An electron beam of 22MeV from a RF linac is injected to the synchrotron. The injection efficiency is 100% for 10 turns of the multiturn injection. About 30% of the accelerated beam is successfully extracted from the synchrotron at the energy of 800MeV.

Introduction

A small synchrotron has commissioned at Mitsubishi Electric Corporation as a booster of the high energy electron facility for the industrial use[1]. The synchrotron can accelerates the electron from 22MeV to 1GeV. An RF linac is chosen as an injector, and the extracted beam from the synchrotron can be used for high energy experiments including the source of a storage ring. The synchrotron has a small conference(34m) with short straight sections.

The beam is injected by an electrostatic inflector[2] and and a bump orbit made by three pulse magnets(perturbators). The beam is extracted by a fast kicker magnet and a septum magnet[3][4][5]. From the requirment to extract within the circulating period of the synchrotron(115nsec), the kicker has a short rise time of 40nsec. The septum maget is designed to excite high magnetic field to obtain enough deflecting angle in the short length. In this paper the experimental results on the beam injection and extraction of the synchrotron are reported.

Injection

Figure 2 shows the desing orbit made by the perturbators and the position of the inflector.

An electrostatic inflector is chosen because of its possibility of the thin septum width to give wide acceptance for the circulating beam and homogeneous field distribution. A capacitance is connected in parallel to the elelctrodes to compensate the current caused by the injecting beam loss on the electrodes. The gap width of the electrodes is adjusted to 7.2mm to decrease beam loss through the inflector. The optimized charging voltage between the electrodes is 50kV.

The kick angle, timing and the pulse width of the perturbators are also adjusted experimentally to accept maximam injection beam. The injection beam current from the linac is 100mA. The beam has ±0.5% energy spread and $1\pi mm \cdot mrad$ emittance in the holizontal(x) and vertical(y) direction. The twiss parameter of the injection beam is adjusted to have minimum beam size at the exit of the inflector.

Figure 3 shows injected beam current measured by a fast current transformer. The beam current after the injection is 1A. The result shows the beam is injected no less than 10 turns. The time decay of the waveform shown in fig.3 is the droop time (10 μsec) of the circuit.

Table 1: The parameters of the injection

Linac	
Injection energy	$22MeV$
Beam current	$100mA$
Energy spread	±0.5%
Emittance	$1\pi mmmrad$
Pulse width	$2.5\mu sec$
Inflector	
Inject position	$x = 40mm$
Deflection angle	12deg
Voltage	$50kV$(DC)
Gap width	$7.2mm$
Perturbators	
Pulse width	$4\mu sec$
Kick angle #1	$8.05mrad$
#2	$13.0mrad$
#3	$11.7mrad$
Performances	
Accepted beam current	$1A$
Accepted turns	10

Extraction

Figure 4 shows the designed orbit of the extraction. The calculated emittance of the accelerated beam is about $0.05\pi mm \cdot mrad$. Table 2 summarizes the extraction parameters of the synchrotron.

The rise time of the kicker magnet current is 40nsec and the pulse length is 150nsec. The charging voltage adjusted at 800MeV extraction is 40kV and the current at the flattop is about 700A. The kicker magnet having C type yoke can move both in the holizontal and vertical directions. A distructive profile monitor is settled on the face of the kicker yoke to adjust the gap center to the circulating beam. The dependence of the x position of the magnet on the extraction efficiency is measured and there is no degradation while the beam center is within the yoke width.

The position of the deflector is also adjustable in the holizontal and vertical directions. The stray field on the beam center from the deflector yoke is shielded by the eddy current in the shield plate set along the yoke side. Hence, there is no effects on the closed orbit distorsion of the circulating beam by the deflector exictation.

Figure 5 shows the waveform of the extracted bunches measured by the wall current monitor at the extraction transport line. Total number of the extracted bunches within the flat top of the kicker field is 6, where the harmonic number of the synchrotron is 15. There is other two extracted bunches before the flat top of the field. Total charge of the extracted bunches were measured by beam dump at the end of transport line. The extracted charge is 30% of the total charge accelerated in the synchrotron. The extracted current (defined as total extracted charge over the number of extracted bunches) is about 70% of the beam current of the synchrotron, which means the beam loss passing through the kicker, deflector, and the transport line is 30%.

