PA46

Correcting Slanted Beam Profiles in Superconducting Storage Rings.

Koji YAMADA, Masayuki NAKAJIMA, and Teruo HOSOKAWA
LSI Laboratories, Nippon Telegraph and Telephone Corporation (NTT)
3-1 Morinosato-Wakamiya, Atsugi, 243-01 Japan

Abstract

In the Super-ALIS superconducting storage ring for synchrotron radiation, the electron beams have been suffering from slanted profiles. These profiles degrade the uniformity of exposure in X-ray lithography. The most possible reason for this slanting problem is x-y coupling originating from the combination of the sextupole components and the vertical closed orbit distortion (COD) in the superconducting bending magnets. In this work, we present the results of correcting profiles in the Super-ALIS by reducing COD and canceling out the sextupole components.

1. Introduction

Compact storage rings for synchrotron radiation (SR) have recently been developed[1,2]. The magnetic fields in superconducting bending magnets for these machines generally have a large amount of sextupole components. In these sextupole fields, vertical closed orbit distortion (COD) creates skew-quadrupole components whose strength is where is the strength of the sextupole kick and is the vertical COD. Such localized skew-quadrupole components make the principal plane of the betatron oscillations slanted to the ordinary (x,y) axes[3]. This means that the beam profiles become slanted. Especially in the condition close to the difference resonance, this problem becomes serious.

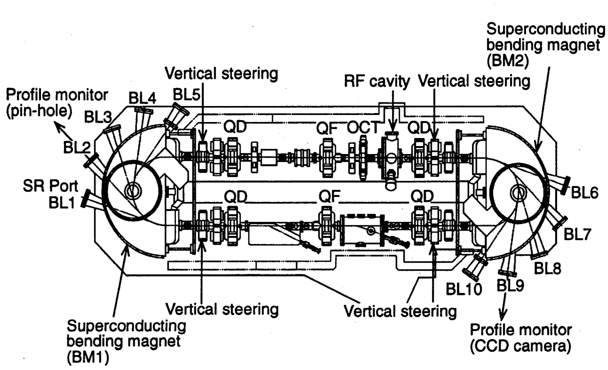


Fig. 1. The superconducting storage ring Super-ALIS.

Such slanted beam profiles are undesirable for experiments using SR. In X-ray lithography beamlines that generally adopt toroidal mirrors, the asymmetry of the beam profiles are much emphasized on the exposure plane and the uniformity of exposure is therefore seriously degraded. In beamlines using monochromators, the intensity is decreased because the slit of the monochromator must be narrow for fine resolution.

Especially in the Super-ALIS superconducting storage ring[4], the slanting of beam profiles is serious because the operation point of the machine must be set close to the difference resonance to increase the beam lifetime. In this work, we present the methods and results of correcting these distorted profiles in Super-ALIS.

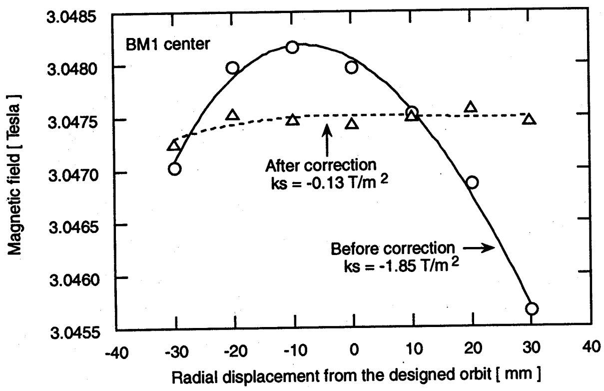
2. Sextupole components of Super-ALIS

Super-ALIS is a compact storage ring for SR as shown in Fig. 1. The machine parameters are shown in Table 1. This machine has two superconducting 180-degree bending magnets; BM1 and BM2. The magnets have a maximum magnetic field of 3 tesla. The uniformity of the field is not much better than that of normal conducting magnets. Therefore, these magnets have cancellation coils for multipole components.

