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Nanohana Project SR Facility Design

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"**Nanohana Project**" is a project that constructs a synchrotron radiation (SR) facility funded largely by investment from private sectors. The applicable industrial fields of SR are wide and including materials, electronics, mechatronics, chemistry, biotechnology, pharmaceuticals and medical sciences. The Nanohana SR is the middle scale facility. Electron beam energy is 2.0 GeV. The SR facility is capable of installing 26 beamlines at the bending magnets and 6 beamlines at the insertion devices. Eight beamlines are planned to install at the bending magnets for the first stage. The major applications of the SR facility are analyses such as XAFS, fluorescent X-ray analysis, photoelectron spectroscopy and X-ray diffraction, and micro-fabrication such as lithography and LIGA. Installation time of two beamlines for lithography and LIGA in eight beamlines may change depending on industrial situation different from the other six beamlines.
Key words:Nanohana Project, SR Facility, Industrial Use, Protein Crystallography

1. INTRODUCTION

Conventional synchrotron radiation (SR) facilities are mainly managed by research institutes or universities. Industrial users can't utilize the facilities as they like. It is difficult to keep the confidentiality of the user's tasks when they utilize the facilities.

The Nanohana Project is a unique plan to construct and manage a SR facility by a private sector. The facility is designed from the standpoint of industrial use. Industrial users can easily utilize the facility without the restriction of conventional SR facilities.

The electron storage ring is 107.5m in circumference and accelerates electrons to 2.0 GeV. The number of bending magnets is 16 and the insertion devices (ID) can be installed at the 6 straight sections of the ring. The maximum of 32 beam lines can be installed. Eight end stations will be provided at the start of operation for analysis, lithography and LIGA process.

Many kinds of material researches are possible by synchrotron radiation light of Nanohana SR facility.- Atomic structures and structural changes in a variety of materials ranging from catalysis, polymers and protein crystals are determined by X-ray diffractions and scattering. Sensitive qualitative and quantitative chemical compositions are measured by X-ray spectroscopy.

2. LIGHT SOURCE DESIGN

2.1 Basic Design Concepts of the SR Facility

The Nanohana SR facility aims for compact, economical and reliable electron ring. The basic design concepts of the SR facility are as follows;

①The critical energy of SR from bending magnet is 4 keV.

②The spectral brilliance of SR from bending magnet is more than 10^{13} photons/sec/mm^2/mrad^2/0.1%b.w. in the spectral range of 1 to 10 keV.

③Number of SR beamline ports is more than 10.

④Storage ring circumference is less than 110 m.

⑤Minimums of three straight sections are necessary for insertion devices.

⑥Electron beam lifetime (1/e) is more than 10 hours.

2.2 Machine Specifications

The linac, booster synchrotron and electron storage ring are designed according to the basic design concepts. The layout of the facility is shown in Fig.1

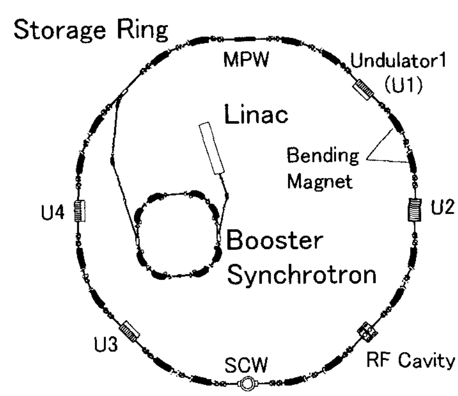

Fig.1 The layout of the facility

The electron beam injector is linac and the booster synchrotron is adopted for electron acceleration between the linac and the storage ring. The specifications of the linac and booster synchrotron are shown in Table I and Table II

Table I Specifications of the linac

Operating frequency	2856 MHz
Output Beam Energy	50 MeV
Bucket Repetition Frequency	178.5 MHz
Macropulse Duration	50 ns
Number of e^- in macropulse	10^{10}

Table II Specifications of the booster synchrotron

Beam energy	50~500 MeV
RF frequency	178.5 MHz
Circumference	26.9 m
Repetition ratio	1 Hz
No. of bending magnets	8

Eight sets of bending magnets are situated along the electron storage ring. Insertion devices such as undulators(U) and superconducting wigglers(SCW) are planned to locate at the straight sections between the bending magnets. The specifications of the electron storage ring are shown in Table III.

