PRELIMINARY TEST OF SUPERCONDUCTING RF CAVITIES FOR PLS-II*

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Abstract

The main part of installation for PLS-II upgrade was finished at June 2012 and is on the way of user operation through elaborate commissioning. Up to now, the achievement is 150mA beam current at 3.GeV with multi-bunch mode with 5 normal conducting cavities which served in the PLS before. With 2 SRF cavities, installed during summer maintenance of 2012, PLS-II will be 300 mA beam current with 20 IDs. One additional SRF cavity will be operated in October 2014, and beam current will rise to 400 mA. The two SRF modules are at the final stage to be installed at storage ring in August 2012. The two main subsystems such as SRF cavities and ceramic windows were tested independently to confirm their performances. Each cavity recorded its accelerating voltage as 3.27 MV and 3.24 MV at 4.2K, respectively. Two RF windows also passed its specification, 300 kW CW travelling wave and 150 kW CW standing wave. One cryomodule was confirmed through the after-fabrication test (FAT) and delivered to PAL site at present, under preparation of horizontal test. The other one is just at last step for the factory acceptance test.

INTRODUCTION

The PLS-II is the upgrade machine from the old PLS, which was a 3rd generation synchrotron light source with 2.5 GeV energy and 190 mA beam current and provided users beam since 1996. The energy and beam current of PLS-II are 3 GeV and 400 mA, respectively. The number of insertion devices at PLS-II is 20, compared to 10 of PLS by modifying TBA to DBA magnetic lattice. It can be possible by shortening bending radius of dipole magnet with same ring circumference of PLS. The expected power loss from 24 BMs and 20 IDs including broad band losses in RF cavities, vacuum chambers, BPMs, gate valves and etc is estimated as high as 500 kW. The RF related parameters of PLS-II are shown Table 1. The design requirements for PLS-II upgrade are low higher- order modes (HOM), high reliability and high power capability. Even though top-up mode operation at PLS-II, long beam lifetime - as long as 10 hours is also important requirement. For required lifetime and sufficient RF bucket height at injection system the energy acceptance (ΔE/E) must be higher than 2.7%, which can be assured by 4.5 MV RF voltage with the over voltage factor of 2.71. With deliberate design and investigation based on the requirements above, the superconducting RF technology was chosen. By selecting SRF cavities with low impedances from cavity HOMs, more stable beam operation at high beam current is expected with low beam emittance. The relative short MTBF (Mean Time Between Failure) compared to NC RF system should be accepted at the initial phase of SRF operation, but with deliberate efforts such as sufficient aging SRF cavities with beam operation and more experiences with training the MTBF at PLS-II is expected to be approached to reasonable standard. Tow SRF modules will be operated from October 2012 and other one will be October 2014. The 1st two modules are the last phase of fabrication.

Table 1: Parameters of PLS-II Storage Ring

Parameters	Values
Energy	3 GeV
Current	400 mA
Emittance	5.6 nm-rad
Momentum compaction	1.38E-3
Harmonic number	470
RF frequency	499.973 MHz
Energy loss per turn	1242 keV
Accelerating voltage	4.5 MV
RF acceptance	2.8 %

SRF DESIGN

PLS-II RF system consists of three 500 MHz SRF cryomodules, three 300 kW power amplifiers and a 700 W cryogenic cooling system, which construct 3 independent RF systems shown in Figure 1. The detail design parameters of RF system are shown in Table 2.

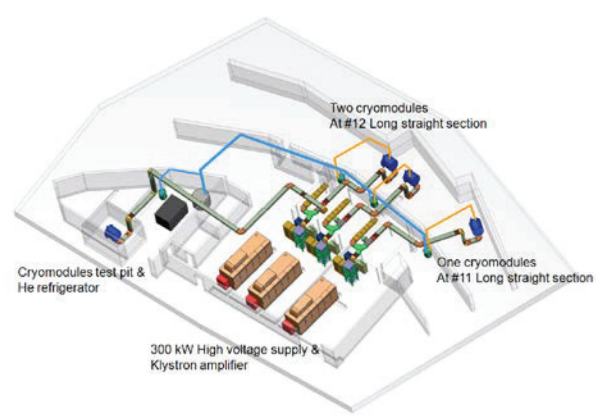

Figure 1: Layout, PLS-II SRF system.

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Three SRF cryomodules with CESR-B type occupy 2 long straight sections (LSS), 6800 mm long. Two modules are in #12 LSS and third one in #11 LSS. The third one occupies only half of a LSS, so the remained half section can be available for a short insertion device.