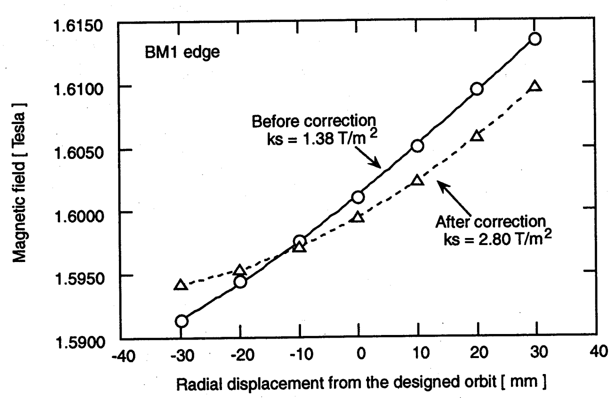
The measured magnetic field at the center of BM1 excited to 3 tesla is shown in Fig. 2(a). The solid line is the field produced without employing cancellation coils. The solid line in Fig. 3 shows the sextupole components along the orbit in BM1. The sextupole component in the magnet is about -1.8 T/m except for the edges. At the edges, the

Table 1. Super-ALIS machine parameters.

Max. energy	600 MeV
Max. bending Field	3.0 T
RF frequency	124.855 MHz
Peak RF voltage	45.0 kV
Betatron tune, horizontal	~1.59
vertical	~0.59
Synchrotron tune	~0.003
Natural emittance	9.35×10^{-7} π m rad
Circumference	16.8 m



(a)



(b)

Fig. 2. Radial distribution of the magnetic field on the median plane in BM1. (a) at the center and (b) at the entrance edge.

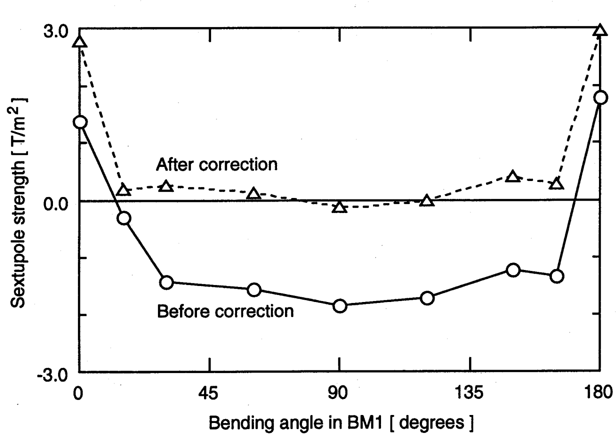


Fig. 3. Sextupole components of BM1 along the designed central orbit.

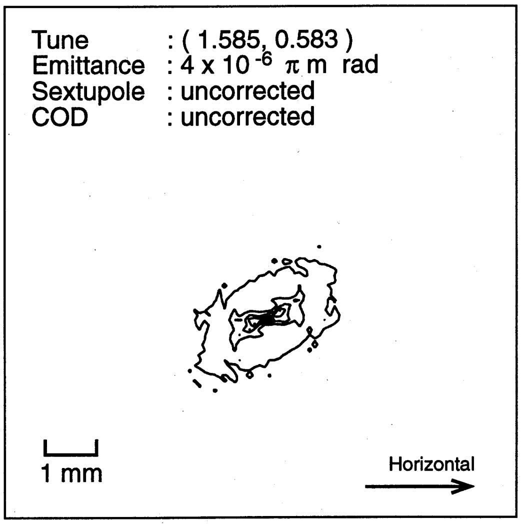


Fig. 4. Simulated beam profile at the 135-degree position in BM1. The betatron tunes are (1.585,0.583) and the CODs are assumed to be -1 mm in BM1 and +1 mm in BM2. The initial horizontal emittance is 4×10^{-6} π m rad.

field distribution is quite different as shown in Fig. 2(b). The effect of these sextupole components on the beam profiles is very serious. As shown in Fig. 4, beam tracking simulations including the sextupole components with the corresponding COD show that even 1-mm vertical COD is critical.

By using cancellation coils, the sextupole components can be reduced to one tenth (except for the edges) as shown by dotted lines in Figs. 2 and 3. At the edges, however, the sextupole components become large even if the cancellation coils are used.

3. Correction of the beam profiles

Before profile correction the sextupole components were present and the vertical COD was large as represented by the solid line in Fig. 5. The beam profiles in this condition are slanted as shown in Fig. 6. The profile was observed from BL9 SR port in BM2. The SR light extracted from the port was telescoped and monitored by a CCD camera.

