TEST OF THE RF SYSTEM FOR DAMPING RING

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RF system for VEPP-5 damping ring is described. The system consists of RF power supply, waveguide section, and 700 MHz cavity. Results of computer simulations and measurements of HOM spectrum and damping efficiency are presented together with the results of cavity testing at operating power level.

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1 INTRODUCTION

The dumping ring provides collecting and cooling the electron and positron bunches with a number of particles of $2 \cdot 10^{10}$ [1, 2] at an energy of 510 MeV. RF system parameters are determined by the requirements to obtain short bunches in the damping ring, which are provided by using the high RF harmonic and large amplitude of the accelerating voltage. Operating frequency of 700 MHz corresponds to the 64th harmonic of the particle revolting frequency in the ring.

The RF system consists of RF generator, Y-circulator, waveguide section, and cavity. Results of testing the RF system with an active load at 60 kW power level were published earlier [3]. Q-factors of the coherent interactions between the beam and the cavity higher order modes (HOMs) were specially decreased down to values about 700 to provide the dumping of HOMs. It was made by connecting three coaxial absorbing loads through the wave-to-coax transitions and beyond-cutoff for the foundation frequency waveguides at the positions of the maximal RF magnetic field for most HOMs. Coupling with the field is provided by cavity slots of size about the inner wavegide dimensions. Cut-off frequency and length of the waveguide is defined by the requirement of the maximal damping of lower parasitic modes and minimal decreasing of the operating mode (TM_{010}) quality factor.

The main dimensions and parameters of the cavity were calculated by the SuperLANS computer code [4]. The cavity parameters are listed in the Tab. 1.

Table 1. Cavity parameters

Operating frequency	MHz	700
Shunt impedance	MOhm	4.24
Q-factor		20000
Transit time factor		0.748
Accelerating voltage	KV	200
Frequency detuning	MHz	±0.8

2 CAVITY DESIGN

The cavity is made of M1 copper at BINP workshop. A schematic drawing of the cavity is shown in Fig. 1.

The step-by-step technology was used when producing the cavity during assembling its parts. Simulation of the cavity was not carried out, so frequency measurements and correction of the inner diameter was made before brazing the disks and shell. Two types of flanges are used to seal the parts and connecting the cavity vacuum chamber to the valves. Power input unit, frequency detuning unit, and measuring loop are sealed by copper gaskets between the flanges made of stainless steel (standard design for such connection type). Three wave-to-coax transitions, vacuum ion pump, and two gaskets are sealed by argon-arc welding thin flanges made of stainless steel.

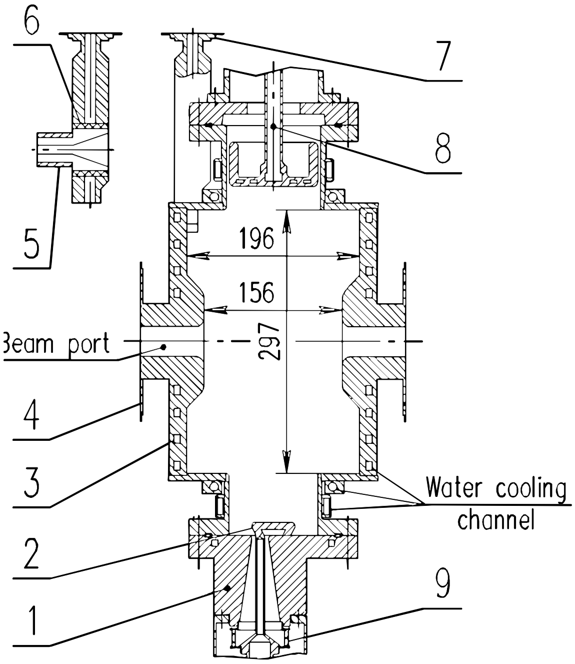

Fig. 1. Schematic of the cavity. 1 – power input, 2 - power input loop, 3 – cavity face wall cooling channels, 4 – valve flange, 5 – wave-to-coax transition, 6 – transition ceramic insulator, 7 - 65x12.5 mm^2 waveguide, 8 – cavity re-tuning unit, 9 – input ceramic insulator.

20x20 mm^2 wires with 8 mm diameter hole are brazed to the shell and flange branch pipes, as well as channels 3 (see Fig. 1) of 10x7 mm^2 cross-section was made at cavity face walls to cool down the cavity. The total water usage of 100 litres/min is provided at a pressure of 4 kg/cm^2.

Power input design is almost the same as for the cavity for the VEPP-4 facility. It contains a cylindrical window made of 22XC ceramics. Coupling between the cavity and RF magnetic field is controlled by rotating the loop to obtain the minimal VSVR value.

Frequency re-tuning is carried out by a plunger of

104 mm diameter. The plunger stroke of ±15 mm provides the frequency re-tuning in the range of ±1.45 MHz. The plunger is provided with cooling channels. Parts of a power input and a plunger having contact with vacuum are covered by TiN to prevent the multipactor RF discharge.

