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DESIGN STUDY OF PULSED MULTIPOLE INJECTION FOR AICHI SR

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Abstract

We have planned to introduce a pulsed multipole injection scheme into the AichiSR storage ring and have decided the specifications of a pulsed multiple magnet and a power supply. We designed a magnet made of a rectangular shaped york with a sextupole–like field distribution. A designed power supply has the temporal responce of a full width of 960 ns. In the numerical calculation based on the designed system, it is confirmed that the pulsed multipole injection scheme could be applied to the AichiSR storage ring. The injection efficiency of about 90 % is expected.

INTRODUCTION

Since March of 2013 the user operation of the storage ring has been started with the top-up injection mode at the Aichi Synchrotron Radiation Center (AichSR), formerly called Central Japan Synchrotron Radiation Facility [1]. The key equipments of the facility are a compact electron storage ring with the ability to supply hard X-rays and full energy injectors for the top-up operation. Up to now, the stabilitiy of 0.2 % for the stored beam current was achieved, however, coherent oscillations of stored beams due to injection kickers are observed. In order to introduce the new injection scheme into AichiSR for suppressing the coherent oscillations, we have designed a pulsed multipole injection system. The system consists of the sextupole-like pulsed multipole magnet and sub micro-sec responce power supply. In the paper, we report the design of the magnet and power supply and the results of beam–tracking calculations.

PULSED MULTIPOLE INJECTION

The pulsed multipole injection scheme was developed and tested at KEK–PF and KEK–AR [2,3]. In this scheme, the injection beam is captured into the accelerator acceptance as a result of pulsed multipole kicks, and the stored beam passes through the center of the multipole magnet, where the field strength is almost zero. Thus, it would avoid to excite coherent oscillation of stored beams and realize high quality photon beams for SR users.

AICHI SR

Schematic image and main parameters of the AichiSR are shown in Fig. 1 and Table 1. The electron energy and the circumference of the storage ring are 1.2 GeV and 72 m, respectively. The natural emittance is 53 nm-rad. The configuration is based on four triple bend cells with twelve bending magnets. Eight of them are normal conducting magnets (normal bends) of 1.4 T and four of them are 5 T super conducting magnets (superbends), respectively. In addition, we

Table 1: Parameters of Accelerators

Storage ring	
Electron energy	1.2 GeV
Circumference	72 m
Current	>300 mA
Natural emittance	53 nm-rad
Betatron tune	(4.72, 3.23)
RF frequency	499.654 MHz
RF voltage	500 kV
RF bucket height	>0.990 %
Harmonics number	120
Energy spread	8.41×10^{-4}
Magnetic lattice	Triple Bend Cell × 4
Normal bend	1.4 T, 39°
Superbend	5 T, 12°
$(\beta_x, \beta_y, \eta_x)$ @superbend	(1.63, 3.99, 0.179)
$(\beta_x, \beta_y, \eta_x)$ @straight section	(30.0, 3.77, 1.20)
Booster synchrotron	
Electron energy	50 MeV – 1.2 GeV
Circumference	48 m
Current	>5 mA
Natural emittance	<250 nm-rad
RF frequency	499.654 MHz
Harmonics number	80
Injection scheme	On-axis (single turn)
Repetition rate	~1Hz
Injector linac	
Beam energy	50 MeV
Charge per pulse	>1 nC
Pulse length	1 ns
RF frequency	2,856 MHz
Repetition rate	~1Hz

have an undulator in straight sections for VUV experiments. The operation current of the storage ring is 300 mA and the injection rate is up to 1 Hz.

The injector system of Aichi SR consisted with a 50 MeV linac and an 1.2 GeV full energy booster. The single bunch injection scheme is employed and the electron beam can be injected into the arbitrary bucket of the storage ring.

