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RECENT DEVELOPMENTS OF UVSOR-III*

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Abstract

A 750 MeV VUV synchrotron light source, UVSOR, has been operational since 1983. After the major upgrade in 2003 and in 2012, the machine UVSOR-III is now routinely operated with small emittance of 17 nm-rad and six undulators, as the beam current is kept at 300mA with top-up injection. New pulsed sextupole magnet for the beam injection has been under testing. New light source development station for FEL, CSR, CHG, LCG etc. was constructed is being developed. Reconstruction of the optical cavity for the resonator FEL has started.

INTRODUCTION

UVSOR was designed and built early in 1980's as a 2nd generation synchrotron light source in the vacuum ultraviolet range with emittance larger than 100 nm-rad and few insertion devices. The most recent parameters of UVSOR are shown in Table 1. The emittance is one of the smallest among the low energy synchrotron light sources below 1GeV. In addition, totally six undulators are operational in this small storage ring. The beam current is kept at 300mA with the top-up injection scheme. In this paper, we briefly review the upgrade history of UVSOR. Then, we describe recent status of the machine and some results from the recent researches and developments on light source technologies.

Table 1: Basic Parameters of UVSOR-III

Beam Energy	750 MeV
Circumference	53.2 m
Cell Structure	Extended DB
Emittance	17 nm-rad
Energy Spread	5.4E-4
Straight Sections for I.D.	4m x 4 1.5m x 2
Beam Current	300 mA (top-up)
Injector	15 MeV Linac 750MeV Synchrotron

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30 YEARS OF UVSOR

In Dec. 2013, we celebrated the 30 year anniversary of the UVSOR Facility. The recent view of the storage ring is shown in Fig.1. In this section, we will give an overview of the history of the facility focussing on the accelerator upgrades.

Figure 1: Recent view of UVSOR-III storage ring.

UVSOR-I

We shall call the machine UVSOR-I, in the period from the first light in 1983 to the first major upgrade in 2003. It consisted of 4 DBA cells with four 3-m straight sections [1]. Its emittance was 120 - 160 nm-rad, depending on the operating betatron tunes. It has two undulators and a superconducting wiggler [2]. The operation energy of the storage ring was initially 600 MeV and was soon upgraded to 750 MeV. However, the energy of the injector remained at 600 MeV.

During this period, many beam-lines were constructed and commissioned. On the other hand, the basic performance of the storage ring was not changed drastically. The research on free electron laser started in 1980's. A new optical klystron of variable polarization was installed in 1990's [3] and the lasing in the deep UV range was demonstrated [4]. A study on the low-alpha operation was carried out [5]. The 3rd harmonic RF cavity was installed, which was effective to suppress the longitudinal instabilities and to improve the Touschek lifetime [6]. The accelerator control system was upgraded [7].

UVSOR-II

In 1990's, construction of 3rd generation synchrotron light sources started all around the world, and continued in 2000's. To meet the increasing demands for brighter

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VUV radiation in Japan, we proposed an upgrade plan which included modification of the magnetic lattice and installation of undulators [8, 9]. In 2003, the first part of the reconstruction was carried out. All the quadrupoles and sextupoles were replaced with combined function multipoles. Four new short straight sections were created, and short in-vacuum undulators were installed [10]. After this major upgrade, we started to call the machine UVSOR-II. In the middle of the 2000's, we replaced the main RF cavity to improve Touschek lifetime [11]. We replaced the magnet power supplies for the synchrotron and the beam transport line, to realize the full energy injection. Also we reinforced the radiation shielding wall. Soon after, we started the top-up operation [12].

In this period, we installed a femtosecond laser system which led to many research results, such as coherent THz radiation [13, 14, 15, 16], coherent harmonic generation [17, 18, 19] and laser Compton scattering [20, 21]. We also continued researches on the free electron laser [22, 23].

UVSOR-III

Based on the research results using the laser, we started construction of a dedicated source development station under the support by MEXT/JST Quantum Beam Technology Program. We moved the beam injection point from a 4m straight section to a 1.5m section. An optical klystron type undulator was installed at the 4-m section.

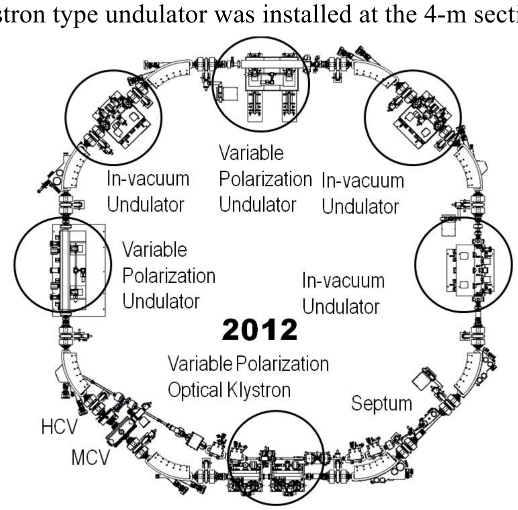

Figure 2: Configuration of UVSOR-III [24].

Soon after this, the second major upgrade was funded and was carried out in 2012. All the 30 year old bending magnets were replaced with combined function ones to reduce the emittance [24]. This enables us to remove one family of the quadrupoles in future when we need more spaces in the ring. One in-vacuum undulator was installed at a short straight section which was the last free space. After this upgrade, we started to call the machine UVSOR-III (Fig. 2). In 2014, after the construction of the new source development station, the undulator that had been parasitically used for the free electron laser [3] was remodelled to a variable polarization one with shorter period length, which would dedicatedly provide brighter VUV radiation to a PES beam-line.

