PROGRESS AND STATUS OF SYNCHROTRON RADIATION FACILITY SAGA LIGHT SOURCE

S. Koda#, Y. Iwasaki, Y. Takabayashi, T. Kaneyasu, SAGA Light Source, Tosu, Japan

Abstract

The Saga Light Source is a synchrotron radiation facility, which consists of a 255-MeV linac and a 1.4-GeV storage ring. Six bending magnets and an APPLE-II and planar type undulator are available as light sources. The facility covers the spectral range from VUV up to hard X-rays of about 20 keV. Eight beam lines are in operation and a hard X-ray beam line is presently being commissioned. Improvements and upgrades to the accelerator have been ongoing since its official opening in February 2006. The stored current in the storage ring has been increased from 100 mA up to 300 mA, and the beam abort time has been steadily decreasing. As new insertion device, a superconducting wiggler was installed in the storage ring in March 2010 and is now under commissioning. This will expand the spectral range into the harder 40-keV X-ray region. In addition, a laser Compton scattering experiment using a CO_2 laser has been carried out. The first 3.5-MeV gamma rays were observed in December 2009.

INTRODUCTION

The Saga Light Source (SAGA-LS) is a synchrotron radiation (SR) facility constructed by the Saga prefectural government in Japan. It was officially opened in February 2006. The SAGA-LS accelerator complex consists of a 255-MeV injection linac and a 1.4-GeV storage ring [1]. The area of the experimental hall was expanded by 40 % in the eastern direction in 2008. The present layout of the hall is shown in Fig. 1. The SAGA-LS produces SR in the range between VUV and hard X-rays. The SR spectrum is shown in Fig. 2. The layout of the accelerators and beam lines are shown schematically in Fig. 3, and the accelerator parameters are listed in Table 1. In the remainder of this article, we will describe the progress and status of the SAGA-LS mainly during the period May 2009 to May 2010.

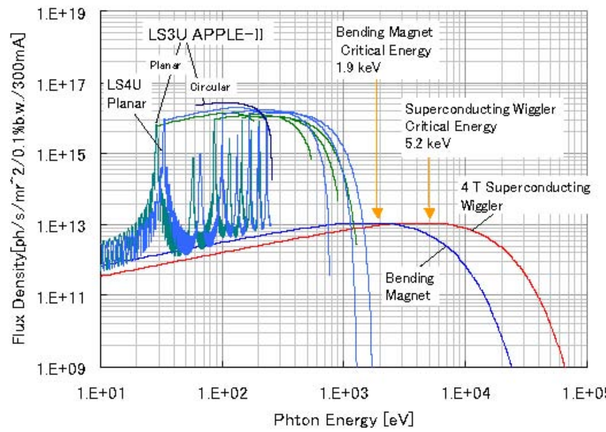

Figure 2: SR Spectrum of SAGA-LS (Superconducting wiggler is under commissioning).

ACCELERATORS AND BEAMLINES

Storage Ring

The current in the storage ring has increased from a value of 100 mA when the facility opened to a value of 300 mA in June 2009. As SR light sources, six bending magnets and a planar (LS4U) and an APPLE-II [2] (LS3U) undulator are currently in operation. In addition, a superconducting wiggler [3] (LS2W) is under commissioning. The APPLE-II undulator was installed in December 2008 and preliminary SR production began in January 2009. The periodicity and minimum gap size of the APPLE-II are 72 and 30 mm, respectively. The maximum K value is 3.5.