Table III Specifications of the storage ring

Beam energy	2.0 GeV
Beam current	300 mA
Beam lifetime	>10 hours
Horizontal emittance	66 nm-rad
RF frequency	178.5 MHz
Circumference	107.5 m
Number of straight section	8
Straight section length	4.5 m
Radiation source	Bending magnets Undulators SC wigglers
No. of bending magnets	16
No. of insertion device	6 (maximum)

2.3 SR Spectrum

The electron storage ring are operated with three operation modes which are the basic mode(BASIC), the low emittance mode(LEM) and the low beta mode(LBM). The spectrums of the bending magnet(BM), superconducting wiggler(SCW) and the superconducting multipole wiggler(MPW) are shown in Fig. 2. The low emittance mode is for much higher brilliance of synchrotron radiation light from the bending magnet. The SCW and the MPW are used with the low beta mode of which function is rather small in the long straight sections in order to restrict the influence of the SCW and the MPW. Maximum field of the SCW is 7.5 T. Maximum field of the MPW is 3T and the periods number is 20.

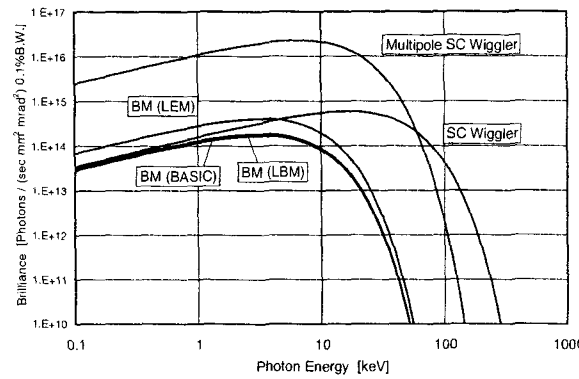

Fig.2 SR spectrums of the BM, SCW and MPW

The basic specifications of the soft x-ray undulators(U1 ~U3)and hard x-ray undulator (U4) are shown in Table IV.

Table IV Basic specifications of the undulators

U No.	λ_0 [cm]	N_p	K_{max}	λ_1 [Å]
U1	4	70	3.775	13.05
U2	3	100	1.998	9.79
U3	2	150	0.707	6.53
U4	0.6	100	0.4	1.96

λ_0 and Np is the undulator period length and the periods number in Table IV. Kmax is the maximum of the K value, and λ_1 is the fundamental wavelength. The spectrums of the undulators are shown in Fig.3.

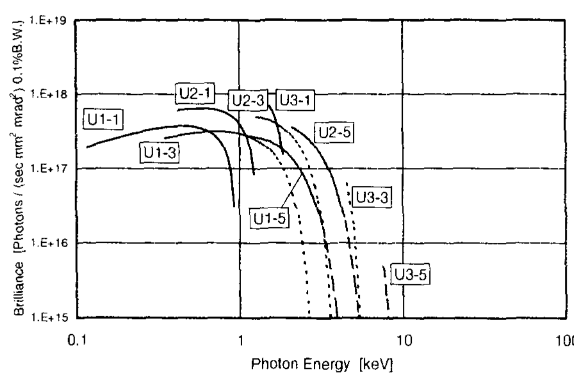

Fig. 3 SR spectrums of undulators

The solid line, dotted line and the dash dotted line show fundamental, the third harmonic and the fifth harmonic respectively in Fig.3.

2. BEAMLINE AND END STATION

Eight beamlines(BL) are planned at the start of operation in the Nanohana SR facility. Beamlines are shown in Table V. The types of beamlines are selected on the basis of user's requirements expressed through interviews and questionnaires. New types of beamlines and end stations will be installed in response to user's requirements in future.

