THE SAGA SYNCHROTRON LIGHT SOURCE IN 2003

T. Tomimasu*, S. Koda, Y. Iwasaki, Saga Light Source, Tosu, 841-0002, Japan
H. Ohgaki, Institute of Advanced Energy, Kyoto University, Kyoto, 611-0011, Japan
H. Toyokawa and M. Yasu moto, PRI, AIST, Tsukuba, 305-8568, Japan
Y. Yamatsu, T. Kitsuka, Y. Hashiguchi, Y. Ochiai, Saga Prefectural Government, Saga, 840-8570, Japan

1 INTRODUCTION

The 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-fold 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. 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.

The Saga-LS consists of 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 steel laminations 0.5 mm thick. The magnet cores of quadrupoles and sextupoles are from A94068-50 steel laminations 0.5 mm 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 $\varepsilon_{\text{rms}}$, the horizontal and vertical beta functions, ($\beta_x$ and $\beta_y$) 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 $\eta_x = (\varepsilon_{\text{rms}} \beta_x)^{1/2}/(\Delta p/p)$. 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 × 5.1 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 aluminum alloy except for eight long straight...
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 wiggl er is to shift the synchrotron radiation
spectrum to the hard X-ray region (ε_w = 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 • (0.1 mrad)^2 • (1%bw)^{-1}], since
the rms irradiation angle of the undulator photons is 0.052
mrad.

The wiggl er 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.

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