Moscow State University CW Race-Track Microtron Status

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I. INTRODUCTION

Continuous wave (CW) race-track microtron (RTM) with the maximum output energy of 175 MeV and beam current 100 mcA is under construction at the Institute of Nuclear Physics of Moscow State University [1]. The main parameters of the RTM are listed in Table 1, its plan view is shown in fig. 1.

Table 1. The main parameters of the RTM

Injection energy	6 MeV;
Energy gain per pass	6 MeV
Maximum number of passes	27
Output energy	24-175 MeV
Energy spread	10^{-3} - 10^{-4}
Transverse beam emittance	0.05 mmxmr
Maximum current	100 mcA
Increase of orbit circumference per turn	1 λ
Distance between end magnets	10 m
End magnet field	1.027 T
End magnet weight, each	18 t
Length of linac	6.24 m
Effective shunt impedance	78 MOhm/m
Number of klystrons	12+1
RF frequency	2450 MHz
Total rf power consumption	205 kW

II. RTM DESCRIPTION.

The cw RTM consists of the following main systems: injector, consisting of electron gun, chopper-buncher, capture section and preaccelerator; injection transport line; main linear accelerator located between two 180^0 end magnets; rf system; cooling and thermoregulating system; beam monitors; control system.

The electron gun beam with the energy of 100 keV passes through the chopper-buncher system and then is accelerated in the capture section and preaccelerator up to the energy of 6 MeV. The 6 MeV beam enters the main linac. After the first acceleration up to 12 MeV the beam is reflected and accelerated in the opposite direction up to 18 MeV. Then the beam enters the first orbit of recirculation. This scheme allows us to provide sufficient beam clearance from the linac on the first orbit. Compensation of beam displacement, because of the influence of the injection magnet M8 and mirror magnets M9, M10, is achieved by means of correct choice of effective lengths and fields of M11 and M12 magnets.

Electron gun [2] consists of a large anode and focusing electrodes confined in a cylinder with the diameter of 300 mm made of magnetic steel which serves as a magnetic shield and vacuum vessel. High voltage and heating current are supplied through a special cable with high voltage conjunction. Cathode, made of impregnated tungsten, has a 3.2 mm diameter of active surface. Measured beam emittance at the energy of 100 keV is 5.8 mmxmrad [3]. Maximum beam current is 10 mA, high voltage stability ∓ 0.1 keV.

The beam parameters are controlled by wire scanners [4], luminescent screens and by rf beam position, current and phase monitor [5].

Chopper - buncher system is intended for forming electron bunches of 10^0 bunch length, ∓ 2 keV energy spread, 4 - 5 mmxmrad transverse emittance, and 100 mcA mean current from 100 keV continuous electron beam [6].

Two types of accelerator structures were tested for RTM project - an on-axis coupled structure and a disk and washer structure (DAW) with radial stems. The results of

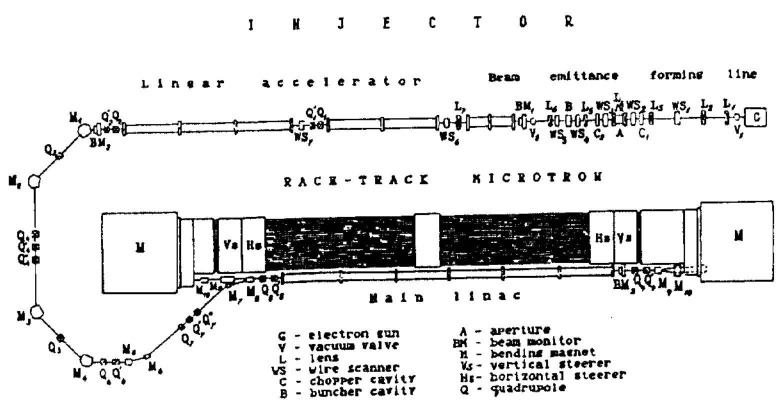

Fig. 1.

Plan view of the cw race-track microtron.

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investigation of DAW structure are described in ref. [7]. During these investigations the problem of parasitic modes was solved, but considerable reduction of effective shunt impedance ZT^2 of this structure because of the radial stems makes it difficult to use this structure for cw machines.

An on-axis coupled structure was adopted for RTM project. The calculated values of the quality factor and the effective shunt impedance Q =17500, ZT^2 =92 MOhm/m, respectively [8,14]. This calculation doesn't take the influence of the coupling slots into account.

