UPGRADE OF MAIN RF CAVITY IN UVSOR-II ELECTRON STORAGE RING

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Abstract

Main RF accelerating cavity in UVSOR-II electron storage ring was upgraded at the spring of 2005. The new RF cavity has the same RF frequency (90.1MHz) and is powered by the same transmitter (max. 20kW) as the previous cavity, however, the new cavity can generate the RF voltage of up to 150kV that is about 3 times higher than the previous one. Because momentum acceptance in UVSOR-II is determined by the RF accelerating voltage, Touschek beam lifetime has become easy due to the upgrade. Just after the installation of the cavity, UVSOR-II has switched daily users runs from 60nm-rad to 27nm-rad because sufficient beam lifetime can be kept even in the low-emittance operation.

INTRODUCTION

The improvement of the UVSOR electron storage ring[1] has been finished successfully at the spring of 2003, and the transverse emittance of the electron beam has been drastically improved from 165nm-rad to 60nm-rad(achromatic optics) and/or 27 nm-rad(chromatic optics). Table 1 shows basic parameters of UVSOR-I (before improvement) and UVSOR-II(after improvement). Users runs have been re-started from September 2003, and until the spring of 2005 UVSOR-II has been operated in 60nm-rad mode for daily users runs, whereas immediate shift of the operating condition from 60nm-rad to 27nm-rad mode has also been strongly requested. In such a low-emittance condition, however, it was difficult to keep sufficient Touschek beam lifetime unless momentum acceptance of the storage ring was improved. Because the momentum acceptance in UVSOR-II is determined by the RF accelerating voltage, it is possible to improve Touschek beam lifetime by increasing the RF voltage.

To improve the condition of the beam lifetime, we have build a new RF accelerating cavity. The new cavity can generate RF voltage up to 150kV without changing RF transmitter, whereas previous cavity has been operated the RF voltage of 55kV with the same transmitter. The cavity has been installed in a short straight section in UVSOR-II at the spring of 2005 and soon has achieved designed RF voltage of 150kV. Because of the improvement, the operating mode for daily users runs has been switched from 60nm-rad to 27nm-rad just after the installation of the new RF cavity.

Table 1: Basic parameters of UVSOR-I and II.

	UVSOR-I	UVSOR-II
Electron Energy	750MeV	750MeV
Circumference	53.2m	53.2m
Maximum Beam Current	500mA	500mA
Number of Super-periods	4	4
Straight Sections	3m$\times$4	3m$\times$4
Emittance	165nm-rad	60/27nm-rad
Energy Spread	4.2×10^{-4}	4.2×10^{-4}
Momentum Compaction	0.026	0.026/0.028

DESIGN OF NEW RF CAVITY

UVSOR-II electron storage ring has two RF accelerating cavity; main RF cavity that has operating frequency of 90.1MHz and is mainly used for accelerating electron beam, and third order harmonic cavity[2, 3] that is used for modulating longitudinal density of the electron bunch. In the improvement we have renewed the main RF accelerating cavity. Table 2 shows basic parameters of previous main RF cavity. Because shunt impedance of the previous cavity was only 1MΩ it was difficult to improve RF accelerating voltage sufficiently; Figure 1 shows dependence of momentum acceptance on the RF accelerating voltage in UVSOR-II. As seen in the figure, the momentum acceptance was less than 1% (0.8%) with the previous RF cavity voltage. In case of UVSOR-II, the momentum acceptance can increase if the RF voltage increases, however, because the RF transmitter in UVSOR-II has maximum output power of 20kW it was difficult to improve the momentum acceptance unless the RF cavity or the transmitter was changed. Another reason for the limitation of the RF voltage was a temperature problem; when the input power increased, the tuning condition of the cavity changed easily. This seemed to be because the temperature control system was not able to cool sufficiently the power loss in the cavity; the shunt impedance was not necessarily large and the clad steel material made the temperature control difficult.

