FIRST TEST RESULTS OF RF GUN FOR THE RACE-TRACK MICROTRON RECUPERATOR OF BINP SB RAS*

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Abstract

A new electron source for the Race-Track Microtron Recuperator is being developed by BINP SB RAS. It will increase average beam current and brightness of synchrotron radiation.

Instead of the static 300kV electron gun operated now we are developing RF gun with the same energy of electrons. This RF gun consists of RF cavity with a gridded thermo cathode mounted on the back wall. RF cavity is driven by a 60 kW generator with last stage equipped by GU101A tetrode tube. Operational frequency of the cavity is 90.2 MHz. It is equal to the second subharmonic of the Microtron RF system frequency. A set of low power electronics controls amplitude of the cavity voltage and its tuner.

This system, including a diagnostics beam line, has been installed to serve as a test bench to test the RF cavity and for beam dynamics studies. In continuous regime the designed 300 kV voltages at the acceleration gap is obtained. This paper summarizes the first test results of the cavity in this configuration.

INTRODUCTION

The RF electron gun for the Race-Track Microtron Recuperator [1] operated in BINP SB RAS (Novosibirsk) is described in [2]. RF cavity of the electron gun is made on base of the Microtron accelerating cavity [3]. The layout of the RF cavity is shown in Fig.1. Only the insertion assembly (3, 5, 11) and the conic nose (4) were designed and build anew. The other parts of the existing cavity were modified to the electron gun design requirements. This cavity is manufactured at the BINP workshop where novel technologies were used widely in the manufacture process such as electron beam welding and turner's work by diamond cutting tool.

CAVITY MANUFACTURE

The cavity cylindrical wall and side walls are made of copper-stainless steel bimetal. We have selected two side walls by ultrasonic scanner for checking the quality of bonding between copper and stainless steel layers.

Assembling of the cavity was made as follows. Firstly, the conic nose (4) was welded to the left side wall (2) (see Fig. 1). Then the left side wall was welded to the cylindrical wall (1), the insertion was welded to the right wall and finally the assembly was welded to the cylindrical wall.

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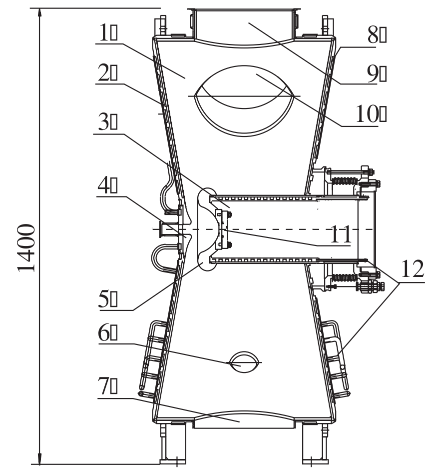

Figure 1: RF gun cavity layout. 1- cylindrical wall, 2-left side wall, 3-insertion, 4-conic nose, 5-electrode, 6-port for sampling loop, 7-vacuum pumping port, 8-right side wall, 9-RF power input port, 10-port for frequency tuning plunger, 11-vacuum cap, 12-water cooling tubes.

Conic Nose Welding

The maximum surface electric field with E_{peak}=10 MV/m is concentrated on the conic nose and on the electrode. To prevent an electric breakdown in the gap these parts were machined by diamond cutting tool using numerically controlled lathe. All other surfaces were mechanically polished by a tangle of thin nichrome wire. Then the conic nose was welded to the left wall in vacuum chamber of BINP electron beam welding installation (see Fig.2).

Welding of the Cavity

Before welding to the right wall the position of the insertion was set so that the resonance frequency of RF cavity under vacuum will be 90.2 MHz. To guarantee this the axial deformation of both discs after welding and deformation of disks under atmospheric pressure of both were accounted for. (see Fig.4). Measurement of the deformations was made only for the left disk. The other side of the cylindrical wall and all other ports were closed vacuum tight during measurements. It was presumed that deformation of the right side wall will be the same. The deformation under atmospheric pressure was measured to be 0.64 mm, welding deformation was 5.5÷7µm.