The schematic view of a standard accelerating section, which is comprised of 17 accelerating and 16 coupling cells, is shown in fig. 2. The section is cooled through 40 circumferential 4 mm-diameter channels bored along the axis on the periphery of the cells; the rf power input cell is cooled separately. For field control, a rf probe, located at the rf power input cell, is used. Plungers for resonant frequency tuning are absent.

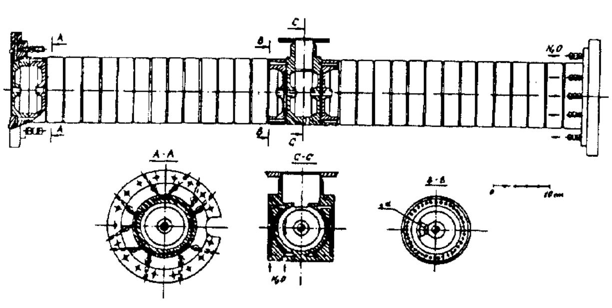


Fig. 2. Construction of accelerating section.

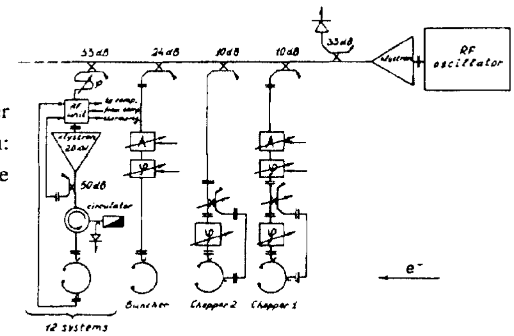
The first neighbour coupling constant of 4.4 % was obtained with the coupling slots located at the cavities' webs, one slot for each web, having an azimuthal span of 55.6^0. The orientation between adjacent coupling slots is 180^0. The tuning of the cells was carried out by lathe turning before brazing and by deforming the webs of the detuned cavities after brazing. Total number of fabricated sections with β=1 is 11. The measured effective shunt impedance for all the sections is 78 $\mp$3 MOhm /m and intrinsic quality factor is 15 000 $\mp$ 500.

A block diagram of the rf power supply system [9] is shown in fig.3. The reference signal, which is generated at the rf frequency of 2449.600 MHz by a stabilized oscillator excites a 3 kW klystron. The klystron output power level may be changed by a computer controlled attenuator. Chopper cavities C1, C2 and the buncher B are excited from the reference signal line through directional couplers with 10 dB, 10 dB, and 24 dB attenuation, respectively. The klystrons supplying the accelerating sections are excited through directional couplers with 33 dB attenuation.

Each of the rf power supply channels, one for each accelerating section, has a phase shifter, a rf unit, a klystron, a circulator with water dielectric load, and a directional coupler for controlling incident wave.

The rf unit is made up on the basis of microstripe rf devices such as a p-i-n attenuator, a phase shifter in the

Fig. 3.



Block-diagram of the RF power supply system: ψ - phase shifter, A - attenuator.

form of a meander line on a ferrite layer, two phase detectors combined with phase shifters for selecting the phase detectors operating points, several diodes, a 5 W rf amplifier and other rf devices. The rf unit forms the klystron input signal as well as signals for phase, amplitude and resonant frequency control systems of the linac, made as local analog computer control subsystems. An important function of the rf unit is to ensure a simple and straightforward start-up of the accelerating sections [10].

The basic klystron parameters are listed in table 2.

TABLE 2

Operating frequency	2450 MHz
Maximum output power	22 kW
Gain	40 dB
Efficiency	55 %
Beam voltage	10 kV
Beam current	4 A
Focusing	By permanent magnets

The construction of bending magnet is shown in fig.4. It consists of main yoke, reverse field yokes, poles, separated from the main yoke by homogenizing air gap, the main coils, and reverse field coils. Sheems are placed in air gaps between main yoke and poles. The configuration and mass of main yoke, position of reverse field yokes, thicknesses of air gaps, sheems and poles were optimized by "FEM12B" code [11]. The height of poles' gap was chosen to be 60 mm in order to leave enough space for

