Recent Progress of the UVSOR Storage Ring

Jun-Ichiro YAMAZAKI, Masahito HOSAKA, Toshio KINOSHITA and Hiroyuki HAMA
UVSOR Facility, Institute for Molecular Science, 38 Nishigo-Naka, Myodaiji, Okazaki 444, Japan

Abstract

The UVSOR electron storage ring at Institute for Molecular Science has been operated for nearly 15 years as a dedicated synchrotron radiation (SR) source. In the fiscal year 1996, approximately 3000 hours was devoted to provide SR, which includes single-bunch operation of 4 weeks. Beam stability and the lifetime have been improved by introducing a double cavity RF system to suppress longitudinal coupled-bunch instability. A free electron laser (FEL) experiment for basic research has also been done on the ring. Because of frequent failures of old devices, many important parts of accelerator system have been replaced and improved in these years.

1 Introduction

The UVSOR storage ring, a light source for the wavelength region from soft X-rays to far-infrared, was constructed at Institute for Molecular Science in 1983 as a 2-nd generation light source. As importance of insertion devices is getting higher, the storage ring has been developed to employ a couple of insertions, and performance of itself has also progressed. Among four dispersion-free straight sections, one is occupied by the beam injection system. Other straight sections are arranged for a conventional transverse undulator (2.5 m-long) widely utilized by many user programs, and for a superconducting wiggler of the wavelength shifter type with 4 T magnetic field [1], which has become to be routinely operated. In addition, an optical klystron employing helical undulators was recently installed to provide polarized photons. The optical klystron is also being used for a basic research work of the storage ring free electron laser (SRFEL) [2].

Table 1 Parameters of the UVSOR Storage Ring

Lattice type	Chasman-Green
Energy	750 MeV
Circumference	53.2 m
Superperiodicity	4
Bending radius	2.2 m
Critical energy	425 eV
Betatron tune	3.16 (horizontal)
	2.64 (vertical)
Momentum compaction α	0.033
Harmonics	16
Main cavity RF frequency	90.115 MHz (nominal)
Main cavity RF voltage	50 kV
Energy spread	0.3 MeV
Natural emittance	115 π nm rad
Beam size at bend	0.39 mm (horizontal)*
	0.27 mm (vertical)*
Bunch Length	170 ps (at zero current)
Beam current	Multi-bunch 240 mA
	Single-bunch 60 mA
Lifetime (multi-bunch)	5 h at 200 mA

* 10 % coupling assumed.

By employing a third harmonic cavity [3], which was commissioned in 1993, the longitudinal coupled-bunch instability is successfully suppressed by introducing the Landau damping, then the beam stability has been greatly improved. Moreover the bunch length of the electron beam is able to be varied by changing the RF phase between the main cavity and the harmonic cavity. It is quite powerful tool to control the optimum bunch length particularly in the SRFEL experiment. However, because of relatively high induced field in the cavity, a complicate operation for tuning angle and power feed is required. Further study for operation of the double RF cavity system is still under way.

Malfunction of devices due to worn-out accelerator system has been severe problem. Most of power supplies for pulse magnets has been replaced recently. In addition power amplifiers for both main RF cavities of a booster synchrotron and the storage ring were switched to all transistor ones. As a consequence of these renewals of devices, the UVSOR

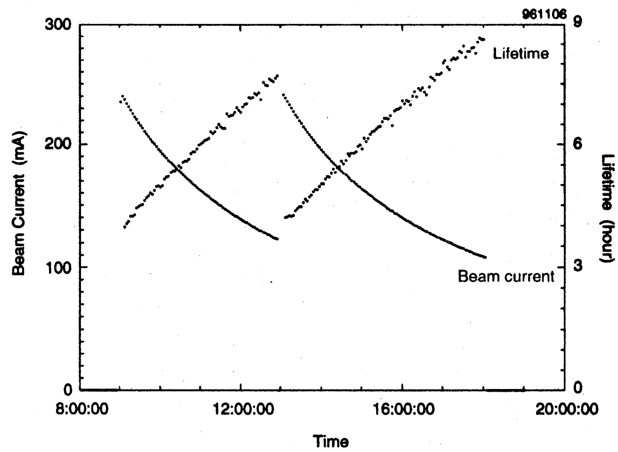

Fig. 1 Typical one-day variations of the beam current and the lifetime at the usual multi-bunch operation.

accelerator complex is continuously working well.

2 Current Status of the UVSOR Storage Ring

Accelerator complex at the UVSOR facility is consisted with a 15 MeV injector linac, a 600 MeV booster synchrotron and a 750 MeV storage ring. Beam injection into the storage ring is usually done twice per day at 9 AM and 1 PM. Repetition rate of the beam acceleration from 15 MeV to 600 MeV on the synchrotron is ~ 3 Hz. The electron beam is ramped up to 750 MeV on the storage ring. Whole procedure of beam injection to store several hundreds mA beam takes only 10 min, so that the user's machine time can be consumed efficiently.