Table 2: Parameters of PLS-II RF System

Parameters	Values
RF type	Superconducting
Number of SRF cryomodule	3
RF voltage	4.5 MV
Required RF power	500 kW
Number of RF station	3
Cryogenic cooling capacity	700 W
Number of klystron, 300 kW	3

OPERATION PLAN FOR SRF SYSTEM

PLS-II is absolute new machine through only 3-years design, fabrication and installation. As a result, the installation of SRF cavities is forced to be delayed due to long lead time for fabrication. With these points, the operation schemes of RF system for PLS-II are compelled to be complicated little bit.

PLS-II was commissioned with 5 normal conducting cavities up to 150 mA with energy, 3 GeV during July to December 2011. Then PLS-II provides synchrotron beam to users now and two SRF cavities will be installed in the storage ring with replacement all NC cavities. The detail operation schemes are described in Table 3.

Table 3: Operation Plan for PLS-II RF System

Period	Cavity	RF power source	RF voltage	Available RF power	Beam current	Touschek lifetime
2011. 7 – 2012. 7	4 NC:	1- 300 kW 2- 75 kW	1.8 MV	150 kW	100 mA	> 7 hrs
2012. 8 – 9	- Dismantlement of all NC cavities - Installation of two SC and commissioning					
2012. 10 – 2014. 7	2 SC	2-300 kW	3.3 MV	350 kW	300 mA	> 25 hrs
2015. 8 - 9	Installing third SC caviy					
2015. 10 ~	3 SC	3-300 kW	4.5 MV	549 kW	400 mA	> 20 hrs

VERTICAL TEST OF SRF CAVITIES

Vertical tests were done to confirm the cavities' performance after surface preparation. The recipe before vertical test was in series of following procedures: careful quality controlled cavity fabrication, degreasing with light chemical etching, then barrel chemical polishing (BCP) as much as 100 μm, high pressure water rinsing (HPR) with conductivity, 12.5 MΩ-m, annealing 10 hours @ 600°C with vacuum environment, final BCP-20 μm and HPR, finally leak tight of cavity assembly for vertical test. The test setup is shown in Figure 2, which is usual configuration of vertical test. During the cavity is submerged over 20 cm. Before RF test, RF cable connection and cold cable losses were calibrated.

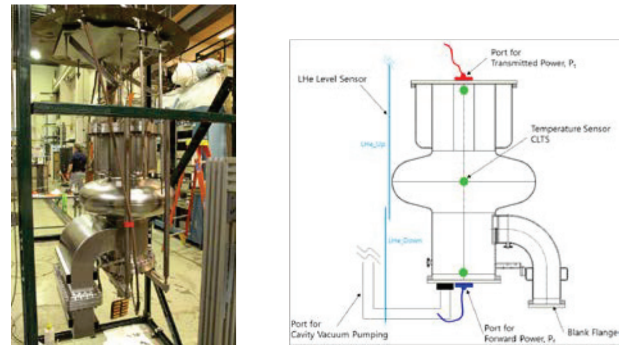

Figure 2: Setup for vertical test.

The resonance frequency was 499.653 MHz and 499.193 MHz respectively for #1 and #2 cavities. The cavities' performance was good enough compared to design specification. As shown in Figure 3 P1 and P2 for PLS-II were recorded Eacc as 3.27 MV and 3.24 MV with Qo, 0.63E9 and 0.74E9 respectively. It is the average or slightly better compared to other data from similar type of cavities. During the vertical test any severe RF processing or subsidiary phenomena would not appear. With smooth VT, two final cryomodules are expected to show their best performance at tunnel.

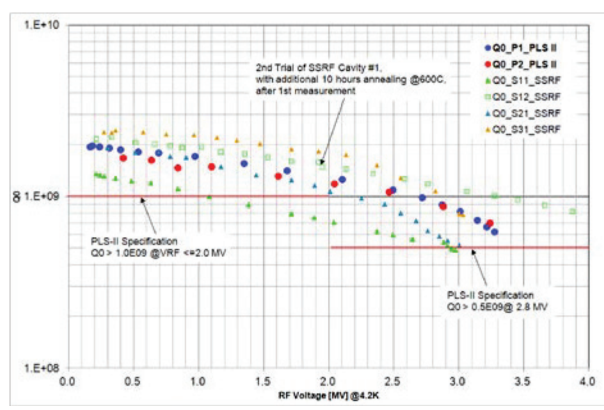

Figure 3: Measured cavities' performance, Eacc vs Q0.

CERAMIC WINDOWS CONDITIONING AND TEST

With Two windows were assembled back to back with a special designed and manufactured pumpout box in between them and with one 500 l/s Ion pump. Then the assembly was baked out to a temperature of 150°C for 72 hours to remove impurity gases as 1st conditioning. To assure the window performance tests was done with two kinds of operation modes such as travelling wave and standing wave. During the window conditioning windows side vacuum as reference was around 1.5E09 mbar and RF power was supplied by IOT.

