# STATUS OF UVSOR

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## ABSTRACT

The UVSOR is a dedicated VUV source for molecular science and related fields. It is a 600MeV (max. 750 MeV) electron storage ring, of which injector is a 600 MeV synchrotron with a 15MeV linac.[1-3] They are located underground for radiation safety. Synchrotron radiation from ordinary bending sections is mainly utilized, and 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 $2.2 \times 10^9$ yen, the cost of building is $1.7 \times 10^9$ yen and the annual running cost is about $4 \times 10^8$ yen.

## INTRODUCTION

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 0.35mm). The waveform of power supplies for the magnets is trianglar whose repetition time is 380ms. The electron beam from the 15MeV 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 5kW power amplifier. Accelerated beam is extracted with a fast kicker and a septum magnet (deflector).

The storage ring is composd of eight bending magnets, and four long and four short straight sections. 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 50μm) at the exit of the inflector. An RF cavity of the ring is excited by a 20kW 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 for measurement of closed orbit distortions,which

Table 1 Parameters of UVSOR

| | Designed | Achieved |
|---|---|---|
| Linac | | |
| Energy | 15 MeV | 15 MeV |
| Synchrotron | | |
| Energy | 600 MeV | 600 Mev |
| Current | 50 mA | 20 mA |
| Circumference | 26.6 m | |
| Bending Radius | 1.8 m | |
| Radio Frequency | 90.1 MHz | |
| Repetition Rate | 1-3 Hz | 2.5 Hz |
| Storage Ring | | |
| Energy | 600 MeV (750 MeV) | 750 MeV |
| Critical Wavelength | 56.9 A | |
| Current | 500 mA | 500 mA |
| Lifetime | 1 h (500mA) | 2.5 h (100mA) |
| Circumference | 53.2 m | |
| Bending Radius | 2.2 m | |
| Tune ($Q_H$, $Q_V$) | (3.25, 2.75) | |
| Radio Frequency | 90.1 MHz | |
| RF Voltage | 75 kV | |
| 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* | |

*10% coupling is assumed.

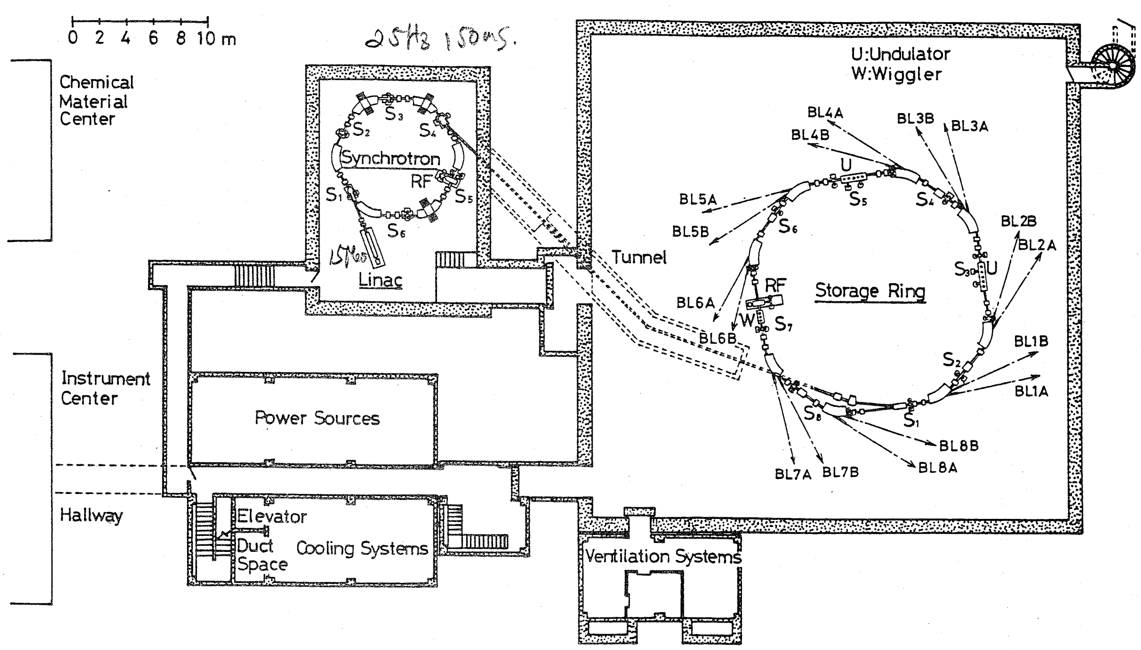


Fig. 1 Plane view of UVSOR

are corrected by trim coils wound on bending magnets and vertical steering magnets. An electrode for an RF knockout system for tune measurement is situated in a short straight section. The electrode is excited by a wideband power amplifier (0.3 - 35MHz , 300W). 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.

