THE NEW 118 MHz NORMAL CONDUCTING RF CAVITY FOR SIAM PHOTON SOURCE AT SLRI

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Abstract

The Siam Photon Source (SPS) is the 1.2 GeV second generation light source in Thailand. It is managed by the Synchrotron Light Research Institute (SLRI). The institute is located inside the campus of Suranaree University of Technology (SUT), which is approximately 20 km from the city of Nakhon Ratchasima (or normally called Korat). Korat is 250 km north-east of Bangkok. Two insertion devices (IDs) have been installed in the SPS storage ring during June to August 2013. These IDs require additional electrical field energy from RF cavity to compensate electron energy loss in the storage ring. The existing RF cavity has been pushed to its maximum capability and the new RF cavity is in the procurement process. The design and study of the new RF cavity will be presented. Electromagnetic fields of the cavity are studied together with the effects to electron beam instabilities.

INTRODUCTION

The SPS is an electron accelerator complex consisting of a 40 MeV linear accelerator (LINAC), a 1 GeV booster synchrotron (SYN) and a 1.2 GeV electron storage ring (STR). The 40 MeV electrons from LINAC are transported by the low energy beam transport line (LBT) to the SYN and accelerated to 1 GeV. The 1 GeV electrons are transported by the high energy beam transport line (HBT) to the STR and further accelerated to 1.2 GeV. The accelerator complex is illustrated in Fig. 1 and the STR specifications are listed in Table 1.

Since the energy of the SYN is only 1.0 GeV, the energy of the beam needs to be ramped up to 1.2 GeV in the STR at each injection. The development activities to upgrade the SPS booster energy to 1.2 GeV are currently ongoing.

Previously, there is only the U60 permanent magnet planar undulator installed in the ring. The existing 118 MHz RF cavity is capable of compensating the electron beam energy loss. During June to August 2013 two IDs, a 2.4 Tesla permanent magnet wiggler (PMW) and a 6.5 Tesla superconducting magnet wavelength shifter (WLS), were installed in the ring to produce higher energy x-rays for SLRI users [1, 2]. These IDs require additional energy from RF cavity, which has been pushed to its maximum capability. The new RF cavity is a necessity.

This paper is organised such that the cavity design is described in the next section. The following section presents the electromagnetic properties of the cavities and the effect to the beam stability. Thereafter the up to date status of the new system is reported. Some concluding remarks are presented in the final section.

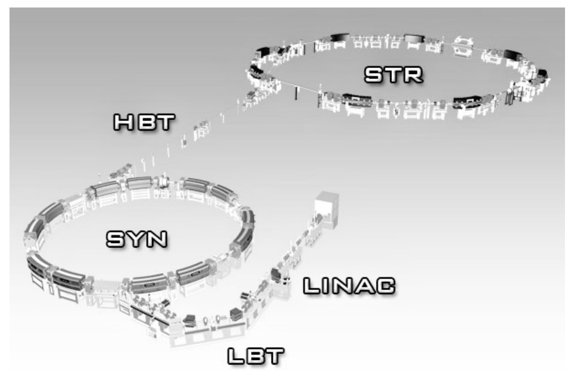

Figure 1: SPS accelerator complex.

Table 1: SPS Storage Ring Specifications

Parameter	Value
Energy	1.2 GeV
Store current	150 mA
Natural emittance	41 nm-rad
Lifetime @ 100 mA	10 hours
Circumference	81.3 m
Revolution time	271.2 ns
Bending radius	2.78 m
Betatron tune horizontal, vertical	4.75, 2.82
Energy loss per turn (all IDs)	82 keV
RF frequency	118 MHz
Harmonic number	32
Bunch length	49.5 mm

CAVITY DESIGN

Present Cavity

The present RF cavity is a normal conducting cylindrical shape. It has a large nose cones, which are separated by a small gap of 23 mm, and has the non-cylindrical shape of beam duct. The maximum gap voltage it can handle is 125 kV. This is limited by the copper loss of cavity surface. It has been trained to safely operate at 5 kW of copper loss. The physical cavity and the one half of the cylindrical symmetric profile are illustrated in Fig. 2.

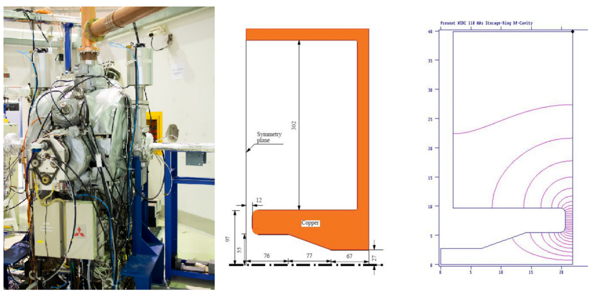

Figure 2: Present RF cavity of the storage ring.

