

RF SYSTEM OF THE RACE-TRACK MICROTRON – RECUPERATOR FOR HIGH POWER FREE ELECTRON LASER

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Abstract

A brief description of the RF system of 100 MeV race-track microtron-recuperator being built in Novosibirsk for the Free Electron Laser project at Siberian center of Photochemistry research is presented. The frequency of RF system is 180.4 MHz. Mode of operation is CW. The RF system consists of 2 parts: the RF system of 2 MeV injector and the RF system of microtron. The injector RF system includes 3 RF cavities - one buncher cavity and two accelerating cavities. The RF system of microtron includes 16 RF cavities operating at a gap voltage of 850kV each. Each of 600 kW 4-tubes power amplifiers supply the RF power to the 8 cavities via distribution waveguide. The control system controls the amplitude and phase of RF voltage in the cavities and provides signals for synchronization of the electron gun. All the 16 cavities (8 sections), two generators are already installed into microtron. The power RF generator, analogous to the ones built for the microtron, were tested in the RF system of VEPP-4 collider. The results of the operation of the injector RF system and status of large RF system for the microtron are discussed.

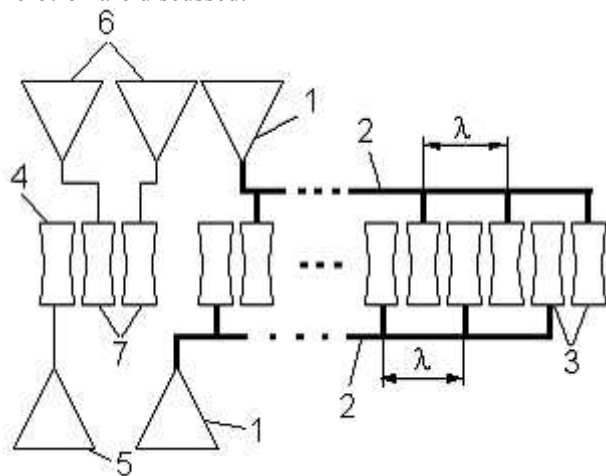


Figure 1: General scheme of RF system for the race-track microtron-recuperator.

1 INTRODUCTION

The project of high power FEL [1] calls for a construction of eight-turns 100MeV racetrack microtron with average current up to 50 mA. The general scheme of the RF system is shown in fig.1. The buncher cavity (4) is fed with RF power by 2.5kW RF generator (5). The two accelerating cavities (7) are fed by two 130 kW

generators (6). The 16 accelerating cavities of microtron (3) are driven by two generators (1) with total output power up to 1.2 MW.

2 RF CAVITIES

The design of the accelerating cavities is described in [2] in details. The shells of cavities are made from bimetal (copper clad stainless steel sheets, 8 mm of copper and 7 mm of stainless steel), produced by diffusion welding. The cavity is cooled by water, the water cooling channels being made in the stainless steel only. The sketch of 2-cavity section is shown in fig. 2.

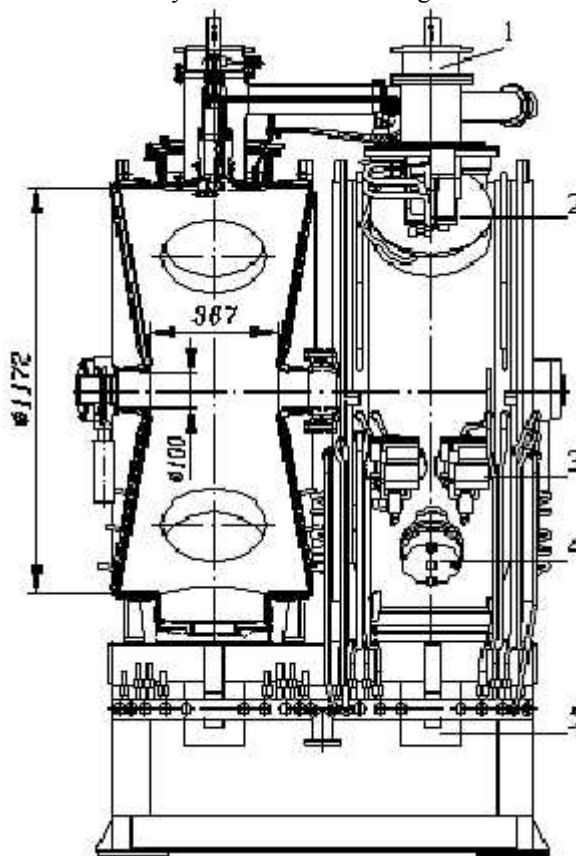


Figure 2: Sketch of the RF cavity.

