UPGRADE OF THE RF SYSTEM OF SIBERIA-2 ELECTRON STORAGE RING / SR SOURCE

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Abstract

The project of upgraded RF System of Siberia-2 Electron Storage Ring / SR Source, Moscow, Russia, is presented. The upgraded RF system will allow increasing of the total accelerating voltage up to 1.5 MV and ensure operation of the storage ring with new superconducting wiggler at beam currents up to 0.3 A. RF system operates at 181 MHz. It consists of 3 single bi-metal cavities, 2 power amplifiers based on GU-101A tetrodes with output power of 200 kW, power transmission lines and control system. Parameters of the upgraded RF system are given, the design of its main elements is shown.

INTRODUCTION

Kurchatov Center of Synchrotron Radiation and Nanotechnology in Moscow operates electron storage ring (ESR) Siberia-2 – a dedicated synchrotron radiation (SR) source [1]. This machine provides synchrotron radiation in the wavelength range of 0.1-2000 Å for various experiments. Maximum energy of electrons is 2.5 GeV. Radiation losses at this energy are 681 keV. Average beam current is up to 200 mA.

The new superconducting wiggler installed in the storage ring will further increase the losses by 340 keV. Accelerating RF system of Siberia-2 ESR operates at 181.14 MHz corresponding to the 75th harmonic of the revolution frequency. The RF system consists of 2 separate channels. Before the upgrade the RF system used to have 2 old accelerating cavities, each one connected via rectangular waveguide to its generator with output power of 200 kW. The cavities provide total accelerating voltage of 1.2 MV needed to ensure the necessary life-time at 681 keV energy loss per turn. The design of the cavities is similar to the one of the cavities used in VEPP-4 collider, Novosibirsk [2]. This design features a copper cavity with water cooling tubes housed in a stainless steel tank. After 15 years of operation leaks in the cavity water cooling tubes began to appear.

The RF system upgrade should result with:

1. replacement of the old double-chamber cavities by new bi-metal ones similar to those used in Novosibirsk FEL [3], which should lead to increased reliability of the machine operation;
2. total accelerating voltage increase up to 1.5 MV (with a possibility to rise it up to 1.8 MV in the future) in order to adapt Siberia-2 storage ring to operation with the new wiggler.

Three bi-metal cavities will be installed in the storage ring upon completion of the upgrade (see Fig.1). A section of 2 cavities already has been installed instead of 1 old cavity. Another old cavity will be replaced by a single bi-metal cavity. A new waveguide distribution system will deliver RF power to the 2 side cavities from one RF generator.

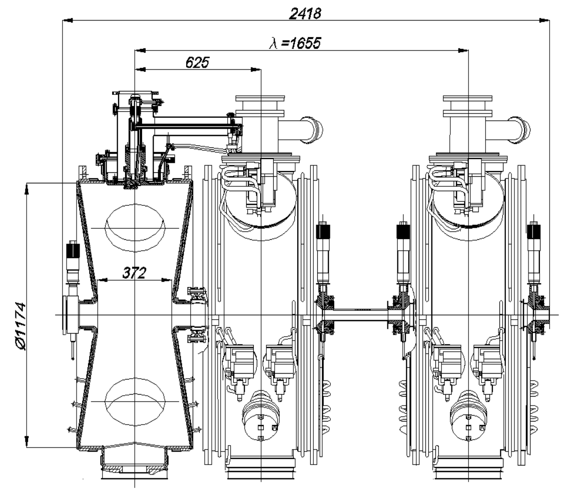

Figure 1: Schematic view of three bi-metal accelerating cavities.

The middle cavity will be fed by the second generator. New set of parameters of the storage ring and its RF system is listed in Table 1. New control system will ensure stable operation of the RF system. At lower beam currents the accelerating voltage may be increased. This will allow installation of additional insertion devices – SR sources.

ACCELERATING CAVITIES

Cavity body (see Fig. 1) is made of bi-metal (7 mm of stainless steel and 8 mm of copper joint together by diffusion bonding). RF currents flow over the inner copper surface.

Cavities operate at TM010 mode. Each cavity has 2 contactless operating mode frequency tuners and 2 higher order modes (HOM) tuners. HOM tuners have butterfly shape with wings along the beamy axis. HOM tuners shift HOM frequencies but have negligible influence on the operating mode frequency. HOM tuners are set to the positions where beam induced HOMs do not cause beam instabilities.

