A BUMP SYSTEM FOR SSRF STORAGE RING

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Abstract

A prototype of the Injection bump system for 3.5Gev storage ring of the proposed SSRF has been built and tested. The required magnetic flux density 0.126T has been achieved. The uniformity of field is 0.14% within ±30mm region.

A coaxial structure adopted in the discharge circuit much reduced the stray inductance as a result the pulse current of 4500A has been gotten under low charging voltage of 9kv. The ferrite saturating inductor connected adjacent to the thyratron are used to help the thyratron turn off gradually and to eliminate the inverse spike voltage.

A switch mode DC power supply was used to charge the pulser, instead of the conventional resonant charging power supply. A repetition voltage stability of ±0.03% has been presented.

1 INTRODUCTION

The SSRF major facilities include an accelerator complex consisting of a preinjector Linac producing 300Mev electrons, a 1Hz Booster synchrotron accelerating particles to 3.5Gev and a 3.5Gev Storage Ring from which X-ray beam line will be drawn.

3.5Gev electron beams are transported and injected into the storage ring. The injection scheme is shown in Fig.1. The bump system specifications are listed in table 1.

Table 1 The specifications of the bump system

	B_{11} B_{12} B_{21} B_{22}
Deflection angle	2.9mr
Field strength	0.12T
Magnetic aperture	122×44(H×V)
Pulse waveform	Half-sine 4μs duration
Amplitude stability	0.5%
Field uniformity	0.8%
Time stability	±10ns

A single bunch or bunch train of 300ns from the booster are deflected by an angle of 144mr in the septum magnets then injected into the storage ring. The bump magnets bring the equilibrium orbit towards to the incoming beam. In order to create an unsymmetrical bump orbit, four same magnets must powered by its own pulser separately. The pulse waveform is half-sine of 4us duration. Because of the revolution time in the storage ring is 1.32us,the beam bunches not only pass through the bump magnets during the top of pulse field but also during its rise and fall edges. Therefore a requirement has arisen that the pulse current waveforms of four pulsers must be as same as possible. In the meanwhile, both amplitude and time stability must be good enough. So that, the switch mode DC charging power supply with ±0.03% amplitude stability and the drift time stabilizer with 2ns adjustment accuracy were necessary.

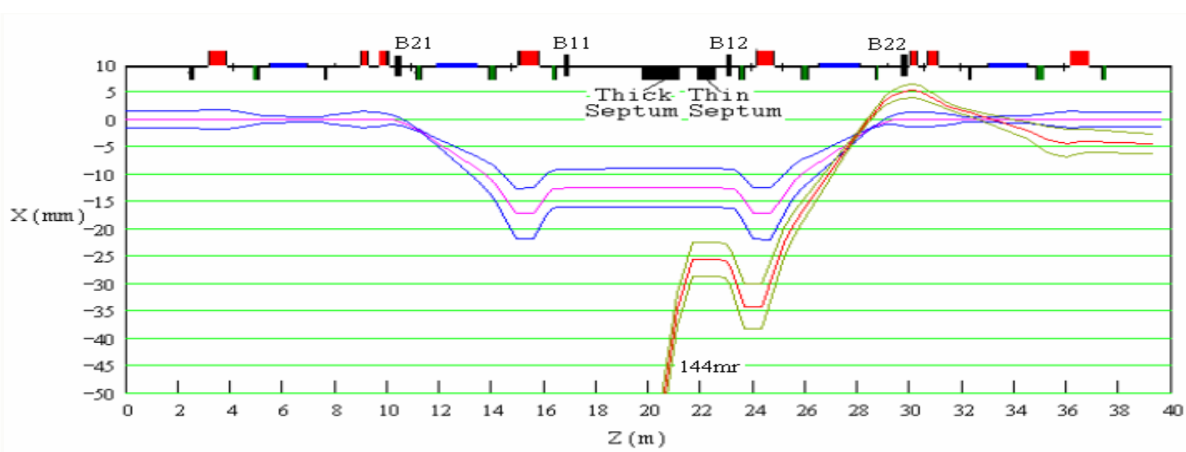

Fig.1 The injection scheme of SSRF storage ring

All of the requirements above are to ensure the lower residual β−oscillation after beams pass through the bump magnet fields.

The prototype consists of a full size bump magnet, a 5KA pulser and a switching mode DC power supply.

2 BUMP MAGNET

The bump magnet has a window frame ferrite yoke in air and an insulated one-turn excitation coil. The magnetic aperture is 44mm vertically by 122mm horizontally. A ceramic vacuum chamber will be placed in it.