The electron beams at typical initial current of 240 mA with multi-bunch mode and of 60 mA with single-bunch mode are supplied for user experiments in regular operation. The lifetime at the initial current in multi-bunch mode is approximately 5 h by employing the double RF cavity system. Figure 1 shows variations of the beam current and the lifetime with the multi-bunch mode a day.

RF power amplifiers for the acceleration cavities in the storage ring and the synchrotron were also replaced by new ones completely composed of many transistor amplifiers. Each identical unit of transistor amplifier generates power of 700 W maximum. In case of a couple of units are in failure, the whole system can, however, continue to run without any fatal errors. Consequently the maintenance of the system is expected to be easy. Maximum output powers of the RF amplifiers are 20 kW (30 units) and 8 kW (10 units) for the storage ring and the booster synchrotron, respectively.

3 Development of Transverse Resonance Kicker

To improve the beam handling on the storage ring, a transverse resonance kicker (TRK) system has been developed lately. On the UVSOR ring, a partial filling method is used to reduce an effect of the ion-trapping in multi-bunch mode. Electron bunch filling was controlled by selecting the RF bucket using a timing control system for the fast kicker extraction of the booster synchrotron so far. However it was difficult to erase specific bunches so that the transverse beam instability due to ion-trapping has been not completely damped and the purity of single-bunch mode has been not very well. The TRK system generates electromagnetic field with a very short duration less than 3 ps. To avoid distortion of the pulse due to reflection, whole system including electrodes and a vacuum chamber was designed to be matched to the intrinsic impedance of 50 Ω [4]. The short pulse is synchronized with the revolution of a specific bunch, which is, moreover, modulated by the betatron oscillation frequency. Because the electron momentum on the ring is high (750MeV/c), a huge power is required to kick out the bunch at once. Meanwhile, using the TRK system the electron bunch is transversely kicked at each turn, and the amplitude of betatron oscillation grows rapidly even with a relatively low kick power. The electrons finally may touch the wall of vacuum chambers or go out of the dynamic aperture. As a result, for example, the impurity ratio of the single bunch became less than $10^{-4\sim5}$ by sweeping the satellite bunches using the TRK (see Fig. 3).

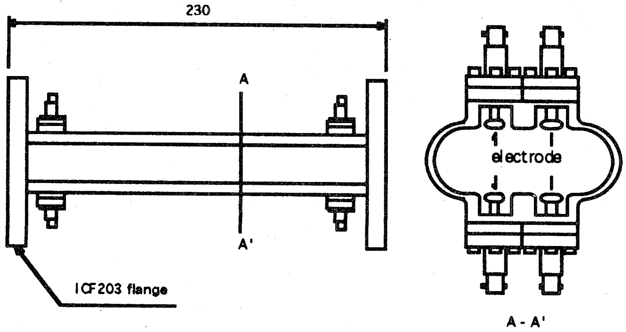

Fig.2 Side view and cross section of the TRK chamber.

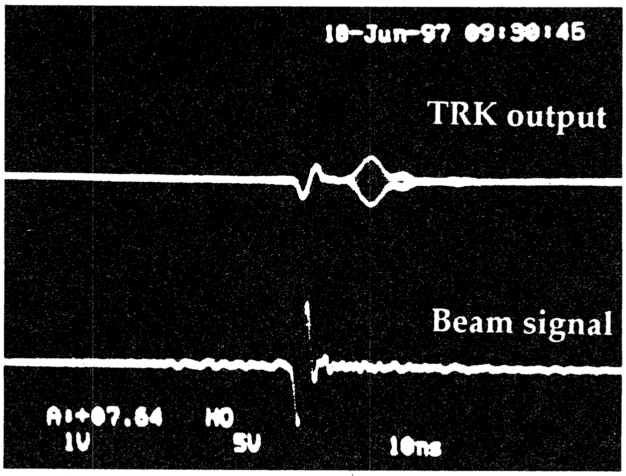

Fig. 3 Satellite bunch sweeping by using TRK applying to a bucket follows the main electron bunch.