Table 1: Parameters of the Siberia-2 storage ring and its RF system after the upgrade

Parameters of the Siberia-2 storage ring	Energy of electrons	E_{max}	GeV	2.5
	Total losses per turn	ΔE	keV	1021
	Beam current	$I_{b\ max}$	A	0.29
	Total accelerating voltage	$2U_1+U_2$	kV	1500
1st RF channel: 200 kW generator, 2 cavities	Accelerating voltage	$2U_1$	kV	820
	Shunt impedance	$2ZT^2$	MOhm	8.6
	Power dissipated in the cavities	$2P_1$	kW	39
	Power transferred to the beam	$2P_{1b}$	kW	157
2nd RF channel: 200 kW generator, 1 cavity	Accelerating voltage	U2	kV	680
	Shunt impedance	ZT^2	MOhm	4.3
	Power dissipated in the cavity	P_2	kW	54
	Power transferred to the beam	P_{2b}	kW	139

On top of the cavity there is a coaxial input power coupler with cylindrical ceramic window. Characteristic impedance of the coaxial is 75 Ohm. Cavity gap voltage is measured by inductive RF probe. Ion-getter pump is attached to the cavity from the bottom. Single cavity of the RF channel #2 has RF shielded gate valves at the beam ports. Two cavities of the RF channel #1 are connected at their adjacent beam ports. The 2 gate valves are installed at the end beam ports of this 2 cavities section. Each cavity is baked at 350ºC and tested up to 900 kV of accelerating voltage at a test stand prior to being installed into the storage ring. Main parameters of the cavities are listed in Table 2.

Table 2: Main parameters of the cavities

Operating frequency, f	181.139 MHz
Tuning range, Δf	±150 kHz
Accelerating voltage, UT	0.1÷0.9 MV
Transit time factor, T	0.9
Quality factor, Q_0	39000
Shunt impedance, ZT^2	4.3 MOhm
Power dissipated in the cavity at UT =0.9 MV , P	94 kW

$$ZT^2 = (UT)^2/2P$$

RF GENERATOR AND FEEDER

RF system has 2 channels. Each channel has RF generator with 2 GU-101A tetrodes in the output stage providing 200 kW output power [4]. RF generators are located quite far from the cavities. RF power is delivered to the accelerator hall via rectangular 986 x 150 mm waveguides. The cavities are connected to the waveguides by 75 Ohm coaxial lines. Schematic drawing of the coaxial line with waveguide to coaxial transition is shown in Fig. 2.

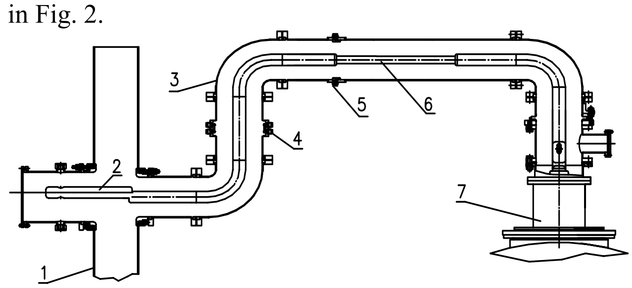

Figure 2: Schematic drawing of the coaxial line with waveguide to coaxial transition: 1 – waveguide, 2 – antenna of the waveguide to coaxial transition, 3 – 75 Ohm coaxial line, 4 – directional coupler, 5 –RF probe, 6 – matching 100 Ohm transformer, 7 – accelerating cavity.

The generator of the 1st RF channel feeds 2 cavities. The waveguide to coaxial transition also functions as a power splitter and ensures matching at 100 kW delivered to each cavity. The generator of the 2nd channel feeds 1 cavity. The waveguide to coaxial transition is designed to provide matching at 200 kW delivered to the one cavity.

Both coaxial lines of the RF power splitter are connected to the waveguide at the same cross-section symmetrically relative to the center of the wide wall. Equivalent circuit of such double waveguide to coaxial transition is a 3 ports network. The ports in the coaxial lines and waveguide may be placed in such cross-sections that the equivalent circuit at the operating frequency becomes as the one presented in Fig. 3. Coaxial ports 2 and 3 are placed inside the waveguide at the distance 45 mm from the wall. Waveguide port 1 is placed at the splitting cross-section. The impedances are normalized to characteristic impedances of the corresponding lines. For such port positions the transformer coefficient at the circuit diagram from ports 2,3 to port1 is equal to $\sqrt{2}$.

