COMPACT SYNCHROTRON RADIATION SOURCE 'AURORA-2' WITH 2.7T NORMAL CONDUCTING BENDING MAGNETS

Takeshi Takayama, Hiroshi Tsutsui and Toshitada Hori

Laboratory for Quantum Equipment Technology, Sumitomo Heavy Industries, Ltd.
2-1-1, Yato-Cho, Tanashi-City, Tokyo 188, Japan

Abstract

A 2.7 T normal conducting bending magnet with a pole gap of 42 mm and a magnetic induction of 160000 AT was successfully developed so we can design a compact synchrotron radiation source which has the performance comparable to the source using superconducting magnets, but is less expensive than it. The source is a racetrack type electron storage ring in which the electron-beam is injected at 150 MeV, accelerated up to 700 MeV and stored. Two types of this synchrotron radiation source have been designed, which are named 'AURORA-2S' for the industrial application such as X-ray lithography and 'AURORA-2D' for scientific researches. 'AURORA-2D' has two relatively long straight sections so that two insertion devices, in particular, superconducting wigglers can be settled. Perturbations of an usual undulator on the electron orbit are not so large, but those of the superconducting wiggler are so large that we need special cares for the operation of 'AURORA-2D'. Working point in the necktie diagram and the distortion of beta-function are discussed.

1 INTRODUCTION

Recently, normal conducting high field magnet was applied to medical cyclotron[1] and the manufacturing cost and process were greatly reduced compared to superconducting cyclotron. This technique is also quite effective for the design of a compact synchrotron radiation source for the industrial application. The higher the field of the bending magnet in an electron storage ring, the shorter the critical wavelength of the synchrotron radiation and the more compact the storage ring. We developed 2.7 T normal conducting bending magnet. Using this magnet, 700 MeV racetrack-type electron storage ring, 'AURORA-2S', was designed for the X-ray lithography. But for scientific applications, higher photon flux density of more than 10^{15} photon/sec mrad^2 0.1%b.w. and/or higher photon energy than those from the bending magnet is desired. 'AURORA-2D', a sister version of 'AURORA-2S', was designed to have two straight sections so that the insertion device such as an undulator or a superconducting wiggler can be settled[2]. A high field superconducting wiggler, however, has a large vertical focusing force in our low energy storage ring and we must consider its effect in the design of ring as a lattice element. In this paper, the effect of superconducting wiggler on the necktie diagram and the distortion of beta-function are described.

2 LATTICE WITH SUPERCONDUCTING WIGGLER

'AURORA-2D' has four horizontally focusing quadrupoles (QF) and four horizontally defocusing quadrupoles (QD) as shown in figure 1. The superconducting wiggler (SW) settled at the center of straight section has spectrum of synchrotron radiation as shown in figure 2. By a 7 T wiggler, photons of energy up to 10 keV are generated.

The effect of SW was studied at the two field strength, i.e. 5 T and 7 T. The necktie diagrams were drawn by changing the field gradient of QF and QD. In figure 3, the necktie diagram without insertion devices is shown. In figures 4 to 7, necktie diagrams with a single 5 T SW, a single 7 T SW, a pair of 5 T SW and a pair of 7 T SW are shown respectively. Without insertion devices, there are four stable islands. By introducing a single SW, the symmetry of superperiod 2 is broken and six stable but smaller islands appear. Inspecting these necktie diagrams, we selected the working point of QF and QD. From no SW to a single 5 T SW, field gradients kf of QF and kd of QD were selected to be kf = 10.2 T/m and kd = -10.0 T/m. For a single 7 T SW, a pair of 5 T SW and a pair of 7 T SW, the field gradients were selected to be kf = 11.1 T/m and kd = -12.5 T/m. For these working point, betatron amplitude functions were calculated and given in figure 8 and figure 9. The distortion of vertical betatron amplitude functions are within the permissible range.

When a single 5 T SW is used, beam is injected at 150 MeV without the excitation of the SW. After injection and accelerated up to 700 MeV, the SW will be excited to 5 T. But, when the SW has more than 5 T, we must excite the SW to the field strength proportional to the beam energy. For example, if we use a 7 T SW at beam energy 700 MeV, the SW must be excited to 1.5 T at the beam injection and, in the acceleration process, the field strength of the SW must be adjusted to the value proportional to the beam energy.

Ring parameters are shown in table 1. The emittance increases when the SW is installed because the dispersion function is not small at the SW in our ring.

3 CONCLUSION

Sumitomo Heavy Industries is now developing a 700 MeV compact SR ring ‘AURORA-2’ using 2.7 T normal conducting bending magnets. It is possible to generate photons of energy more than 10 keV by installing a superconducting high field wiggler.

REFERENCES

[1] W. Beeckman, Y. Jongen, A.Laisné and G. Lannoye, Nucl. Instr. and Meth. B56/57 (1991) pp. 1201-1204.