New Cavity

The new RF cavity was designed based on the MAX-IV RF cavity [3].The MAX-IV RF cavity is of normal conducting, entire copper, capacity loaded type. It has the resonant frequency of 100 MHz. This frequency is closed to 118 MHz of the SPS RF system. The decision was made based on the limited budget for the new system and the MAX-IV RF cavity prototype has been qualified for the production. The slightly change in dimensions do not need to build another prototype for testing. This helps saving time and budget.

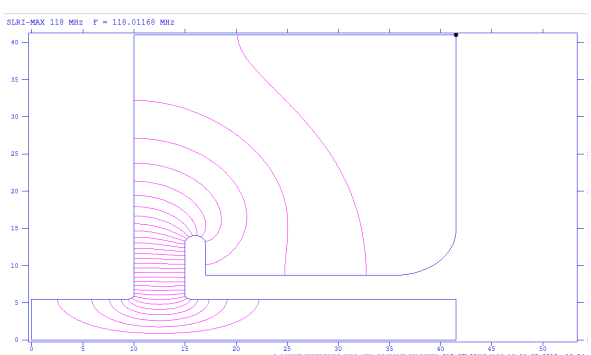

Figure 3: Superfish geometry of the new cavity.

The cavity is design according to MAX-IV 100 MHz storage ring RF cavity. The resonant frequency will be changed to 118 MHz according to the modification of cavity dimensions, which can be changed only a few dimensions. The cavity length and the inner rod diameter is kept the same dimensions as for the MAX-IV cavity. The 118 MHz resonant frequency can be reached by changing the capacity plate size. The cavity will have an acceleration gap of 5 cm, and dimensions of the inner profile, modelled in Superfish [4], described in Fig. 3. The cavity should withstand more than 30 kW of Cu losses, giving a peak acceleration voltage of 300 kV. The fundamental properties of the new cavity is listed together with the present cavity [5, 6] in Table 2.

Table 2: Properties of RF Cavities

Properties	Present cavity	New cavity
Resonant frequency (MHz)	118	118
Unloaded quality factor (Q_0)	24000	22000
R/Q [Ω]	174	138
Shunt impedance (R_s=V^2/P) [MΩ]	4.2	3.0
Measured R_s	2.7	2.6
Acceleration gap voltage [kV]	125	300

BEAM INSTABILITY

The electromagnetic fields properties of the new RF cavity were studied using a computer program COMSOL [7] on a high computing Sida cluster of PSU grid centre [8]. The higher order modes (HOM) excited in this cavity are obtained and theirs R/Q property is calculated.

The excitation of multibunch instabilities from the RF cavity in a storage ring can be studied from a cavity impedance spectrum of all HOMs. It is represented by the threshold impedance, Z^{th}, which can be obtained from

$$Z_L^{th} = \frac{1}{N_c}\frac{1}{f_{L,HOM}}\frac{2E_0Q_s}{I_b\alpha\tau_s}, \qquad (1)$$

$$Z_{x,y}^{th} = \frac{1}{N_c}\frac{2E_0}{f_{rev}I_b\beta_{x,y}\tau_{x,y}} \qquad (2)$$

for the longitudinal and transverse case, respectively [9]. Where N_c is the number of cavities, E_0 is the beam energy, I_b is an average beam current, Q_s is the synchrotron tune, α is the momentum compaction, $f_{L,HOM}$ is the longitudinal HOM frequency, f_{rev} is the revolution frequency, $\tau_{x,y,s}$ is the damping times, and $\beta_{x,y}$ is the beta function at the cavity. The threshold impedances of the SPS storage ring have been calculated and plotted together with the HOM impedances of the new and present cavity in Fig. 4 and Fig. 5 for the longitudinal and transverse case, respectively. The threshold impedances are calculated at 150 mA electron beam of 1.2 GeV energy.

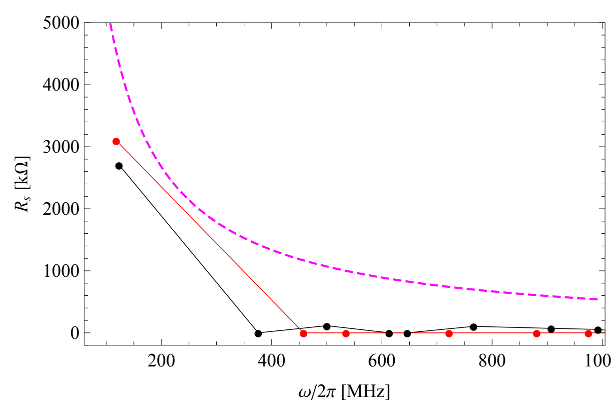

Figure 4: The longitudinal impedance spectra of the present (black) and new (red) cavity and the impedance thresholds (dotted line).