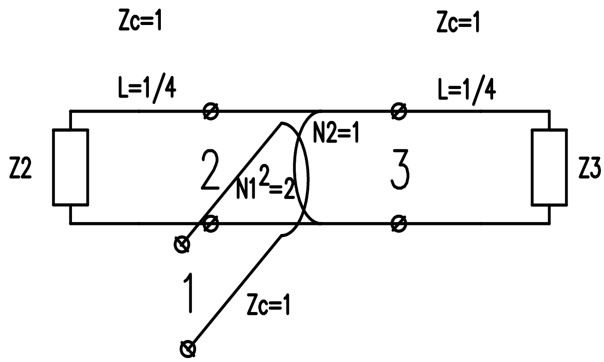

Figure 3: Equivalent circuit of double waveguide to coaxial transition: 1 – waveguide port, 2 and 3 – coaxial line ports, Z_c – normalized characteristic impedance, Z2 and Z3 – cavity input impedances.

The currents driving the cavities are measured at the coaxial line cross-sections corresponding to the voltage nodes at strong detuning of the cavities. The distances from ports 2 and 3 up to the corresponding voltage nodes are chosen divisible by odd number of the quarter wave length at the coaxial lines. For such case cavities driving currents are equal, depend only on the port 1 voltage and do not depend on values of Z2, Z3. Cavities voltages are proportional only to the corresponding input impedances. If the equivalent distance between port 1 and anode of the output generator tube is divisible by number of the half wave length, the port 1 voltage will be limited always by the maximum anode voltage.

CONTROL SYSTEM

Control system regulates amplitude and phase of the cavity voltage, ensures automatic frequency tuning and provides synchronization signals for injection.

RF system operates in a regime when beam loading of the cavities is relatively high. This might lead to a beam instability [5] developing on the following scenario. After a deviation of the beam phase, the beam induced current changes the total cavity voltage amplitude and phase so that the beam synchronous phase deviates in the same direction. This deviation might exceed the initial deviation of the beam phase which leads to the instability.

The simulations proved that this instability may be suppressed in the entire operating range of beam currents by choosing properly the parameters of the feedback system stabilizing the cavity voltage amplitude. The results of the calculations are shown in Fig. 4.

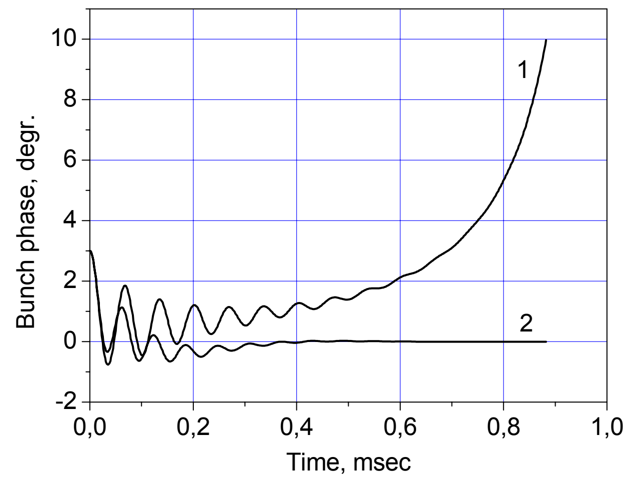

Figure 4: Bunch phase motion: 1 – without feedback, 2 – with feedback.

The simulations modeled movement of the electron bunch in the Siberea-2 storage ring. Initial bunch phase deviation for both plots is 3 deg. The relaxation segment consists of the damping synchrotron oscillations. After that instability builds-up without a feedback (plot 1). A feedback suppresses the instability (plot 2). Beam current in the 1st case is 0.24 A, in the 2nd case – 0.3 A.

CONCLUSION

Main elements of the upgraded RF system of the SIBERIA-2 storage ring are discussed. The RF system provides acceleration of 0.29 A beam current to energy of 2.5 GeV with the superconducting wiggler switched on. Presently the section of two new cavities took place of the old one and the third new RF cavity is at the stage of testing. The upgraded RF station will begin to operate in 2009.

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