OVERVIEW

OVERVIEW OF THE UVSOR FACILITY

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1. General Description

Institute for Molecular Science (IMS) is inter-university research institute, established in 1975. It has six departments and six research facilities working organically. Departments are Departments of Theoretical Studies, Molecular Structure, Electronic Structure, Molecular Assemblies and Applied Molecular Science, and Coordination Chemistry Laboratories. Research Facilities are Computer Center, Low-Temperature Center, Instrument Center, Chemical Materials Center, Equipment Development Center and Ultraviolet Synchrotron Orbital Radiation (UVSOR) Facility. In IMS, there are 85 scientific staffs including 16 guest staffs, 42 technical staffs and administrative staffs. Lodging facilities for visitors are provided.

The UVSOR is a dedicated VUV source for molecular science and related fields. It is a 600 MeV (max. 750 MeV) electron storage ring, of which injector is a 600 MeV synchrotron with a 15 MeV linac.[1-3] They are located underground for radiation safety as shown in Fig.1. Synchrotron radiation from ordinary bending sections is mainly utilized. Three insertion devices can be installed. The UVSOR Facility had been proposed since 1975. The construction started in 1980 with fabrication of measurement systems. In 1981, the construction of the light source started and its commissioning was succeeded on the 10th November, 1983. The number of beam lines at the first stage is 14,[4] but eventually more than 20 beam lines can be attached to the ring. Experiments have been made since September, 1984. The total cost of the light source and the measurement systems is about 2.2×10^9 yen, the cost of building is 1.7×10^9 yen and the annual running cost is about 4×10^8 yen. These values do not include salaries of IMS staffs.

