ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-THCDMH05

NEW RF SYSTEM FOR VEPP-5 DAMPING RING

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Abstract

The VEPP-5 injection complex serves to obtain high-intensity electron and positron bunches for injection into colliders of the Institute of Nuclear Physics SB RAS. The old RF System operated at 700 MHz - the 64 harmonic of the revolution frequency. Due to the large beam length from LINAC up to 70% of the particles were lost during injection.

Therefore, in 2015, the decision was made to install into the ring the new RF cavity operated at the first harmonic of the ring revolution frequency of 10.94MHz. To reduce the geometric dimensions, ferrites were used in the cavity. The RF cavity was manufactured, and RF power amplifier and a new RF control system were prepared. After testing the RF system at the stand, in August 2017 the RF cavity was installed instead of the former 700 MHz cavity. The new RF system is now in operation since September 2017. The paper presents main features of the cavity design and fabrication. RF power amplifier and operation of the control system are described.

INTRODUCTION

In the Damping Ring (DR) [1 - 3] of the VEPP-5 injection complex, bunches of particles with a duration of ~ 5 nsec are injected with a significant energy spread (See Table 1). The particles in the DR circulate and during the time of damping the energy spread decreases and it becomes possible to inject them into the colliders for experiments with colliding electron-positron beams.

The transition to a lower harmonic of the RF system increases the capture of particles injected into the DR. One can also consider the proposal to increase the pulse duration from the electron gun to increase the charge of particles injected in a single cycle.

Table 1. Damping Ring Designed Parameters

Parameter		Value
Revolution frequency		10.94 MHz
RF ratio		64
Particles energy		510 MeV
Particles number		$2 \cdot 10^{10}$
Energy loss per turn		5.9 keV
Orbit compaction factor		0.022
Injection repetition rate		50 Hz
Energy spread e+, e-		3%, 1%
Energy spread of damped particles		0.07 %
Damping time	H	11.3 msec
	V	17.5 msec
	L	11.9 msec

RF CAVITY

The available length of the gap in the ring for the cavity is 600 mm. To reduce the geometric dimensions, ferrites are used in the cavity. In Russia ferrite rings of two suitable standard sizes are manufactured at the factory of JSC "FERROPRIBOR" in St. Petersburg: 250 x 180 x 25 and 180 x 110 x 20.

Using only one larger ring size is not desirable and does not pass. For required RF voltage amplitude of ~ 10kV at the frequency of 10.9 MHz, cooling of rings is difficult due to the large amplitude of RF magnetic field in the ring and, correspondingly, the large dissipated power density.

It was decided to use both ring sizes. At the request of the customer, the manufacturer reduced the outer diameter of the inner ring from 180 mm to 174 mm. At first, the modules were manufactured in which a smaller ring was inserted into a larger one and rings were glued to a copper disk (see Fig. 1). The disk has a tube with water soldered along the external perimeter of the disk. As an adhesive, the organosilicon compound PentElast-712 type A was used.

The inner ferrite rings are cut into two halves along their diameters and glued together with a gap of 1.3 mm to equalize the average RF magnetic field in the large and small rings. In the gap between the halves of the inner ring, part of the magnetic flux may be closed through the

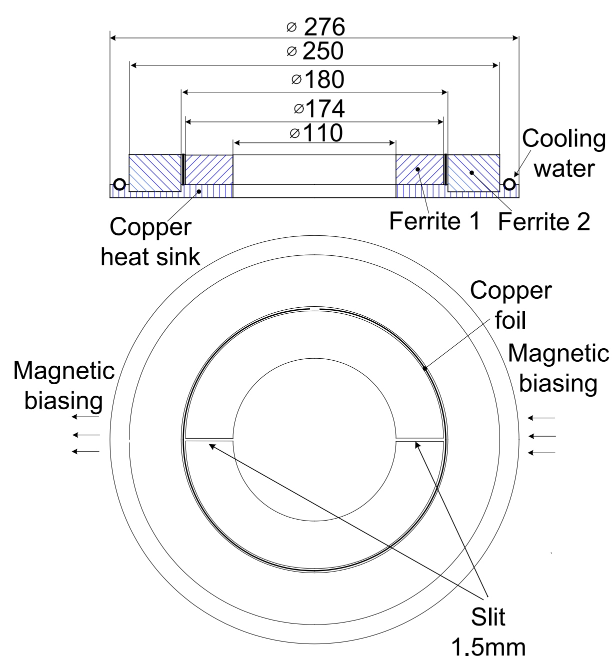

Figure 1: Ferrite module.

