DEVELOPMENT OF AN EDDY-CURRENT SEPTUM MAGNET FOR THE SSRF STORAGE RING

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Abstract

An eddy-current septum magnet has been developed for injection of SSRF storage ring. The performance of the magnet is very good, the stray field outside of the septum is less than 2 Gauss. To reduce the stray field, a curved septum is adopted, its average thickness is 4.5 mm while its thickness at the exit of the magnet is 1.4mm. To reduce the stray field further, a section of iron tube will be used as the vacuum chamber for storage ring near the septum magnets, which is coated with nickel on the inside surface.

1 INTRODUCTION

The SSRF consists of 300 MeV linac, synchrotron and 3.5 GeV storage ring. The SSRF synchrotron is required to accept the electron beam of 300 MeV from the linac, accelerate the beam energy up to 3.5 GeV and eject the electron beam to make stacking into the SSRF storage ring with the repetition rate of 1 Hz. One eddy-current septum magnet and one kicker magnet will be used for the synchrotron injection, three septum magnets (one eddy-current type and two DC type) and two kicker magnets will be used to eject the beam from the synchrotron, and two septum magnets (one eddy-current type and one DC type) and four bump magnets will be used to make stacking into the storage ring. At the R&D stage, one eddy-current septum magnet prototype and one bump magnet prototype for SSRF storage ring injection were developed. In this paper, the design, the construction process and the experimental results of the eddy-current septum magnet are reported

2 DESIGN

The design requirements of the eddy-current septum magnet used for injection of the SSRF storage ring are listed in table 1.

Table 1: Design requirements

Deflection angle	31 mrad
Aperture (H × V)	26×15 mm^2
Magnetic length	0.6 m
Septum thickness	2.5 mm（at exit）
Uniformity	±1%
Stability	±0.2%
Stray field	0.2%
Waveform	Halfsine
Pulse width	60μs
Repetition rate	1 Hz

The theoretical analysis shows[1] that the maximum of stray field on the outside surface of the septum is

$$B_m = \frac{2\sqrt{2}\tau}{\sqrt{\pi e}\lambda_c d\sigma\mu_0} B_0 ,$$

where B_0 is the amplitude of the main field, τ is the pulse width of excited current, λ_c is the characteristic length of stray field decay outside of the septum, d is the average thickness of the septum, σ and μ_0 are electric conductivity and magnetic permeability of the septum material respectively. One can see that the maximum of stray field is proportional to the excited current pulse width, is inversely proportional to the thickness of septum and is also inversely proportional to the conductivity of the septum material. So when the eddy-current septum magnet of SSRF is designed, the following measures are firstly taken to reduce the stray field.

1) the narrow width of 60μs half sine pulse is chosen as the exciting current pulse.
2) the copper of oxide free, which has high conductivity, is used to make the septum.
3) a curve-shaped septum, which makes the average thickness of the septum to be 4.5 mm while the thickness at the exit of the septum magnet is only 1.4 mm, is adopted.

In order to reduce the stray field further, a section of iron tube coated with nickel on the inside surface will be used as vacuum chamber of the storage ring near the septum magnets. The iron tube has high magnetic permeability, which can shield the stray field greatly. The nickel coating can improve the vacuum performance of the tube[2].

The simulation results[1] of OPERA-2D show that the stray field in front of the septum is much less than 0.2% at any position and at any time. The OPERA-3D simulated field configuration of one quadrant of the septum magnet is shown in fig. 1. It can be calculated that the effective magnetic length of the septum is 617 mm.

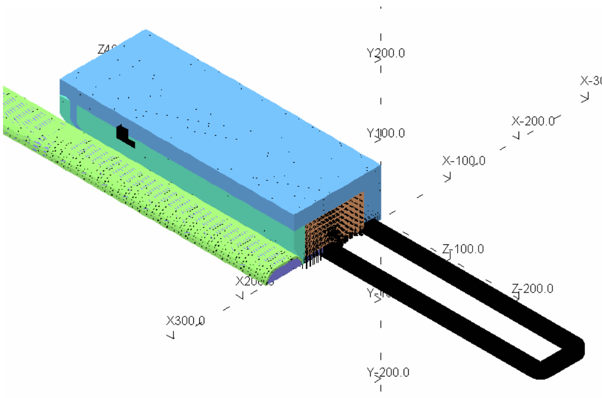

Fig. 1 The OPERA-3D simulated field configuration

3 CONSTRUCTION

Since the eddy-current septum magnet is a kind of fast pulsed magnet, two issues need to be considered carefully. The first one is the eddy current loses in the core. In order to reduce the losses, the core of the SSRF septum is made of 0.15 mm thick laminations stamped from WTG150 silicon steel with C-5 surface insulation coating. The C-5 is a kind of semi-organic material, which has good electric insulation properties and low outgassing properties in vacuum. Secondly, the outgassing properties and the radiation resistance of the insulation material of the core and coil are crucial to the construction of the septum, because all of them will be put into the high vacuum and some of them will be bombed directly by lost electrons and synchrotron radiation photons. The coil, which is wound the return yoke, is made of the oxide free copper tube insulated with Kapton. The copper septum is electron-beam wielded with the surrounding stainless steel plates. The ceramic feedthroughs are used to conduct the coil out of the septum magnet. One picture of the prototype septum is shown in fig. 2.

