ACCELERATORS OF THE CENTRAL JAPAN SYNCHROTRON RADIATION FACILITY PROJECT (II)

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Abstract

Central Japan Synchrotron Radiation (SR) Facility Project is making progress for the service from FY2012. Construction of the SR building is almost completed in the Aichi area of Japan, and the installs of accelerators will start in a few week. The key equipments of our accelerators are an 1.2 GeV compact electron storage ring that is able to supply hard X-rays and a full energy injector for top-up operation. The beam current and natural emittance of the storage ring are 300 mA and 53 nmrad. The circumference is 72 m. The magnetic lattice consists of four triple bend cells and four straight sections. The bending magnets at the centers of the cells are 5 T superconducting magnets and the critical energy of the SR is 4.8 keV. The injector consists of a 50 MeV linac and a booster synchrotron with the circumference of 48 m. To save construction expenses, the injector is built at inside of the storage ring. More than ten hard X-ray beam-line can be constructed. One variable polarization undulator will be installed in the first phase. The top-up operation will be introduced as early as possible.

INTRODUCTION

Synchrotron radiation (SR) facilities have been used successfully for basic researches in the world. Recently, an SR facility as a tool not only for basic research, but also for engineering and industrial research and development is strongly required. For this purpose, a new SR facility is under-constructed in the Central Japan area, which is one of middle parts of Japan [1, 2]. The SR facility has been designed at the Nagoya University Synchrotron Radiation Research Center (NUSR) [1] in collaboration with Aichi prefectural government, Aichi Science & Technology Foundation (ASTF) [2], industries, and other universities in the area.

An SR facility project has been proposed at Nagoya University since 1991 [3]. In the meantime, the Aichi Prefectural government has been planning a new research and development complex "Knowledge Hub" for industries and the SR facility proposed at Nagoya University has been considered to be one of the leading facilities for "Knowledge Hub". Therefore, the prefecture, industries, universities, and research institute in the Central Japan area, have been working together to realize this plan. After a long effort construction of the SR facility was started from 2010, and the service will start in FY2012.

We reported the conceptual design of the accelerators at last conference [2]. In this paper, latest changes of the accelerators designs are reported. In addition, construction progress of the equipments are also described.

Figure 1: Photo of the radiation shielding wall in the center of experimental room (under-construction).

ACCELERATORS

The key equipments of the accelerators are a compact electron storage ring with the ability to supply hard X-rays and full energy injectors for the top-up operation. A photograph of the radiation shielding wall in the center of experimental room is shown in Fig. 1. The accelerators consist of an electron storage ring, a booster synchrotron ring, and an injector linac. The booster and injector linac are located inside of the storage ring on the same floor, and the accelerators are separated from the experiment hall by a single shielding wall. The roof of shielding wall is used as the power source area for the accelerators.

The parameters of accelerators are summarized in Tab. 1.

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Table 1: Parameters of Accelerators

Storage ring	
Electron energy	1.2 GeV
Circumference	72 m
RF frequency	499.654 MHz
Current	>300 mA
Natural emittance	53 nm-rad
Energy spread	8.41×10^{-4}
Betatron tune	(4.72, 3.23)
Magnetic lattice	Triple Bend Cell × 4
Normal bend	1.4 T, 39°
Superbend	5 T, 12°
Booster synchrotron	
Electron energy	50 MeV – 1.2 GeV
Circumference	48 m
RF frequency	499.654 MHz
Natural emittance	220 nm-rad
Injection scheme	On-axis (single turn)
Repetition rate	1 Hz
Injector linac	
Beam energy	50 MeV
RF frequency	2,856 MHz
Normalized emittance	$< 100\ \pi$.mm.mrad
Charge per pulse	>1 nC ($\lvert dp/p \rvert < 0.5\%$)
Gun Pulse length	0.56, 0.70, 1.05 ns

The electron beam is injected from the booster synchrotron with the full energy from the first phase of the operation, and the top-up operation will be introduced as early as possible in our project.

Storage Ring

The circumference of the storage ring is 72 m with the energy of 1.2 GeV, and the natural emittance is 53 nm-rad. The lattice configuration is Triple Bend Cell, which consist of a super-conducting magnet (superbend) and two normal conducting magnets (normal bends). Optical functions of the storage ring are shown in Fig. 2.

There are twelve bending magnets at the storage ring. Eight of them are normal bends of 1.4 T and four of them are 5 T superbends, respectively. The critical energy of the SR from the superbends is 4.8 keV. Spectra of photon Flux from the bending magnets are shown in Fig. 3. The bending angle of superbends is 12 degree and two or three hard X-ray beam-lines (BLs) can be constructed at each superbend, so that ten or more hard X-ray BLs can be constructed. The number of BLs from normal bends is more than 16. In addition, an APPLE-II type undulator will be also installed in straight sections for VUV experiments. The design parameters of the undulator are summarized in Tab. 2.

Injectors

The linac consists of a 100–kV thermionic electron gun, a pre-buncher, a 13MeV-buncher and a couple of 1.5 m accelerations tubes. The 100-kV gun is a Pierce type geometry using an Y-845 (CPI) cathode. The electron beams are generated with a reputation rate of 1 Hz, and the pulse length can be selected from 0.56, 0.70 or 1.05 ns. The normalized emittance at the exit of linac is estimated to less than 100 π.mm.mrad.