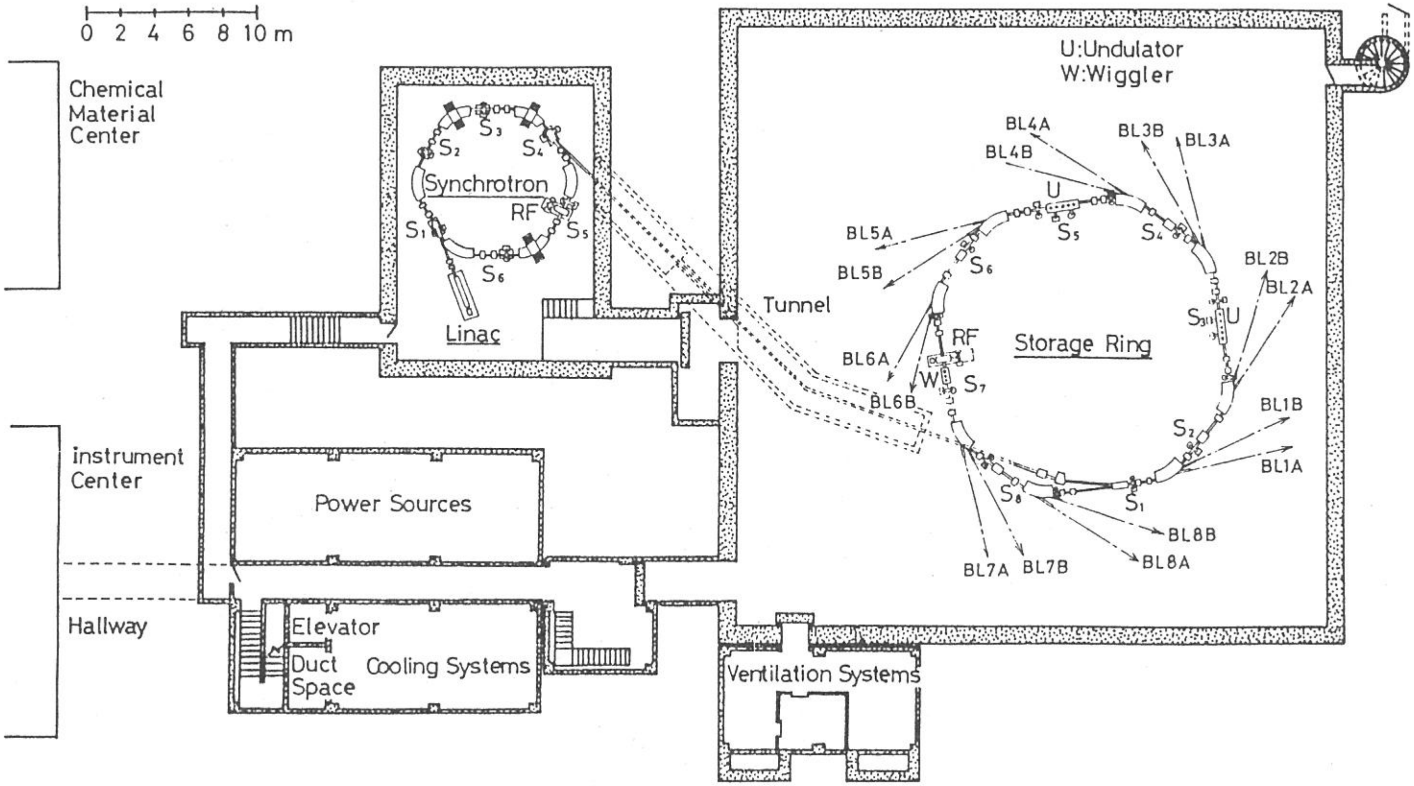

Fig. 1 Plane view of the basement of the UVSOR Facility.

Staffs of the UVSOR Facility are a director (Prof. H. Inokuchi), two associate professors, two research associates, six technical staffs and an adjunct associate professor. Associate Professors T. Kasuga and M. Watanabe are responsible for the light source and measurement systems, respectively. Staffs of Department of Molecular Assemblies are main users in IMS as well as the promoters of the UVSOR project. The UVSOR Facility is responsible for the operation of the light source and beam lines for users outside IMS.

Proposals can be applied twice per year, which are judged by a steering committee. Items of proposals are Joint Studies, Cooperative Research and Use of Facility. In 1984, 4 proposals of Use of Facility were approved. In 1985, for the first item, 3 proposals are approved, for the second, 14 proposals and for the third, 32 proposals. Experimentalists should be registered as radiation worker. Monday is a day for machine study and days from Tuesday to Friday are for users. Users' time is 9:30-13:00 and 13:30-18:00. The injection is twice per day. 37 weeks will be delivered to users in this fiscal year. During the injection, experimentalists should keep out from the storage ring room. (Shield blocks against the radiation due to the decay of stored current are put around the ring.) Users' meeting is usually held once per year and activity report will be published.

2. Light Source

2.1 Overview

Plane view of the light source is shown in Fig.1 and design parameters are given in Table 1. The booster synchrotron consists of 6 bending magnets, 6 doublets of quadrupoles and 6 long straight sections. These magnets are lamination type (thickness of lamination is 0.35 mm). The waveform of power supplies for the magnets is trianglar whose repetition time is 380 ms. Electron beam from the 15 MeV linac is injected by means of an electro-static septum (inflector) and 3 bump magnets (perturbator). The beam is accelerated by a usual re-entrant type RF cavity, which is excited by a 5 kW power amplifier. Accelerated beam is extracted by means of a fast kicker and a septum magnet (deflector).

Table 1 Parameters of UVSOR

	Designed	Achieved
Linac		
Energy	15 MeV	15 MeV
Frequency	2.856 GHz	
Synchrotron		
Energy	600 MeV	600 MeV
Current	50 mA	15 mA
Circumference	26.6 m	
Periodicity	6	
Bending Radius	1.8 m	
Tune (Q_H, Q_V)	(2.25, 1.25)	
Harmonic Number	8	
Radio Frequency	90.1 MHz	
Repetition Rate	1-3 Hz	2.5 Hz
Storage Ring		
Energy	600 MeV (max. 750 MeV)	750 MeV
Critical Wavelength	56.9 Å	
Current	500 mA	330 mA
Lifetime	1 hr (500 mA)	2 hr (100 mA)
Circumference	53.2 m	
Periodicity	4	
Bending Radius	2.2 m	
Bending Field	0.91 T	
Tune (Q_H, Q_V)	(3.25, 2.75)	
Harmonic Number	16	
Radio Frequency	90.1 MHz	
RF Voltage	75 kV	
Radiation Damping Time		
Horizontal	45.4 ms	
Vertical	40.9 ms	
Longitudinal	19.5 ms	
Emittance		
Horizontal	$8\pi \times 10^{-8}$ m rad	$16\pi \times 10^{-8}$ m rad
Vertical	$8\pi \times 10^{-9}$ m rad*	
Beam Size (at the Center of Bending Section)		
Horizontal ($2\sigma_H$)	0.64 mm	
Vertical ($2\sigma_V$)	0.46 mm*	
Bunch Length (2σ)	0.17 ns	