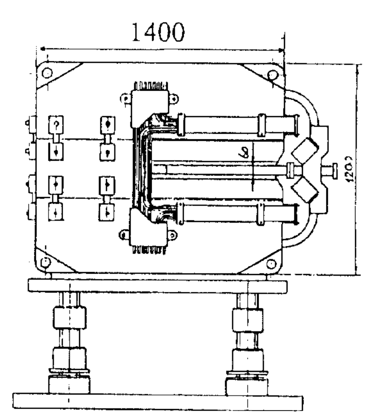


Fig. 4. Construction of bending magnet.

vacuum chamber and correcting plates. The size of poles is 1500x700 mm . Magnets were fabricated from steel 10. Vacuum chambers were made of aluminum alloy. Special computer controlled coordinate table with Hall probe was designed for field measurements. The accuracy of probe movement by step motors in two directions is about 0.05 mm. The measurements of field uniformity are in progress.

Control system is described elsewhere [12]. The function of the control system of the microtron is to support means for an easy programming of accelerator's behavior, when being adjusted, and to meet requirements of experimental work. Local feedback loops are needed to control parameters of RF accelerating sections.

Performance of the 6 MeV injector is described in ref [13]. The injector linac (fig.1) comprises a capture section consisting of 17 accelerating cells of a biperiodic on-axis coupled structure with tapered β, and five accelerating sections of 17 accelerating cells each with β=1. The beam is focused by a solenoidal lens, L7, and a quadrupole pair, Q1 Q1' . In order to measure the beam energy and energy spread, a 45^0 dipole magnet is used. Fig.5 shows the beam photos after three accelerating sections , at the exit of the linac, and after the dipole magnet. In the last case, the beam energy was 6.2 MeV. The beam dispersion of 3.5 mm corresponds to the energy spread of $\mp$20 keV. The minimum energy spread of $\mp$15 keV was obtained at the energy of 6 MeV.

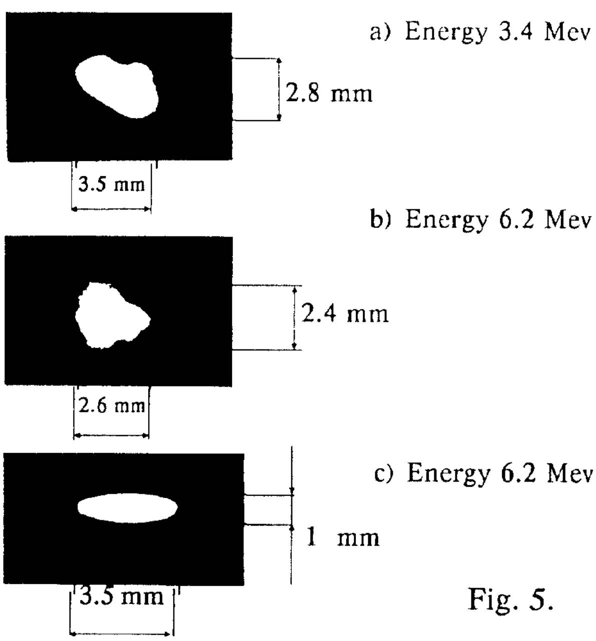
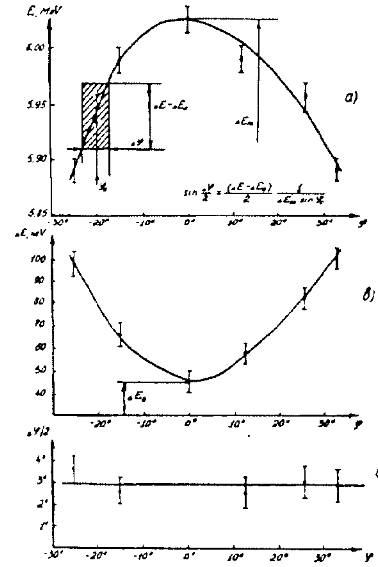


Fig. 5.

The dependence of beam dispersion from the last section accelerating phase was used to estimate the electron bunch phase length. Since, as far as such a bunch has a finite phase length, an additional energy spread occurs when the bunch is shifted relative to the last section accelerating field maximum. Fig.6 shows : a) beam energy, b) energy spread, c) estimates of the bunch phase length -

Fig. 6. Calculated and measured dependencies of
a) energy of the beam;
b) energy spread of the beam;
c) phase length of the bunch ,
upon the phase of the last accelerating section.



versus the accelerating phase of the last section. The estimated bunch phase length is 6 ∓ 2^0.

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