The aim of the improvement was to increase the beam lifetime by increasing accelerating voltage and easing Touschek effect. Figure 2 shows calculation of change in Touschek beam lifetime on the accelerating voltage at 60nm-rad (achromatic optics) and 27nm-rad (chromatic optics) when multi bunch (12bunches) operation with 500mA. At the RF voltage with the previous RF cavity, Iτ product for

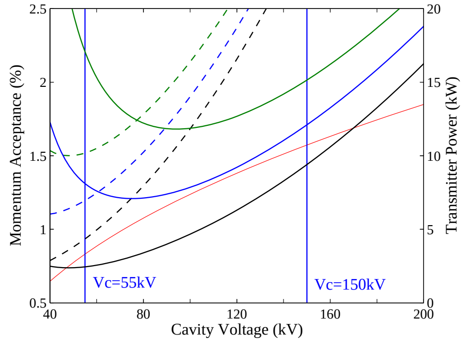

Figure 1: Calculation of dependence of momentum acceptance on cavity voltage in UVSOR-II (red curve). Broken and solid curves correspond to RF transmitter output with the cavity voltage for previous and present RF cavities. Green, blue and black curves correspond to the transmitter output when beam current is 500, 300 and 100 mA.

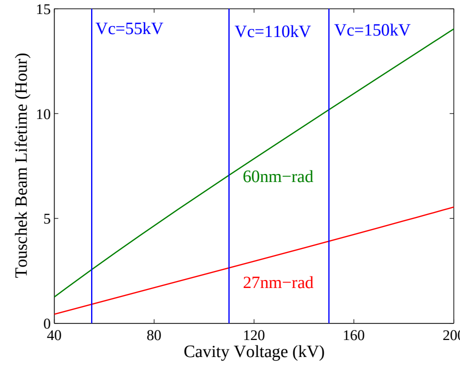

Figure 2: Calculation of dependence of Touschek beam lifetime on the cavity voltage for 60/27 nm-rad operation in multi bunch (12bunches) operation with the beam current of 500mA. The x-y coupling of 3% and bunch lengthening effect because of the harmonic cavity are assumed in the calculation.

Touschek beam lifetime is 1650 mA·Hour in the achromatic optics and the x-y coupling of 3%. To keep comparable Touschek beam lifetime under chromatic beam optics, it is necessary to increase the RF voltage higher than 110kV, as seen in the figure. To improve the RF voltage

Table 2: Basic parameters of previous/present main RF cavity.

	Previous	Present
Frequency	90.1 MHz	90.1 MHz
Cavity voltage	55 kV	150 kV
Shunt impedance	1 MΩ	2.45 MΩ
Unloaded Q	8370	20300
Coupling	1.75	1.34
Structure	Re-entrant×1	Re-entrant×1
Inner diameter	1000 mm	964 mm
Bore radius	50 mm	55 mm
Material	SUS+Cu	Cu(OFHC)
Tuner	Plunger×1	Plunger×2

we have built a new main RF cavity[4]. Figure 3 shows a drawing of the new RF cavity. For comparison, basic parameters of the new cavity are also shown in Table 2. Basic design of the new cavity is unchanged compared to the previous one, however, the shunt impedance and unloaded quality factor become 2 and 2.5 times larger; it is speculated that the improvement is caused by improvement of RF-contact between the cavity and nose cones. Required transmitter output for the cavity voltage for the new cavity is also shown in Fig. 1.

The previous cavity was made from clad steel plates (SUS+Cu), whereas the new cavity is made from OFHC; that makes temperature control to be easier. SUS materials are partly used as mechanical supports in out-of-vacuum surfaces. The new cavity has 2 movable plunger-type tuners; one is used for automatic tuning control and the other is usually fixed. These tuners have enough tuning range for operation of the cavity (full width of 400 kHz for each tuner). Input coupler for previous cavity was air-cooled,whereas new coupler has water-cooling channel to cool especially ceramic window part. To prevent multipactoring phenomenon at the ceramic window of the coupler, TiN coating has been performed on the window surface.

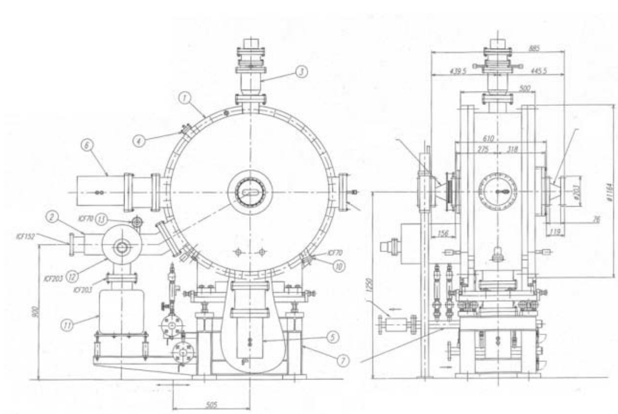

Figure 3: Drawing of the new main RF cavity.