The booster synchrotron has a circumference of 48 m and is operated with single bunch. The electron beam is injected from the booster with the full energy from the first phase of the operation. The on-axis single turn schemes are employed for the injection and extraction at the booster. A 50 MeV beam from the linac is injected by a couple of a pulsed septum and a first kicker and accelerated to the energy of 1.2 GeV. This accelerated beam is extracted by another couple of a pulsed septum and a first kicker and injected to a particular rf bucket of the storage ring. At first phase, the bumped injection scheme by using four pulsed magnets is employed and we have considered the possibility of a pulsed multi-pole injection scheme [4] for one of the future upgrade plans.

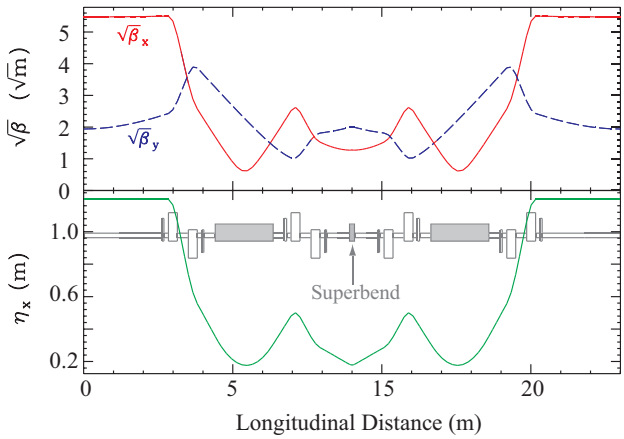

Figure 2: Optical functions of the storage ring.

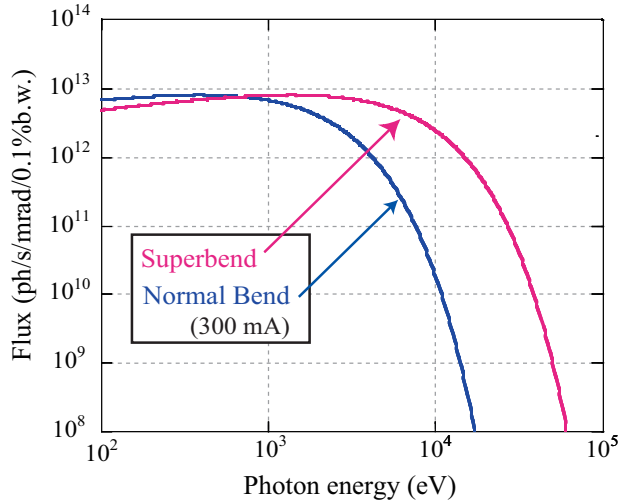

Figure 3: Spectra of photon Flux from the bending magnets.

Figure 4: Photo of a superbend at manufacturing factory

Timing System

The timing system for the accelerators is designed for the purpose to synchronize the accelerators and to realize the stable top-up operation.

The master oscillator consists of a Phase-locked loop circuit (PLL) and two Direct Digital Synthesizers (DDSs). The 1 GHz master clock generated by the PLL is divided in two. Each signal enters into the DDS that generates 249.825 and 168 MHz, respectively. After passing through each frequency multiplier and band pass filter, the 499.65 ($\times$2) and 2856 ($\times$17) MHz rfs can be obtained. The tunable range of the 499.65 and 2856 MHz is $\pm$ 1 MHz and $\pm$ 100 kHz, respectively, and the frequency resolution of the output rfs is 0.1 Hz.

Both the storage ring and booster synchrotron are synchronized with same 499.654 MHz rf and the rf phases can be adjustable by delay lines. For the linac system, a phase reset signal for the 168 MHz DDS and a start /stop signal of 2856 MHz rf can be triggered by using 16bit–counter of 499.65 MHz rf.

Table 2: Design parameters of the undulator

Undulator type	APPLE-II
# of period	33
Period length	60 mm
Magnetic material	Nd-Fe-B
Gap range	24 – 200 mm
Vertical polarization mode	
Peak field	0.36 T
K_y, Deflaction parameter	2.02
First harmonic energy	74.9 eV
Horizontal polarization mode	
Peak field	0.60 T
K_x, Deflaction parameter	3.33
First harmonic energy	34.8 eV
Circular polarization mode	
Peak field	0.31 T
K_x/K_y, Deflaction parameter	1.73
First harmonic energy	57.1 eV
Dimensions	
Length	1990 mm
Height	2282 mm
Width	1330 mm
Total mass	$\sim$ 5 t

SUMMARY

Central Japan Synchrotron Radiation Facility is under constructed not only for basic research but also for engineering and industrial research and development. The accelerators of this facility consist of a compact storage ring, that is able to supply more than ten hard X-ray BLs, and a full energy injector for the top-up operation.

Currently, six BLs are under-constructed for the service start of 2012. Those are BLs for a hard X-ray XAFS, a soft X-ray XAFS, a soft X-ray to ultraviolet spectroscopy, a small angle scattering, X-ray diffraction, and an X-ray fluorescence analysis.

ASTF is responsible for the operation and management, and NUSR is responsible to run the equipments and support the users technically and scientifically. The commissioning of accelerators will start in the spring of 2012 and the start of the service is scheduled in the late of FY2012.

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