For the beam injection, the "bumped injection scheme" is employed by using four pulsed dipole magnets, labeled as "Pulsed dipole" in Fig. 1. In Fig. 1, it is found that the bump orbit is about one half of the circumference. Moreover the precise closed bump orbit could not be realized due to multipole fields in the bump orbit. In actual, the coherent oscillation of stored beams was observed by turn-by-turn beam

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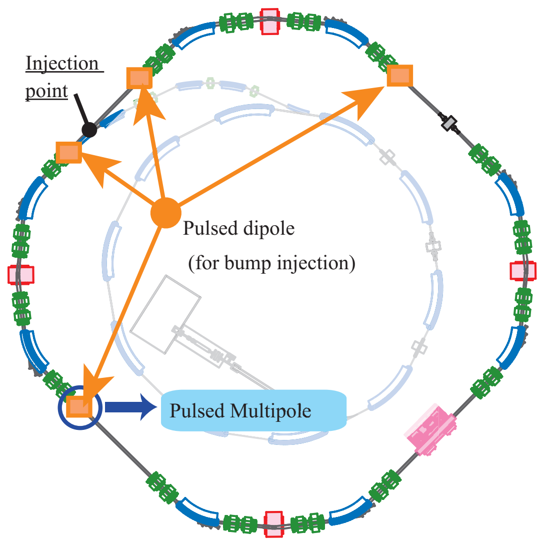

Figure 1: Schematic image of AichiSR storage ring.

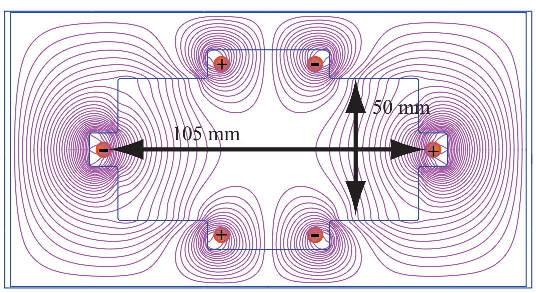

Figure 2: Cross-section of designed pulsed multipole magnet.

monitors [4] and the horizontal amplitude is evaluated to be 350μm, which correspnds one third of the beam size.

Based on the numerical calculation, we select the position about 13 m downstream from the injection point because it required the adequate kick angle for beam injection. The phase advance from the injection point to the location of the pulsed multipole magnet was about 67 degrees.

Table 2: Parameters of Multiple Magnet

Magnet	
Core length	200 mm
Vertical gap	50 mm
Horizontal gap	105 mm
Inductance	1.8 μH
Power supply	
Max. peak current	2.0 kA
Max. voltage	23 kV
Inductance	1.8 μH
Pulse duration	0.9 μs

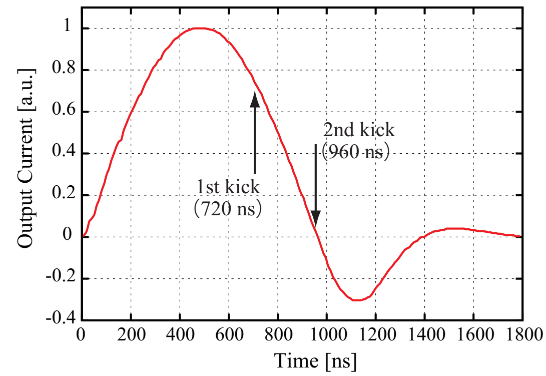

Figure 3: Temporal responce of designed pulsed multipole magnet and power supply.

PULSED MULTIPOLE MAGNET

Figure 2 shows the cross-section of the designed pulsed multipole magnet with field distribution calculated by Poisson cord [5] and the parameters are listed in Table. 2. The designed magnet consists of a rectangular shaped york and a single-turn coil. The geometry of the york were determined in consideration of shapes of the ceramic chamber with keeping a clearance of 2 mm. The core lenght is 200 mm, the vertical and horizontal gap is 50 and 105 mm, respectively. The position configuration of each coil–bar is detemined by using Poisson cord with reducing a residual field of the magnet center. In the calculation at the output current of 1.4 kA, the field strenght of 0.018 T, which corresponds to the kick angle of 1 mrad, is obtained at the first kick amplitude of −20 mm and the residual field in the range of ±1 mm from the magnet center is suppressed to be less than 0.07 mT. However keeping this performance for actual manufacrured magnet is too difficult, then we have considered to apply the field–compensation technique to premanufactured magnet [6].

