DESIGN OF A THIRD HARMONIC LANDAU CAVITY FOR THE SRRC STORAGE RING

Ch. Wang, L.H. Chang, T.T.Yang, R.H. Tzeng, M.C. Lin, W.K. Lau, C.C. Kuo
Synchrotron Radiation Research Center, Hsinchu 300, Taiwan

Abstract

We present here our design of the SRRC third-harmonic Landau cavity to be operated on the first stage in a passive mode for bunch lengthening so as to increase the Touschek life-time. Its implementation will also be helpful for suppression of the longitudinal coupled-bunch instabilities observed in the storage ring of SRRC. The cavity profile was optimized with the 2D code URMEL with the following criteria: (1) maximization of the shunt impedance; (2)minimization of the maximal power flow density on the cavity surface; (3) feasibility of the mechanical constructions. A prototype is now under construction.

1 INTRODUCTION

The storage ring of SRRC, as one of the third generation synchrotron light sources, has routinely operated at 1.3-1.5 GeV since 1993. The beam current lifetime is about 5 hours at 200 mA when the 1.8 Tesla wiggler and the transverse feedback system are on. Such short beam life-time is mainly limited by the Touschek scattering[1]. This limitation can be released by the implementation of a Landau cavity[2], cooperated with the 500 MHz storage ring main RF cavities, to provide a flat profile of the accelerating gap voltage. It can lengthen the bunch and therefore increase the Touschek life-time. Moreover, the Landau damping can be enhanced with Landau cavity. This will be helpful for the suppression of the longitudinal coupled-bunch instabilities observed in the storage ring of SRRC. Here, we present our design of the SRRC third harmonic Landau cavity. A prototype is being constructed.

2 DESIGN CONSIDERATIONS

The SRRC Landau cavity will be operated in the third harmonic after we considered among the following factors: the percentage of bunch lengthening[3], the feasibility of cooling capability[4], the constraint on the cavity length (for available length of 260 mm), and the availability of the RF source for active operation in the future. The cavity profile was optimized with the 2D code URMEL[5] by the maximization of the shunt impedance R_s as well as by the minimization of the maximal power flow density p_{max} on the cavity surface subject to the feasibility of the mechanical constructions. We used the definition of shunt impedance $R_s = V_c^2/2P_c$. Here P_c is the power dissipated on the cavity surface; V_c is the effective voltage seen by the electron beam as it travels through the cavity gap, i.e., the gap voltage. The power flow density p_{sur}, in terms of Watt/m^2, is given by $p_{sur} = \frac{1}{2} R_{sur} H_{tan}^2$, where R_{sur} is the surface resistivity expressed as $R_{sur} = \sqrt{\omega\mu/2\sigma}$ and is 0.0101Ω for the oxygen-free copper (OFC) at 1498.98 MHz at 27^{o}C.

2.1 Maximization of the shunt impedance: The optimization of the cavity profiles began from a pill-box cavity with a beam pipe radius of 40 mm. The SRRC standard aluminum vacuum chamber has an elliptical cross-section with a horizontal full axis of 2x40 mm as well as vertical full axis of 2x19 mm. The shunt-impedance R_s is inverse proportional to the radius of the cavity beam pipe. Moreover, the larger the beam pipe radius, the longer the copper beam pipe is to be required to minimize the reduction of cavity shunt impedance due to field penetration in the aluminum vacuum chamber. A neck with 60 mm diameter for the Landau cavity was then selected in order to compromise between the acceptance reduction and the shunt impedance increment.

A taper of 65 mm was selected for smooth transition of the beam pipe cross-section from a circular one (the neck) with radius of 30 mm to the SRRC standard elliptical vacuum chamber. Such taper has a slope similar to that of the wiggler chamber, and its contribution to the broad-band impedance can be ignored, based on our wiggler experience. With such design, not only the constraint of the available cavity length is fulfilled, but also the fundamental mode of the Landau cavity is fully concentrated in the available longitudinal length of 260 mm.

For simplicity, we assumed that the cavity has a round beam pipe with diameter varied from 60 mm to 80 mm in our 2D modeling. Two optimized cavity profiles are finally available: bell-shape one with and without nose-cone, as shown in Fig. 1 and 2.

The fundamental frequency of the Landau cavity was adjusted to be closed to three times of the storage ring accelerating frequency, i.e., 499.660-499.666 MHz, by slight variation of the cavity height. The profile of the cavity shape with nose-cone shows a decrease of the resonance frequency of the TM$_{010}$-like fundamental modes. An increment of the shunt impedance of 15% is achieved for the cavity with nose-cone. A simple bell-shape cavity was selected for our application because technicalwise it is more or less easier to construct.