[2] T. Hori and T. Takayama, ‘”AURORA2” Compact Advanced SR Ring as an X-ray Source’, submitted to ICSRS-AFSR’95(Oct.25-27,1995:Pohang, Korea)

Table 1 Parameters of AURORA-2D storage rings with/without wiggler(s).

PARAMETERS OF SR RING	A2D		1W5T	2W5T	1W7T	2W7T
BEAM ENERGY(GeV)	0.15	0.7	0.7	0.7	0.7	0.7
CIRCUMFERENCE(m)	21.946	21.946	21.946	21.946	21.946	21.946
MAGNETIC RIGIDITY : Bρ(T*m)	0.5	2.335	2.335	2.335	2.335	2.335
RF VOLTAGE(kV)	20	220	220	220	220	220
HARMONIC NUMBER	14	14	14	14	14	14
RF FREQUENCY(MHz)	191.244	191.244	191.244	191.244	191.244	191.244
ENERGY APERTURE(MeV)	1.003	6.576	6.528	5.881	5.883	5.795
ENERGY LOSS(KeV/TURN)	0.051	24.423	26.404	28.385	28.313	32.204
SYNCHROTRON FREQUENCY(MHz)	1.80088	0.83106	0.83013	0.91346	0.91348	0.91148
MOMENTUM COMPACTION FACTOR	0.13471	0.13471	0.13455	0.16311	0.16311	0.16280
BETATRON TUNE						
HORIZONTAL	1.690	1.690	1.690	1.675	1.675	1.675
VERTICAL	1.703	1.703	1.791	2.097	2.097	2.168
EMITTANCE (π nm*rad)	*713.741	399.658	505.332	618.598	697.831	837.685
ENERGY SPREAD(MeV)	*0.074	0.433	0.439	0.434	0.449	0.469
RADIATION DAMPING TIME (msec)						
LONGITUDINAL	197.176	1.940	1.805	1.613	1.617	1.441
HORIZONTAL	509.428	5.013	4.566	4.741	4.751	4.020
VERTICAL	426.464	4.196	3.881	3.611	3.620	3.182
TOUSCHEK LIFETIME AT 1 AMPERE (hour)	*0.187	5.642	7.520	7.046	8.307	9.439
QUANTUM LIFETIME (hour)	>1E+32	> 1E+32	> 1E+32	1.59E+31	5.40E+28	4.31E+24
KF(T/m)	2.2	10.2	10.2	11.1	11.1	11.1
KD(T/m)	-2.1	-10.0	-10.0	-12.5	-12.5	-12.5

*result of ZAP calculation at 500mA

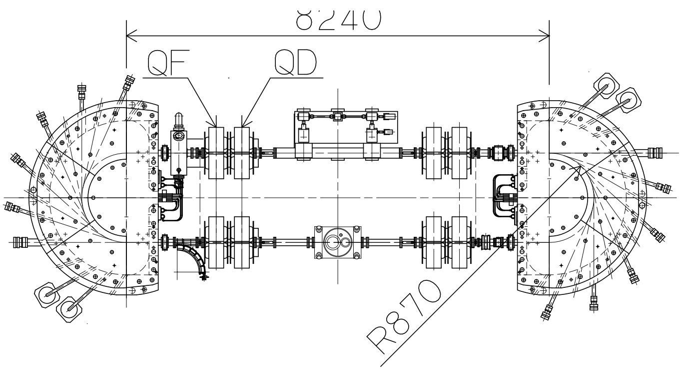

Figure 1. Top view of AURORA-2D.

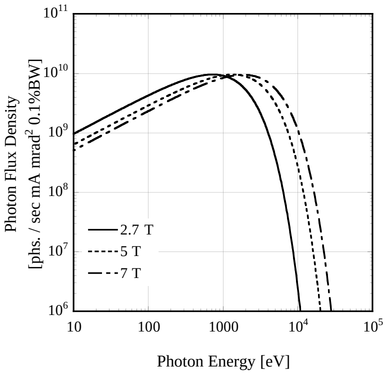

Figure 2. Spectrum from bending magnet, 5T wigglers and 7T wigglers.

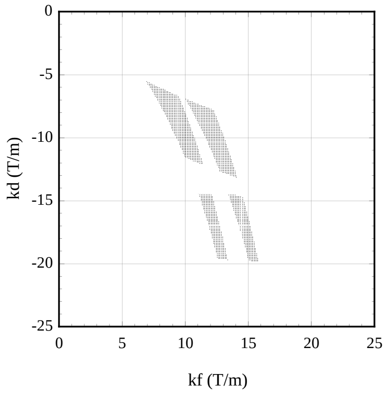

Figure 3. AURORA-2D no Insertion device. Working point is kf=10.2 T/m, kd= -10.0 T/m.

