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ACCELERATING RESONATOR FOR THE VEPP-2 STORAGE RING

by

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A b s t r a c t

The resonator of the VEPP-2 storage ring operates in two oscillation modes: the antiphase mode (natural frequency 75 MHz, shunt resistance about 1 Mohm) and in the inphase mode (natural frequency 25 MHz, effective shunt resistance about 7.5 kohm). The operating accelerating voltage of up to 300 kv at the third-harmonic of the rotational frequency is ensured by the first mode. The second mode is used to recapture the particles from three separatrices onto one. Full account is taken in the resonator design of the required spectrum of higher natural frequencies, so that coherent synchrotron and betatron oscillations are adequately damped out.

The design of the described accelerating system is determined by the properties of the VEPP-2 storage ring. The latter has a single experimental section of relatively short length. Accordingly, efficient recording of the various events can be achieved only if the particle bunches are short, e.g. of the order of 15 to 20 cm. The bunch length reduction can be achieved by increasing both the accelerating-voltage amplitude and the high-frequency multiplicity. The third harmonic was therefore chosen for the operating frequency. This means, however, that three bunches of electrons and positrons may be produced during the storage time. To produce a single bunch the storage process must be operated on the first harmonic, followed by transition to the third harmonic. The accelerating system must therefore ensure operation at both first- and third-harmonic frequencies. Moreover, to ensure beam stability against the spontaneous growth of phase and betatron oscillations, the position of the natural frequencies of the higher resonant modes of the accelerating system must satisfy relatively stringent conditions[1,2].

The restricted length of the segment corresponding to the accelerating resonator has led to the development of a system having two operating natural frequencies corresponding to the first (25.2 MHz) and third (75.6 MHz) harmonics of the rotational frequency of the particles. The resonator is shown schematically in Figure 1.

The resonator 4 contains a tube with disks 2 at the ends (the "bobbin"). This forms the inner conductor of the coaxial line with the disk capacitances at the ends. The natural frequency corresponding to the resonance mode is approximately 75.6 MHz, i.e. it is equal to the third harmonic. This mode is the anti-phase mode. The electric field in the gaps is in the same direction as the motion of the particles. The "bobbin" 2 is suspended at the end of the rod 3 located at the voltage node of the anti-phase mode and has therefore no effect on the field distribution.

In addition to the anti-phase mode the resonator can also maintain the in-phase mode with a resonance frequency of about 25.2 MHz. For this mode the capacitance is formed by joining the disk capacitances in parallel, and the inductance is provided by a shorted segment of the coaxial line formed by the rod and the tube 6. Shorting is achieved by the blocking capacitance 8, which means that a constant voltage of about 6 kv can be applied to the "bobbin" in order to prevent resonance discharge across the working gaps. The rod is taken out of the evacuated volume through the ceramic insulator 5. The resonator body 4 is situated in the outer vacuum chamber.

For the in-phase mode the "bobbin" operates as a drift tube. The effective accelerating voltage at the first-harmonic frequency is about 25% of the voltage across each gap.

Retuning to the resonance frequencies is achieved by two devices. One of them varies simultaneously the two capacitive gaps through the elastic deformation of the walls of the resonator 4. This affects both resonant frequencies. Independent adjustment of the in-phase mode (25.2 MHz) is achieved by rotation about the vertical axis of five shorted frames 7 which are in the inductive part of the resonator.

The anti-phase mode is excited with the loop 1 which lies in the symmetry plane of the resonator. The loop is introduced through a ceramic insulator. To excite the in-phase mode the feeder passing from the 25.2 MHz oscillator is connected through the capacitor 10 to the blocking capacitor 8. The reactance of the latter is 1/50 of the total capacitive reactance of the in-phase mode. This ratio was chosen in order to match the resonator to the 60 ohm feeder.

The above excitation system ensures satisfactory decoupling of the exciting devices.

