Nagoya University Photo-Science Nanofactory Project

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Abstract. Nagoya University has a project to construct a new synchrotron light facility, called Photo-Science Nanofactory, to develop a wide range research on basic science, industrial applications, life science and environmental engineering in collaboration with universities, research institutes and industries. The key equipment of the facility is a compact electron storage ring, "Nagoya University Small Synchrotron Radiation facility (NSSR)," which is able to supply hard x-rays. The plan of the specifications is as following. The energy of the stored electron beam is 1.2 GeV. The circumference is 62.4 m. Natural emittance is about 60 nmrad. The configuration of the storage ring is considered based on the Triple Bend Achromat with twelve bending magnets. Eight of them are normal conducting magnets. Four of them are 5T superconducting magnets (super-bends). The bending angle is 12 degrees and two or three hard x-ray beam lines can be constructed for each super-bend. The number of beam lines from normal conducting bending magnets is more than 16. In addition, we will install two undulators in straight sections. The electron beam is injected from a booster synchrotron with the energy of 1.2 GeV as full energy injection. A 50 MeV linac is used as an injector to the booster synchrotron. The top-up operation is also planned.

Keywords: storage ring, hard x-ray source, synchrotron radiation, superconducting magnet
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INTRODUCTION

Nagoya University has a plan to construct a new synchrotron light facility with compact storage ring. Since users of synchrotron radiation in Nagoya University are dominantly aiming at technological applications, the hard x-ray region will be mostly used. In order to develop a wide range research on basic science, industrial applications, life science and environmental engineering in collaboration with universities and industries by using synchrotron radiation of x-ray region, we propose to construct a research facility called "Photo-Science Nanofactory" at Nagoya area, the geographical center and the most powerful industrial center in Japan.

The main equipment of Photo-Science Nanofactory is a compact electron storage ring, Nagoya University Small Synchrotron Radiation facility (NSSR). NSSR is a compact source that provides a wide and flexible capability for research and education. Clean rooms and peripheral equipments are installed around the light source, so that users can work in one continuous operation from making materials to analysis. In Fig. 1 we show a plan of the organization of Photo-Science Nanofactory. A research thrust center, a research and collaboration management center and a collaboration laboratory are arranged for convenience of the users.

Since compact storage rings operate with rather low energy, they usually cover from the VUV to the soft x-ray wavelength range. However, compact sources capable of delivering a hard x-ray range are very attractive. In order to help the hard x-ray experiments for studies on XAFS, x-ray diffraction, macromolecular crystallography, we have a plan to install 5T superconducting bending magnets (super-bends) in our storage ring of NSSR.

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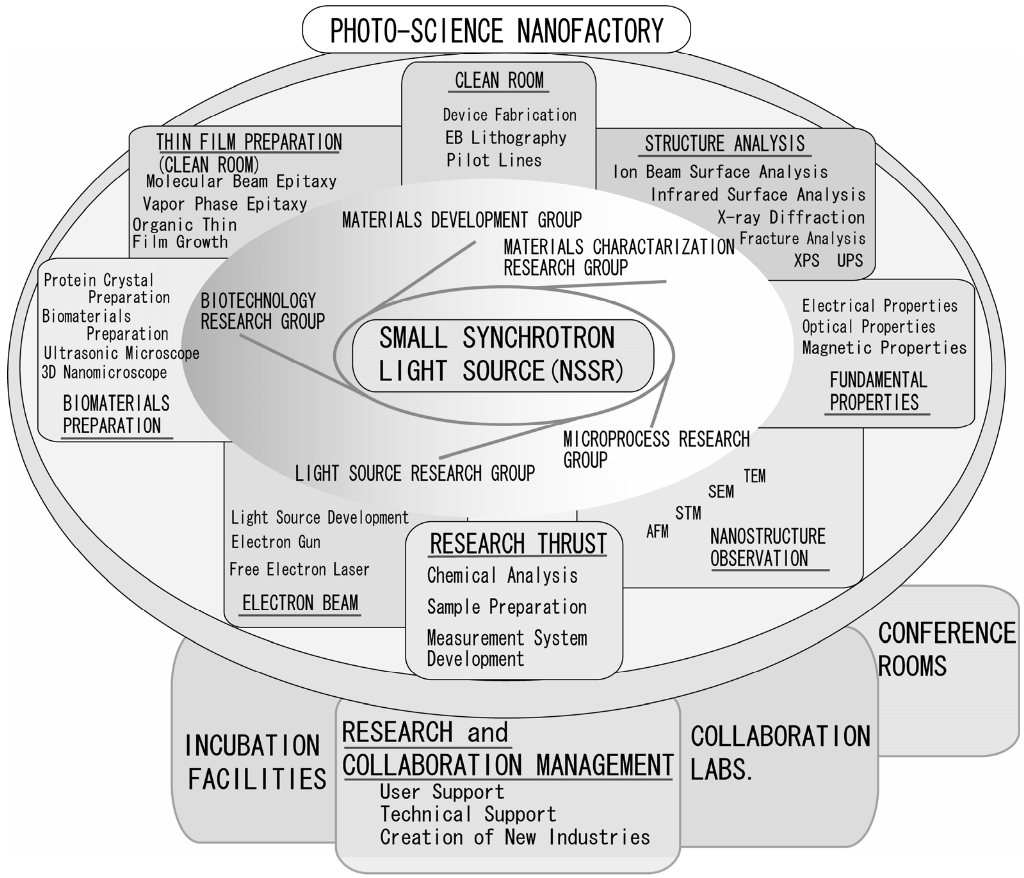