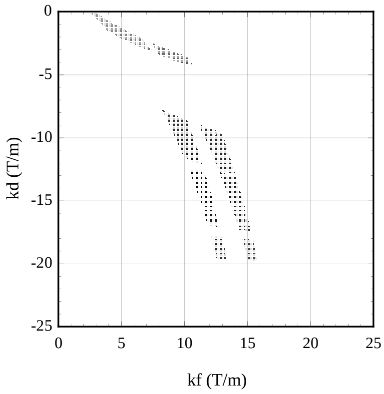

Figure 4. Single 5 T wiggler. Working point is kf=10.2 T/m, kd= -10.0 T/m.

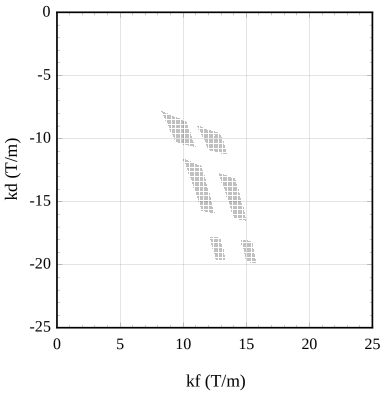

Figure 5. Single 7 T wiggler. Working point is kf=11.1, kd=-12.5 T/m.

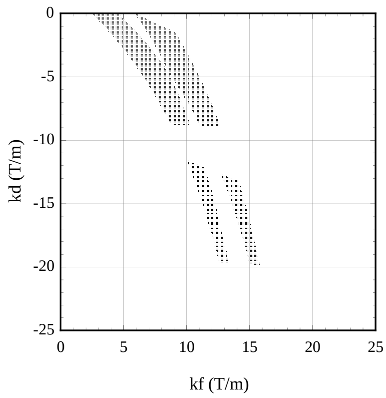

Figure 6. Double 5 T wiggler. Working point is kf=11.1, kd=-12.5 T/m.

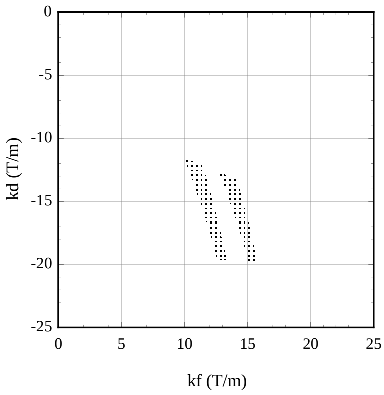

Figure 7. Double 7 T wiggler. Working point is kf=11.1, kd=-12.5 T/m.

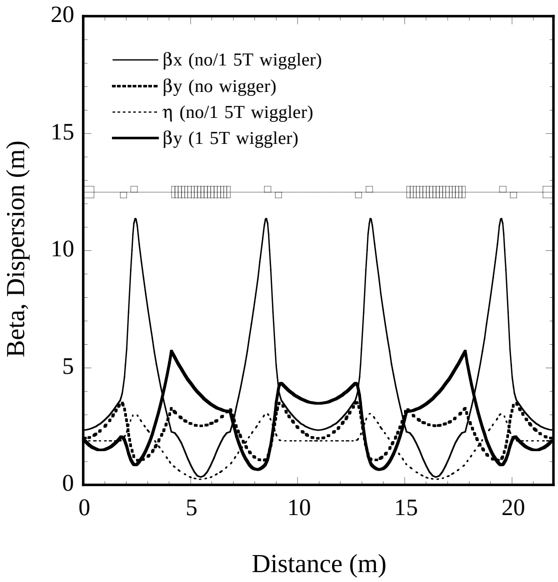

Figure 8. Lattice of no and single 5 T wiggler type.

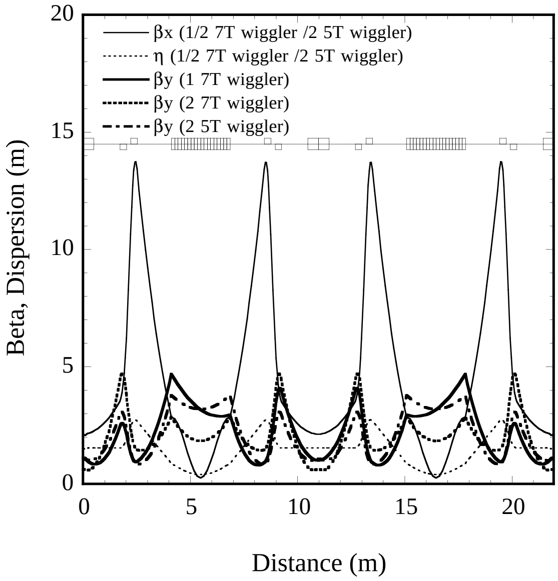

Figure 9. Lattice of single, double 7 T wigglers type and double 5 T wigglers type.