Control system

All pulse magnets are driven from the control room. The charging voltage of each pulse modulator can be ajusted manually or automatically from the host computer. The main trigger pulses are produced from a timing generator of the CAMAC(K3655) module, and delay circuits are inserted after the timing generator. The trigger pulse of the kicker is synchronized with the cavity frequency in order synchronize magnetic field flat top to the beam bunches. Figure 6 shows the block diagram of the control system.

Conclusion

An electron beam of 22MeV from RF linac is injected in the synchrotron. The beam current after the multiturn injection is 1A. The beam is injected no less than 10 turns by the multiturn injection. The 30% of the accelerated beam is extracted at 800MeV from the synchrotron. The number of the extracted bunches is 6 to 8. The extracted beam can be used for various high energy experiments.

Acknowledgments

The authors wish to thank Dr.Nakanishi for the original design of the injection and extraction orbits.

REFERENCES

1. S.Okuda, et al., "A Facility of High Energy Electron Beam for Industrial Reserch.",Proc. of the Particle Accelerator Conference, TRA21,1991
2. S.Nakata, et al., Proc. of the 6th Symposium on Accelerator science and technology, 172-174 1987
3. S.Nakata, Proc. of the Particle Accelerator Conference, 1535-1534,1987
4. C.Tsukishima, et al., Proc. of the annual meeting of the Japanease Society for Synchrotron Radiation Research, 1989
5. S.Nakata, et al., Proc. of the 7th symposium on Accelerator science and technology, 172-174 1989

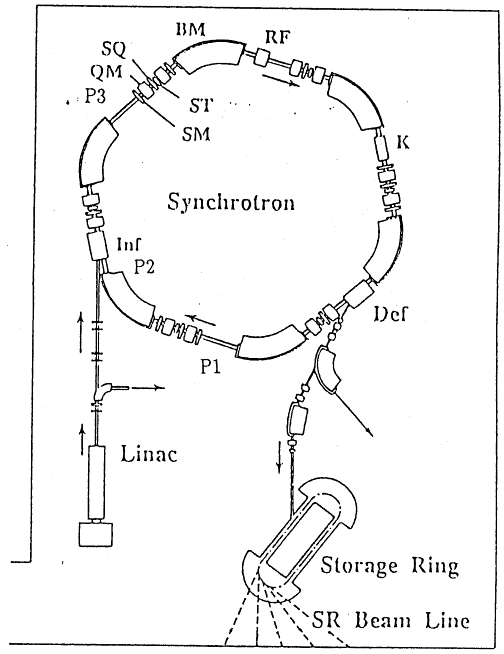

Figure 1: The high-energy electron beam facility and the synchrotron layout. BM: bending magnet, QM: quadrupole magnet, SM: sextupole magnet, ST: steering magnet, SQ: skew quadrupole magnet, RF: RF cavity, Inf: inflector, P1,P2,P3: perturbator, K: kicker, Def: deflector.

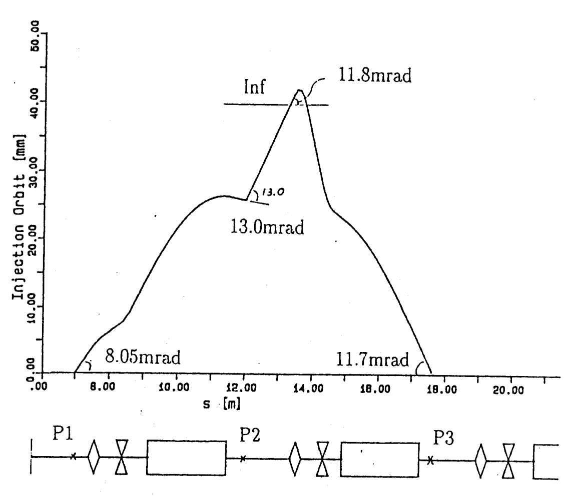

Figure 2: The bump orbit of the injection to the synchrotron. The beam energy is 22MeV.