*10% coupling is assumed.

The storage ring is composd of eight bending magnets, and four long and four short straight sections as shown in Fig.2. The beam is injected into the storage ring by means of a septum magnet (inflector) and 3 bump magnets (perturbator). The vacuum systems of the beam transport line and the storage ring are separated by a thin polyimide film (thickness of 50 μm) at the exit of the inflector. An RF cavity of the ring is excited by a 20 kW power amplifier. The RF power amplifier of the synchrotron and that of the storage ring are driven by the same master oscillator, therefore the synchronized transfer of the bunched beam is quite easy.

Button type position monitors are set around the ring to measure closed orbit distortions. The orbit distortions are corrected by trim coils wound on bending magnets and vertical steering magnets. An electrode for an RF knockout system to measure tunes of both horizontal and vertical directions is situated in a short straight section. The electrode is excited by a wideband power amplifier (0.3 - 35 MHz, 300 W). Another RF knockout electrode and 21 DC electrodes for ion-clearing are installed.

The beam current can be measured by a DC current transformer. It is monitored every one minute by a micro-computer and the e-folding lifetime is calculated. The profile of the beam is observed using a television camera, and beam size is estimated from the video signal from the camera.

Two outlets of synchrotron radiation are available for each bending section. A permanent magnet undulator and a superconducting wiggler are installed at S_3 and S_7 long straight sections, respectively.5) Fig. 3 shows the intensity distribution from ordinary bending sections and the superconducting wiggler. Fig. 4 shows that from the undulator. (Units of intensity in these figures are different.)

2.2 Construction and Commissioning

The construction of the light source was started in 1981. The magnet system, the RF system and the vacuum system of the booster synchrotron and the pre-injector linac were completed in March 1982. These components were installed in the building for the synchrotron and aligned precisely by the autumn. The