In Fig. 3, the history of the synchrotron radiation beam-lines at the UVSOR facility is shown. In 1980's and 1990's, we constructed many beam-lines but most of them utilized the bending radiation. In 2000's, we started the scrap-and-build. The total number of the beam-lines decreased but the number of undulator beam-lines increased in accordance with the accelerator upgrades.

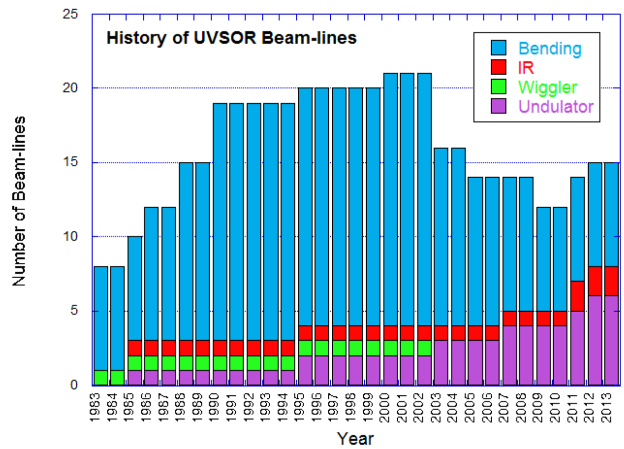

Figure 3: History of UVSOR beam-lines.

RECENT MACHINE STATUS

In these years, UVSOR-III is operated for about 40 weeks in a year. Mondays are dedicated to the machine studies. From Tuesday to Friday, the ring is operated for users. The operation time is from 9am to 9pm, but, on Thursday, the machine is operated all night long. Thus, the total beam time for users in a week is 60 hours. So far, we have found some problems as follows and continue machine studies to solve them.

In the UVSOR-III optics, we cannot close the local bump orbit under the present capability of the kicker dipoles. Thus, the movement of the stored beam during the injection is inevitable, which can affect the users experiments during the top-up operation. We have tried an injection scheme with a pulsed sextupole [25]. We have succeeded in injecting the beam with much smaller perturbation to the stored beam, however the injection efficiency was still low, about 25%. This should be improved to 50% or higher for the routine operation.

Since the start of the operation of UVSOR-III, we have observed sudden beam losses by a few mA to a few 10 mA or even more which happen several times a day. In many cases, we observed beam blow-ups during the losses. The frequency seems gradually decreasing but, even three year after the upgrade to UVSOR-III, we still observe them.

UVSOR-III has six undulators. One is dedicated to the source development studies and other five are routinely operated for users. Two of them are APPLE-II type polarization variable undulators and three are in-vacuum

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short period ones. The dipole errors of the undulators are corrected locally by correction dipoles. The quadrupole effects are also corrected by the additional windings on the neighbouring quadrupoles locally. However, we observe that the injection efficiency varies depending on the gap values of the undulators. In some cases, we observed interference between undulators.

We had a few hardware troubles in these years. A vacuum leakage happened at the 3rd harmonic cavity. It took place in a cooling water channel at the nose cone. We succeeded in stopping it temporally with sealant. We have constructed a new nose cone and wait for the next chance to replace it.

A few years ago, we discovered a significant RF noise leaking from a ceramics beam duct at a kicker dipole. We have finally removed the duct during the spring shut down in 2015 and have found that the electric conductivity between the flanges was lost. The Au coating inside was damaged for some reason. Fortunately, we had a spare and have replaced it.

RECENT RESEARCHES AND DEVELOPMENTS

In this section, we briefly introduce the recent research activities at UVSOR-III. The details are described in the literatures.

At UVSOR-II and III, we have observed intense terahertz emission in the single bunch operation with high beam current, which was presumably due to the micro-bunching instability [26, 27]. Thanks to the relatively large bunch length and an ultra-fast THz detector, we succeeded in observing the spatio-temporal behaviour of the micro-bunching instability for the first time [28].

At the new source development station, we have started reconstruction of the optical cavity for the resonator free electron laser, which was removed from the ring a few years ago (Fig. 4). Also, we have started construction of a dedicated beam-line which utilizes the coherent deep UV and VUV radiation produced at the station.

For the future project of the facility, we carried out a feasibility study on the high repetition rate VUV free electron laser based on a superconducting linear accelerator along with development of superconducting electron gun in collaboration with KEK [29].

We are developing spin-polarized electron guns, towards spin resolved inverse photoelectron spectroscopy in collaboration with Nagoya U. [30], which would be a complementary technology to PES.

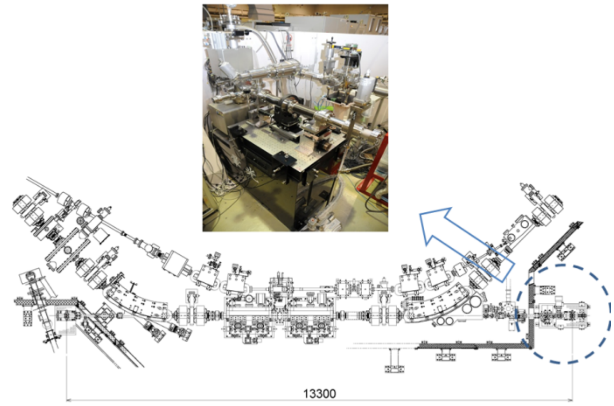

Figure 4: Optical cavity under reconstruction at UVSOR-III BL1U.

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