THE SAGA SYNCHROTRON LIGHT SOURCE IN 2003

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Abstract

The Saga third-generation synchrotron light source (Saga-LS) is being constructed and is operated before the fall of 2004 in Tosu, Saga Prefecture in the northern part of Kyushu-island. The Saga SLS consists of a 262-MeV electron linac injector and an eight-hold symmetry 1.4-GeV storage ring with eight double-bend (DB) cell and eight 2.93-m long straight sections. The DB cell structure with a distributed dispersion system was chosen to produce a compact design. The circumference is 75.6 m and the emittance is 15 nm･rad at 1.4 GeV. Six insertion devices including a 7.5-T wiggler can be installed. The critical energies of synchrotron light from the bending magnet and the 7.5-T wiggler are 1.9 keV and 9.8 keV, respectively. The 262-MeV linac beam is used for injection and a 40-MeV linac beam branched off from the first accelerator tube (AT-1) is used for two-color infrared (IR) free electron laser (FEL) generation. We are planning to supply high brilliant photon beams covering wavelength range from 34 keV to 0.063 eV by using the Saga 1.4-GeV storage ring with six insertion devices including the 7.5-T wiggler and the IR- FEL facility.

1 INTRODUCTION

The Saga-LS consists of the 262-MeV linac injector and the 1.4-GeV storage ring with eight DB cells and eight 2.93-m long straight sections. The DB cell structure with a distributed dispersion system was chosen to produce a compact design. The circumference is 75.6 m and the emittance is 15 nm･rad at 1.4 GeV. Six insertion devices including a 7.5-T wiggler can be installed. The 262-MeV linac beam is used for injection and a 40-MeV beam from the AT-1 is used for two-color IR-FEL generation. The Saga-LS project is operated by the Saga Prefectural Government.

The building has been constructed in fall of 2002 in Tosu, Saga Prefecture. Tosu is 25 km north-east of Saga and 25 km south of Fukuoka. The ring magnets, vacuum chambers made of aluminum alloy except for the long straight sections and four tempearature controlled cooling water systems for the linac accelerator tubes, the ring cavity, klystrons, magnets and wave guides are already ordered in 2002 and the other parts are ordered in 2003. The installation of the Saga SLS starts in fall of 2003. The commissioning will start in October 2004.

2 THE SAGA 1.4-GEV STORAGE RING

The layout of the Saga 1.4-GeV storage ring, the 262-MeV linac injector and the two-color IR-FEL facility [1] is shown in Figure 1. The C-shaped dipoles, symmetric closed yoke type quadrupoles and sextupoles are used. The symmetric closed yoke consists of an upper and a lower half bolted vertically with each other for setting their vacuum chambers. The C-shaped dipole cores are fabricated from A94068-100 steel laminations 1.0mm thick. The magnet cores of quadrupoles and sextupoles are from A94068-50 steel laminations 0.5mm thick. The laminations are compressed and glued with a packing factor no less than 97 %. The main coils are made of water-cooled hollow copper conductor insulated with fiberglass and vacuum impregnated with epoxy. Trim coils and power supplies for a 1~2% field adjustment are prepared for the dipoles and quadrupoles. Steering coils are built in sextupole magnets. The magnet control system is discussed elsewhere [2]. For magnet support and precise alignment, the spherical rod end bearings are used.

The lattice has been designed by relaxing the constraint of zero-dispersion in the long straight section as MAX-II [3]. For various dispersions, the rms electron beam sizes are calculated from the electron beam emittance ε_x, the horizontal and vertical beta functions, (β_x and β_y) and the relative momentum spread $\Delta p/p$, assuming 1 % coupling ratio in the vertical direction. The horizontal beam size is minimized for a dispersion $\eta_x = (\varepsilon_x\beta_x)^{1/2}/(\Delta p/p)$. The minimum value is close to $2^{1/2}\ \eta_x\ (\Delta p/p)$. The beam emittance is also minimized by distributing dispersion. Figure 2 shows the circumference of medium-scale storage rings and their emittances at a 1.4-GeV operation energy. The solid line shows the present lowest emittance of available medium-scale storage rings. It well demonstrates that the Saga storage ring is of compact and lowest-emittance type. Table 1 shows main parameters of the Saga ring magnets and stored beam.

Eight 2.93-m long straight sections are used for six insertion devices (IDs), a septum magnet, four kickers, various type beam monitors and an RF cavity. The available lengths for IDs are 2.5 m × 5 and 1.6 m × 1. In total, twenty beam ports are constructed and more than twenty beam lines can be installed. All vacuum chambers are made of aluminium alloy except for eight long straight

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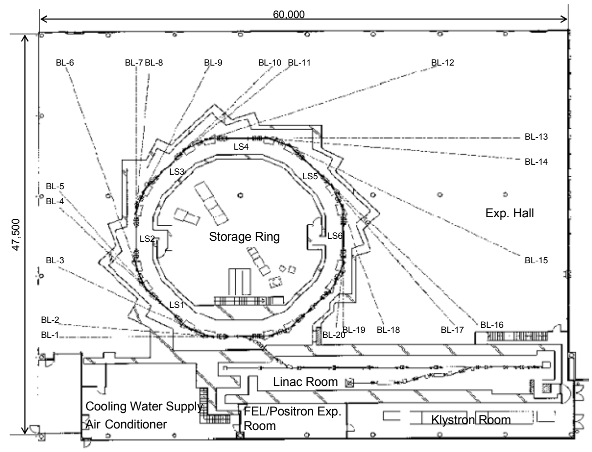

Figure 1: Layout of the 1.4-GeV Saga storage ring, the 262-MeV linac injector and the two-color IR-FEL facility.