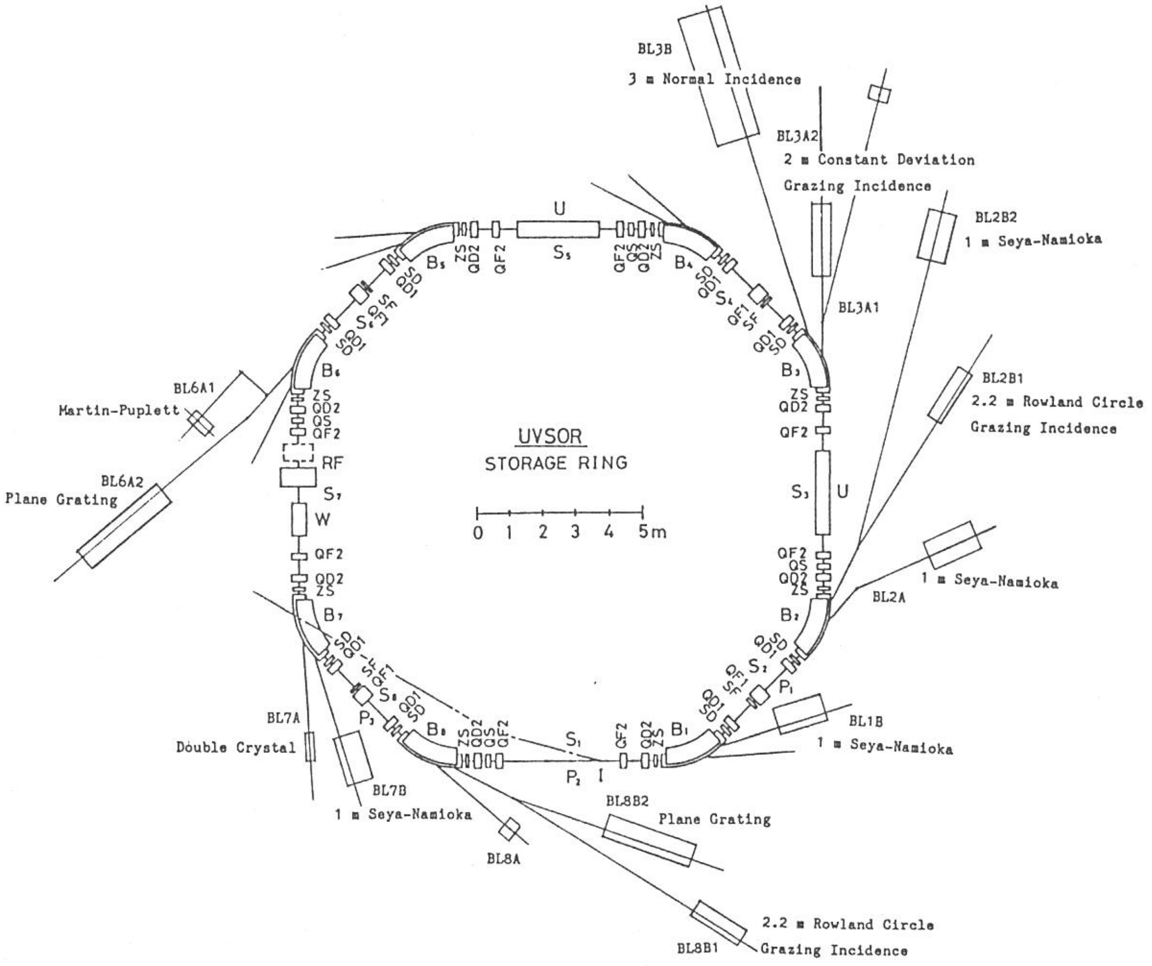

Fig. 2 Plane view of the UVSOR storage ring.

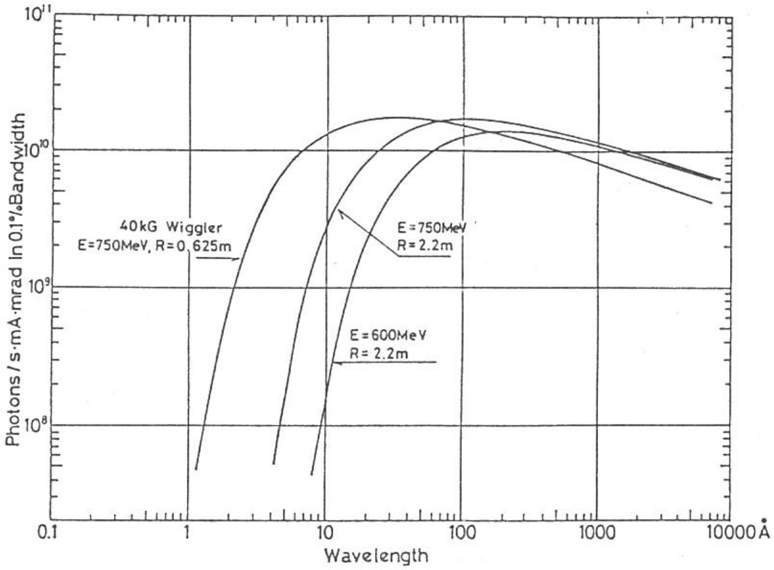

Fig. 3 Intensity distribution of the radiation from ordinary bending sections and the superconducting wiggler.