Table V Beamlines of the SR facility

	Type	Application
1	Total Reflection Fluorescent X-ray Spectroscopy	Detection of contaminants on the surface of a wafer
2	Topography, Measurement of Reflectivity	· Analysis of defects in a crystalline lattice · Analysis of a thin layer
3	XAFS, Fluorescent X-ray Spectroscopy	· Structural analysis of heavy elements(Si-Ca) in substances · Detection of very small amounts of components
4	XAFS, Fluorescent X-ray Spectroscopy	· Structural analysis of heavy elements (V-Ru, Cs-U) in substances · Detection of very small amounts of components
5	X-ray Diffraction	Protein structural analysis
6	XAFS, Photoelectron Spectroscopy	Analysis of solids surface structures, chemical states of materials and electronic states
7	Lithography	Development of exposure process
8	LIGA process	Development of a micro-machining process

The BL-1 and BL-2 are useful for the development of semiconductor devices. The end stations of the beamlines are clean rooms with Class 1000 ratings.

The BL-3 is used for the same purpose as BL-4 though the energy range is different. XAFS is a powerful method to analyze the structure around the target element, irrespective of the state of the material. The most of users become interested in this application via interviews and questionnaires.

Protein crystallography is one of the notable fields in the Post-Genome age. X-ray diffraction method is a possible solution for the structural analysis of the protein crystals. Users in the medical and life science field will use the BL-5.

The BL-6 is a soft X-ray beamline for the use of surface analysis of materials. The beamline has a wide applicability in the field of organic or inorganic chemistry.

SR is not only a tool of analyses but also a light source used for manufacturing processes. The SR facility provides a light source for users developing new manufacturing processes of micro devices. The detailed design of the BL-7 and BL-8 will be done in compliance with user's requirements in future.

The beamlines of the SR facility consist of standard and reliable components. The optics of the hard X-ray beamlines from BL-1 to BL-5 are the combination of a standard double-crystal monochromator and a focusing mirror as shown in Fig. 4.

A diffraction grating monochromator is applied for the BL-6.

Standard measurement tools and utilities are prepared for applications in the end stations. Users can bring their own measurement system.

2.5 Building

The SR facility consists of an experimental building and an administration building. The experimental building is rectangular shape and 79.2 m by 97.2 m in size as shown in Fig.5.

The height is 15 m. The building houses the ring, beamlines and end stations. The control room is located at the second floor of the upper end of the building. The operator in the control room has the access to the interior of the ring via an elevated catwalk. Overhead hoist cranes supported from the ceiling serve to carry equipments from the truck area to the hall.

The ring is located in the center of the building. Beamlines extend from the ring in the hall. Extended area for a medical end station using a long beamline is provided outside of the building.

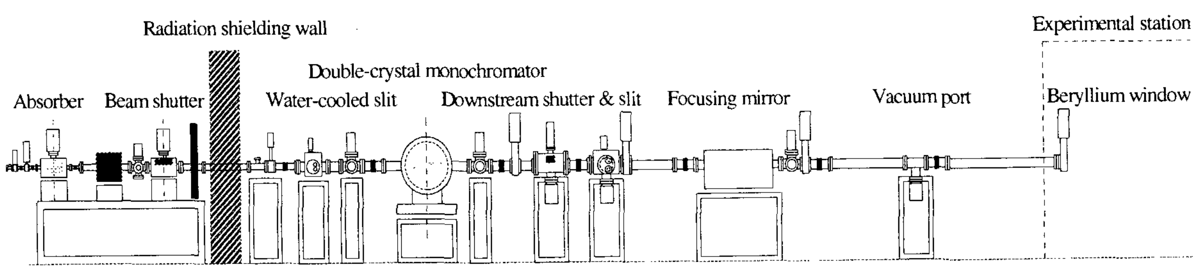

Fig.4 Layout of components in the hard X-ray beamline

; has a bed room, a conference room and rental laboratories for user's convenience. The users in the administration building gain access to the experimental building via the connecting corridor at the second floor.

3. Management Plan

3.1 Basic Policy for Operation

The Nanohana Project is planned for every private sector to utilize the SR facility without complicated procedures. The SR facility is operated by the following policy.

- The facility is open for every private sector.
- The confidentiality of the user is preserved.
- The facility can be utilized in a short waiting time after application.
- Technical support staffs serve the users who are not familiar with the facility.