4 UV-FEL Oscillation Using Helical Optical Klystron

A helical optical klystron employing the SPring-8 type undulators was installed in 1996 [5]. The permanent magnet array is consisted with three lanes. The vertical and the horizontal magnetic fields are provided by the center lane array and the side lane arrays, respectively. Phase between the center lane and the side lanes can be changed mechanically, so that complete helical with both helicities, ellipsoidal and planar modes of magnetic field are able to be produced. Because the beam chamber is not fully

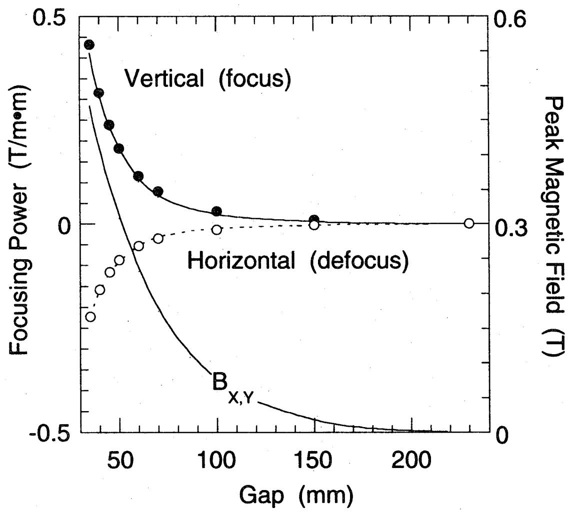

Fig. 4 Measured focusing powers (circles) and calculated ones (solid lines) against the gap length. Peak magnetic field of undulator is also shown

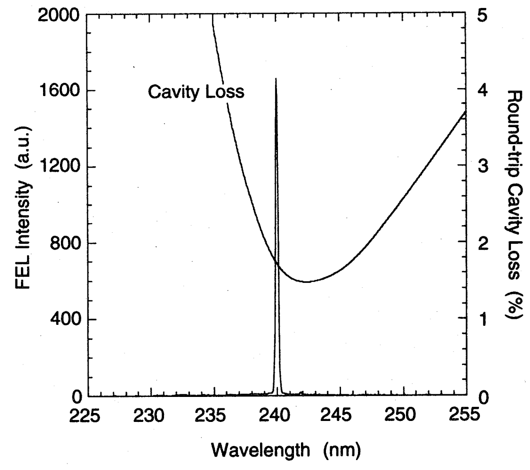

Fig. 5 Measured FEL spectrum around the wavelength region of 240 nm. Round-trip cavity loss is also plotted as a function of the wavelength.

surrounded by the magnet arrays like a conventional helical undulator, an ante-chamber type vacuum pipe containing a NEG pump became to be available and the optical klystron is fully retractable.

Figure 4 shows measured vertical and horizontal focusing power of the UNKO-3 and predicted ones deduced from the calculation of the magnetic field. One can see a good agreement between the calculation and the experiment, and notices the focusing power is very strong. By using additional windings of the quadrupoles, the lattice function can be completely corrected in a gap range down to 55 mm for the beam energy of 600 MeV. The distortion of the beta functions increases up to ± 20 % in a smaller gap less than 40 mm because the correction current for the quadrupoles is insufficient, however we have not observed a serious bad influence for the beam at the such small gap [6].

In the lasing experiments, we have used dielectric HfO_2/SiO_2 multilayers fabricated by an ion-beam sputtering for the cavity mirrors. Number of layers has been optimized to obtain the maximum reflectance, so that the transmittance was rather low. Although photon absorption rate of Hf increases rapidly as the wavelength becomes shorter than ~ 260 nm, we have obtained an FEL oscillation around the shortest wavelength of 240 nm as shown in Fig. 5. Because the band width of the mirror reflectance is very narrow, a region which the FEL wavelength was able to be varied was only from 239 nm to 243 nm .

Acknowledgement

The authors are greatly in debt to Dr. Shiro Takano of SPring-8 who designed the TRK electrodes with complex consideration of impedance matching. It is also a pleasure to appreciates the staff member of the UVSOR facility for their help. These works are partly supported by the special research program of Institute for Molecular Science.

References

[1] E. Nakamura, H. Hama, J. Yamazaki, T. Kinoshita, O. Matsudo, H. Yonehara, T. Kasuga, G. Isoyama and M. Watanabe, J. Elec. Spec. 80 (1996) 421.

[2] S. Takano, H. Hama and G. Isoyama, Nucl. Instr. and Meth. A331 (1993) 20.

[3] K. Tamura, T. Kasuga, M. Tobiyama, H. Hama, G. Isoyama and T. Kinoshita, Jpn. J. Appl. Phys. 33 (1994) 59.

[4] S. Takano, private communication.

[5] S. Kimura, M. Kamada, H. Hama, X.M. Marechal, T. Tanaka and H. Kitamura, J. Elec. Spec. 80 (1996) 437.

[6] H. Hama, K. Kimura, M. Hosaka, J. Yamazaki and T. Kinoshita, Nucl. Instr. and Meth. A, in press.