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HIGH-FREQUENCY POWER SUPPLY OF THE VEPP-2 STORAGE RING

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by

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Abstract

The equipment described in this paper consists of two tuned power amplifiers, a master oscillator, and a control system. One of the amplifiers, operating at a wavelength of $\lambda_i = 4$ m, has a rated power of 150 kw, so that it can be used to develop a voltage of up to 300 kv across the accelerating gap, which is necessary to ensure a short bunch length. The other amplifier has a rated power of 20 kw and operates at a wavelength $\lambda_2 = 12$ m. It is used to take the stored particles from three seperatrices onto one. The common master oscillator and the control system ensure correct phasing of the voltages at the two frequencies. The control units stabilize the operation of the system, automate the operation of recapture, and contain feedback circuits which suppress electromechanical oscillations of the resonator.

The accelerating system of the VEPP-2 storage ring operates at two frequencies, namely, the first (25.2 MHz) and third (75.6 MHz) harmonics of the rotational frequency[1]. The first harmonic is used during the storage process and ensures that two bunches are produced. The third harmonic is used to reduce the bunch length owing to the high voltage and multiplicity, so that the various events are more efficiently recorded.

The system described below supplies the accelerating resonator at the two frequencies mentioned above. Moreover, it incorporates devices which perform the functions of control and stabilization.

A block diagram of the high-frequency supply system for the VEPP-2 storage ring is shown in Figure 1. The master generator 1 excites the power amplifiers 5 and 6 for the first (25.2 MHz) and third (75.6 MHz) harmonics through the modulators 3, 4, and the controlled phase shifter 2. The frequency instability of the master generator lies within the limits of $\pm$ 0.5 x 10^{-4}, and the oscillator can be adjusted within 1% of its mean frequency.

The power amplifier for the 25.2 MHz harmonic is the KV.15/25M "Ural" short-wave transmitter with an output power of 20 kw. This ensures that an alternating voltage with an amplitude of up to 50 kv is developed across the accelerating resonator gap, which corresponds to an effective accelerating voltage of about 12.5 kv (ref. 1).

The power amplifier operating at 75.6 MHz was designed and built at the Institute of Nuclear Physics. It consists of a three-stage tuned amplifier with a push-pull output stage consisting of two GU-53A tetrodes with grounded grids. The preliminary amplification stages are also of the push-pull type but are based on smaller tubes and incorporate circuits very similar to the output stage.

The design of the output stage is illustrated schematically in Figures 2 and 3. The anode circuit is in the form of a shorted section of a two-conductor line whose length is less than one-quarter of the wavelength. It is shunted by the interelectrode capacitances of the tetrodes. The resonance frequency of the circuit can be varied by moving the plate 1 relative to the resonance circuit. The main result of this is a change in the inductance of the circuit. The resonance frequency of the circuit can be varied in this way by ± 3.5% of its mean value. The advantage of this arrangement is that there are no contacts whose presence at high power would be undesirable.

The plate 4 which joins the screen grids of the tetrodes also provides the blocking capacitance in the screen grid circuit. The load is connected to the anode circuit through the capacitive coupling provided by the plates 12. The outputs are added in a single feeder with the aid of the half-wave coaxial line segment 18. The entire anode circuit is surrounded by a copper envelope 14.

The input circuit of each tetrode consists of the input capacitance of the tetrode, the inductance of the lead, and the capacitor 9 across which the input voltage is applied through the coaxial line 6. The chokes 7 decouple the high-frequency component of the heater supplies and the cathode circuit.

The maximum output power of this stage is 150 kw. This power was reached during tests under pulsed operation (duty ratio = 20). Prolonged tests under continuous operating conditions were carried out at an output power of 40 kw. Tests at maximum power were postponed until spare tubes become available. The output power of 40 kw enabled us to develop a potential difference with an amplitude of up to 300 kv across the accelerating resonator.

The accelerating system for the storage ring is shown in Figure 1 in the form of two separate resonators 7 and 8 with characteristic frequencies of 25.2 and 75.6 MHz, respectively, connected (through feeders) to the outputs of the power amplifiers. Each resonator can be monitored for voltage and feeder current. The feeder currents are stabilized by the automatic regulation circuits 13 and 14 which act on the output power of each amplifier 5 and 6 through the modulators 3 and 4 in the 25.2 and 75.6 MHz channels.

