

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

V.S. Arbusov, A.S. Bushuev, V.N. Volkov, N.G. Gavrillov, E.I. Gorniker, E.K. Kenjebulatov, A.A. Kondakov, S.A. Krutikhin, Ya.G. Kruchkov, I.V. Kuptsov, G.Ya. Kurkin, V.Yu. Loskutov, L.A. Mironenko, S.V. Motygin, V.N. Osipov, V.M. Petrov, A.M. Pilan, I.K. Sedlyarov, A.G. Tribendis, N.G. Fomin
Budker Institute of Nuclear Physics
630090 Novosibirsk, Russia, Lavrentyev Ave. 11

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.

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. RF cavities are driven by a 2.5 kW amplifier and two high power single-tube 130 kW RF amplifiers respectively. The RF system of microtron includes 16 RF cavities operating at a gap voltage of 850kV each. Two 4-tubes power amplifiers supply the RF power of 600 kW each to the cavities via distribution feeders. In the high power amplifier stages the tetrodes GU-101A are used.

The control system controls the amplitude and phase of RF voltage in the cavities and provides signals for synchronization of the electron gun. The results of the operation of the injector RF system and status of large RF system for the microtron are discussed.

PACS numbers: 41.60.Cr

1 INTRODUCTION

The project of high power FEL [1] calls for a construction of eight-turns 100 MeV 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 2.5 kW 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 of 1.1 MW, which is limited by the existing anode power supply.

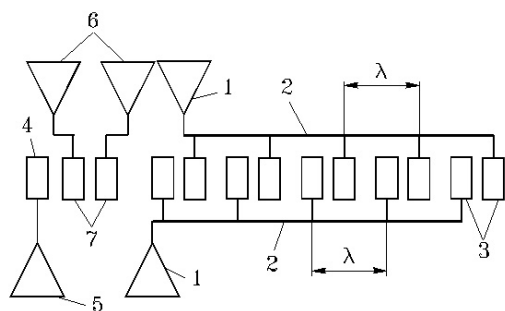


Fig. 1. General scheme of RF system for the race-track microtron-recuperator.

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. 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.

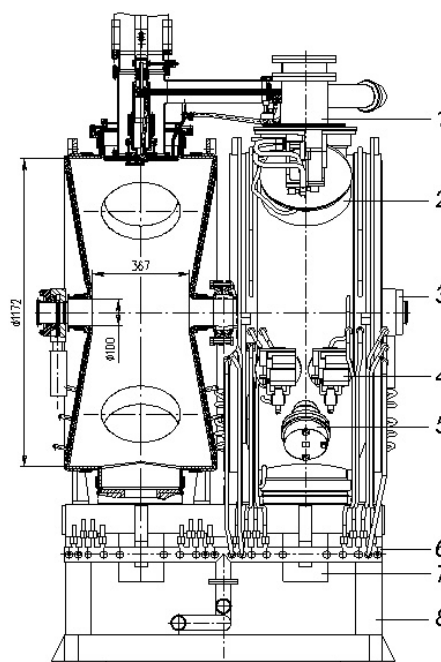


Fig. 2. Sketch of the RF cavity.

The parameters of the fundamental E010-like mode are given in Table 1.

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/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 300°C. 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 CW RF generators [4] were developed and produced at BINP. The generators have a modular design.

Anode rectifier (8 kV, 320 A) was developed and produced at BINP too. Anode rectifier has a protection system for a quick (50 microsec) switching-off the anode voltage if breakdown occurs.

There are two generators with output RF power up to 600 kW each. Each generator consists of four stages (fig.3). First and second preliminary stages (4) are realized on basis of the 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 GU-101A and GU-92A tetrodes are produced at SVETLANA, St. Petersburg.

The system for dividing RF power between the ac-

celerating cavities (1) consists of the 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 its waveguide.

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

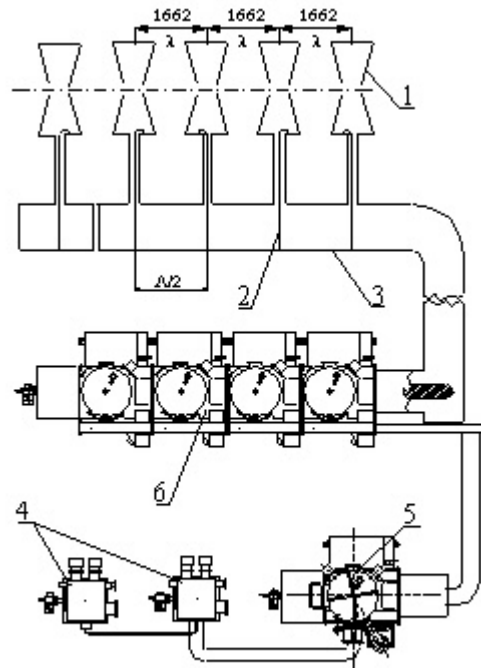


Fig. 3. 8-Cavities channel of RF system of microtron.

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 equals to two free-space wavelengths. 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 by 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 control electronics controls the amplitude of accelerating RF voltage and performs phasing of the RF generators with RF system of the 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 the cavities which are connected to one RF generator are phased mutually by a proper design of the RF power distribution system. In this case the error of mutual phasing of RF voltages of the channel is determined by error of the cavities tuners.

An RF signal, representing the total voltage seen by the beam when crossing the 8 cavities driven by a common RF generator, is synthesized from the sampling signals of each cavity and used 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 placed 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 the microtron. The two generators for them (2×600 kW) are placed in separate room. The tests of the entire RF system will be performed after the completion of assembling of the waveguide – coaxial power distribution system.

The power RF generator, analogous to the ones built for the microtron, were tested in the RF system of VEPP-4 collider. The output power of 500 kW and efficiency of 53% for the output stage were achieved.

REFERENCES

1. B.Baklakov et al. Status of FEL project for Siberian center of Photochemistry research // *Proc. of XIII Russian conference on SR applications*, July 17-21 2000, Novosibirsk, Proceedins of conference, p. 24-29.
2. N.Gavrilov et al. *RF Cavity for the Novosibirsk Race-Track Microtron-Recuperator*, preprint 94-92 of Budker INP of Siberian Branch of Russian

- Academy of Sciences, Novosibirsk, 1994.
3. E.Kenjebulatov et al. Setup for Measuring RF Characteristics of Accelerating Cavities // *Proceedings of XVII International Conference on High Energy Accelerators*, September 7-12, 1998, Dubna, Russia, p. 131-133.
4. V.Arbuzov et al. High Power Module Design RF generator for Storage Rings and Accelerators // *Proc. of XVI Conference on Charged Particles Accelerators*, October 1998, Protvino.
5. B.Baklakov et al. The 8kV Power Supply for RF Generators Anode Feeding // *Proc. of XVII International Conference on High Energy Accelerators*, 1998, Dubna, Russia.
6. V.Arbuzov et al. RF System of Electron Injector for the Race-Track Microtron-Recuperator and Results of its Operation with Electron Beam // *Problems of Atomic Science and Technology. Issue: Nuclear-Physics Research* (35). 1999, # 4, p. 26-28.