Each resonant cavity is equipped with 2 contactless plunger tuners (2) for the fundamental mode tuning and two HOM tuners (3). The coaxial power input coupler (1) with cylindrical ceramic window is placed on top of the cavity. Before the installation in the cavity each input coupler is tested on a special test bench up to the RF voltage equivalent to 400kW in travelling wave mode. A

sampling loop (4) is used to measure the operating gap voltage. An ion vacuum pump (5) is mounted to the cavity bottom.

After the assembly of the cavity, parameters of the fundamental and higher order modes are measured on a special stand [3]. The frequencies and Q-factors of the cavity modes up to 1500 MHz are measured for different positions of the tuners. The HOM tuners shift the resonant frequencies of the higher order modes, while their influence on the fundamental mode is rather weak. A bead-pull measurements are carried out to study the distribution of electric field along the cavity axis and to calculate the R_{shunt}/Q values. Based on the measurement data, the HOM tuners may be set to the positions corresponding to the weak interaction between the electron bunch and higher order modes.

Table 1: The parameters of the accelerating cavity

Resonant frequency	f_0	180.4	MHz
Tuning range	Δf_0	320	kHz
Quality factor	Q_0	40000	
Shunt impedance	$R=U^2/2P$	5.3	MOhm
R/Q value	ρ	133.5	Ohm
Gap voltage	U	0-950	kV
Dissipated power at $U=950$ kV	P	85	kW

After completion of the measurements, the two resonant cavities are assembled into a section, which is evacuated and baked in a furnace at 300C. The vacuum in the cavity after baking is better than 10^{-7} Pa. Before the installation in the microtron accelerating string, all the cavities are tested at high CW RF power on a special stand to process away multipacting. The cavity on the test stand is driven by one of the injector generators. The cavity is tested up to 1100 kV gap voltage.

The cavity is designed so that the fundamental mode resonant frequency shift due to the RF heating of the cavity walls is quite small. The change of frequency is only about 10 kHz when the gap voltage changes from 100 kV to 900 kV.

3 RF GENERATORS

High Power tube RF CW modular design generator [4] was developed and produced in INP.

Anode rectifier 8 kV, 320 A was developed and produced in INP too. Anode rectifier has a protection system for quick (50 μ s) turn-off anode voltage if breakdown takes place.

There are two generators with output RF power up to 600 kW for each. Each generator consist of four stages (fig.3). First and second preliminary stages (4) are realized on basis of tube GU-92A. Third preliminary stage (5) is performed on basis of one-tube module with GU-101A. Output four-tube module stage (6) combines the power from four tubes GU-101A.

Two generators with one-tube module output stages with GU-101A operate at the RF system of the injector of microtron-recuperator.

The tubes GU-101A and GU-92A tetrodes are produced at SVETLANA, St. Petersburg. The system for dividing RF power between the accelerating cavities (1) consists of rectangular waveguide (3) and of the coaxial lines (2) connected to the inputs of the cavities.

The accelerating cavities are divided into two groups. Each group consists of 8 cavities and is connected to itself waveguide.

The scheme of one 600 kW channel is shown in fig. 3 too. The waveguide has cross-section 958 x 415 mm.