The mutual phasing of the first and third harmonics in the 75.6 MHz channel is achieved by the controlled electronic phase shifter 2. The phase difference between the 25.2 and 75.6 MHz signals is measured by the phase meter 15. The error signal from the output of the phase meter 15 is fed into the controlled phase shifter and modifies the phase of the third harmonic voltage.

The first and third harmonic resonators are provided with devices for automatic tuning to the characteristic frequencies. Each of these devices incorporates a phase meter (9 and 19 in Figure 1) which measures the phase difference between the accelerating gap of the resonator and the feeder current. The error signals from the outputs of the phase meters 9 and 10 are fed into the servos 11 and 12 tuning the characteristic frequencies of resonators 7 and 8. The resonator can be detuned to a given amount relative to the angular frequency of the particles by feeding a positive or a negative constant voltage to the error signal circuit.

Tests performed on the resonance system have shown the presence of self-excited electromechanical oscillations[2] in the 75.6 MHz resonator above a threshold value of 70 kv. Automatic frequency tuning of the master oscillator was used to suppress these oscillations. This was achieved by feeding the alternating component of the output voltage of the phase meter 10 in the automatic tuning system for the 75.6 MHz resonator to a controlled reactive element in the oscillatory circuit of the master generator 1. The alternating component affects the frequency of the master generator, and the damping introduced by this automatic tuning loop into the electromechanical oscillations not only suppresses the self-excitation but damps down oscillations of the walls of the resonance system due to external mechanical impulses. This reduces parasitic amplitude modulation of the voltage across the resonator[3].

Resonance discharges across the gaps in the accelerating system are prevented by applying a constant potential difference of about 5 kv from the high-voltage source 16 to the elements of the accelerating system.

In the case of first-harmonic storage of the particles, the third-harmonic resonator is detuned (with the 75.6 MHz voltage switched off), so that its characteristic frequency is much less than the third harmonic of the particle rotation frequency. The detuning is chosen so that the third-harmonic voltage induced in the resonance system by the stored particles is much less than the accelerating voltage associated with the first-harmonic. This ensures that a single bunch is produced.

At the end of the storage process the 75.6 MHz voltage phased in the required fashion is switched on, and the third-harmonic resonator is tuned until the working voltage appears across it.

The operations of resonator detuning and tuning, and also the switching on of the 75.6 MHz voltage, are carried out automatically by a programmed device not shown in Figure 1.

R e f e r e n c e s

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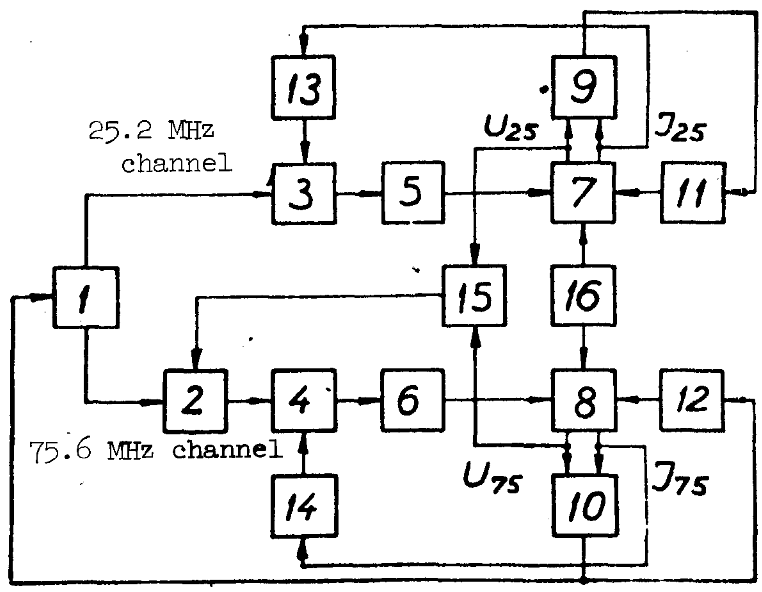

Figure 1. Block diagram of the high-frequency supply for the VEPP-2 storage ring:

1 - master oscillator; 2 - controlled phase shifter; 3 - modulator for the 25.2 MHz channel; 4 - modulator for the 75.6 MHz channel; 5 - power amplifier for the 25.2 MHz channel; 6 - power amplifier for the 75.6 MHz channel; 7 - the 25.2 MHz resonator; 8 - the 75.6 MHz resonator; 9 - phase meter for the self-tuning of the 25.2 MHz resonator; 10 - phase meter for the self-tuning of the 75.6 MHz resonator; 11 - servos for the 25.2 MHz resonator; 12 - servos for the 75.6 MHz resonator; 13 and 14 - automatic regulation circuits; 15 - phase meter; 16 - high-voltage source