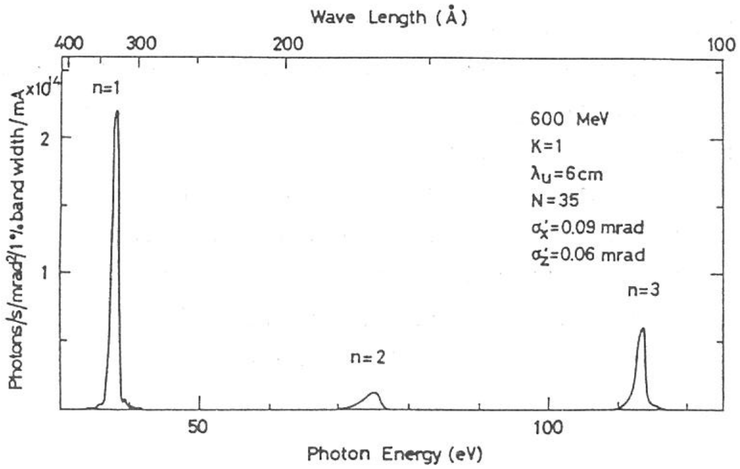

Fig. 4 Intensity distribution of the radiation from the undulator at the S_3 straight section (courtesy H. Kitamura).

test of the linac was successfully done at the end of 1982. As the pulse power supplies for synchrotron magnets were not finished at that time, small DC power supplies were connected to the magnets to test the injection scheme of the synchrotron. It was a serious problem encountered in the test that the injected beam was lost in several turns after injection. The cause of this problem was the mismatch between the vertical closed orbit and the vertical aperture of a beam monitor in front of the inflector, and it was solved by widening the beam monitor. The pulse power supplies for the magnets were finished in July 1983. The injected beam was accelerated without any difficulty. A fast kicker and a septum magnet for the beam extraction were installed in September 1983. After the installation of the fast kicker, the injection of the electron beam into the synchrotron became impossible. This problem was caused by remanent field of the kicker, and DC bias current is superposed upon the high voltage pulse to solve the problem. In succession, the beam extraction from the synchrotron and the transport of the extracted beam were tried.

Almost all components of the storage ring were delivered in March 1983, and basic parameters of these components were measured and installed in the ring by August. The injection of the electron beam into the storage ring was begun on the 10th of November, and the first electron beam was stored on that evening. Since then, efforts were devoted to measurements of important parameters of the ring, search for the optimum operating point, and studies of the behavior of the stored beam.

2.3 Performance and Beam Characteristics

The design parameters with achieved ones are tabulated in Table 1. The design energy of the synchrotron is easily achieved. Though the final beam current of the synchrotron is 1/3 of the designed value, time required to accumulate the electron beam in the storage ring is short enough. It takes only several minutes to accumulate the beam current of 100mA. The maximum stored current of the storage ring up to now is 330 mA, and at this current, a window glass for an optical beam monitor cracked. An attempt to increase the maximum stored current was not made after that time. The e-folding lifetime of the beam at 100 mA is about 2 hrs. This figure is very close to the lifetime estimated considering the Touschek effect and the effect of the vacuum pressure (3×10^{-9} Torr at 100 mA). The beam size is estimated from the video signal from the television camera used to monitor the beam profile, and the emittance is estimated from the measured beam size and the beta functions at the radiant point. The measured emittance is twice the designed value. This disagreement must be due to inaccuracy in estimating the beam size. Injected beam (600 MeV) can be accelerated up to 750 MeV without appreciable beam loss.

Single bunch operation of the storage ring was tried successfully.[6] The maximum beam current in a single bunch up to now is 25 mA, and a ratio of number of electrons in an adjacent bucket to that in the aimed bucket is about 0.1 %. The first experiment using the single bunch mode was done in September 1985.

Since the first beam was stored, efforts have been devoted to improving the performance of the ring. Some inconvenient phenomena have been found during the accelerator studies. One of the most serious problems was the growth of the vertical size of the electron beam.[7] This phenomenon is explained by the ion-trapping effect. DC clearing electrodes and an RF knockout electrode were installed to clear ions. These two ion-clearing techniques are used together to improve the beam size. The improvement of the beam profile is shown in Fig.5. Fig. 5 (a) and (b) are pictures of the beam profile without and

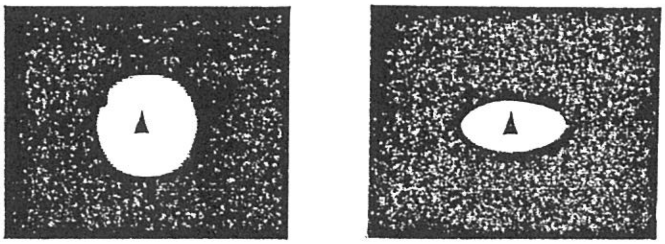
a) b)

Fig. 5 Improvement of Profile (a) Ion-Cleaning OFF, b) Ion-Cleaning ON) with the ion clearing by these two methods, respectively. The second problem is the longitudinal coupled-bunch instability induced by the parasitic resonances of the RF cavity. We have no way except the temperature control of the cavity to avoid the parasitic resonances for the present.