FIGURE 1. Organization of Photo-Science Nanofactory.

ACCELERATORS OF NSSR

The feature of NSSR plan is a compact synchrotron radiation source for supplying hard x-rays. In Fig. 2 we show the layout of accelerators and beam lines of NSSR. The circumference of the storage ring is 62.4 m and the harmonic number is 104 for 500 MHz of RF frequency. The energy of the stored electron beam is 1.2 GeV. In order to obtain hard x-rays, we will install super-bends in the storage ring. The configuration of the storage ring is based on the Triple Bend Achromat (TBA) with twelve bending magnets. Eight of them are normal conducting. The field strength is 1.4 T and the bending angle is 39 degrees. Four of them are 5T super-bends. The bending angle is 12 degrees and two or three x-ray beam lines can be constructed for each super-bend. All bending magnets are separated function magnets. The current in the storage ring is more than 300 mA. Natural emittance is about 60 nmrad. The number of beam lines from normal conducting bending magnets is more than 16. In addition, we will install two undulators in straight sections.

The electron beam is injected from a booster synchrotron with the energy of 1.2 GeV as full energy injection because we want to avoid changing the current of the super-bends. Full energy injection also enables us to operate on top-up injection. A 50 MeV linac will be used as an injector to the booster synchrotron. The booster synchrotron and the injector linac are constructed on underground level. The electron beam is transported from the booster synchrotron to the storage ring under the ground, so that we can extract beam lines of synchrotron radiation from all the bending magnets without interference of electron beam transport line.

In order to generate hard x-rays from compact storage ring, which is operated with rather low energy, we can use high field wavelength shifter conventionally. However, it is difficult to extract sufficient number of beam lines from wavelength shifters. On the other hand, we can extract two or three hard x-ray beam lines from one super-bend, so that more than 10 hard x-ray beam lines can be constructed in our facility. In addition, instead of the wavelength shifters in the straight sections, we can use straight sections for other insertion devices. Super-bends have been used in ALS storage ring [1], which are good examples of our project.