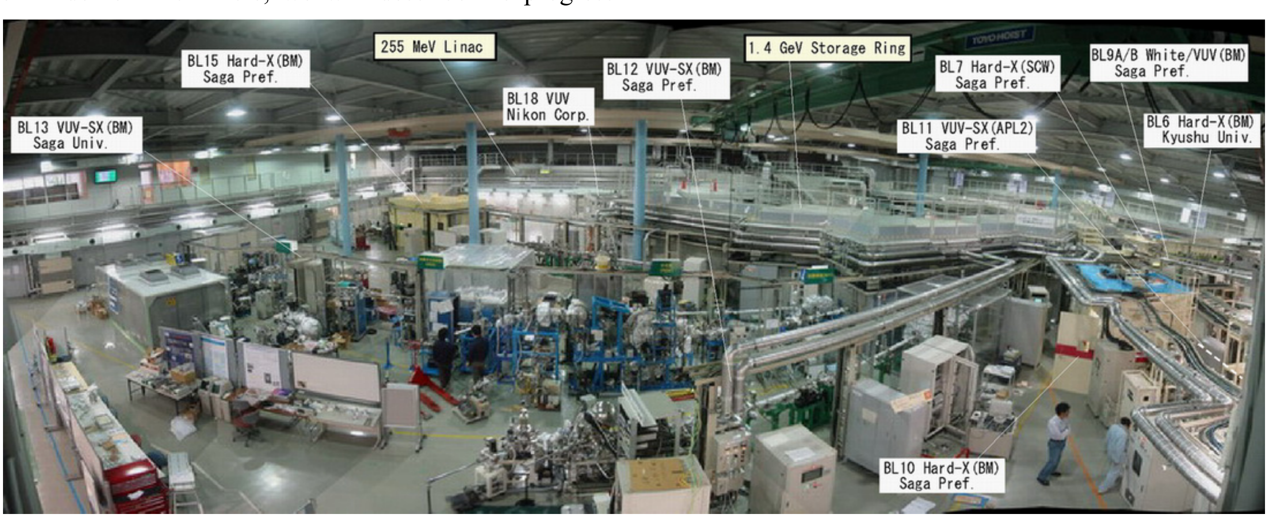

Figure 1: Experimental hall of SAGA-LS

#koda@saga-ls.jp

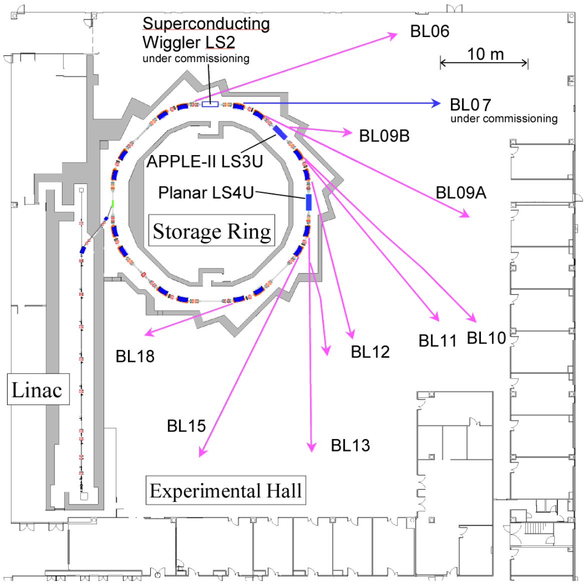

Figure 3: Layout of accelerators and beam lines.

Table 1: Accelerator parameters

Storage Ring	
Maximum energy	1.4 GeV
Circumference	75.6 m
Natural emittance	25.1 nmr
RF frequency	499.8688 MHz
Harmonic number	126
RF voltage	550 kV
Betatron tunes (H/V)	5.796/1.825
Energy spread	6.7×10^4
Momentum compaction 0.013	0.013
Beam current	300 mA

Linac	
Energy	255 MeV
Repetition rate	1 Hz
RF frequency	2856 MHz
Macro-pulse width	200 ns
Macro-pulse charge	12 nC

To compensate the linear coupling, which depends on the pole gaps of both undulators, a skew correction system was developed [1]. The system has further been improved to compensate for the skew dependence on the phase of the APPLE-II magnet array, and has enabled beam line users to control the pole gap for horizontal, circular and vertical polarizations. The goal is to enable complete two-dimensional skew correction for the gap and the phase.

Linac

The manual control devices (grid pulser, gun gate valve, klystron modulators, and phase shifter) were modified to allow them to be controlled by personal computers via a LAN. A new injection control system was developed in the LabView environment. The system controls the modified devices and the injection devices of the kickers and the septum. Consequently, the linac injection sequence from start-up to shut-down is almost completely automated for daily user operation.

Beam Lines

Specifications of the beam lines are shown in Table 2. The new beam lines BL6 (Kyushu Univ.), BL10 (APPLE-II) and BL11 began operating in 2009, and at present there are a total of eight beam lines available [4]. In addition, beam line BL7 of the superconducting wiggler is currently being commissioned.