As mentioned above, the cavity taper sections have a full 3D structure, as shown in Fig. 3, which was modeled by the 3D code SOPRANO/OPERA[6]. Because the cavity higher order modes are beyond the cut-off frequency of

0-7803-4376-X/98/$10.00

Table 1: Calculated results for the proposed cavities with and without nose-cone. The maximal surface power flow density $p_{sur,max}$ and total dissipated power P_c are at the gap voltage of 250 kV. 3D results for the cavity without nose cone calculated by the code SOPRANO are shows a good agreement with the 2D URMEL results. The simplification of the elliptical taper section (3D-e) by a circular taper section (3D-c) seems to be reasonable.

nose cone	freq [MHz]	Rs [MΩ]	$p_{sur,max}$ [w/cm^2]	P_c [kW]
with	1499.88	1.62	41.50	19.32
without	1499.78	1.41	36.15	22.22
(3D-c)	1504.76	1.37	37.95	22.81
(3D-e)	1504.01	1.38	37.45	22.58

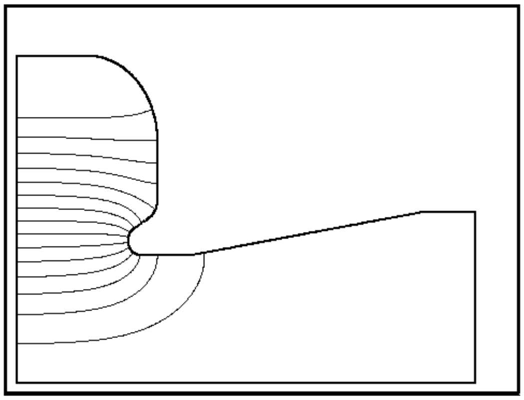

Figure 1: The optimized profile of a 1.5 GHz Landau cavity (with nose-cone). The field pattern of the TM$_{010}$-like mode is calculated by the 2D code URMEL.

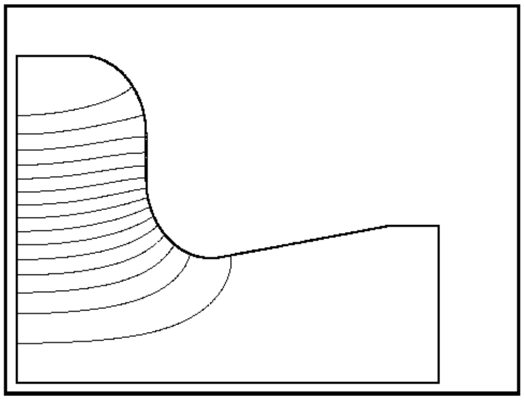

Figure 2: The optimized profile of a 1.5 GHz Landau cavity (without nose cone). The field pattern of the TM$_{010}$-like mode calculated by the 2D code URMEL is given.

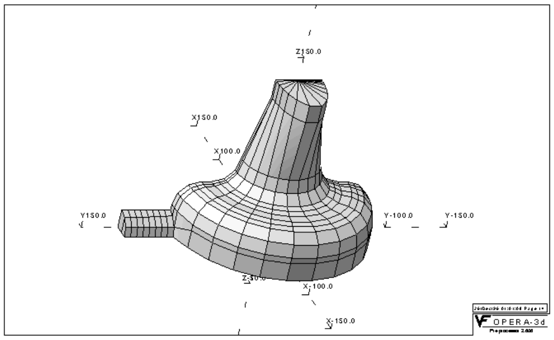

Figure 3: A 3D schematic drawing for the 1.5 GHz Landau cavity

the SRRC standard vacuum chamber, it HOM effects on the beam dynamics may be neglected. In Table 1, the calculated results for the proposed cavities are listed.

2.2 Mechanical tuners: The tuning range should be large enough to compensate the following factors: the frequency shift due to the modeling uncertainty, mechanical tolerance, cavity temperature variation, structure deformation from the vacuum pressure, 3D structure beam pipe, coupling network, pick-up probes, etc. On the other hand, the tuning resolution should be fine enough for the selection of the optimal cavity tuning angle so as to optimize the bunch lengthening percentage. Therefore, two cylindrical mechanical tuners will be implemented, as shown in Fig. 3. For simplicity of numerical modeling, only one tuner was modeled. One of the tuners will be driven by the micro-stepping motor, and the other is adjusted manually. The motorized tuner will have a small diameter such that the tuning resolution can be improved in a range of 2x500 kHz. The other tuner will have a larger diameter to guarantee a reasonable tuning range for different modes of operation.

The 2D code URMEL was first applied for a rough estimation of the required tuner diameters, in which the cylindrical tuner was assumed in the simulation with a ring disk of same volume. However, the 3D code predicts that as the tuner pulls out from the cavity surface, its effects on the frequency shift decay quickly. The modeling uncertainty will be compared with the measured data later, and the tuner final dimensions will be directly determined by the cold test of the prototype for the practical reasons. It is expected to be no fatal consequence by simplifying the tuner circuit without chock structure. Nevertheless, a careful numerical study will be performed in next step.