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adjacent large ring. In this case, there would be an additional load of field in it. To exclude this effect, a screen of copper foil is inserted into the gap between the rings.

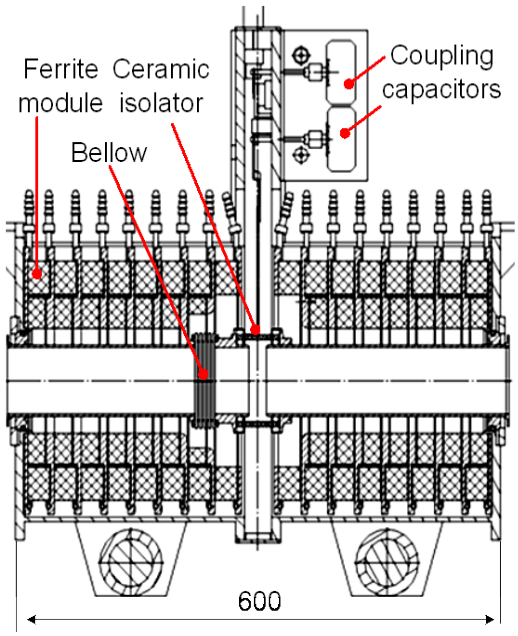

Figure 2: Cross section of RF cavity.

Then these modules were glued in two packages of 8 pieces for each half of the cavity.

The vacuum chamber with a bellow and a ceramic insulator are installed into the shells on both sides of cavity halves on sliding ring spring contact (helicoflex). On both sides of the accelerating gap at right angles, strip conductors from two vacuum variable capacitors KP1-4 5-100 pF, 25 kV are welded. Other capacitor leads are connected to ground. With the help of these capacitors, the resonant frequency of the operating mode of the cavity and the symmetry of the voltages on both halves are tuned.

Table 2. Main Parameters of RF Cavity

Parameter	Value
Operational frequency, MHz	10.94 MHz
Q - value	80
Shunt impedance, kOhm	16 kOhm
Amplitude of gap voltage	≤9.5 kV
Mode of operation	CW
Power dissipation in cavity	≤2.5 kW
Beam current, mA	100 mA
Power density in ferrite, W/cm^3	0.22
Average amplitude of RF magnetic field	62 Gs

The RF cavity is excited from two power inputs with antiphase voltages through the coupling capacitances C3, C4 (see Fig. 2, 3). The cavity is also equipped with capacitive voltage dividers of RF voltage at both sides of resonator V1c, V2c and at power inputs V1f, V2f for monitoring and controlling the RF amplitude and phase voltage of the cavity and for tuning its resonant frequency.

RF POWER AMPLIFIER

The transistor power amplifier is supplied by the company "Triada TV", Novosibirsk. One control signal drives two blocks of terminal amplifiers. The antiphase voltage is applied to the power inputs of the cavity halves. Each block contains four amplifying cells using transistors BLF188.

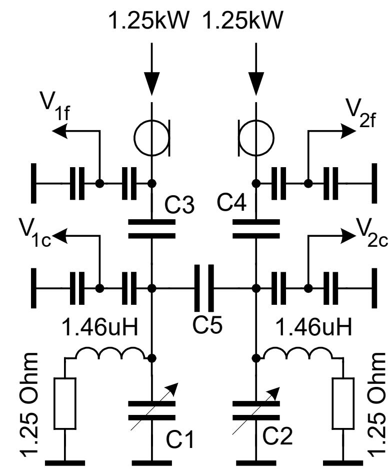

Figure 3: Equivalent schematic of RF cavity/ C1, C2 - 82pF, C3, C4 – 22pF, C5 – 8 pF.

The maximum output power of each output is 3.7kW. Input power does not exceed 1W. VSWR of the generator load is under 1.2 and is determined by C3, C4 values. The device is operated in RF system as a linear power amplifier.

RF CONTROL SYSTEM

Block- diagram of control system is shown in Fig.4.

There are 4 feedback loops to control and stabilize parameters of RF system.

RF cavity gap voltage is adjusted by regulating output power of the Gain Control module (See Fig.4). The regulating signal is generated by Modulator by the sum of the detected voltages on the halves of the cavity and the reference voltage from DAC.