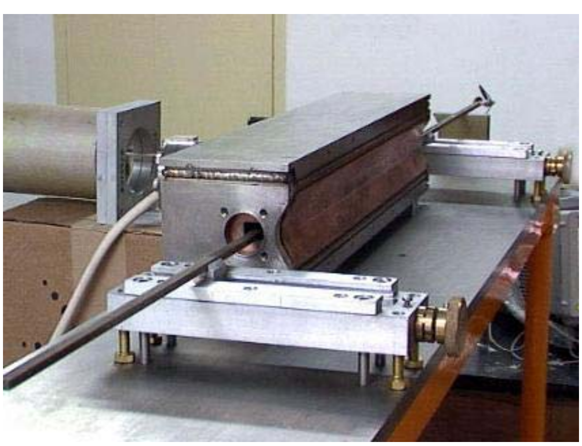

Fig. 2 The picture of the SSRF septum

4 MEASUREMENT

The waveforms of the main field and stray field are shown in fig. 3 and fig. 4

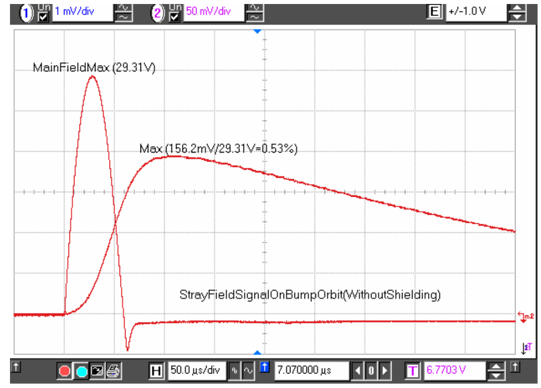

Fig. 3 The waveform of the stray field and main field

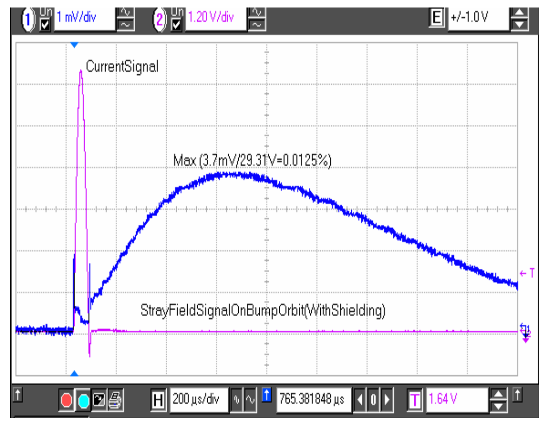

Fig.4 The stray field with the iron tube shielding

The maximum of the stray field on bump orbit without the iron tube is 0.53% of the peak of main field, and with the iron tube shielding, only 0.013% of the peak of main field. The stray field distribution in front of the septum is shown in fig. 5,

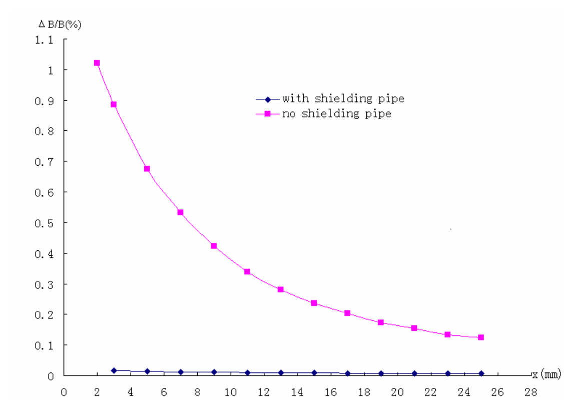

Fig. 5 The stray field in front of the septum

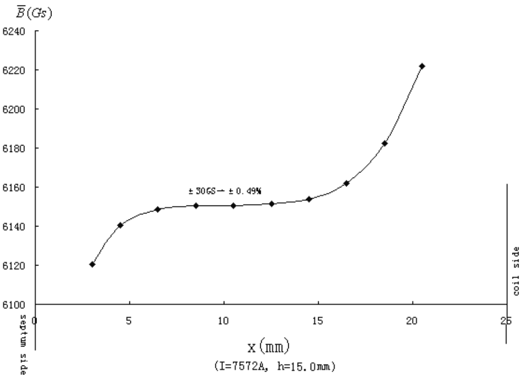

Fig. 6 The distribution curve of the main field

one can see that the stray field in front of the septum is greatly decreased by the iron tube, it is reduced down to 0.1% at any position.

The main field distribution in the gap is shown in fig. 6, the uniformity of the main field in the range from 3.5 mm to 18.5 mm is about±0.5%. By measuring the longitudinal distribution of the main field, one can get that the effective magnetic length is 615 mm. The stability of the peak of the main field is better than ±0.1% within 30 minutes.

The vacuum performance of the septum magnet is also good, after three times baking, the vacuum inside the septum is up to 5.11×10^{-7} Torr.

6 CONCLUSION

The design and construction of the eddy-current septum magnet for storage ring of SSRF is completed successively. All measured specifications of the magnet are well satisfied with the design requirements. The stray field on bump orbit is much lower than 0.2% with the iron tube shielding.

REFERENCES

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