COMPLETION OF THE AUSTRALIAN SYNCHROTRON STORAGE RING RF SYSTEM COMMISSIONING

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Abstract

The installation and commissioning of the Australian Synchrotron Storage Ring RF System (SR RF System) was completed. SR RF System consists of four sets of 500MHz 150kW-CW klystron and 750kV normal conducting cavity. After the cavity aging, the RF System achieved 48 hours continuous operation in November 2006. The paper will present the design and commissioning results.

ASP SR RF SYSTEM

The Australian Synchrotron Project [1] storage ring RF system comprises four RF stations. Each RF station consists of control panels, a klystron, a high voltage power supply (HVPS), an RF distribution system, and a single cell normal conducting cavity. The RF system achieves a total peak cavity voltage of 3MV and makes up the total power loss due to synchrotron radiation. The cavity RF amplitude, phase, frequency, and the klystron efficiency are controlled and regulated by a low level electronics (LLE) that is one of the control panels.

Control Panels

The control panels (Figure 1) comprise four panels below.

- RF System Control Panel
  The operation and monitoring functions of the RF system are realized by the Experimental Physics and Industrial Control System (EPICS) operator interface. Figure 2 shows the EPICS control screen of the single RF station.
- LLE
- HVPS Control Panel
- Vacuum Control Panel

Figure 1: Control panels after installation.

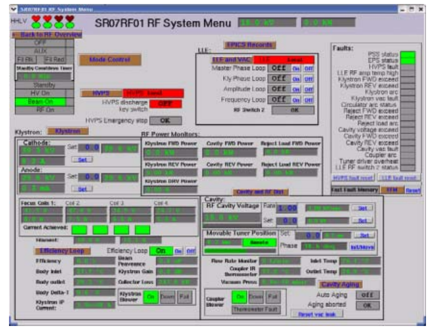

Figure 2: EPICS control screen of the single RF station.

The LLE comprises the independent units below.

- RF Low Level Control Unit pre-amplifies the RF master signal up to +43dBm, regulates the cavity RF amplitude and phase by the feedback loop, and cuts off the RF drive within 10 microseconds in the case of trip.
- Movable Tuner Control Unit regulates the cavity RF tuning by the feedback loop.
- PLC modulates the klystron anode voltage in order to optimize the klystron efficiency [2], and automatically controls the cavity voltage in the cavity aging mode.
- Remote control phase shifter shifts the phase of two cavities by 180 degrees to damp the SR electron beam for diagnostics.

Table 1 shows some of the main performance parameters of the LLE.

Table 1: LLE performance

Function	Parameter	Value
Amplitude Loop	Stability	< +/- 0.5 %
Phase Loop	Stability	< +/- 0.5 degrees
Fast Interlock	Rise/Fall Time	< 10 microseconds for the whole circuit
Power Measurement	Accuracy	< +/- 0.3 dB

Klystron, RF Distribution, and HVPS

The klystron E3774U (Figure 3) amplifies the RF output of LLE. The E3774U is the efficiency improved version of the E3774 that has been supplied to KEK-PF, New SUBARU, SAGA Light Source and others. The filament has two heating mode, one is red heating (normal) mode, and the other is black heating (standby) mode.

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Figure 3: Klystron E3774U after installation.

The RF distribution system was designed to be capable of continuous operation at full reflected power in the test load mode; the cavity is disconnected from the RF distribution system.

The HVPS (Figure 4) supplies DC high voltage power to the klystron. The input voltage is regulated by the induction voltage regulator (IVR). Short circuit energy less than 15 joules is achieved by the IGBT high voltage switch to protect the klystron. The closed cooling system of the cubicle actualizes no heat radiation and a dust free system.

Figure 4: HVPS after installation.

Figure 5 shows the schematic of the HVPS. Table 2 shows some of the main performance parameters of the klystron E3774U, the RF distribution system, and the HVPS.

Table 2: Klystron, RF distribution and HVPS performance

Equipment	Parameter	Value
Klystron	Max. power	>= 150 kW (CW)
	Beam perveance	0.8 microP
	Efficiency	> 60 %
RF Distribution System	Load VSWR of klystron	< 1.2
	Circulator VSWR	< 1.05
	Reject load VSWR	< 1.05
HVPS	DC output	39.6 kV – 6.3 A
	Voltage ripple >300 Hz	< +/- 0.5 %
	Max. rectification	24
	Short circuit energy	< 15 joules
	Efficiency	> 90 %

RF Cavity

Four normal conducting cavities are used for the SR RF system. The cavity consists of a single cell, an on-centered damper, an off-centered damper, a SiC duct, a movable plunger tuner, and an input coupler. Figure 6 shows the cavity pair after installation.

Figure 6: Cavity after installation.