The most important parameters of the resonator are given in the table below:

Table 1. Resonator parameters

Parameters	Anti-phase mode	In-phase mode
Effective accelerating voltage (amplitude), kv	300	12
Q value	12,000	2,000
Shunt resistance (referred to the accelerating gap with the effective voltage), kohm	1,000	7.5

The higher resonant modes of the resonator can be split into two types, depending on the structure of the electromagnetic fields in the region of interaction with the beams. Symmetric modes have a maximum longitudinal component of the electric field along the axis of symmetry. They can therefore be excited by short particle bunches if their frequency is close to the resonant frequency. It was shown in ref. 1 that the symmetric mode can give rise to a phase instability of the beams if its natural frequency is close to $n\omega_s + \Omega_o$ where ω_s is the rotational frequency of the particles, Ω_o is the frequency of synchrotron oscillations, and n is an integer. This quantity is not very different from $n\omega_s$, i.e. from a harmonic of the rotational frequency. Since the rotational frequency can be varied within certain limits, one must try to ensure that none of the symmetric modes has a natural frequency approaching $n\omega_s$.

Antisymmetric modes, i.e. those which have one period of field variation in azimuth, are particularly dangerous among the asymmetric modes in the sense of stability. Such modes have maximum magnetic fields along the axis, and can therefore interact with transverse (betatron) oscillations. It was found in ref. 2 that an anti-symmetric mode may lead to betatron instability if its natural frequency is close to $n\omega_s - \omega_n$ where ω_n is the betatron oscillation frequency.

It is well known that the cavity resonator has an infinite set of resonant modes. It is clear that only those modes will be dangerous from the point of view of stability whose natural wavelength is not less than the bunch length. This condition restricts the spectrum of dangerous modes and ensures that the suppression of such modes is not a hopeless task.

Studies of higher-order modes were carried out by numerical and experimental methods. The results obtained by the different methods were then compared.

The experiments were carried out with a 1:1 resonator model which was investigated in the frequency range up to 1700 MHz. The natural frequencies of the resonant modes and their characteristic resistances referred to the accelerating gaps were determined. A study was also made of the field structure in the resonator. Electric and magnetic probes inserted into the accelerating gaps along the resonator axis were used for the purposes of excitation and detection. This enabled us to investigate separately the symmetric and anti symmetric modes. The spectra were investigated with wide-range sweep oscillators.

The characteristic resistances were determined by introducing into the gap an ampule filled with water ($\varepsilon = 81$) and measuring the shift of the resonant frequency. The Q-factor of the resonant modes was measured on the finished resonator. The coupling resistance for a given mode was then determined from the formula $R_{coupling} = \rho Q$ where ρ is the characteristic resistance and Q is the Q-factor.

Figures 2 and 3 show a summary of all the measurements of the higher resonant modes. Each diagram represents a long frequency axis (in MHz) divided into 100-MHz sections situated under one another. The oblique shaded bands at the points of intersection with the frequency axis segments indicate the dangerous zones for synchrotron (Figure 2) and betatron (Figure 3) radial and vertical oscillations, into which parasitic resonances should not enter.

Our study of the higher resonant modes has enabled us to correct the resonator dimensions, which govern the main natural frequencies. Operating tests on the resonator have shown that there is a working region of rotational frequencies in which coherent instabilities do not appear.

R e f e r e n c e s

1. V.L. Auslender, M.M. Karliner, A.A.Naumov, S.G. Popov, A.N.Skrinskiĭ, and I.A. Shekhtman, Atomnaya Energiya, 20 (1966) 210
2. N.S.Dikanskiĭ, M.M.Kurliner, A.N.Skrinskiĭ, V.E.Shapiro, and I.A.Shekhtman, Atomnaya, Energya, 22 (1967) 188

