EFFECTS OF INSERTION DEVICES IN THE HIGH FIELD ILSF STORAGE RING*

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Abstract

Effects of an insertion device in a ring are usually divided in two parts. The first effect is related to the magnetic field of the ID and the second one is due to the radiation from the ID which has been separately investigated in this article. We have studied the effects of different planner insertion devices in the ILSF ring and discussed with detail the changes of beam parameters in the presence of super conducting wiggle magnet in medium straight section of ring where the optical functions have the lowest values. The compensation of beta beating has been also done by fine adjustment of the nearest quadrupole magnets to the ID.

INTRODUCTION

The radiation coming from a dipole magnet of a storage ring is very useful for a broad range of applications, but the insertion devices(IDs) are indispensable part of a modern 3rd generation synchrotron light source. They are used for the special experiments which need hard x-rays, monochromatic radiation of higher brightness, elliptically polarized radiation, etc.

Table 1: Main parameters of primary insertion devices of ILSF

	IVU-21	W80	SC-W31
λ(mm)	21.6	80	31
N period	92	12	60
L (m)	2.1	1	1.9
B_y (T)	0.79	1.73	2.10
Gap(mm)	5.7	12.5	12.4
K (T.cm)	1.60	12.98	6.30
Type	Planar/Pure	Planar/Hybrid	Planar / Superconductive

There are two major effects due to the perturbation of the electron beam by IDs in a ring. The first is the shift of the tune due to the magnetic field of the IDs, which results in beta beating and a smaller dynamic aperture. The second is the change in emittance and energy spread of the electron beam due to the energy radiated from the IDs. In this article we evaluate analytically the effects of the IDs in the ILSF storage ring and compare it with the simulation results. The primary ILSF beamlines will be based on conventional parameters of planar IDs whose poles are parallel and produce a sinusoidal magnetic field [1]. As listed in Table 1, these devices with very similar parameters are widely used in synchrotron radiation facilities around the world.

BETA BEATING AND TUNE SHIFT

The quadrupole effects associated with an insertion device cause tune shift and beta beating [2]. Different values of the optical functions in the straight sections of the ILSF lead to different effects of the IDs on the beam parameters. Due to lower values of the optical functions, they will have no significant effect in medium straight sections in comparison with long and short straight sections [2]. Since the superconducting wiggler magnet (SCW-31) has the highest value of magnetic field, we expect the strongest effects on the beam parameters. In the following we study the effects of high field SCW-31 with the length of 1.9 m and maximum field of 2.1 T (see Table 1). We have assumed that the SCW-31 is placed in one of the medium straight sections of ILSF lattice. In the presence of SCW-31, only changes in vertical beta function were observed while horizontal beta function did not change any more. The distorted beta function in the presence of SCW-31 is calculated with BETA [3] code and depicted in figure 1. The effects of IDs on transverse tune have been summarized in Table 2.

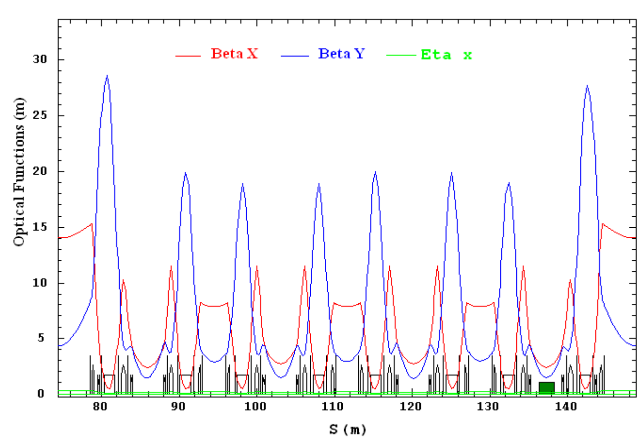

Figure 1: Optical functions in one super period of the ILSF storage ring. The SCW-31 is specified with a green box in a medium straight section.