Table 2: Specifications of beam lines

BL	Source	Photon Energy	Method	Organization	Status
BL06	Bending Magnet	30-1200 eV	XAFS,SAXS	Kyushu Univ.	Operating
BL07	Bending Magnet	4.2-37 keV	XRD,XAFS	Saga Pref.	Commissioning
BL09A	Bending Magnet	White(>3 keV)	LIGA	Saga Pref.	Operating
BL09B	Bending Magnet	10-50 eV	Photo Excitation	Saga Pref.	Operating
BL10	Undulator (APPLE2)	30-1200 eV	PEEM, ARUPS	Saga Pref.	Operating
BL11	Bending Magnet	3-23 keV	XAFS, SAXS	Saga Pref.	Operating
BL12	Bending Magnet	40-1500 eV	XPS, XAFS	Saga Pref.	Operating
BL13	Undulator (planar)	15-600 eV	ARPES	Saga Univ.	Operating
BL15	Bending Magnet	3-23 keV	XAFS, XRD Imaging	Saga Pref.	Operating
BL18	Bending Magnet	~92 eV	Irradiation Multilayer Refrection	Nikon Corp.	Operating

ACCELERATOR OPERATION

Operation Cycle

The weekly operation schedule is as follows. Monday is a machine study day and the remaining weekdays are user operation days. No operation occurs on Saturday and Sunday. Typical daily profiles of beam current and energy are shown in Fig. 4. Beam injection and user service times are 2 and 10 h/day, respectively. Monthly and annual user times are about 200 and 1500 h, respectively.

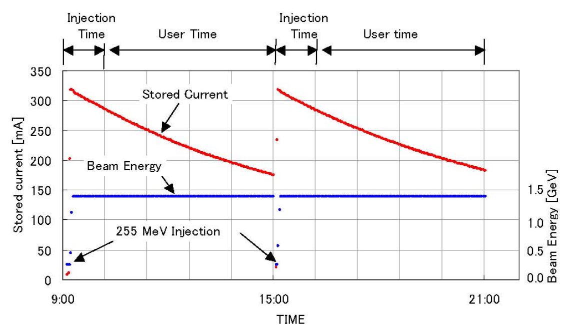

Figure 4: Beam current and energy during a typical operation day.

Beam Abort

Since the facility opened, significant improvements in operation stability have been achieved. Figure 5 shows the beam abort ratio, which is defined as the ratio of the beam abort time to the practical user operation time. Since the opening of the facility, this has been dominated by accidents involving the linac klystron and the power supply for the bending magnets of the storage ring.

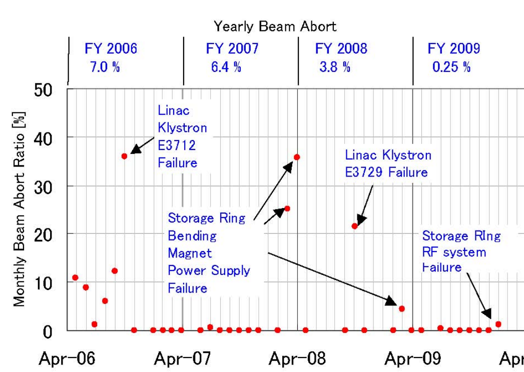

Figure 5: Beam abort ratio between 2006 and 2009.

DEVELOPMENTS

Superconducting Wiggler

A superconducting wiggler (SCW) has been developed [3] and was installed in the long straight section LS2 in March 2010. The installation is shown in Fig. 6. The SCW was planned as a response to user requests for a harder X-ray range of 2-40 keV. The peak field is 4 T, which corresponds to a critical SR energy of 5.2 keV. The SCW is a three-pole hybrid-magnet-type wiggler. To reduce the heat load on the cryogenic system, only the main pole is a superconducting magnet and the side poles are normal 1-T conducting magnets. Considering in particular the operation stability of the cryogenic system, a cryogen-free system using a GM cryocooler was employed. This directly cools the superconducting coil and the iron pole via mechanical contacts. A magnet excitation study using the beam will be undertaken soon.

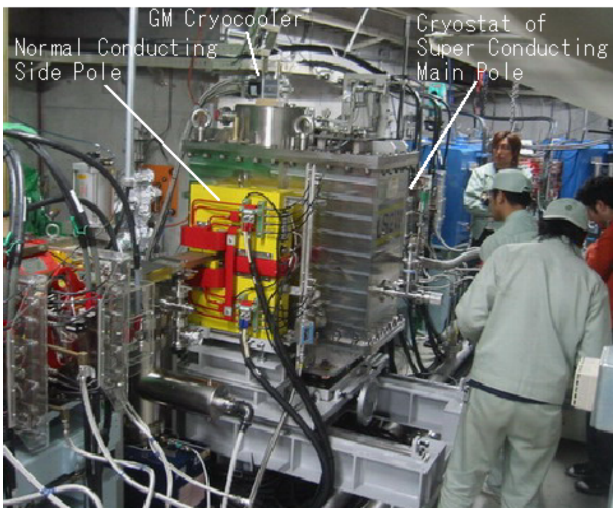

Figure 6: SCW just after installation at LS2.