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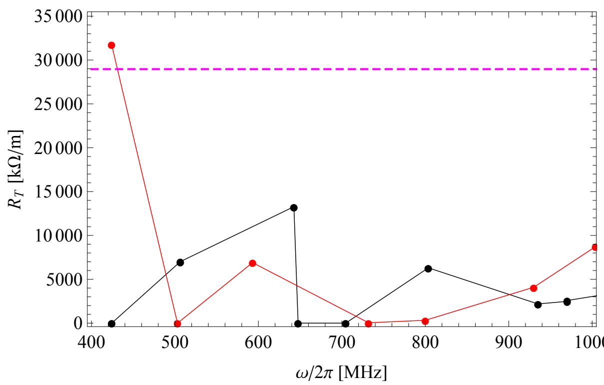

Figure 5: The transverse impedance spectra of the present (black) and new (red) cavity and the impedance thresholds (dotted line).

The highest longitudinal HOM spectra in Fig. 4 is definitely the fundamental mode for accelerating the beam, which is 118 MHz. Form these spectra, The SPS storage ring can be operated without being affected by longitudinal multibunch oscillations. In contrast to the longitudinal case, the transverse multibunch instabilities may still affect the operation of the storage ring. The limiting mode is the first dipole frequency of the new cavity, which can be suppressed by using a proper designed HOM coupler. This coupler is being designed by MAX-lab [3].

THE STATUS UPDATE

The new RF system has been sectioned into three main parts; RF cavity, high power RF amplifier, and low level RF system. The new cavity design is finalised and the fabrication contract will be signed within June 2014 with Research Instruments GmbH (Germany), the same company that build the MAX-IV cavity. The delivery is expected to be one and half year after the manufacturing drawing is approved.

The maximum output of the high power RF amplifier required for this upgrade is 80 kW. This is calculated from an electron beam of 150 mA at 1.2 GeV. The energy loss per turn from a synchrotron radiation is foreseen to be 100 keV/turn according to all IDs that will be installed in the ring. The 15 kW of power will transfer to electron beam and the remaining power will be dissipated at the cavity in order to maintain the accelerating gap voltage of 300 kV. This high power amplifier will utilise the solid state amplifier technology for a design. The specification of amplifier is finalised. The procurement is in progress and is expected to finish no later than July 2014. The delivery time is approximately one year after the design is approved.

The low level RF (LLRF) system is an essential part of the system. It controls the operation of the system by regulating the amplitude and phase of the RF field, from the high power amplifier, and resonant frequency of the cavity to compensate for transient beam loading and temperature variations. A digital LLRF (DLLRF) system will be utilised for the new RF system due to higher flexibility than an analog system. The existing LLRF is a DLLRF, which will be easy for synchronizing the two system in the future if there is a requirement of instantaneously operate two cavities. The procurement is done and the delivery will be the beginning of 2015.

CONCLUDING REMARKS

It has been shown that the new RF cavity is a necessity for the SPS in order to provide a hard x-rays for users. The new cavity was designed based on the MAX-IV RF cavity. This cavity will provide maximum accelerating gap voltage of 300 kV, which is sufficient to compensate beam energy loss 100 keV/turn of 150 mA electron beam at 1.2 GeV energy. The cavity needs a proper designed HOM coupler to suppress the transverse multibunch instabilities. This coupler is in the design process.

The new RF system will be ready for operating within two year, mid of 2016. The new cavity will be operated as the main RF system for the SPS storage ring, while the existing RF system will remain in the ring as the backup system. In the next phase, these two system will run in synchronize for giving a higher RF energy acceptance of the ring and a higher beam lifetime.

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REFERENCES

[1] P. Sudmuang et al., “Commissioning of the 2.4T Multipole Wiggler and the 6.5T Superconducting Wavelength Shifter at the SIAM Photon Source”, TUPRO068, IPAC’14, to be published.

[2] S. Srichan et al., “Operation of SLRI Cryogenic System for a 6.5 T Superconducting Wavelength Shifter”, WEPRI113, IPAC’14, to be published.

[3] Å. Andersson et al., “The 100 MHz RF System for the MAX IV Storage Rings”, MOPC051, IPAC’11.

[4] K. Halbach and R. F. Holsinger, "SUPERFISH - A Computer Program for Evaluation of RF Cavities with Cylindrical Symmetry", Particle Accelerators 7 (1976) 213-222.

[5] K. Hass et al., “Characterization and Conditioning of RF Systems of the Siam Photon Source”, WEAM05, APAC’01.

[6] Y. Yamamoto et al., “Performance of the 1 GeV Electron Storage Ring for the Synchrotron Radiation Source at SORTEC”, EPAC’92.

[7] COMSOL Multiphysics Software; website: http://www.comsol.com.

[8] PSU Grid Centre Thailand; website: http://www.psu-grid.psu.ac.th/

[9] F. Marhauser et al., “HOM Damped 500 MHz Cavity Design for 3rd Generation SR Sources”, MPPH033, PAC’01.