It is possible to correct the inaccuracy of the resonance frequency and cathode radial position by deformation of thin copper membrane close to the welding contact within ±0.5 mm. The cathode position is controlled by a rough tuning mechanism installed on the right side wall.

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Figure 2: The left side wall with the cone nose installed into the vacuum chamber before the electron beam welding.

Figure 3: The left wall welding to the sidewall.

Figure 4: Measuring tool of the welding axis deformation.

Plunger Modification

Two existing plungers for frequency tuning of the cavity during operation were modified to expand the frequency tuning range up to 150 kHz. The plungers were elongated by 30 mm by a copper caps that were welded by electron beam (see Fig.5). A thin layer of titanium nitride was sputtered onto the vacuum side of plungers to prevent multipacting, using the magnetron sputtering system and technology developed at BINP [4]. Before sputtering they were cleaned for UHV requirements in ultrasonic bath with 5% detergent, rinsed with deionised water, dried with dust-free air and stored in plastic bag.

RF Power Input and Coupler

RF power input of Microtron RF cavity 180.4MHz was worked into RF power input of our project. The loop area for the coupler should be increased 3.3 times according to the calculation. The loop was cut into two segments before brazing with the ceramic insulator in a vacuum furnace. As a result the pressure to the ceramic insulator due to a thermal expansion was excluded. After the brazing the loop segments were joined again by electron beam welding.

The sampling loop was modified also. The old loop was cut off and the new one longer by 40 mm was fixed on its place by electron beam welding (see Fig. 6).

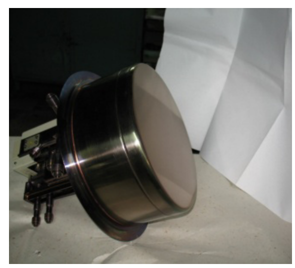

Figure 5: The modified plunger.

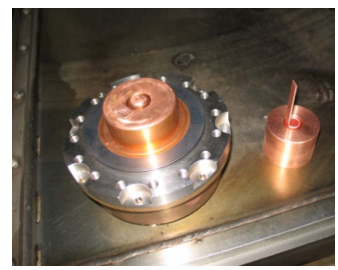

Figure 6: Sampling loop modificating components.

CAVITY PREPARATION

The cavity was tuned to resonance frequency of 90.2 MHz by adjusting the rough tuning mechanism. Then the RF power input position was adjusted by rotation to reach the VSWR of 3.21. In this case the power input will be matched during operation with a 100 mA current beam accelerated up to the energy of 300 keV. The unloaded Q-value was measured to be 25100. The sampling loop was rotated to have ~2W at 300 kV on the cavity gap and calibrated. Then RF power input and the sampler were welded to cavity ports. The all-metal gate vacuum valve with DN40 was installed at the beam pipe of the cavity and instead of the gridded cathode assembly a cap was installed.

Baking Out

Baking out under vacuum of the cavity allows to:

a) Clear out the surface from residual gas for better vacuum condition under RF; b) identify faulty components before processing under RF power. During baking out the cavity was heated to 220-240ºC with gradient of 10ºC/hr, was kept at this temperature for 70 hours and then cooled down to the room temperature with a controlled gradient (see Fig. 7). The vacuum pressure of $1.7 \cdot 10^{-7}$ Pa was obtained.

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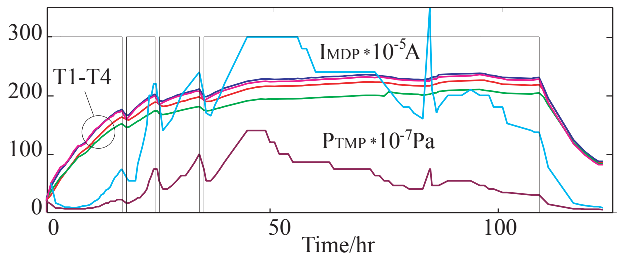

Figure 7: The baking out process. T1-T4 is temperatures of different sensors of the cavity in ºC, I_{MDP} is the current of magnetic-discharge pump, P_{TMP} is the pressure measured at the turbo molecular pump connection.