The frame is made of 24 C-type nickel-zinc ferrite blocks, 12 blocks are stacked and fixed by polysulfone plates, forming a half yoke. In closed positon two half of yoke are seperated by a 1mm thick copper plate to attenuate any remaining closed flux of the wake field when beams pass through the yoke.

The magnetic yoke length is 0.3m. The ferrites was made in China of which the performances close to the ferrite type as 8c11 from Philips: B_S >0.3T, μ_0 >1000.

As the magnets are in air, a critical part of design is the electrical insulation of the coil. The straight sections of the coil that pass through the ferrites yoke have been embedded in polycarbonate bars and fixed at the end of coil. It is shown in Fig.2. Test results have proved that this solution is satisfiable. Both polysulfone and poly carbonate are all the good materials against radiation.

The tests results showed that the excitation efficiency is 0.126T/4.5kA and the uniformity of field is 0.14% within ±30mm region.

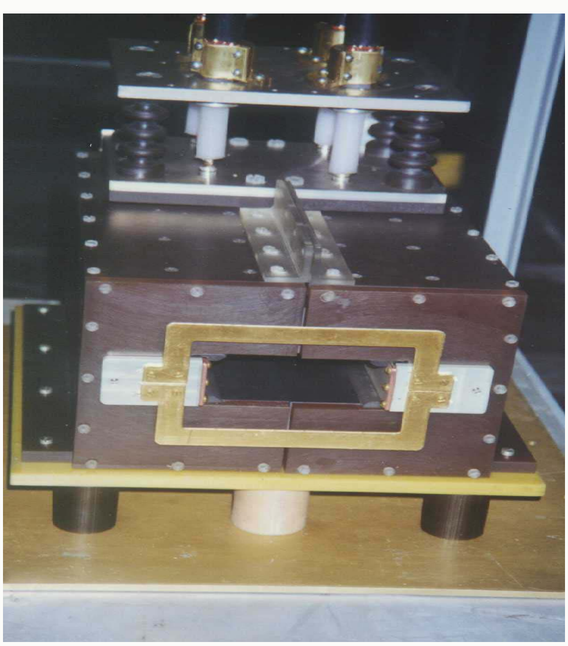

Fig. 2 The bump magnet (without shielding)

The another critical part of the bump magnet is manufacture of the ceramic vacuum chamber. We have few experiences and also have to spend a lot, so the work will be done in next step.

3 PULSE CIRCUIT DESCRIPTION

The pulser circuit diagram is shown in Fig.3 which producing a half-sine pulse current of 4us duration The total inductance LM of the bump magnet including its connector stray inductances is 1.27μH. The thyratron in the circuit was used as a switching element. While the thyratron in open, the main capacitor C0 is being charged up to a voltage E_C equal to the value of that from the switch mode DC power supply. By triggering the thyration, the capacitor C0 will be discharged through the plasma of thyratron and the bump magnet coil with a heavy pulse current will excite the fields in bump magnet.

In order to save some energy, a ring-back circuit composed of a diode stack DR and an inductor LR is connected across the main capacitor, which will recover part of the stored energy after the thyratron ceases to conduct. The RF-CF filter in the circuit is used for the elimination of higher mode oscillation on the pulse current waveform.

Obviously, the pulse current waveform in LC discharging loop is half-sine, because the thyratron CX1154 is unidirectional switch. Both amplitude Ip and duration τ of the pulse current by following formula:

$$I_P = E_C \Big/ \sqrt{\frac{L}{C}} \qquad \tau = \pi\sqrt{LC} \qquad L = L_M + L_S + L_{cable}$$

E_C	charging voltage
C	capacitance of main capacitor
L	total inductance of discharging loop
L_M	inductance of the bmup magnet
L_{Cable}	equivalent lumped inductance of transmission cables
L_S	total stray inductances

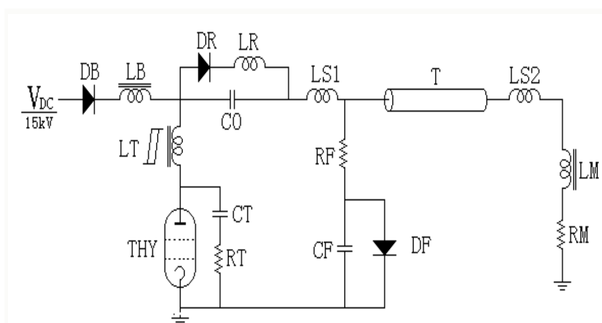

Fig.3 The pulser circuit

3.1 Measures for reducing stray inductance L_C

Firstly, a capacitor with low stray inductance was designed and manufactured specially for used as the main capacitor. Its stray inductance is less than 30nH. Because it has no high voltage bushing, two metal concentric rings insulated by plastic wall on the topside are two electrodes forming a coaxial structure.