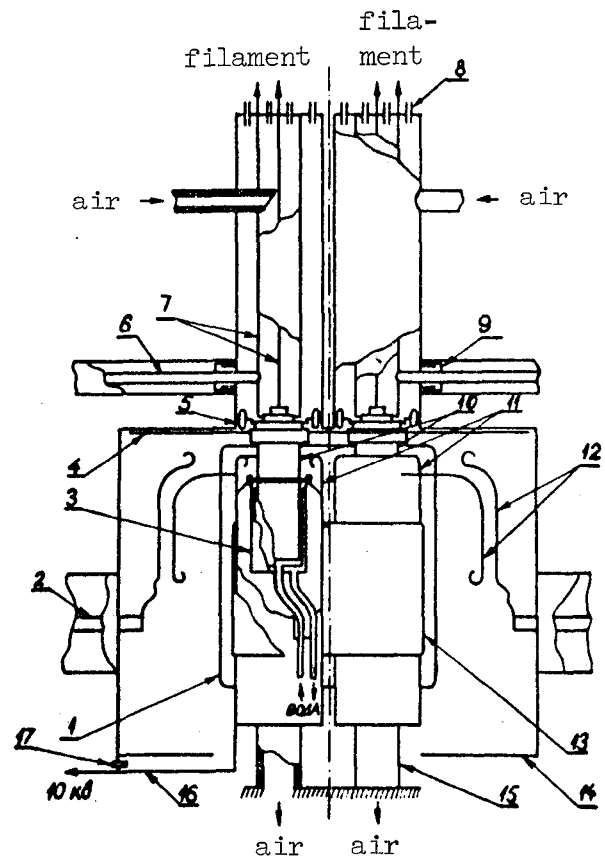

Figure 2. Output stage of the 75.6 MHz power amplifier:

1 - tuning plate; 2 - output coupling line; 3 - tank of the water-cooling system for the anode; 4 - screen grid plate; 5 - blocking capacitor in the circuit of the first grid; 6 - input coupling line; 7 - cathode and filament chokes; 8 - blocking capacitors; 9 - input capacitor; 10 - GU-53A tubes; 11 - two-conductor line in the anode circuit; 12 - coupling plate; 13 - shorting bar; 14 - envelope; 15 - insulator; 16 - anode choke; 17 - blocking capacitor.

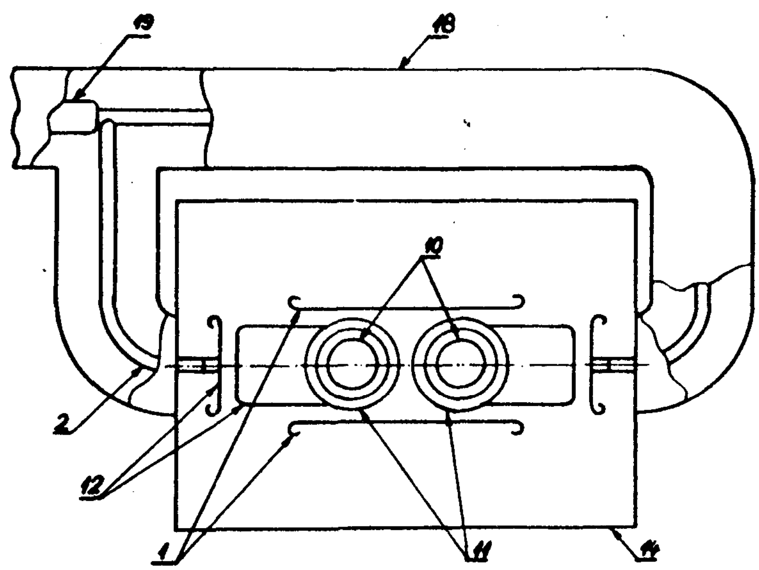

Figure 3. Output stage of the 75.6 MHz power amplifier (in plan):

1 - tuning plate; 2 - output coupling line; 10 - GU-53A tubes; 11 - two-conductor line in the anode circuit; 14 - envelope; 18 - half-wave matching line; 19 - feeder coupling to the resonator system.