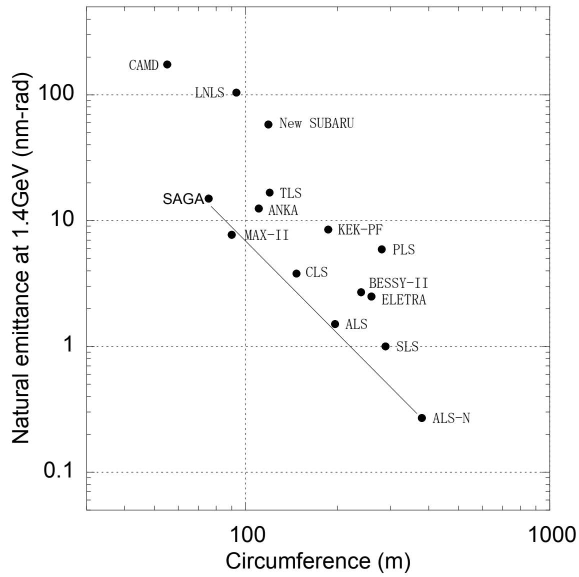

Figure 2: Circumferences of medium-scale storage rings and their emittances at 1.4 GeV.

sections. The chamber at the quadrupoles and sextupoles is 100 mm wide and 40 mm high because the damping time is of the order of 1 second due to the 262-MeV injection. The calculated dynamic aperture [4] for a stored beam is the same as the physical aperture of the vacuum chamber.

A 500-MHz RF damped cavity with SiC beam-duct [5] is used for stable storage of high-current beam and the expected RF voltage is 500 kV for a 90-kW RF power.

At the present, we are planning to install a 7.5-T superconducting wiggler, two permanent magnet undulators, and five beam lines for soft X-ray scanning and X-ray imaging microscopes [6], for XAFS [7] and crystallography.

The wiggler is to shift the synchrotron radiation spectrum to the hard X-ray region (ε_c = 9.8 keV) and a permanent magnet undulator (λ_u = 5 cm, K=1.2, N=49, photon energy 200 eV) provides high intensity photons of 4.8×10^{15} [photons/s・(0.1mrad)$^{-2}$ ・ (1%bw)$^{-1}$], since the rms irradiation angle of the undurator photons is 0.052 mrad.

The wiggler is three-pole planar type like the 5-T wiggler of Electrotechnical Laboratory TERAS Ring [8] and the 7-T wiggler of the Louisiana State University, Center of for Advanced Micro-structure and Devices [9]. Betatron-tune shift induced by the 7.5-T wiggler can be corrected by reducing the exciting current applied to QF1-QD1 doublets installed on each side of the wiggler to 95~85 %, at most, of the exciting current applied to the other QF1-QD1 doublets. The insertion effect of the 7.5-T wiggler for the beam parameters is also shown in Table 1 as key parenthesis.

Figure 3 shows the magnetic lattice of one full cell. The separation between the bending magnets is 1300 mm. Small magnets installed at the down stream of QF2 magnets are for steering. Vacuum chambers are also shown in Fig.3. Total pumping speeds of sputter ion pumps and titanium getter pumps are 8800-l/s and 48000-l/s, respectively.

Table 1. Main parameters of the Saga storage ring magnets and stored beam.

Electron beam energy	0.2~1.4 GeV	
Beam current & life	300 mA & 5 hs at 1.4 GeV	
Circumference	75.6 m	
Lattice	DB(A) × 8 (eight fold symmetry)	
Straight sections	2.93 m × 8	
Emittance (nm-rad)	15	[35 (7.5-T wiggler)]
Tunes (ν_x,ν_y)	6.796, 1.825	[6.796, 1.825]
Momentum compaction	0.008074	
Energy spread	0.000672	[0.00079]
Radiation loss (keV)	106	[123]
RF frequency (MHz)	499.8	
RF power & field	90 kW & 500 kV	
Harmonic number	126	
Bunch length σ(mm)	8.8	[10.35]
Beam sizes at straight section (coupling = 0.01) at η=0.62		
σ_x (μm)	580	[680]
σ_y (μm)	34	[52]
Injection energy (MeV)	262	
Dipoles & number	11.25^o edge focusing & 16	
Radius & field	3.2 m & 1.459 T	
Number of quadrupoles	40 (16QF1, 16QD1, 8QF2)	
Length (m)	0.2(QF1), 0.2(QD1), 0.3(QF2)	
Max. gradient(T/m)	27(QF1), 27(QD1), 25(Qf2)	
Number of sextupoles	32 (16SF, 16SD)	
Length (m)	0.10(SF), 0.14(SD)	
Max. gradient(T/m^2)	150	