2.3 Thermal loading: Setting the Landau cavity gap voltage at 250 kV, the corresponding maximal power flow densities on the thermal spot are 41.50 and 36.15 W/cm^2 for the copper cavity with and without nose-cone, respectively. Such thermal spot is compatible for the RF cavities for the B-Factory with a maximum power flow density of 33 W/cm^2 and with 150 kW dissipation power load[8]. For such a thermal loading, the mechanical design as well as construction for the cavity cooling channels is obviously quite challenging. A numerical connection between the code URMEL and the finite element code ANSYS[7] has been established to verify the feasibility of the mechanical design[4].

2.4 Multipactoring: In addition to the built-in temperature sensors, ion gauges will be mounted on the cavity beam pipes to serve as interlock units to avoid any unexpected break-down or damage of the Landau cavity. The ion gauge is one of the most sensitive detectors to reflect any abnormal operation conditions of the cavity. Such a interlock signal will electronically directly connect to the low-level systems of the main RF systems for the storage ring.

However, an unfavorable situation might be involved due to multipactoring which resulting in a higher vacuum pressure. Basically, the multipactoring may be finally depressed by long-term RF power conditioning. However, the SRRC third harmonic Landau cavity will be first operated in a passive mode. An off-line RF conditioning will be impossible. It will be inconvenient, if there is any multipactoring in between the operating gap voltage range of the Landau cavity up to 250 kV[3]. To be more conservative, a coating of about 100 Angstroms titanium on the cavity inner surface will be applied to decrease the coefficient of secondary electron emission. Besides, it will also decrease the shunt impedance. About 16% of extra reduction on the shunt impedance (1.2 MΩ) was assumed for estimation on the bunch length performance. A setup and procedure for the titanium coating, similar to the one developed by Wisconsin Synchrotron Laboratory, will be adopted[9]. A numerical simulation by using the code TW-TRAJ[10] to predict the possibility of multipactoring is in progress.

2.5 Coupling network: There are some intrinsic disadvantages, if the Landau cavity is operated in the passive mode[11]. Therefore, the Landau cavity will be operated in an active mode in the next step. To avoid long term interference to the machine normal operation, the cavity is designed to be suitable for the operation of both modes. A coupling port will be reserved and terminated by a flange during the period of passive operation. A hole coupler will be selected for the sake of mechanical simplicity. The final size of the coupling hole will be determined experimentally.

2.6 External circuit: Suitable klystrons are available for active operation of the Landau cavity. Either of the Varian tube VKL-7811W with transmitter of VKL-7811W or Thomson tube TH2466 with transmitter of H20424 provides a 1.5 GHz, 5 kW, CW RF source with bandwidth of few MHz. Moreover, the Varian tube VKL-7811ST with transmitter VKL-7811ST, original designed for operation at the central frequency of 1.3 GHz, is possible to be modified for the operation at the central frequency of 1.5 GHz with 10 kW, CW output. The RF power will be transported by wave-guide WR650.

3 DISCUSSION

The construction of a prototype third harmonic Landau cavity is in progress at SRRC. Its photograph can be found elsewhere[4]. The cold test measurements for the prototype will be started soon. The Landau cavity is planned to be installed in the summer next year.

Acknowledge: We have benefited the discussions with Å. Andersson, J. Byrd, M. Eriksson, B. Rimmer, and E. Weihreter. We appreciate R.A. Bousch, K. Kleman, Kroll, R. Parodi, J.M. Wang, and W.T. Weng, for kindly providing technical information and/or numerical codes. We thanks for their kind technical support on our project.

4 REFERENCES

[1] C.C. Kuo, et al., ”Beam Lifetime Investigations at SRRC”, 1996 EPAC conference proceedings.

[2] A. Hofmann and S. Meyers, ”Beam Dynamics in a Double RF System”, 11th Int. Conf. on High Energy Accelerators, 1980, Geneva, pg 610.

[3] L.H. Chang, et al., ”Effects of the Landau Cavity on the Beam Dynamics”, this conference.

[4] T.T. Yang, et al., ”On the Mechanical Design of a 1.5 GHz Landau Cavity”, this conference.

[5] URMEL is a 2D code of RF structure frequency domain solver, developed by T. Weiland.

[6] SOPRANO is a 3D commercial code of RF structure frequency domain solver in the numerical package of OPERA, a product of Vector Field Limited.

[7] ANSYS is a commercially available 3D finie element code suitable for simulation of thermal expansion, structure deformation, etc., a product of Swanson Analysis System, Inc..

[8] H.D. Schwarz, et al., ”DEsign of a High-Power Test Model of the PEP-II RF Cavity”, 1993 PAC conference proceedings.

[9] K. Kleman, private communication, 1996.

[10] TW-TRAJ is a 2D code suitable for simulation of cavity multipactoring, developed by R. Parodi and P. Fernandes, 1990.

[11] R. Biscardi, ”Bunch Length Control in the NSLS VUV Ring”, Nucl. Instrum. & Mech. A 366, pg. 26, 1995.