The facility is equipped with rental laboratories, conference rooms and bedrooms for user's convenience.

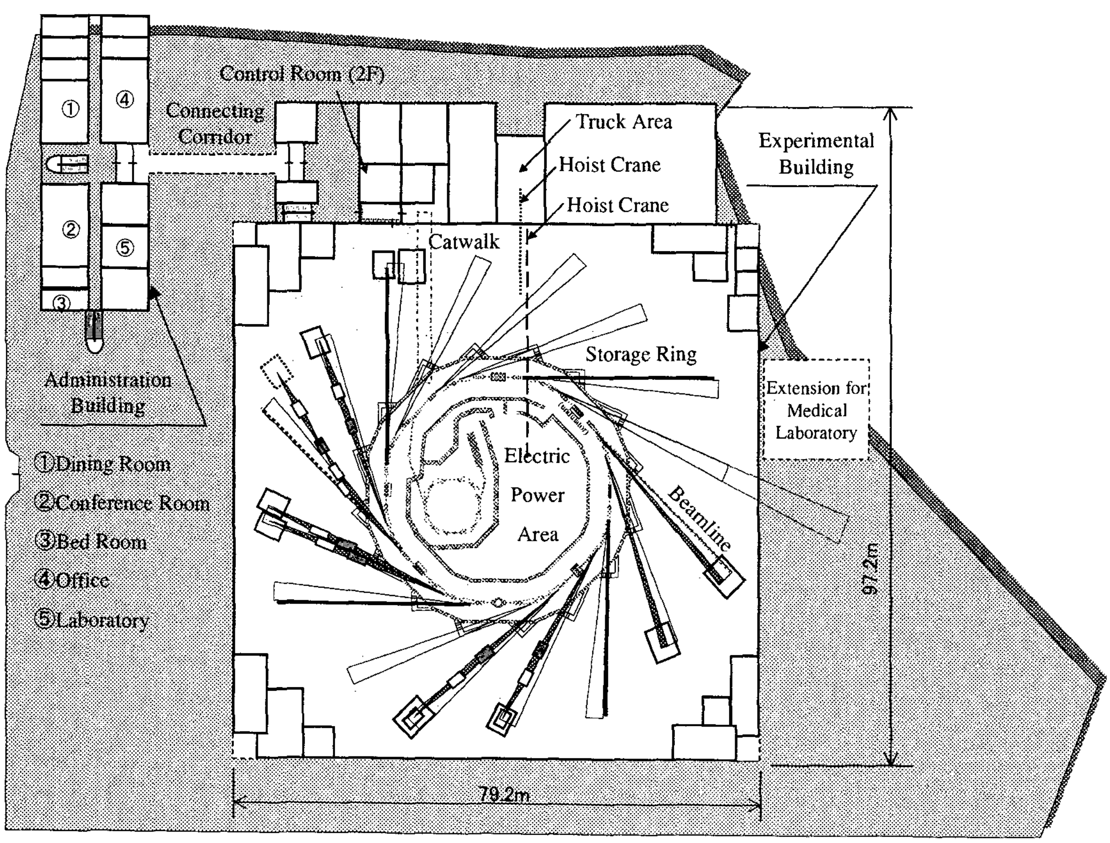

Fig.5 The Nanohana SR building

3.2 Utilization System of the Facility

Three kinds of utilization systems are provided for the users of the end stations in the SR facility. The first is the owner's system. The users can own their end stations by themselves. The second is the rental system. The users can carry out the experiment with their experimental apparatuses or the rental apparatuses provided in the end stations in the SR facility.

The third is the entire application system. The users can get the experimental data by entrusting the experiment. This system is convenient for the users who are not familiar with a synchrotron radiation light. The system is also beneficial for the users in charge of routine tasks.

4. Summary

The Nanohana Project is progressing with the cooperation of the expert on synchrotron radiation light and the users. Detailed design of the facility is completed except the beamlines and the end stations. Requirements of the users were investigated to reflect the design of the beamlines and the end stations. Investigation is continuing with the cooperation of the users. The Nanohana Project is updated to realize the first SR facility by a private sector.

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