Two outlets of synchrotron radiation are available for each bending section. An undulator with 35 periods for vacuum ultraviolet synchrotron radiation and a superconducting wiggler were installed in March 1984.[5] Another undulator with 19 periods for the FEL experiment was set in 1986.

## CONSTRUCTION AND COMMISSIONING

The construction of the light source was started in 1981. The magnet , the RF and the vacuum systems 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 test of the linac was successfully done at the end of 1982. Since the pulse power supplies for synchrotron magnets were not finished at that time, small DC power supplies were connected to the magnets for the test of 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.

## PERFORMANCE

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 e-folding lifetime of the beam at 100mA is about 2.5 hrs. This figure is very close to the lifetime estimated considering the Touschek[9] effect and the effect of the vacuum pressure (3 x $10^{-9}$ Torr at 100mA). 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 about twice as much as the designed value. This disagreement is due to the enlargement of the horizontal beam size caused by the longitudinal coupled-bunch instability through the non-zero energy dispersion function. Injected beam (600MeV) can be accelerated up to 750MeV without appreciable beam loss.

Single bunch operation of the storage ring was tried successfully.[6,7] The maximum beam current in a single bunch up to now is 50mA, 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.[8,9] 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. 2. Fig. 2(a) and (b) are pictures of the beam profile without and 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 installed a longitudinal active damping system to suppress the instability. The system consists of sixteen independent feedback loops; each of them corrects energy deviation of a certain bunch in sixteen bunches individually. The phase oscillation due to the instability was satisfactorily damped with this system. The phase oscillations without and with the feedback system are shown in Fig. 3(a) and (b) respectively. A signal from a button monitor was displayed on a oscilloscope triggerd by a signal synchronized to a certain bucket. As seen in the figure, the phase oscillation due to the instability is completely suppressed with the aid of the feedback system.

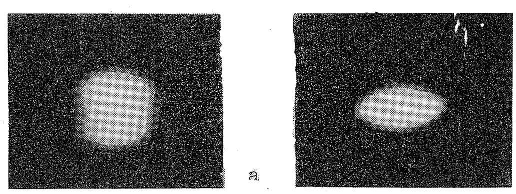


Fig. 2 Beam Profile (a: Ion Clearing off , b: on)

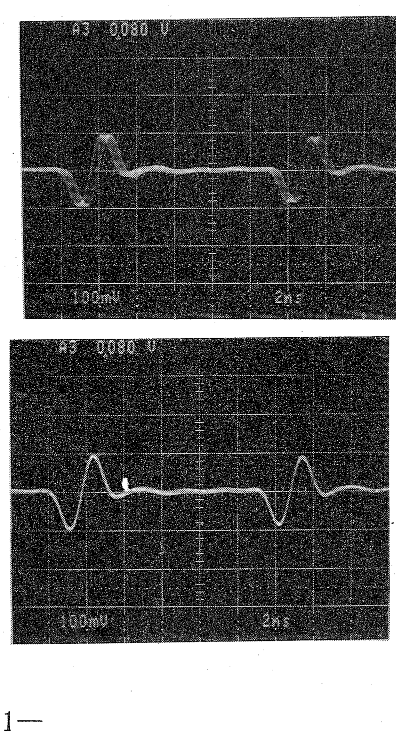


Fig. 3
Synchrotron Oscillation
a: Longitudinal Active Damper off
b: on

FRONT END OF BEAM LINES

Schematic diagram of the beam line is shown in Fig. 4. Horizontal acceptance angle of the front end is 80mrad. 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 10ms and leak rate is 1 Torr l/s. The first pre-mirrors are made of quartz and their surfaces are coated with platinum or gold. At present, they are not cooled.