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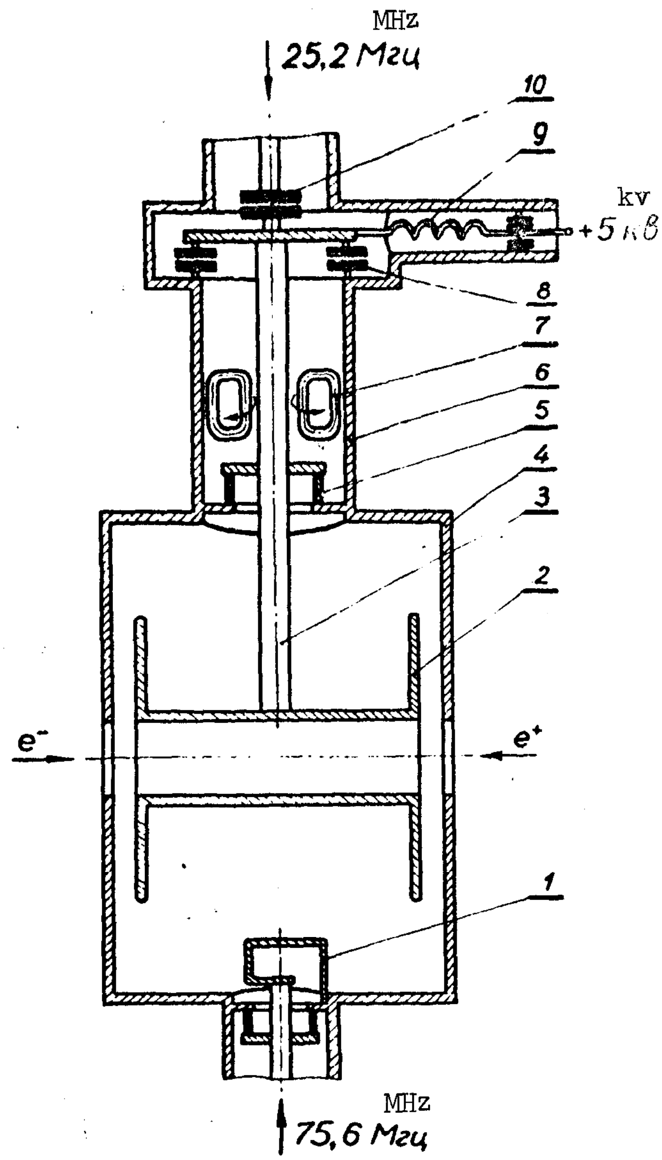

Figure 1 - Schematic drawing of the resonator:
1 - excitation loop for the third harmonic; 2 - tube with discs (bobbin); 3 - rod; 4 - resonator body; 5 - ceramic insulator; 6 - outer tube of the shunting inductance; 7 - frames for the first-harmonic tuning; 8 - blocking capacitor; 9 - choke; 10 - blocking capacitance