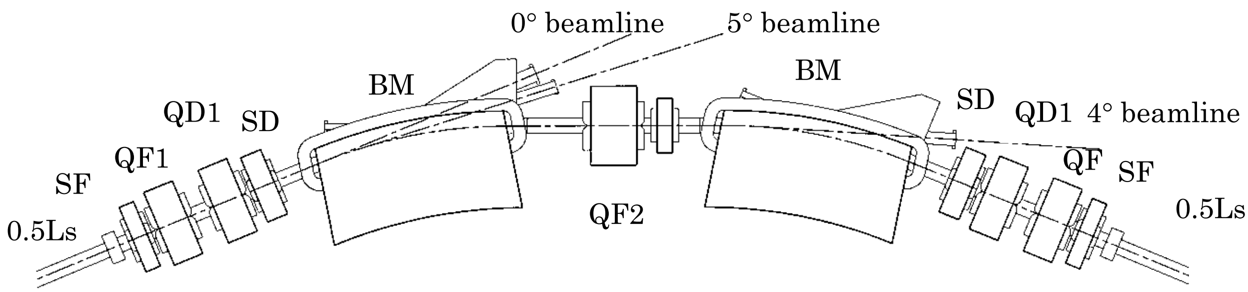

Figure 3: Magnetic lattice of one full cell (9447.23mm)

3 THE 262-MEV LINAC FOR ELECTRON INJECTION AND FEL OSCILLATION

The 262-MeV linac injector is operated in two modes; 1-μs and 9-μs macro-pulse operations. The 262-MeV electron beam with macropulse length of 1μs is for the storage ring injection and the 25~40-MeV electron beam with macropulse length of 9 μs is for two-color FEL oscillation. The linac consists of a 120-keV thermionic triode gun, a 714-MHz prebuncher, a 2856-MHz standing-wave type buncher, and six Electrotechnical Laboratory type accelerating tubes. The accelerating tubes with a length of 2.93 m are of linearly narrowed iris type to prevent beam blow up effect [10].

An electron gun with a dispenser cathode and a grid pulser emits 0.6-ns pulses of 2.3 A at 22.3125 or 89.25-MHz. These pulses are compressed to 60 A × 10 ps by the prebuncher and the buncher. The RF source for prebuncher is a 714-MHz semiconductor type RF source. A 2856-MHz klystron (Toshiba E3729, 36 MW) is for the buncher and the first two accelerating tubes.

At the injection mode, a 2856-MHz klystron (Toshiba E3712, 88 MW) is used for the following four accelerating tubes. At the FEL mode, the 9-μs macropulse electron beam is accelerated up to 40-MeV at the end of the AT-1.

The electron beam consists of a train of several ps, 0.6-nC microbunches repeating at 22.3125 or 89.25-MHz like the Free Electron Laser Research Institute (FELI) linac [10]. The 1-μs macropulse operation mode at the 262-MeV is for electron injection and an electron charge of 12-nC (0.6-nC × 20 pulses) is injected to the storage ring per second. The beam energy is ramped from 262-MeV to 1.4 GeV after beam storage in a minute, since all magnets are made of laminations of 1mm or 0.5mm thick steel. The RF frequencies of the linac accelerator tube and the ring cavity are selected to be 2856 and 499.8-MHz to achieve time overlap on the macropulse of the IR-FEL and the SR so as to do pump-probe experiments [12].

Before installation of the 7.5-T wiggler in the fall of 2005, we expect that the stored beam current and its lifetime will be 300-mA at 1.4-GeV and 5 hours, respectively.

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REFERENCES

[1] T. Tomimasu et al., Proc. of APAC01, Beijing (2001) p.340.
[2] H. Ohgaki et al., this Proceedings.
[3] A. Andersson, M. Eriksson, L.-J. Lindgren, P. Rojsel, and S. Werin, Nucl. Instru. Meth. A343 (1994) 644.
[4] Y. Iwasaki et al., this Proceedings.
[5] T. Koseki, M. Izawa, and Y. Kaimiya, Tech. Report of ISSP No.2980 (May 1995) pp.1-8.
[6] M. Yasumoto et al., Proc. of APAC01, Beijing(2001) p.349.
[7] Y. Kondo, S. Koda, and Kamada, REPORTS OF THE FACULTY OF SCIENCE AND ENGINEERING SAGA UNIVERSITY, 31(2), (December 2002) pp. 21-27(in Japanese).
[8] S. Sugiyama et al., J. Syn. Rad. (1998). 5, 437.
[9] V. M. Borovikov et al., ibid. p. 440.
[10] T. Tomimasu, IEEE Trans. NS-28(3),(1981)3523.
[11] T. Tomimasu, E. Oshita, Y. Kanazawa, and A. Zako, Nucl. Instr. Meth. A429 (1999) 141.
[12] M.Yasumoto et al., Jpn. J. Appl. Phys. 41(2002) Suppl. 41-1, pp. 44-48.