3 HOM DAMPING

The accelerating cavity has poor azimuthal symmetry, and every non-symmetric mode is separated into two orthogonal oscillations with different frequencies. Their azimuthal orientations are determined by location of the equivalent inhomogeneity. For example, at least two waveguides are needed to shunt orthogonal dipole modes. Three waveguides located with azimuthal symmetry always have noticeable coupling with non-symmetric separated modes and great coupling with symmetric ones. Coupling with the field is provided by holes in the cavity of the size averaged out to the inner size of the waveguides.

HOM power propagates through the waveguide by the fundamental TE_{01} mode and must be absorbed by the matched load, decreasing by so doing the damping time of parasitic oscillations. It is known that the matched regime can be provided by two manners: by placing absorber into the waveguide (i.e. into the vacuum in our case), or by using the mode transformer TE_{10} into TEM (wave-to-coax transition) and dissipating the HOM power in the matched load. The both methods have their own disadvantages; in the first case there are problems with the cooling and noticeable gas emission, in the second case — the standard wave-to-coax bandwidth generally cannot exceed an octave. The choice of the wave-to-coax transition design is determined by the specific parameters of the accelerator and the cavity. The traditional wave-to-coax design with cylindrical 22XC ceramic window has been chosen. The power transmitted through the wave-to-coax transition is limited by the coaxial cable safe power level (> 1.5 kW). Schematic of the wave-to-coax transition is shown in Fig. 1, frequency dependence of VSWR is shown in Fig. 2.

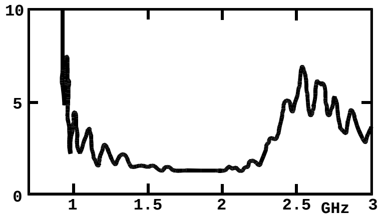

Fig. 2. VSWR of the wave-to-coax transition vs. frequency.

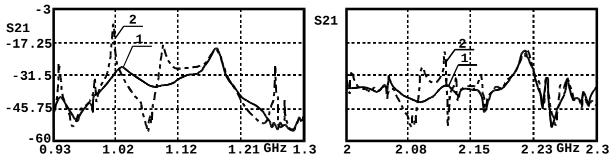

Fig. 3. S21 parameter vs. frequency: left – loads connected to wave-to-coax transition, right – loads not connected to wave-to-coax transition.

The measured bandwidth at VSWR<2 is about octave. HOM damping efficiency was measured by S-parameters method using P2-83 network analyser and low-coupling antennas. Figure 3 presents the measurement results for S21 parameter within a frequency range.

HOM quality factors within 0.9–2.2 GHz frequency range (i.e. within the range where HOMs with large R/Q value are located) do not exceed 100 for the most HOMs. The fundamental mode (E_{110}) quality factor decreasing when connecting the loads to the wave-to-coax transition is about 7.5%.

4 CAVITY TESTING

After assembling, the cavity was heated at workbench during 24 hours at a temperature of 150°C, and then inserted into the damping ring and connected to the systems of RF power supply, water cooling, and control. Vacuum 160 l/s ion pump provided 10^{-9} Torr vacuum without RF. Conditioning was started in pulsed mode, which prevented discharge path memorizing, limited discharge energy, and allowed us to provide the required pressure level by varying the relative pulse duration. After 2 hour conditioning the nominal voltage of 300 kV in continuous mode was obtained in the cavity at pressure of 10^{-8} Torr. The reflection coefficient in the cavity power supply feeder line corresponded to the one measured at low power level. The maximal heating was observed at a place of waveguide connection. Frequency detuning at 20 kW dissipating power level was – 150 kHz. The general view of the cavity is shown in Fig. 4.

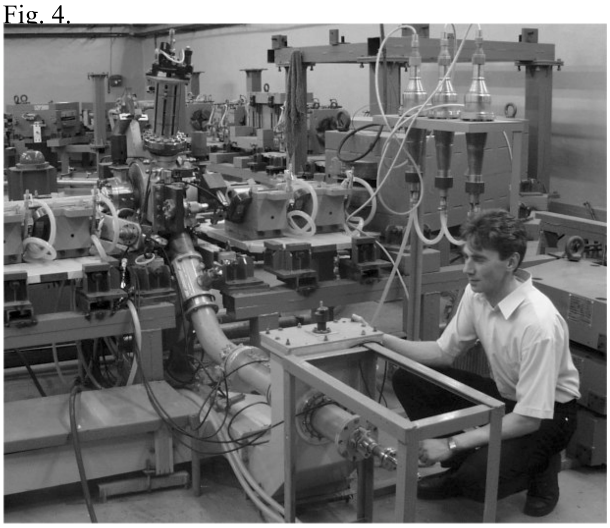

Fig. 4. General view of the cavity.

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