Another coaxial structure is copper tube placed horizontally housing a thyratron, a ferrite ring stack and a pulse current transformer, shown in Fig.4.

Fig.4 Coaxial structure (a cover removed)

Two coaxial structures are connected in series, then transmission cable inner and outer conductors are connected to the toroidal electrode of the main capacitor and copper tube separately.

3.2 The saturable inductor[1]

For thyratron application, toroidal geometries of the inductor are ideal. Ferrites can easily be manufactured in toroid form, but it has one significant disadvantage: the saturation flux densities are about 4500 Gauss. This requires either many turns on a core or a large core sectional area. Since circuit inductance must be keep to a minimum, a minimum inductor is obviously not an alternative. Construction of a large cross section of material may also increase the size of the discharge loop, thus the inductance, but that can be improved by installing the ferrites stack with thyratron in the same coaxial structure. The saturable inductor consists of 10 MnZn ferrite toroids in a stack. Each toroid has a 10cm O.D, 5cm I.D, and 2cm thickness.

If the relative permeability μ_r of ferrite under saturation is 2, then L=0.14µH, but if without coaxial structure, the L=0.24µH.

4 SWITCH MODE DC POWER SUPPLY[2]

A switching mode power supply with a phase shifting resonate inverter was designed instead of the conventional resonate charging power supply. This technique was two independent inventor circuits which both drive current in the primary windings of a high voltage transformer. The inventers in this configuration can operate in two modes. During the main charge period when full power is required the inventers run synchronized in phase and a maximum output current is produced. When the load voltage is closely approaching the demand voltage, a phase shift is introduced between the switching cycles of the two inventers resulting in a reduction of the output current.

For stabilizing the output voltage, a feedback system based on controlling the phase drift was designed and works well.

The test on this prototype of bump system gave good results producing charge voltage amplitude repeatability of better than 0.03% at repetition 1Hz.

5 TEST AND MEASUREMENT RESULTS

The inductance of the bump magnet with connectors was measured using Agilent 4284A LCR meter, the result is 1.275 µ H at 10kHz. According to the pulse current waveform shown in Fig.6 in the discharging loop, the total inductance L can be evaluated, L=2.0 µ H. So the total stray inductance L_S=0.725 µ H. The amplitude of pulse current of 4500A was achieved at 9kv charging voltage. Fig.5 also shows us that the pulse waveform is very nice without any high order harmonics oscillation.

The anode voltage of the thyratron was measured and shown in Fig.6. The peak inverse voltage is less than 7.5kV with a rise time of 1 µs. This conditions that came from using the saturetable inductor and the RC snubber are very favored the thyratron operating with long life.

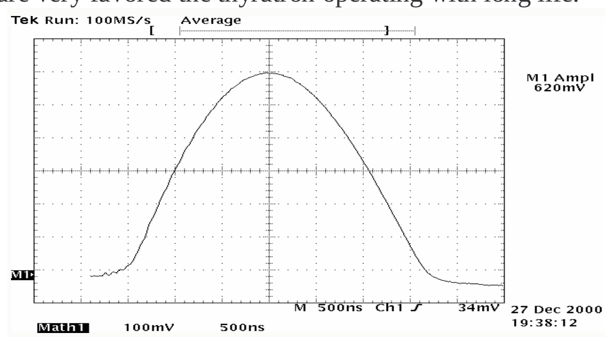

Fig.5 Pulse current waveform (725A/div, 500ns/div)

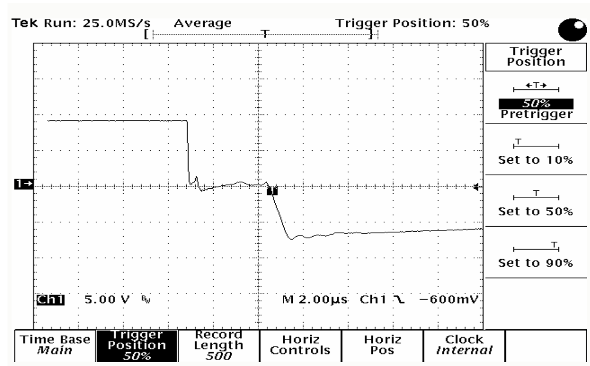

Fig.6 Thyratron anode voltage(5KV/div, 2 µ s/div)

REFERENCES

[1] Rai-Ko Sun, "Experiment on the Injection Beam Kicker Magnets", PEP-266, April 1978.

[2] G.L. Bees, A.Tydeman, "Capacitor Charging Power Supply Design for High Pulse to Pulse Repeatability Applications", Published by the IEE, Savoy Place, London WC2R OBL, UK.