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Table 2: The effect of IDs on vertical tune

	Q_x/Q_y	ΔQ_y(BETA)	ΔQ_y(Theory)
Without ID	18.265/11.328	0	0
SC-W31	18.265/11.333	5.4E-3	5.8E-3
W80	18.265/11.330	1.8E-3	1.8E-3
IVU-21	18.265/11.329	8E-4	9.5E-4

As given, the analytic calculation results are in agreement with simulation results of BETA [3] code. The distorted optical functions are compensated by four quadrupoles adjacent to the ID while the regular quadrupoles adjust the tune to its nominal value. The strengths of the quadrupoles nearest to SCW-31 before and after beta correction are listed in Table 3. As calculated, the maximum relative verified gradient is less than 1.4 %. The calculated beta beating due to SCW-31 before and after correcting is shown in figure 2. It is obvious that the beta beating after correction is less than 1% in both horizontal and vertical directions except at location of the ID.

Table 3: Gradient of adjacent quadrupoles to SCW-31 before and after beta beating correction

	Original gradient (T/m)	Gradient with SCW31 (T/m)	Relative change (%)
QF2W	1.902	1.894	-0.42
QD2W	-1.716	-1.740	+1.39
QD3W	-2.110	-2.136	+1.23
QF3W	2.000	1.994	-0.30

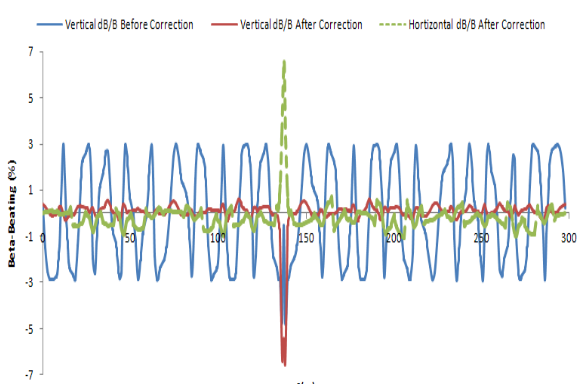

Figure 2: Beta beating ($\Delta\beta/\beta$) along the ring with one SCW-31 in medium straight section before and after correction. The picked point represents beta beating in SCW-31.

DYNAMIC APERTURE REDUCTION

In addition to the focusing effects, the IDs shrink the dynamic aperture. The other source of dynamic aperture shrinkage is the perturbed symmetry of the lattice due to the low value of the beta function in the medium straight sections [4,5]. Figure 3 shows the effect of SCW-31 on the dynamic aperture for on momentum electrons before and after correction.

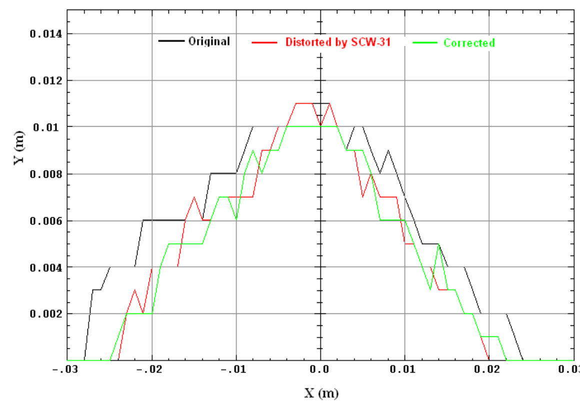

Figure 3: Dynamic aperture at the center of long straight section of ILSF ring with/without SCW-31.

It should be pointed out that study of dynamic aperture for off momentum particles showed a significant reduction of dynamic aperture in particular for -3% energy deviations which was not seen in bare lattice. This is shown in figure 4. This effect is again caused by the symmetry breaking of the sextupoles [6]. Three resonance islands (figure 5) appear in the phase space of particles with -3% energy deviations while they do not appear in the bare lattice. To clarify this effect, the working tune point of the machine in the presence of ID is plotted in figure 6 which indicates that the tune point for -3% energy deviation is near the third dangerous resonance $3Q_x$=18.33.