The cavity was designed based on the KEK-PF type HOM (Higher order mode) damped cavity that has been supplied to KEK-PF, New SUBARU and SAGA Light Source. In order to meet the requirement of the ASP SR RF system, the cavity length was decreased so that two

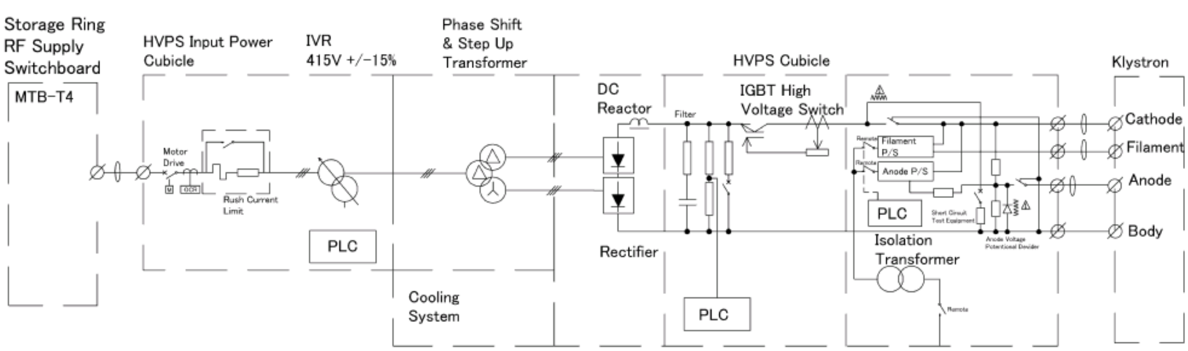

Figure 5: Schematic of the HVPS.

cavities could fit into two meters length, the shunt impedance was increased by 5 percent from the original KEK-PF type cavity, and the longitudinal HOM impedance was damped below 20 k ohm / GHz @ < 2 GHz [3]. Table 3 shows some of the main performance parameters of the cavity.

Table 3: Cavity performance

Parameter	Value
Resonant frequency	499.654 +/- 0.4 MHz
Voltage	750 kV / cavity
Q-value	> 39,000
Longitudinal modes HOM shunt impedance	< 20 k ohm / GHz (0.5 to 2GHz)
Cavity length	1m / cavity
Effective shunt impedance $R_{sh} = V^2 / (2P_{in})$	> 3.57 Mega ohm

RF SYSTEM COMMISSIONING

After the factory test at Japan, the equipment was shipped to the ASP site. The HVPS cubicles and the RF cavities were reassembled at the site. After the installation, the commissioning of the HVPS, the klystron, and the RF cavity started.

A DC high voltage withstand test of the HVPS was performed at 70kV. The results of the full load performance test were the voltage ripple less than 0.4 % p-p, the efficiency larger than 96 %, and the total harmonic distortion at the simultaneous operation of the four HVPS less than 2.5 %.

The commissioning and the performance test of the klystron were performed in the test load mode. All the klystrons achieved the maximum power greater than or equal to 150 kW at the DC input of 39.6kV – 6.3A. The base data for the anode modulation were taken for deciding the anode voltage as a function of the klystron output power. The klystron anode voltage is increased as the klystron output increases so that the klystron efficiency can be maintained at high levels. After the decision of the anode voltage function, the klystron efficiency was measured by increasing the klystron output. Figure 7 shows the measurement results of the station SR07RF02.

The RF cavities were reassembled at the site. The helium leak test, the baking, and the low level test were performed. The vacuum pressure was less than 2E-7 Pa. The Q-value was larger than 39,000. The aging of the input coupler and the RF cavity started from the power of a few kW by using the single RF cavity. After the cavity voltage of 750 kV was achieved for the single RF cavity, the cavity pair aging was performed. The main cause of trips during aging process was the cavity reverse power exceed. Finally, the continuous operation test was performed. All of the four RF stations achieved the 48 hours continuous operation at the RF cavity voltage of 750 kV. Figure 8 shows the continuous operation test result of the station SR07RF02.

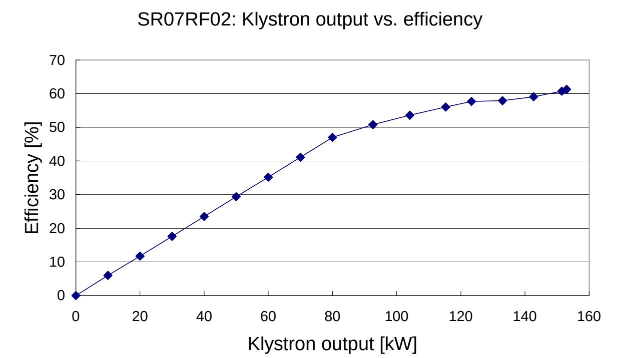

Figure 7: Result of the klystron efficiency measurement for the station SR07RF02.

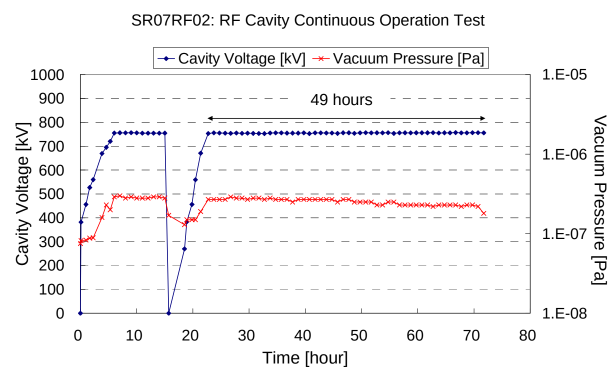

Figure 8: Result of the RF cavity continuous operation test for the station SR07RF02.

CONCLUSIONS

The 500MHz SR RF system was installed and its commissioning was completed. All of the four klystrons achieved the maximum power greater than or equal to 150kW in the test load mode. All of the four RF stations achieved the 48 hours continuous operation at the RF cavity voltage of 750 kV. After the completion of the commissioning, the RF system has been used for the storage ring beam commissioning and the operation.

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