RF POWER TEST

RF Stand Layout

The 60 kW RF power generator with the tetrode GU-101A at the output stage was tested with equivalent of the load. Then it was connected with RF cavity by 100 m rigid coaxial line. The RF generator, low level control electronics were created at BINP. The RF power was measured by two methods: by directional coupler positioned on the coaxial line close to RF generator, and by a calibrated sampling loop of RF cavity.

The cavity is equipped by water cooling stand with the water flow meters and temperature sensors fixed on cavity surface.

The cavity was connected via bellows to a pumping system with rough pump, turbo-molecular pump, vacuum gauge and residual gas analyzer. In addition to RF measurements, data regarding X-ray emission, arcing were logged and used for distant control of the test regime (see Fig. 8). A fast interlock system on the vacuum controller's output switched off RF if residual gas pressure exceeded 10^{-6} mbar. After RF processing the vacuum better than $5{\cdot}10^{-7}$ mbar was obtained.

RF Power Tests

During RF processing we were raising the RF cavity gap voltage by 5-10 kV steps. Conditioning was started in pulse mode to perform RF power conditioning otherwise due to the multipacting discharge there was a deterioration of vacuum to inadmissibly low level. After several days of RF conditioning 300 kV of the gap RF voltage was reached in CW mode and was kept for a least one day without any vacuum activity. We reached 470 kV in a pulse mode.

During the testing dependency of resonance frequency on RF power was measured. Due to heating of different cavity parts the resonance frequency drifted in the range of 300 kHz when the RF power is switched on, so the plungers tuning range of 150 kHz is not sufficient. To overcome this problem we suppose to use an ancillary Master Oscillator of the control system. When the RF power is switched on and the RF cavity is warming up the ancillary Oscillator and cavity tuner are operated so that frequency of ancillary oscillator would coincide with that of the Microtron Master Oscillator. Then the system is switched to the Microtron Master Oscillator.

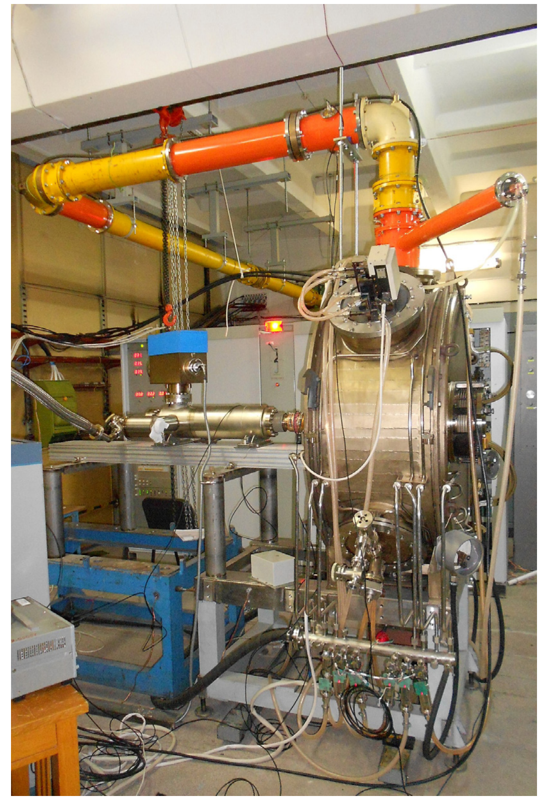

Figure 8: RF stand of the conditioning at high RF power.

During testing we compensated the total frequency drift of the cavity resonance frequency down to 100 kHz by redistribution of the water flow in different cooling channels. The maximal water flow of 12 l/min was directed to the insertion and minimal flow of about 1 l/min to the cavity cylindrical wall. The maximal temperature of about 60ºC was at the membrane connecting the insertion with right side wall. The vacuum in continuous mode was measured to be $4{\cdot}10^{-6}$ Pa.

At maximal gap voltage of 300 kV the X-ray radiation of 36 mR/hr was measured at the distance of 1.7 m from cavity.

CONCLUSION

RF gun cavity has been tested; operated gap voltage of 300 kV is obtained. Now the work with the cathode installation and beam diagnostics hardware is underway.

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