ELECTRON BEAM INJECTION SEPTUM

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Abstract

The SuperKEKB project [1] is in progress toward the initial physics run in the year 2018. It assumes the nano-beam scheme, in which the horizontal emittance of the colliding beams is $\varepsilon_x = 4.6$[nm]. The horizontal emittance of the injected beam is $\varepsilon_x = 1.46$[nm]. To achieve such a low emittance, it is vitally important to preserve the emittance during the transport of the beam from the linac [2] to the main ring (MR). One of the most difficult sections is the injection system. Because of the low emittance beam, the dynamic aperture is smaller than that for the KEKB injection. Furthermore, it has been pointed out that the injected beam has possibility of leading to blowup in the ring, which is caused by a beam-beam interaction with the stored positron beam. To get over these difficulties, the synchrotron injection [3–5] is adopted as a backup option. The optics study for electron injection and the R&D for the septum magnet had been reported in [6]. The production and operation of actual septum magnet for the electron injection are reported in this paper.

INTRODUCTION

In KEKB accelerator [7], the beam injection had been performed with the betatron injection scheme which inevitably induces betatron oscillation [8].

The SuperKEKB project contains an upgrade of the KEKB accelerator, thus the old KEKB systems will be reused for the SuperKEKB accelerator as many as possible. Regarding the injection system for the electron ring (HER) of SuperKEKB, only the half of injection septum magnets are totally reconstructed to be capable of the injection of very low emittance beam in the nano-beam scheme. Therefore, new septum prototype has been designed according to the study of the injection orbit [9].

Injection Parameters

Parameters listed in Table 1 are derived from the design orbits [6].

The allowed effective septum width $w_{\rm eff}$ is $w_{\rm eff} = 5.32$[mm] for the betatron injection and $w_{\rm eff} = 3.34$[mm] for the synchrotron injection. Therefore, $w_{\rm eff} < 3.34$[mm] is required; the septum magnet has to be reconstructed to be capable for the SuperKEKB injection system.

SEPTUM DESIGN FOR SUPERKEKB

The concept design is shown in Fig. 1. The effective width of the septum is 3.3 mm; it means the 1.7 mm reduction from the KEKB septum. The items of that reduction are that the septum conductor thickness is reduced from 1.5mm to 1.0mm, the 0.5 mm^t magnetic shield plates are reduced from two to one and instead the pipe for the stored beam consists of the magnetic material with the copper coating to the inner wall.

Table 1: The injection parameters are listed. The betatron and synchrotron injection parameters are in the center and right columns respectively.

Parameter	Betatron	Synchrotron
Kicker height	28.5 mm	28 mm
Slope angle	-1.88 mrad	-1.89 mrad
K_1 (QI4E)	0.1498	0.1437
Height at QI4E	29.5 mm	29 mm
$n_{\rm R}\sigma_{x\rm R}$	2.1 mm	3.49 mm
$n_{\rm I}\sigma_{x\rm R}$	0.374 mm	0.37 mm
Δx	7.8 mm	7.2 mm
$\Delta x'$	-0.62 mrad	-0.52 mrad
Allowed $w_{\rm eff}$	5.32 mm	3.34 mm

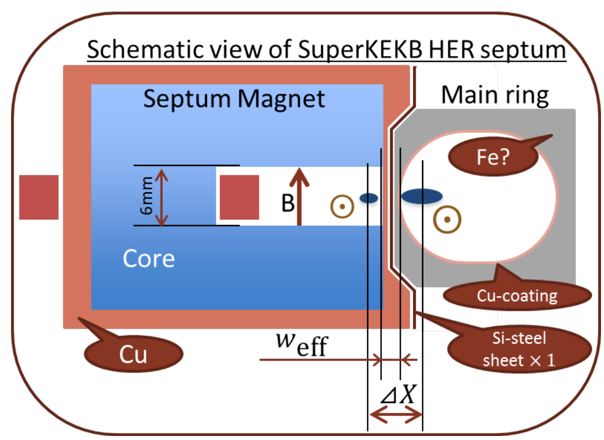

Figure 1: The concept design of the septum magnet.

The septum magnets for KEKB requires the long baking term for its difference of thermal conductivities for construction materials. It takes about one week to temperature going up to 150 °C. The SUS tightening bolt used to fix the lamination structure restricts the temperature rising rate. Therefore, the lamination structure is fixed with the welding in the new design (Fig. 2).

Four septum magnets are used to the electron injection for KEKB-MR and two of them on downstream side were reconstructed. Since the installation space for septum magnets is narrow, 2 septum magnets are put in one vacuum chamber as shown in Figure 3.