To cure the slanted profiles, two methods can be proposed; reducing vertical COD and canceling the sextupole components by cancellation coils. In practical reducing COD seems to be easier than canceling sextupole components. However, we must take into account the high sensitivity of COD to profile slanting

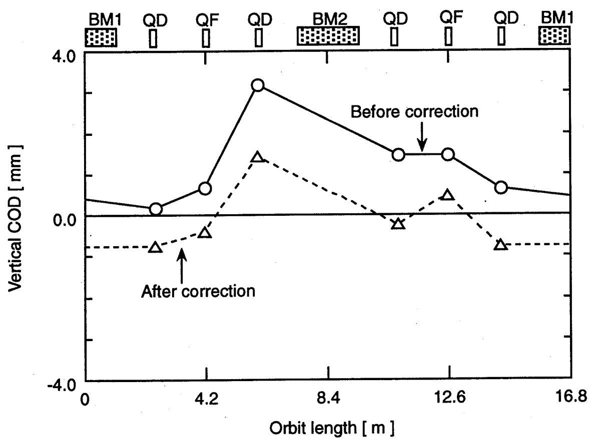


Fig. 5. Vertical CODs in the experiments for profile correction.

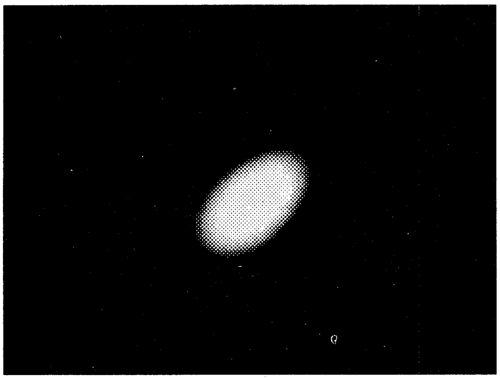


Fig. 6. Beam profiles before correction.

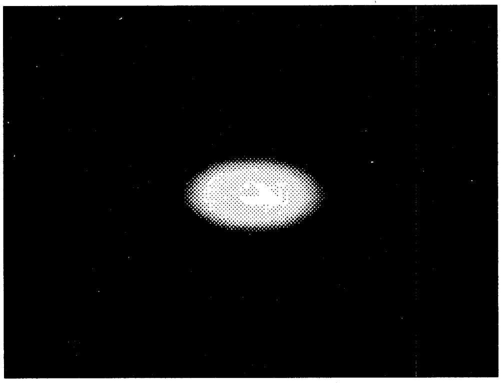


Fig. 7. Beam profiles with canceled sextupole components and reduced COD.

as described in Section 2. If the sextupole components are not reduced, COD must be reduced with 0.1-mm precision. However, such a high sensitivity is not preferable for stable operation of storage rings. Moreover, such precise COD reduction might be technically difficult especially in superconducting bending magnets. This is mainly because the median plane of the magnetic field, which is mainly determined by the shape and position of the coils as well as the yoke geometry, may be slightly displaced from the geometrical median of the iron yoke. The restricted number of steerings also makes precisely reducing COD difficult.

To correct the beam profiles, therefore, we first reduced the vertical COD as small as possible and then canceled the sextupole components. The vertical COD was reduced as shown by the dotted line in Fig. 5. The resulting beam profiles are shown in Fig. 7. The slant angle of the beam profiles was completely corrected and the intensity distribution on the exposure plane of the X-ray lithography beamline was greatly improved.

4. Summary

We can draw the following conclusions about slanting beam profiles in superconducting SR rings.

1) The vertical COD in the large sextupole component of a superconducting bending magnet generates large x-y coupling. This coupling seriously distorts beam profiles.
2) Theoretically, this problem can be corrected by either reducing vertical COD or the sextupole components.
3) In a real machine, however, using both methods makes it easier to correct the profiles and to ensure stable operation of the machines.

References

[1] T. Takayama and SHI Accelerator Research Group, Rev. Sci. Instrum. vol. 60 (1989) p.1786.
[2] A. R. Jordan, R. J. Anderson, R. C. Lobel, A. S. Bhutta and D. E. Andrews, Proc. of 1989 Intern. Symp. on MicroProcess Conference (1989) p.104.
[3] S. Peggs, IEEE Trans. Nucl. Sci., vol. NS-30 (1983) p.2460.
[4] T. Hosokawa, T. Kitayama, T. Hayasaka, S. Ido, Y. Uno, A. Shibayama, J. Nakata, K. Nishimura and M. Nakajima, Rev. Sci. Instrum., vol. 60 (1989) p.1783.