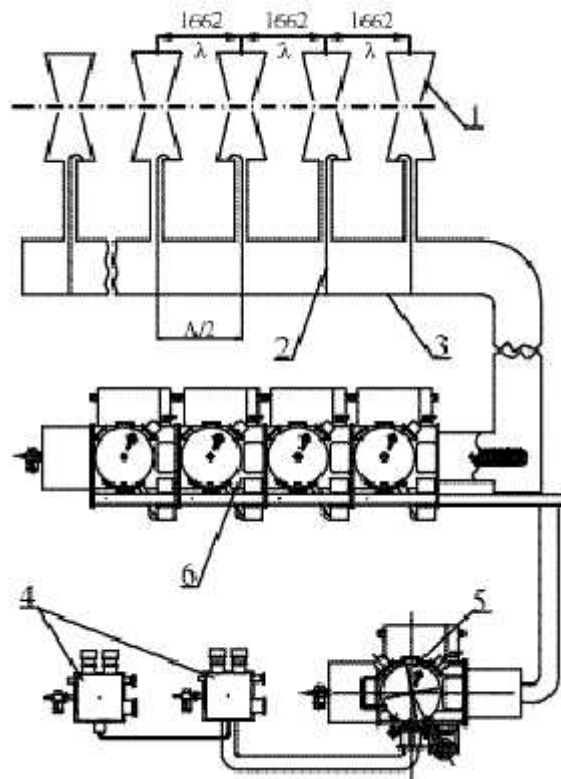


Figure 3: 8-Cavities channel of RF system of microtron.

The RF cavities, driven by a single RF power source, are located at a distance of one free-space wavelength (1662 mm) from each other. Coaxial lines connect cavities with a rectangular waveguide, which is used as a power distribution unit. Waveguide dimensions are chosen so that the waveguide wavelength was equal to two free-space wave lengths. Therefore, the coax-to-waveguide transitions (2) are spaced by each half of the guide wave length.

Each cavity has a main coupler of a loop type. It is connected to the waveguide with a short coaxial line using a coax-to-waveguide transition, which is placed near a small sidewall of the waveguide. The lengths of all coaxial lines are equal. For obtaining the right phasing of cavity fields, the main coupling loops in the neighboring cavities of a group are rotated on 180°.

Power distribution along the cavity chain is proportional to the distribution of cavity shunt impedances. If the shunt impedances and tunes of the cavities are equal, the driving powers are also equal.

Matching of the dividing waveguide is performed with inductance stub in waveguide.

4 CONTROL SYSTEM

The low level electronics of the Control System controls amplitude of accelerating RF voltage and performs phasing of the RF generators with RF System of Injector. RF voltages of both RF generators are controlled independently and both channels have the same design.

There is a feedback loop to control amplitude of accelerating voltage. The sum of DC voltages from amplitude detectors of RF cavities sampling signals are compared with the reference DC voltage from DAC by means of an operational amplifier. Output of the operational amplifier controls gain of a stage of the RF generator.

RF voltages of cavities which are connected to one RF generator are phased mutually by a proper design of the RF power distribution system i.e. by choice of length of wave guides, coaxial lines and distances between RF cavities. In this case the error of mutual phasing of RF voltages of the channel is determined by error of the cavities tuners.

The total RF voltage seen by the beam when crossing the 8 cavities driven by a common RF generator is synthesized from sampling signal of each cavity for phasing of RF voltage of each RF channel to the Injector. A phase meter compares this synthesized signal with the common reference RF signal of RF System. Output of the phase meter controls a phase shifter in one stage of the RF generator. For initial phase setting a manually controlled phase shifter is used which is switched between the RF reference voltage source and the phase meter.

5 UP TO DATE STATUS

The injector has been operated at beam current of 45 mA and the energy of the accelerated electrons of 2MeV. The buncher cavity was operated at the gap voltage of 100 kV, and the accelerating cavities - at 770 kV each. The power, transferred to the beam in the accelerating cavities was 31.5 kW. More detailed description of the injector and the results of its operation are given in [6].

All the 16 cavities (8 sections) are already installed into microtron. The two generators for them (2×600kW) are placed in separate room. Now the whole RF system is assembled. The adjustment of RF system on a high power level is conducted.

Now the output power of 400 kW and efficiency of 50% for the each output stage is achieved. The sum of the gap voltage of 8 accelerating cavities were about 5.5 MV.

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