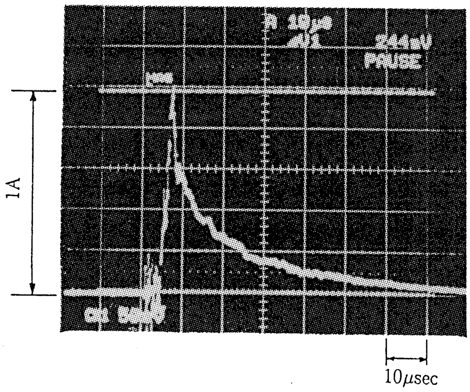

Figure 3: Measured beam current at injection. The beam current aflet the injection is 1A, The time decay is the droop of the current transformer.

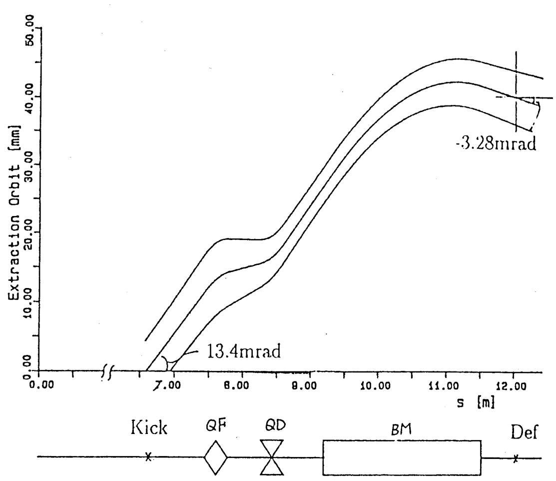

Figure 4: The extraction orbit by the kicker and the deflector. The beam energy is 800MeV.

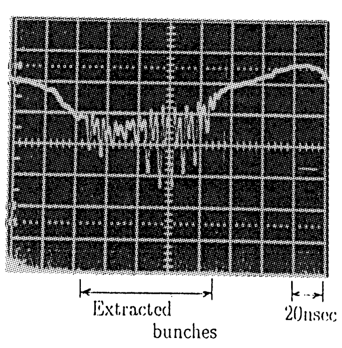

Figure 5: The extracted bunches from the synchrotron. Total number of extracted bunches is 5 to 7.

Table 2: The parameters of the extraction

Synchrotron	
Extraction energy	$800MeV$
Energy spread	0.05%(design)
Emittance(x)	$0.4\pi mm \cdot mrad$(design)
Harmonic number	15
Kicker	
Kick angle	$13.4mrad$
Length	$600mm$
Gap height	$15mm$
Peak field	$800gauss$
Voltage	$40kV$
Rise time	$40nsec$
Deflector	
Length	$700mm$
Gap height	$9.0mm$
Septum Width	$2.5mm$
Peak field	$1.6T$
Deflection angle	$21.5deg$
Pulse width	$2msec$
Performances	
Extracted bunches	$6 \sim 8bunches$
Efficiency	30%

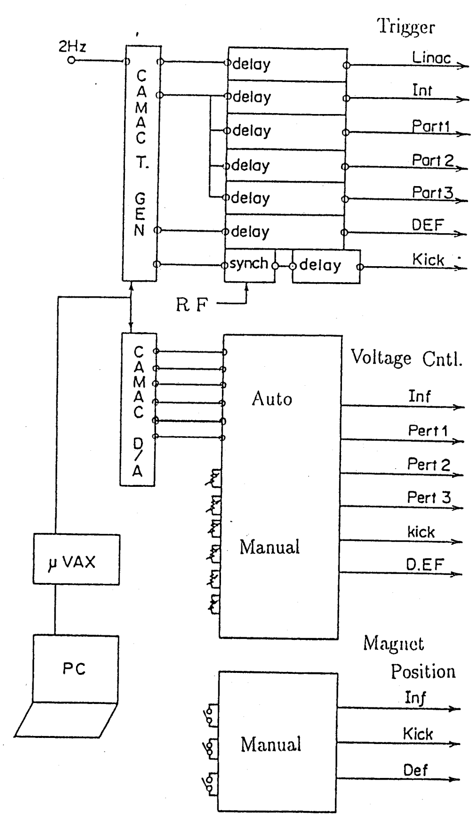

Figure 6: Block diagram of the control system