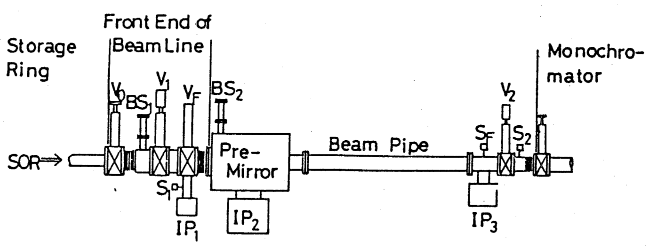


Fig. 4 Schematic diagram of beam line. $V_0$: manual valve. $V_1$ and $V_2$: pneumatic valves. $V_F$: fast closing valve. $BS_1$ and $BS_2$: beam shutters. $S_1$, $S_2$ and $S_F$: vacuum gauges which control $V_1$, $V_2$ and $V_F$, respectively. $IP_1$-$IP_3$: sputter ion pumps.

BEAM LINES AND EQUIPMENTS

The list of beam lines at UVSOR is given in Table 2. They cover the wavelength region from far infrared to soft X-ray. The beam lines BL2A, BL2B2, BL3B and BL8B2 are mainly used by staff of Department of Molecular Assemblies in IMS. The others are mainly for users outside IMS. The UVSOR Facility has been responsible for the construction and the maintainance of these lines.

On BL2A, BL2B2 and BL3B, gas phase experiments have been carried out throughout the year, while BL6A2, BL7A, BL7B, BL8A and BL8B2 have been used primarily for solid state experiments. Recently, especially noteable achievements have been on BL7A, where K edge absorption spectra of light elements were measured with high resolution and also on BL8B2 where angle-resolved photoelectron spectroscopy studies of organic solids had begun. In 1986, two beam lines were opened to users: they are BL3A1, which uses undulator radiation without a monochromator and BL6A1 which exploits the infrared part of the synchrotron radiation using a Martin - Puplett interferometer. In 1987, BL1B with a 1m Seya-Namioka monochromator and BL8B1 with a 2.2m Rowland circle grazing incidence monochromator were opened to users. It was decided to utilize BL5B as a calibration port for plasma diagnostics devices under the direction of the Institute of Plasma Physics, Nagoya University.

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 data buses are both IEEE-488 and CAMAC.

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Table 2 Beam Lines at UVSOR

| Beam Line | Monochromator,Spectrometer | Wavelength Region | Acceptance Angle(mrad) Horiz. | Vert. | Experiment |
|---|---|---|---|---|---|
| BL1B | 1 m Seya-Namioka | 6500-300 A | 60 | 6 | Gas & Solid |
| BL2A | 1 m Seya-Namioka | 4000-300 A | 40 | 6 | Gas |
| BL2B1* | 2 m Grasshopper Grazing Incidence | 600-15 A | 10 | 1.7 | Gas & Solid |
| BL2B2 | 1 m Seya-Namioka | 2000-300 A | 20 | 6 | Gas |
| BL3A1 | None (Filter, Mirror) | | (U) 0.3 | 0.3 | Gas & Solid |
| BL3A2* | 2.2 m Constant Deviation Grazing Incidence | 1000-100 A | 10<br>(U) 0.3 | 4<br>0.3 | Gas & Solid |
| BL3B | 3 m Normal Incidence | 4000-300 A | 20 | 6 | Gas |
| BL5B* | Plane Grating | 2000- 20 A | 10 | 2.2 | Calibration# |
| BL6A1 | Martin-Pupplet | 5 mm-50 μm | 80 | 60 | Solid |
| BL6A2 | Plane Grating | 6500-80 A | 10 | 6 | Solid |
| BL7A | Double Crystal | 15-8 A<br>15-2 A | 2<br>(W) 1 | 0.3<br>0.15 | Solid |
| BL7B | 1 m Seya-Namioka | 6500-300 A | 40 | 8 | Solid |
| BL8A | None (Filter) | | 25 | 8 | Irradiation, User's Instr. |
| BL8B1 | 2.2 m Rowland Circle Grazing Incidence | 440-20 A | 10 | 2 | Solid |
| BL8B2 | Plane Grating | 6500-80 A | 10 | 6 | Solid |

* : under construction. # : Institute of Plasma Physics, Nagoya University.
U : with an undulator. W : with a wiggler.