Phase of RF cavity voltage in reference to the voltage of the Master Generator is sensed by Phasemeter 1. Signal of RF cavity voltage comes from the differential RF amplifier for both sampled voltages. Phasemeter 1 controls the Phase Shifter. It is possible to change and adjust the phase of cavity voltage from DAC for injection of particles of different types – electrons and positrons.

Damping of coherent bunch oscillation. The energy of particle injected into the DR is relatively low, and the radiation damping of the particles in the ring quite is small - the synchrotron oscillation decay time is ~ 50 msec and the phase motion of the beam often became unstable, which prevented further accumulation of particles.

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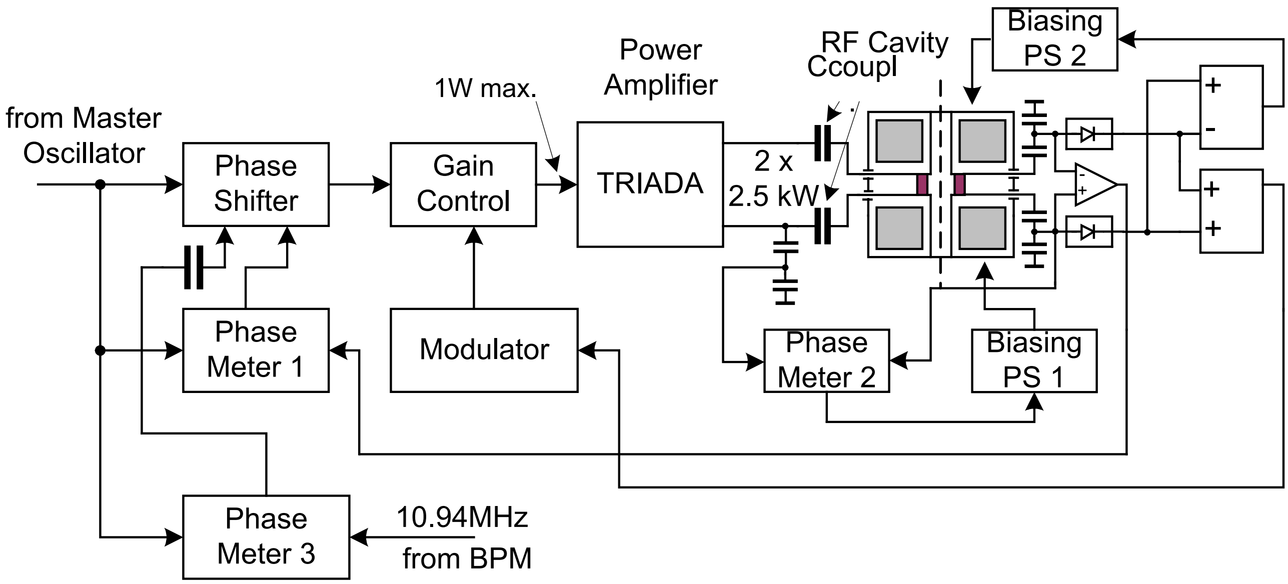

Figure 4: Block-Diagram of RF System 10.94 MHz.

Using a bandpass filter, the first harmonic voltage is extracted from the voltage of the beam position monitor (BPM). This voltage is applied to the Phase Meter 3 together with the RF signal of the Master Oscilator. Variable component of the Phase Meter 3 output signal after appropriate phase correction is fed to the Phase Shifter. The damping time of the bunch phase oscillations in the ring decreased to a few milliseconds, and no instabilities of the bunch motion are observed.

RF cavity tuning. The instability of the cavity operational frequency, which is associated mostly with the change of ferrites temperature, is compensated by magnetization of ferrites. Two electromagnets with independent power supply PS1 and PS2 create a field in the ferrite rings perpendicular to the axis of the resonator, and independently each half of the resonator is tuned. Tuning of the operational antiphase mode of the cavity oscillation is realized by tuning to resonance one half of the cavity. Phase Meter 2 by RF signal from the first half of the cavity and RF signal from its power input controls PS1.

The other cavity half is tuned by the Biasing PS2. It is controlled so that detected amplitudes of the cavity halves are equal.

Computer control of the Control System is realized by a homemade module with the CANBUS interface. It has sufficient number of ADCs, DACs, I/O registers for control and monitoring parameters of the new RF System.

CONCLUSION

The new RF System is being operated since October 2017. Now the damping ring beam energy is reduced to 390 MeV, beam energy loss is 2.1 keV per turn. A regular production of positrons is 6 mA/sec. This is quite sufficient for supplying both BINP colliders for their effective operation.

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