2.4 Undulator and Wiggler

An undulator with 35 periods and a superconducting wiggler were installed in the storage ring in March 1984. The undulator is planer type and the gap is movable between 27 and 80 mm. One period in 35 periods is composed of 8 blocks of permanent magnets made of $SmCo_5$ and the length of the period is 60 mm. The maximum magnetic field of the undulator is 0.3 T at the minimum gap. Though the horizontal closed orbit was deformed slightly (max. 3 mm at 32 mm gap), appreciable tune shifts were not observed and the lifetime of the beam was not affected.

A horizontal orbit bump is formed by the wiggler, which is composed of 3 sets of superconducting coils. The inner and outer size of the middle coil (main coil) are 30 mm W x 110 mm L x 55.8 mm H and 118.4 mm W x 198.4 mm L x 55.8 mm H. Those of the outer coils (auxiliary coils) are 30 mm W x 136 mm L x 40.8 mm H and 97.4 mm W x 203.4 mm L x 40.8 mm H. The space between the center of the upper coil and that of the lower coil is 140 mm. The maximum field produced by the main coils is 4 T. The tune shifts and the vertical closed orbit distortion due to the excitation of the wiggler is not negligible. A quadrupole magnet and a vertical steering magnet were installed near the wiggler to correct the influence of the wiggler.

3. Measurement Systems

3.1 Beam Lines

Schematic diagram of the beam line is shown in Fig. 6. Horizontal acceptance angle of the front end is 80 mrad. It is composed of a manual valve (V_0), a beam shutter, a pneumatic valve (V_1) and a fast closing valve (V_F). After the front end, a pre-mirror chamber, beam pipes and a pneumatic valve (V_2)are connected. V_0, V_1 and V_2 use viton O-rings, while V_F is an all metal valve. Closing time of V_F is 10 ms and leak rate is 1 Torr l/s. When accidental leakage occurs, the combination of V_F and V_1 can prevent the leakage so that the pressure deterioration at the outlet of synchrotron radiation is below 1 x 10^{-3} Torr. In July 1985, an accidental leakage occurred from a sample chamber at BL7B. At that time the beam current decreased by amount of 10 mA, but the lifetime soon recovered.

Between a pre-mirror chamber and a monochromator, an acoustic delay line is inserted. The acoustic delay line can delay propagation time of the front of leakage by 10 ms. However in our case, even if the fast closing valve shuts before the front arrives, the leak from the fast closing valve is dominant on the vacuum deterioration of the ring. If the effect of leakage should be neglected, it is recommended that one should use combination of a fast closing valve with a negligibly small leak rate and the acoustic deley line.

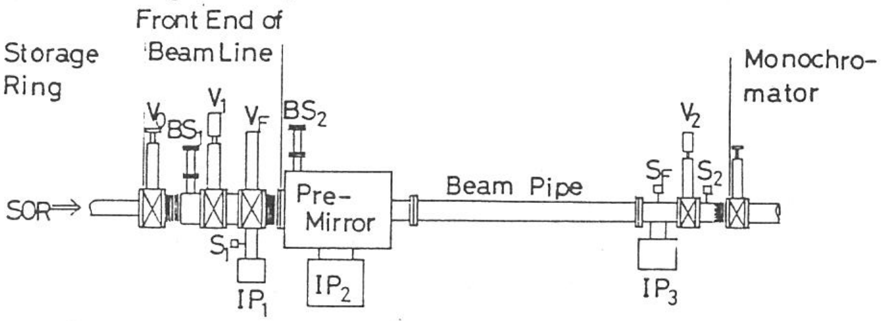

Fig. 6 Schematic diagram of beam line. V_0: manual valve. V_1 and V_2: pneumatic valves. V_F: fast closing valve. BS_1 and BS_2: beam shutters. S_1, S_2 and S_F: vacuum gauges which control V_1, V_2 and V_F, respectively. IP_1 - IP_3: sputter ion pumps.