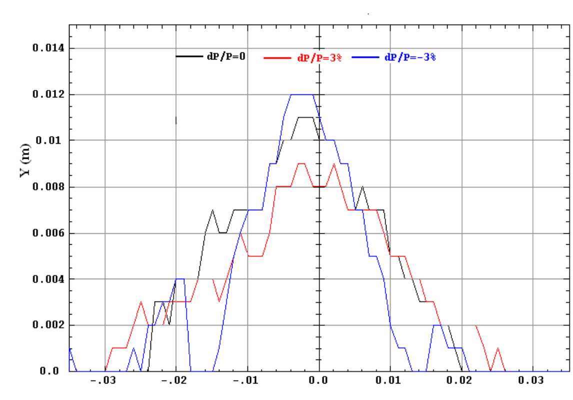

Figure 4: Dynamic aperture with SCW-31. The on/off momentum particles have been tracked 3000 turns through the ring.

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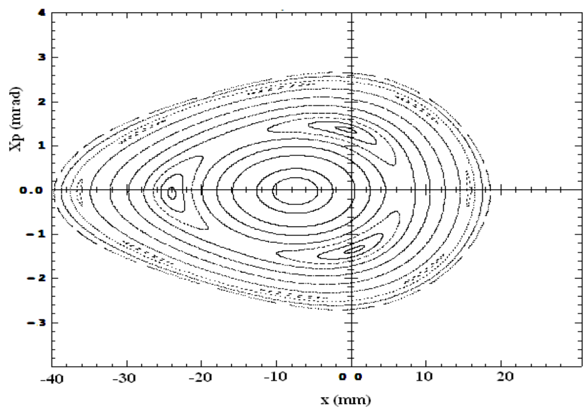

Figure 5: Horizontal phase space for a particle with -3% energy deviations. The SCW-31 is included in the ring.

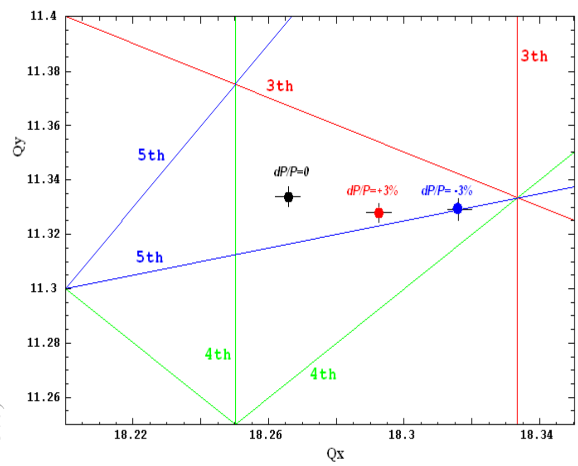

Figure 6: Working point of ILSF lattice with SCW-31 for on/off momentum.

A possible cure could be either in small modifications of tune or in fine optimization of the sextupole magnets.

EFFECTS OF RADIATION FROM IDS

The other major effect of the IDs is the change in emittance and energy spread due to radiation. The changes in energy spread, emittance and energy loss per turn for different planar IDs in ILSF ring obtained from OPA [7] simulations are listed in the Table 4.

Table 4: The effect of IDs placed in a medium straight section of the ILSF ring on energy spread, energy loss per turn and emittance

	Energy spread ($\times 10^{-3}$)	Energy loss (KeV)	Emittance (nm.rad)
Without ID	1.041	1016.7	3.278
SC-W31	1.043	1063.9	3.701
W80	1.040	1031.3	3.381
IVU-21	1.038	1024.2	3.293

CONCLUSION

The effects of the commonly used IDs have been studied. The most sever effects are related to the high field superconducting wiggler magnet at the medium straight section of the ILSF ring. In the presence of SCW-31, the optical functions have been cured by fine tuning of the nearest quadrupoles to it and the residual beta beating is kept less than 1% in both horizontal and vertical directions except at location of the ID. No huge variation of the ring parameters due to the radiated x-ray from IDs is found. More study with the IDs measured field map could be recommended.

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