CONSTRUCTION OF SEPTUM MAGNETS

The septum magnets were successfully constructed and installed after the endurance tests of the 50Hz, 10-hour continuous operation were passed.

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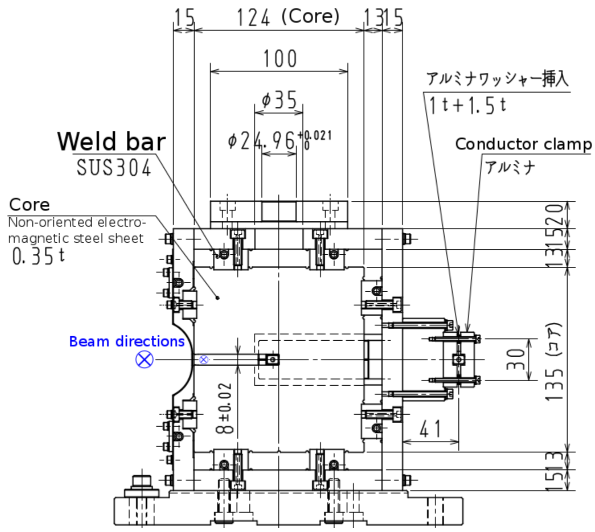

Figure 2: The cross section of the new design of the septum magnet. Every silicon steel plate is welded to all of the 8 weld bars.

Alignment of Septum Magnet

It is the most important that the distance between MR beam pipe and the septum conductor of SE1. Its final distance between the septum and the MR beam duct has been about 0.2-0.3 mm, where the specification is satisfied.

OPERATION IN PHASE 1

The electron beam injection into SuperKEKB-MR was started at Feb. 1, 2016. Once the stable injection was achieved, it had been kept until the end of Phase 1. The injection rate increased successfully with continuous fine adjustments (Fig. 4).

The septum temperature interlock has been triggered, because of the unknown noise effect.

It has been found that the logged temperature jumps up and down to ~ ±10°C (Fig. 5). This effect has been seen in the several channels for septum magnets which are not only new septum but also old KEKB septum magnets.

SUMMARY AND CONCLUSION

The electron injection septum magnets for SuperKEKB-MR has been constructed, installed and operated in Phase 1. The installed position satisfies the requirement. The stable electron injection has been achieved for Phase 1 optics. There has been the problem that the temperature jumps for the unknown noise. It will be investigated in Phase 2 operation.

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Figure 3: The top view of 2 septum magnets and the SuperKEKB main ring beam duct is shown. The beam passes from the left side to the right side. The right(left) side septum is named SE1(SE2).

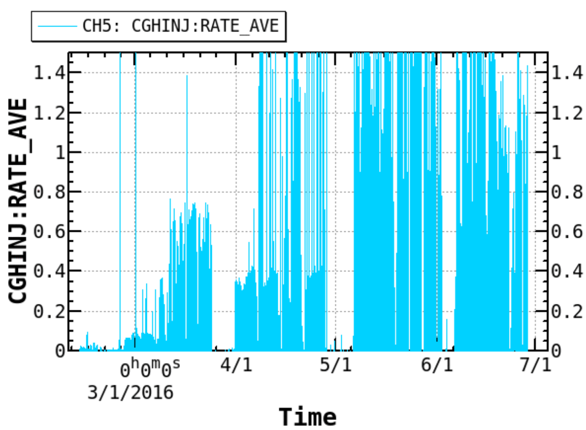

Figure 4: The electron beam injection rate is shown. It increased successfully with continuous fine adjustments.

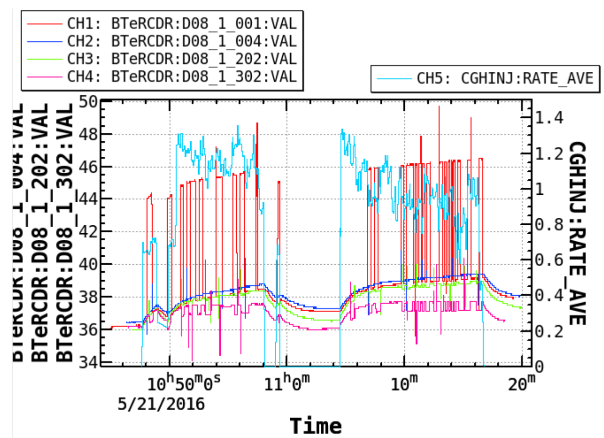

Figure 5: The temperature variations of septum conductors of SE1-4 and the injection rate are shown. Especially, the temperature of the septum conductor of SE1 is jump up or down about 10 °C. There is no correlation between the temperature and injection rate, except there is no jump without injection.

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