The first pre-mirrors are made of quartz and their surfaces are coated with platinum or gold. At present, they are not cooled.

3.2 Experimental Equipments

Monochromators listed in Table 2 are located as shown in Fig. 2 . They cover wavelength region from far infrared to soft X-ray. The beam lines and monochromators of BL2A, BL2B2, BL3B and BL8B2 are mainly used by staffs of Department of Molecular Assemblies in IMS. The others are for users outside IMS. The UVSOR Facility is responsible for the maintainance of these lines. A monochromator of BL7B was made by Equipment Development Center, equipped with time resolving instrument made by Instrument Center. BL6A2 and BL7A were made in cooperation with adjunct associate professors of UVSOR. BL1B, BL2B1, BL3A1, BL3A2, BL6A1 and BL8B1 were made or are under construction in cooperation with visiting scientists. BL8A is opened to users who bring their own optical instruments and to those who make irradiation experiments, such as lithography. A double crystal monochromator (BL7A) usually used at the ordinary bending section, can be used in combination with the wiggler radiation a few or several weeks per year. BL3A2 and BL3A1 are undulator radiation ports with and without a monochromator, respectively. The use of oil diffusion pumps is allowed only in the case of evacuating molecular beam sources. Standard DC detecting systems and counting systems are provided. Micro-computors are used individually. The date buses are both IEEE-488 and CAMAC.

4. Building

The UVSOR building is a four-storied building, whose whole area is 2750 m^2. It has rooms to accomodate the storage ring, the synchrotron, power supplies, chillers, heat exchangers, air conditioners and the control system. It has also small rooms such as an electronics shop, a machine shop, a dark room, a computer room and offices. Both the synchrotron and the storage ring rooms have x-y cranes. As the synchrotron room inclined when the storage ring room was completed, the magnet system of the synchrotron had to be aligned precisely again. Each beam line has its own pit for cabling and piping cooling water, compressed air and helium gas. The amount of toxic gas as for the sample is limited and it should be handled in drafts. Ordinary and emergency ventilation systems are provided.

Table 2 Monochromators at UVSOR

Beam Line	Monochromator, Spectrometer	Wavelength Region	Acceptance Angle(mrad)		Experiment
			Horiz.	Vert.	
BL1B*	1 m Seya-Namioka	6500-300 Å	60	6	Gas & Solid
BL2A	1 m Seya-Namioka	4000-300 Å	40	6	Gas
BL2B1*	2.2 m Rowland Circle	440-20 Å	10	2	Gas
	Grazing Incidence				
BL2B2	1 m Seya-Namioka	2000-300 Å	20	6	Gas
BL3A1	None (Filter, Mirror)		(U) 0.3	0.3	Gas & Solid
BL3A2*	2 m Constant Deviation	1000-100 Å	10	4	Gas & Solid
	Grazing Incidence		(U) 0.3	0.3	
BL3B	3 m Normal Incidence	4000-300 Å	20	6	Gas
BL6A1	Martin-Puplett	5 mm-50μ m	80	60	Solid
BL6A2	Plane Grating	6500-80 Å	10	6	Solid
BL7A	Double Crystal	15-8 Å	2	0.3	Solid
		15-2 Å	(W) 1	0.15	
BL7B	1 m Seya-Namioka	6500-300 Å	40	8	Solid
BL8A	None		25	8	Irradiation, User's Instrum.
BL8B1*	2.2 m Rowland Circle	440-20 Å	10	2	Solid
	Grazing Incidence				
BL8B2	Plane Grating	6500-80 Å	10	6	Solid

* : under construction. U : with an undulator. W : with a wiggler.

5. Future Plan

A second undulator will be installed in spring of 1986. Some fundamental experiments of FEL using the undulator will be done. We will start to make a plan of the second stage of the measurement systems, using six unused outlets of synchrotron radiation.

Acknowledgements

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