Figure 3 shows the temporal responce of assumed pulsed multipole magnet and power supply. We assume a half-sine pulse shape with the temporal responce of 960 ns and a reflection current with 30 % the main peak. As a maximum load current required of 2.0 kA for the magnet is selected according to the numerical calcualtion result, the dischage voltage of greater than 23 kV is required considering the total electric inductance of 3.6 μH.

INJECTION CALCULATION

Figure 4 shows the calculated beam distribution in the single kick injection case (i.e., it is assumed no reflection current for the temporal responce of the magnet power supply). At the first turn, the injection beam has the horizontal amplitude of 20 mm and divergence of 1 mrad. The kick angle for the first turn beam is estimated to be about −1 mrad and the invariant quantity becomes reduced to the smaller than the accelerator acceptance. Then most of beams can be captured and the injection efficiency of 89 % is expected.

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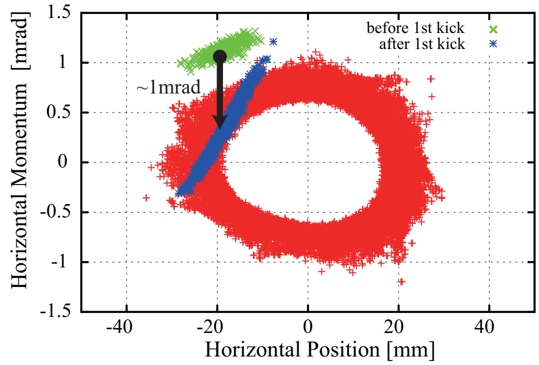

Figure 4: Calculated beam distribution in single kick injection case.

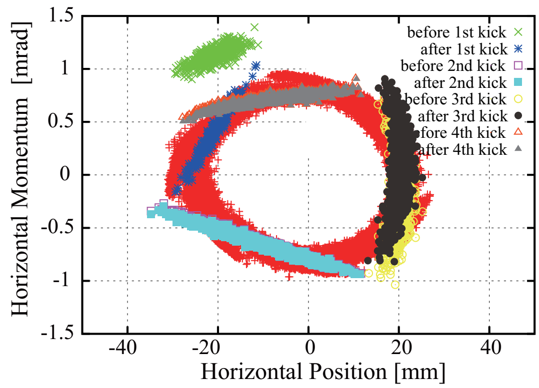

Figure 5: Calculated beam distribution in multi kick injection case.

Figure 5 shows the calculated beam distribution in the multi kick injection case (i.e., it is assumed 30 % reflection of the magnet power supply exists). Although the injection beam experience over four kicks, only first and third kicks works effectively because the kicks of second and third timing is estimated to be relative small. In the ideal case, the reduced invariance is slight smaller than that of the single kick injection case and the injection efficiency of 91 % is expected.

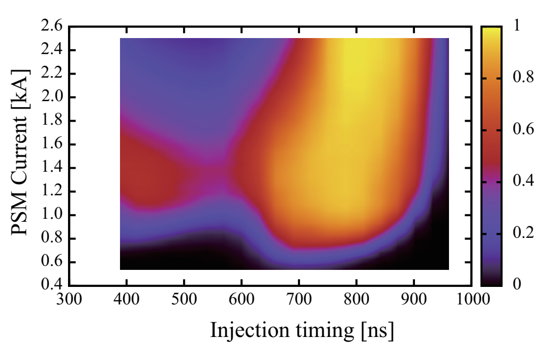

Figure 6: Estimated injection efficiency as functions of the injection timing and the load current in multi kick injection case.

Estimated injection efficiency as functions of the injection timing and the load current in multi kick injection case is shown in Fig. 6. It is found that when the load current is greater than 1.0 kA and the injection timing is selected after 700 ns, sufficient injection efficiencies could be expected. The maximum injection efficiency is obtained with the load current of 1.4 kA and the injection timing of 720 ns, which correspond the case of Fig. 5.

CONCLUSION

In order to apply the pulsed multipole injection scheme to AichiSR, a pulsed multipole magnet and power supply have been designed. As a result of the calculation in the ideal case, it is numerically comfirmed that the injection scheme could be sufficiently introduced with high injection efficiencies. To realize these results in the actual machines, further investigations on the varius operation parameters of the storage ring should be done.

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