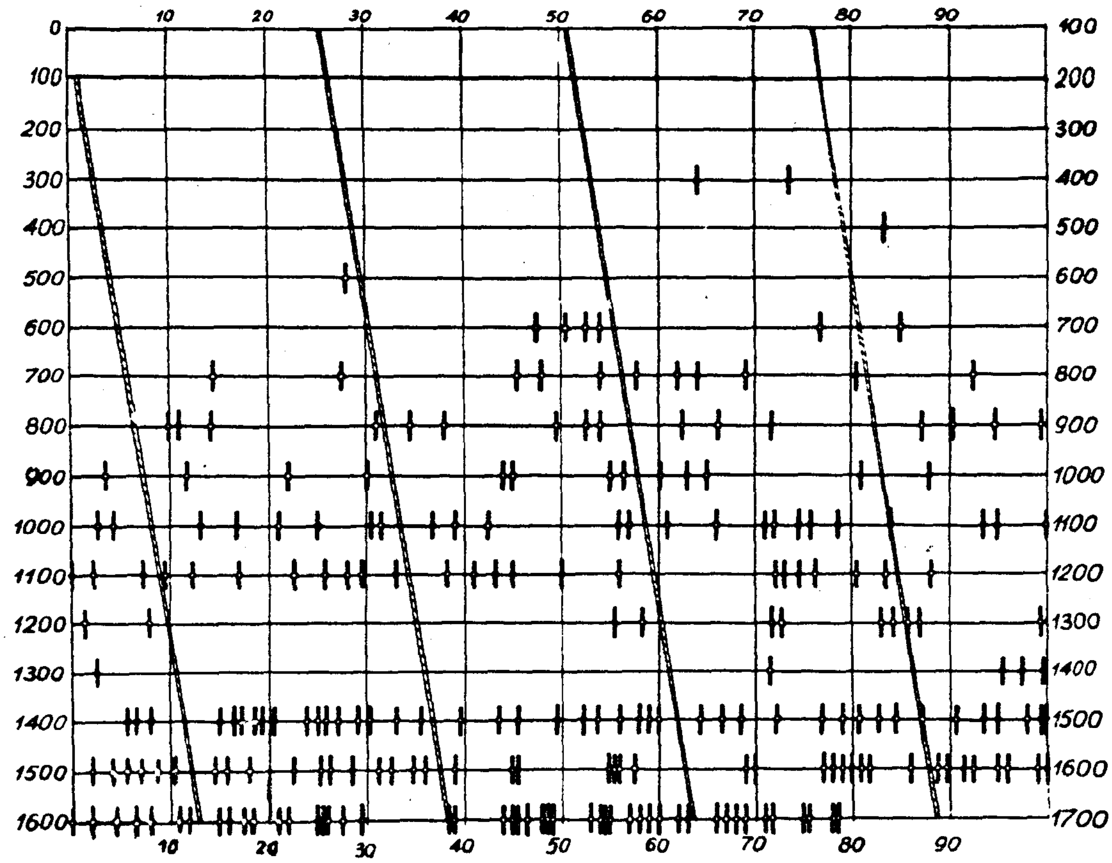

Figure 2 - Diagram of symmetric resonant modes

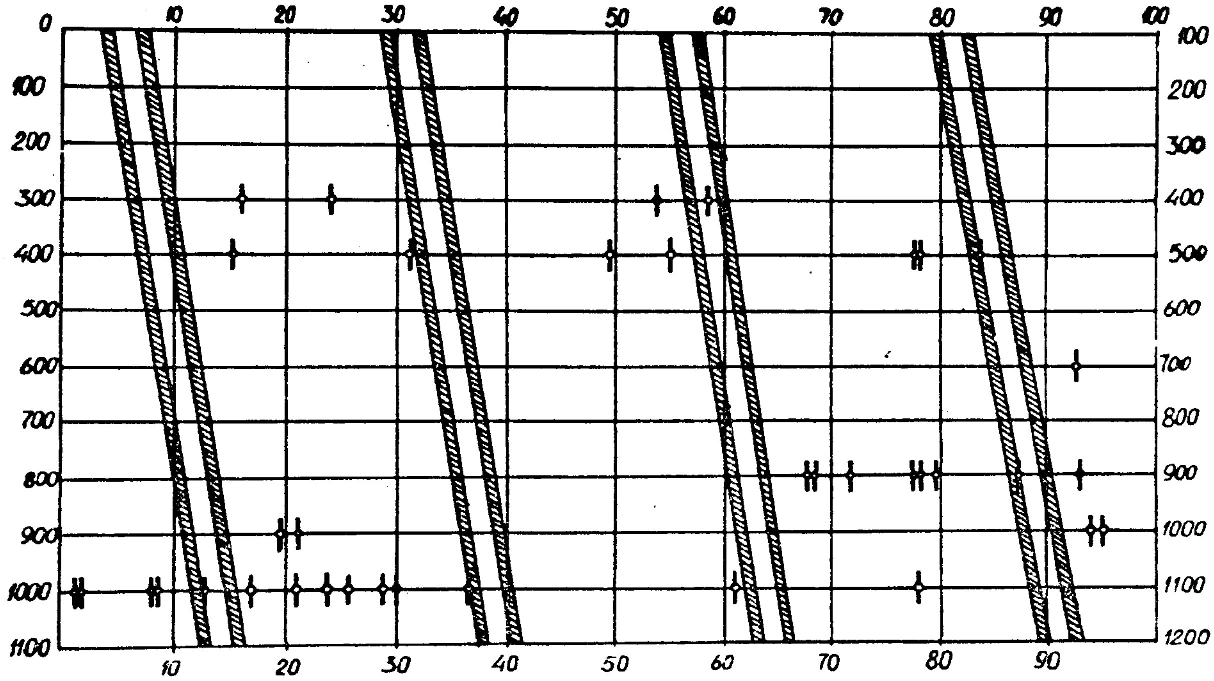

Figure 3 - Diagram of anti symmetric resonant modes