OPERATIONAL EXPERIENCE OF NEW RF CAVITY

At the spring of 2005, we have installed the new RF cavity in UVSOR-II. Figure 4 shows a photograph just after installation of the cavity. Previous RF cavity was settled in a long straight section, however, to make full use of the long straight section for insertion devices the new cavity has been installed in a short straight section in narrow vacant space of 885mm. High-power commissioning went smoothly, and designed RF voltage of 150kV was achieved easily. The cavity has one sputtering ion pump(400l/sec.)

and one titanium sublimation pump(2400l/sec.), however, initially the vacuum condition of the cavity was not sufficiently good; the typical vacuum pressure in the cavity was 4×10^{-7} Pa when the RF was off whereas the averaged pressure in other sections in the ring was less than 3×10^{-8} Pa when the beam was off. To improve the vacuum condition another titanium sublimation pump was added to the cavity; consequently the pressure has improved in less than 1×10^{-7} Pa when the RF is off at present.

Figure 5 shows change in the Iτ product defined by the multiplication of the beam current and the beam lifetime on the RF voltage in the low-emittance mode (27nm-rad). As seen in the figure, the product at 110/150kV has improved about twice/three times as much as that in around the previous cavity voltage of 55kV. Because of the improvement, the operating condition for users runs has been shifted from 60nm-rad to 27nm-rad after the installation of the present RF cavity. At present, typical Iτ product in daily users run (multi bunch, 27nm-rad, 350mA) is about 1200 mA-Hour that is almost the same as that in previous operation condition (60nm-rad, 55kV) though present RF voltage has been settled in 110kV.

Because of the improvement of the RF voltage, not only the improvement of the beam lifetime but also compression of the bunch length is expected. Figure 6 shows experimental results and calculations of natural bunch length in 600/750 MeV under single-bunch operation. The natural bunch length has become 63/90 ps in 600/750 MeV when the RF voltage is 150kV; that corresponds to less than 70% in the previous cavity operation. The compression of the longitudinal bunch size can contribute improvement of laser gain in storage ring free electron laser[5].

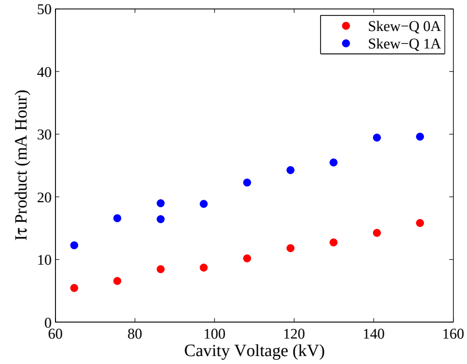

Figure 5: Change in Iτ product on the cavity voltage in the new RF cavity in single-bunch operation. During the measurement harmonic cavity was detuned; no artificial bunch lengthening condition.

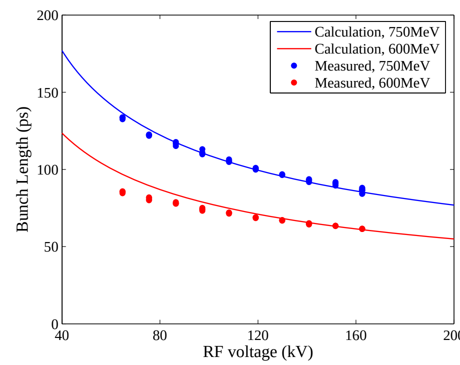

Figure 6: Natural bunch length in various RF voltages. The measurement was performed in low beam current (<0.5mA) and detuned harmonic cavity.

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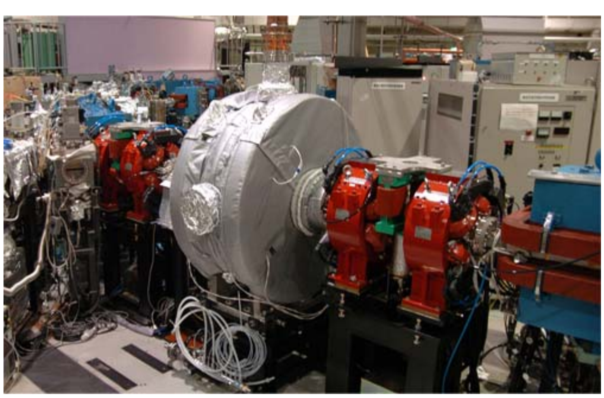

Figure 4: Photograph of new cavity covered with jacket heaters. A view from outside the storage ring.

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