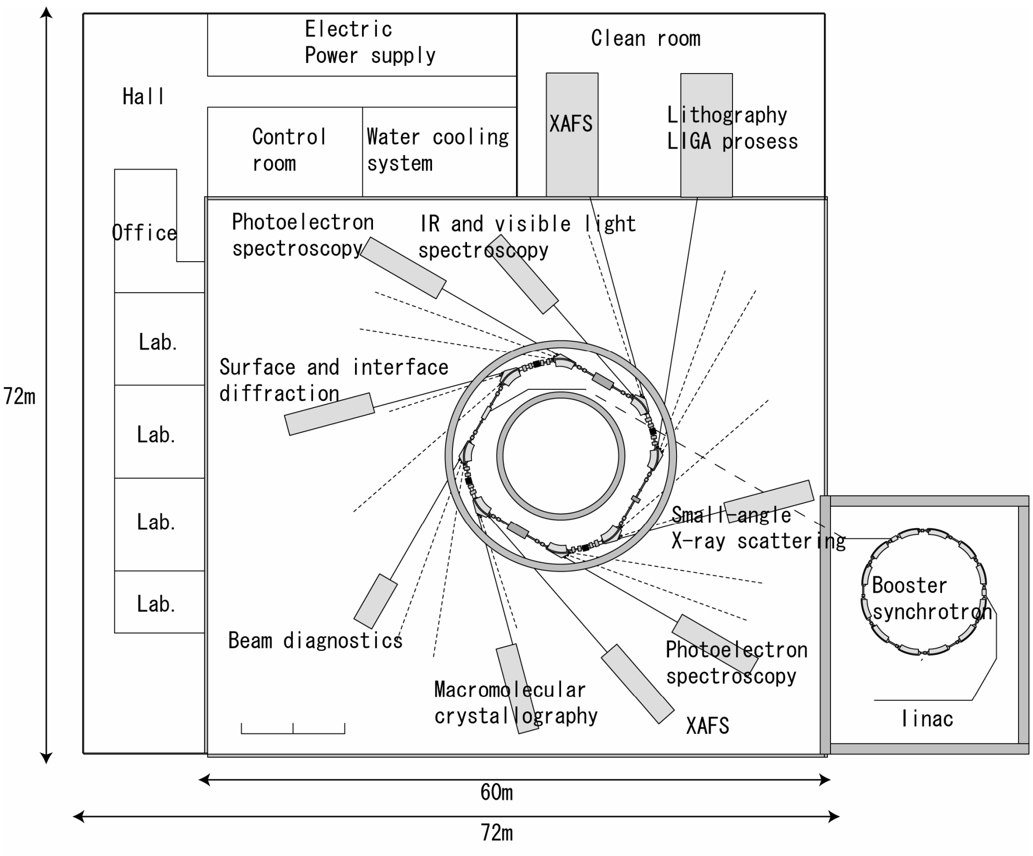

FIGURE 2. Layout of accelerators and beam lines of NSSR.

TABLE 1. Parameters of NSSR.

Storage ring	
Beam energy	1.2 GeV
Current	300 mA
Circumference	62.4 m
Normal conducting bending magnets	1.4 T, bending angle 39° × 8
Superconducting bending magnets	5 T, bending angle 12° × 4
RF frequency	500 MHz
Output power of Klystron	100 kW
Natural emittance	～60 nmrad
Magnetic lattice	Triple Bend Cell × 4
Straight section	4 m × 2
Booster synchrotron	
Maximum beam energy	1.2 GeV
Bending magnets	1.1 T
Circumference	37.2 m
RF frequency	500 MHz
Injector linac	
Beam energy	50 MeV
Current	10 mA
Repetition rate	1 Hz
RF frequency	2856 MHz

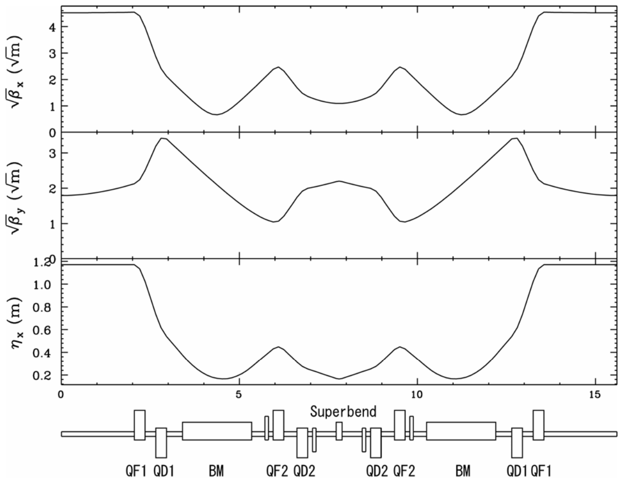

FIGURE 3. Optical functions of NSSR storage ring.

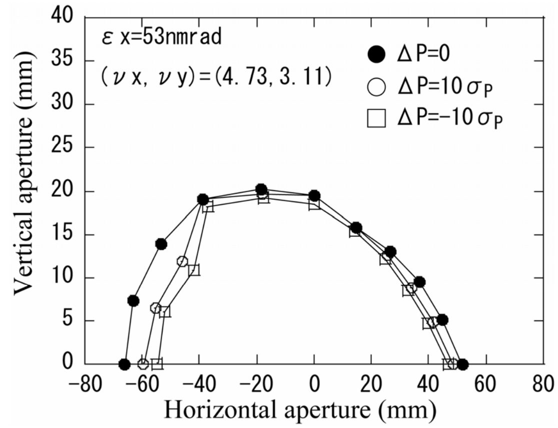

FIGURE 4. Dynamic aperture of NSSR storage ring.

In Fig. 3 we show beta functions and dispersion function of 1/4 of NSSR storage ring. The configuration of the storage ring is based on the Triple Bend Achromat. We will install super-bend as the center bending magnet of TBA. There is 1.2 m dispersion at the straight section. The natural emittance on this condition is 53 nmrad. We calculate dynamic aperture by using SAD (Strategic Accelerator Design) [2] program as shown in Fig. 4. The dynamic apertures are sufficiently wide.

SUMMARY

Nagoya University has a plan to construct a new research center called "Photo-Sicience Nanofactory" with compact synchrotron light source NSSR (Nagoya University Small Synchrotron Radiation facility) for developing a wide range research on basic science, industrial applications, life science and environmental engineering in collaboration with universities and industries by using synchrotron radiation of x-ray region. The beam energy and circumference of the NSSR storage ring are 1.2 GeV and 62.4 m. The essence of this plan is the install of superconducting bending magnets in the storage ring, so that about 10 beam lines can be supplied for hard x-ray users.

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