Travelling Wave (TW) Mode: The test setup is as simple as shown in Figure 5. RF Power travelled to 350 kW water load installed to end of wave guide through two windows. During applying RF power to windows, the vacuum pressure and water flow rate were interlock signals as 5E-8 mbar and 12.5 liter/min, respectively. A various kinds or pulse with different duty cycle as 1%, 5%, 10%, 20%, 50% and continuous wave and power levels up to 278 kW were applied for RF conditioning step by step manually to reduce trips during 4 days. In CW mode the power was raised up to 300 kW and the RF was kept on for eight hours. The pressure decreased from 2.9E-9 mbar at the beginning of the long term test to 2.0E-9 mbar after 8 hours without any kind of trip. The temperature differences between window center and edge were recorded as 20.3°C at #24 and 29.0°C at #25. The RF conditioning and test with CW is depicted in Figure 4.

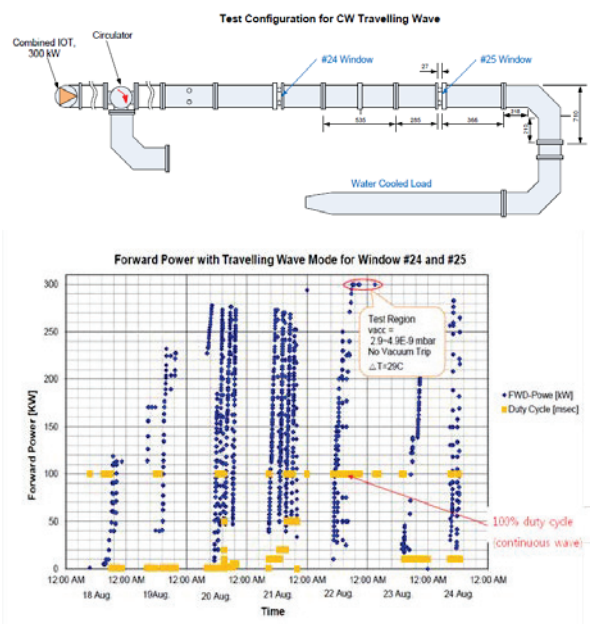

Figure 4: Test setup (upper) and processing history for TW mode (lower).

Standing Wave (SW) Mode: The test setup is simple as to block waveguide at the proper position after 2nd (#25) window with blank flange. The proper position of blocking is that one window gets the maximum RF voltage meanwhile the other should get the minimum RF voltage. To find its configuration several trials were done with help from simulation results via CTS Microwave Studio. Finally the optimal setup for #24 windows was decided as shown in Figure 5. And the other windows setup was done with same manner. RF conditioning for SW mode test was done only 5 hours with as shown in Figure 5 because windows were conditioned sufficiently from TW mode conditioning and test. At 4 hours with CW152 kW power and 100% duty cycle at #24 window, The vacuum and cooling water temperature were maintained stably and the maximum temperature difference was 47.2°C, while at #25 window, CW power was 153 kW and maximum temperature difference was 56.7°C. SW mode power 153 kW is equivalent to 612 kW TW mode power. The overall time needed for standing wave conditioning of window #25 was approximately 24 hours.

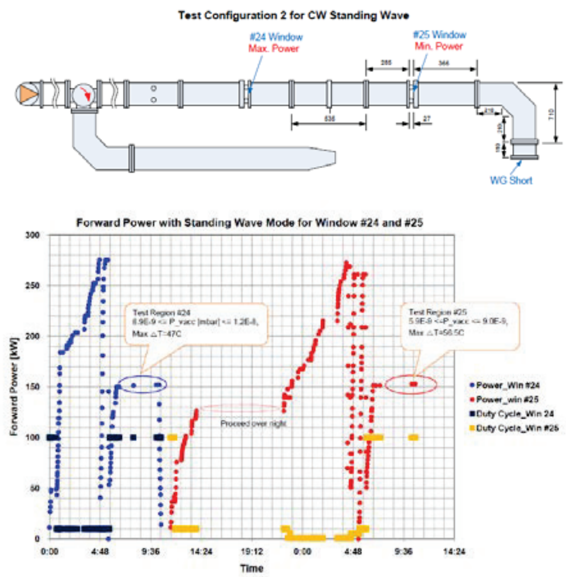

Figure 5: Test setup (upper) and processing history for SW mode (lower).

CRYOGENIC PERFORMANCE TEST

After fabricating #1 module all cryogenic performances such as leak check, statics heat loss, tuner operation, controllability, module external Q and resonance frequency were checked last April. Even though there were some trivial defects all specification and specified performances were shown with improvement. #2 module is under assembly for post manufacturing performance test at June.

FUTURE PLAN

The site acceptance tests will be done in coming June and July this year, then they will be put into storage ring in August. Through 2 months RF conditioning and beam commissioning PLS-II will produces synchrotron radiation from SRF power at October 31, 2012.

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