Laser Compton Scattering Experiment

A laser Compton scattering (LCS) experiment has been carried out [5] for applying to a practical beam energy monitor and gamma-ray user applications. We concentrated on the generation of gamma rays using a CO_2 laser with a wavelength of 10.6 microns. The LCS produces 3.5-MeV gamma rays. As electron repulsion by the LCS is smaller than the RF bucket of 14 MeV, the LCS has the advantage of not reducing the beam life time. Therefore, gamma-ray production can coexist with the daily operations for SR users. The long straight section LS8 was used as the interaction region for electrons and laser photons. A detector and laser port were placed in beam line BL01 as shown in the upper part of Fig. 7. The first experimental results were obtained in November 2009 and 3.5-MeV gamma rays were observed. The lower part of Fig. 7 shows the first detected gamma-ray spectrum by the BGO detector. We have studied the properties of the LCS gamma rays and have improved the laser optics.

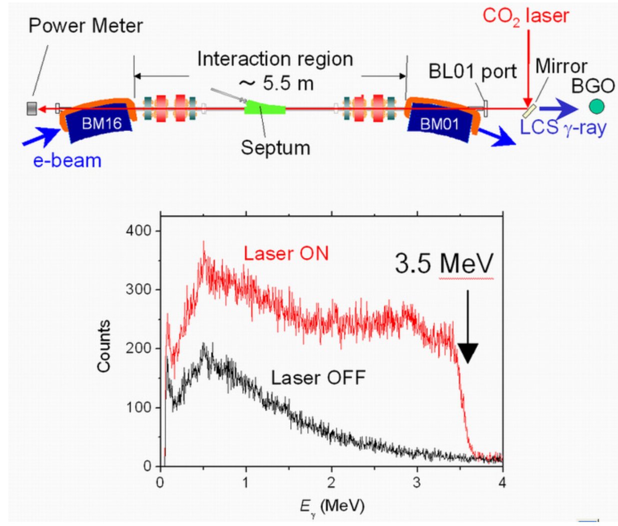

Figure 7: LCS experiment setup (upper) and observed gamma-ray spectrum (lower).

SUMMARY

The performance of the SAGA-LS as a SR light source has been improved since it was officially opened. The beam current is now 300 mA, and the beam abort time has been steadily decreasing over the past four years. Eight beam lines, including two undulator lines, are currently in stable operation. A hybrid SCW has just been installed in beam line BL7, and both are now being commissioned. The photon energy range of the SAGA-LS will be further extended by the SCW. In addition, successful detection of gamma rays occurred in the LCS experiment.

REFERENCES

[1] T. Kaneyasu, Y. Takabayashi, Y. Iwasaki, S. Koda, "Present Status of Synchrotron Radiation Facility SAGA-LS", PAC'09, Vancouver, WE5RFP014, p. 1 (2009).

[2] S. Sasaki, "Analyses for a planar variably-polarizing undulator", Nuclear Instruments and Methods in Physics Research A347, p. 83 (1994).

[3] S. Koda, Y. Iwasaki, Y. Takabayashi, T. Kaneyasu, T. Semba, Y. Murata, M. Abe, "Design Study of Superconducting Wiggler for SAGA-LS Storage ring", The 6th Annual Meeting of Particle Accelerator Society of Japan, Tokai, Japan WPLSA13, p. 112 (2009).

[4] T. Okajima, "Present Status and Future Development of the SAGA Light Source", The 157th Meeting on X-Ray Studies on Mechanical Behavior of Materials, Kyoto, Japan, p. 16 (2009).

[5] T. Kaneyasu, Y. Takabayashi, Y. Iwasaki, S. Koda, "Status of Gamma-ray Generation Experiments by Laser Compton Scattering at SAGA-LS", The 6th Annual Meeting of Particle Accelerator Society of Japan, Tokai, Japan WPLSA15, p.237 (2009).