PULSED MAGNET SYSTEMS FOR THE SSRF INJECTION AND EXTRACTION

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Abstract

The injector and the storage ring of the Shanghai Synchrotron Radiation Facility (SSRF) have been built and the commissioning procedure and results are satisfactory. A total of fourteen pulsed magnets are used for the SSRF injection and extraction. The stability of 0.05%, low leakage field of less than 0.01% and identical kicker field are emphasized so that the residual closed orbit disturbance can be minimized for top-up injection. The design and performance of these pulsed magnet system are described.

INTRODUCTION

The SSRF accelerator consists of 150MeV LINAC, Booster synchrotron and 3.5 GeV storage ring. During half year of commissioning, the results indicate high performance of the pulsed magnet systems for booster injection and extraction and storage ring injection. A total of fourteen pulsed magnets are used for the injection and extraction.

Single turn on axis injection into the booster is performed by a septum and a fast kicker. The booster extraction process is implemented by the complex of a fast kicker magnet, three slow bump magnets and three septum magnets.

For storage ring injection system, four identical kickers with coated ceramic vacuum chamber and two septa are equipped. The magnets are installed at a 12m long straight section of the SSRF storage ring. The identical magnetic field waveforms of kickers and minimized leakage field of septum are most important.

SEPTUM

The type of septum is chosen to be eddy current shielded magnet. All septa for injection and extraction have similar designs. The magnet core is C shaped, 0.1mm laminations, operation in vacuum chamber. The shielding action is provided by the eddy currents flowing inside a 2.5-10 mm copper sheet. Lengthways axis of the core is designed to follow the beam trace so that maximizing the beam aperture and increasing the thickness of shielding sheet. The magnet is excited with a 60 micro-second pulse of half sine wave. To lower the impedance seen by the stored electron beam, the storage ring septum magnets have an additional OFC tube with a special cross-section placed alongside the magnet. Moreover, a magnetic screen [1] is placed around the stored beam to minimize the septum leakage field (Figure 1). Table 1 shows the parameters of storage ring septum. At the maximum bumped beam position which is 14.5mm away from the stored beam center, the leakage field was measured to be below 50 μT·m.

Table 1: SR septum parameters

Beam Energy(GeV)	3.5
Deflection (mrad)	52
Magnetic Field(mT)	800
Core Length (mm)	800
Aperture H*V(mm)	32 * 12
septum thickness(mm)	2.5-10
leakage field (μT·m)	<50
Pulse width (μs)	60
Waveform	half sine
Peak Current (A)	8500
Stability (rms)	0.03% (p-p 0.1%)
Jitter (rms)	15ns (p-p 48ns)

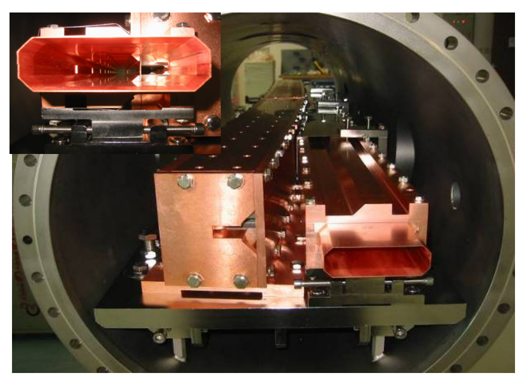

Figure 1: SR injection septum

KICKER AND BUMPER

The booster injection and extraction kickers are in-vacuum ferrite kicker magnets with window-frame core. The kicker pulser is located near the kicker magnet in tunnel. Thyratron and PFL cable are main components of the pulser which provides trapezoidal current pulse to excite kicker magnet (Table 2).

Four identical kickers with ceramic vacuum chamber are installed at a long straight section of the SSRF storage ring for symmetric bump up of the stored beam. The kicker magnet is conventional window-frame ferrite core type. The ceramic chambers are used to allow external time varying field to penetrate the vacuum chamber and to carry the beam image current. The main difficulty is matching the resistivity of the metallization inside the ceramic vacuum chambers. The ceramic chambers currently in use have DC resistances of 1.960Ω ±3.1%. The kicker is excited by 3.8 μs width half-sine pulse of 3.6kA peak current. By comparing pairs of pulsers, we conclude that the pulser waveforms can be matched to within $\pm 1*10^{-3}$ during the complete pulse. Measurement results show that field homogeneity is better than ±1.0% in the region ±15mm*±5mm relative to the chamber center. Amplitude stability is better than 0.3%(p-p), and jitter is less than 2ns. The pulse width mismatch between four kickers is adjusted to be less than ±3ns.

Table 2: Booster kicker parameters

	Injection	Extraction
Beam Energy(GeV)	0.15	3.5
Deflection (mrad)	9.17	1.64
Magnetic Field (mT)	12	24
Core Length (mm)	400	800
Waveform	trapezoidal	trapezoidal
Rise/Fall time (ns)	94 (fall)	250 (rise)
flat-top duration (ns)	310	249
Peak Current (A)	300	600
Stability (rms)	0.06% (p-p 0.25%)	
Jitter (rms)	0.6ns (p-p 2.1ns)	

For the booster extraction, three bump magnets are equiped at extraction section. C-shape frame core enables easy installation outside the beam chamber. The magnets are excited by half sine wave current of 200ms length. Long pulse avoids the attenuation of field when it passes through the metal vacuum chamber. With 70A peak current the bumper can deflect 3.5 GeV beam with 3.1 mrad. Each bumper is driven by a dedicated DC power supply which is programmed by a 0-5V remote controlled source.

COMMISSIONING

For SSRF storage ring, top-up injection will be a prospective operation mode. Top-up operation implicates that highly reliable systems are needed since the injections will happen frequently during the whole user run. Very careful set-up of the injection is required since the distortion of the stored beam will directly affect the data acquisition of the experiments and any particle losses during injection may hit the optic components of the beam line through open beam-shutters [3].

For injection system, septa are stressed on minimizing the leakage field, while kickers are emphasized on achieving the best possible tracking in time and amplitude of the magnetic field waveforms so that the residual closed orbit disturbance is minimized. Mismatch between kicker pulses and the timing jitter of pulser system should be minimized. Four kicker pulsers are triggered by a DG535 unit to ensure the sub-nanosecond delay adjustment and the jitter requirement. Users can easily adjust the delays of pulse trigger through a soft IOC communicating to DG535 via Agilent E5810A.

During first stage commissioning, the residual orbit disturbance in horizontal plane is reduced to about 100μm by tuning the kicker amplitude and trigger delay. However, the vertical disturbance is rather large, approximately 300μm. This is believed to be caused by alignment problem of the kicker magnets. Initial horizontal rotation error between different kickers is larger than 3mrad. After this error is reduced to less than 0.5mrad by re-align kicker magnets, the vertical disturbance is significantly decreased to around 50μm [2]. This value can be lowered through further fine tuning of the whole system.

CONCLUSION

The pulsed magnet systems for injection and extraction were successfully installed and operated in the SSRF booster and storage ring. The test and commissioning proved that the injection and extraction systems are highly reliable. These magnets, power supplies and controllers operated perfectly and excellent injection efficiency is achieved. Further effort on the pulsed magnet systems will be done for further improving the performance and reducing the disturbance.

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