MAGNETIC FIELD INFLUENCE ON RF-STRUCTURES ELECTRODYNAMICS CHARACTERISTICS And SPARKING LIMIT.

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In linear accelerators the focusing magnetic field influence on phase and power spectra of beam, as a rule, is not taken into account, and the recommendations at the focusing system parameters choice are reduced to definition the magnetic field longitudinal components necessary for focusing [1]. However, use of such valuations at designing of focusing systems is frequently insufficient, as far as a number of work, containing experimental results, indicating the essential dependence of the accelerator RF-structure electrodynamics characteristics (EDC) on value and distribution form of the focusing magnetic field along accelerator axis is well known [2,3].

The conducted analysis has given the basis to consider, that this phenomena nature is connected with power absorption in resonant volumes by the RF-discharge in a residual gas. Therefore for definition of the magnetic field influence on accelerating structures EDC a prototyping technique was offered [4]. The given technique consists of researched processes modelling on a separate element of a periodic accelerating system and subsequent generalisation of results received at prototyping for more difficult accelerating structures cases with the elementary ratio help, determining the RF-discharge average parameters.

In this report the theoretical and experimental results of the high-vacuum RF-discharge plasma influence to accelerating structures EDC research are performed, as well as experimental research results of the single gap cylindrical cavity magnetic insulation (MI).

The characteristics measurement of the RF-discharge, arising in S-band cylindrical cavity, was performed at the experimental stand, created on basis single-gap cavity, excited at the lowest mode of electrical prick [4]. The magnitudes received during set-up of self frequency f_0 and quality Q_0 were equals (2797,5±0,1) MHz and $(9,8 \pm 0,5) \cdot 10^3$, accordingly. The magnetic field in the cavity was created by special focusing solenoids of two types [4]. By work in a continuous mode the solenoids feed was executed from the current stabilised source. In a pulsing mode the power supply system start was executed from the previous pulse through the delay line.

During experimental work quality and frequency shift dependencies on the current in the focusing solenoids I and on power level entered the cavity for various solenoids inclusions (fig.1) were received. As it is visible from the figure, the increase only entered power in three times (in magnetic field absence) results in reduction cavity loaded quality Q_l to 10÷12% and frequency shift Δf_0 occurrence. Availability a magnetic field results in the further reduction Q_l (up to 20÷22%) and increase Δf_0 (on 150 kHz). The heaviest change Q_l and Δf_0 takes place in a range of currents I, appropriate the magnetic field induction value, at which resonant conditions realisation in equations, of describing behaviour the RF-discharge in parallel and normal electrical magnetic field at frequency 3 GHz [5] is possible. It testifies to essential magnetic field influence for a cylindrical cavity EDC.

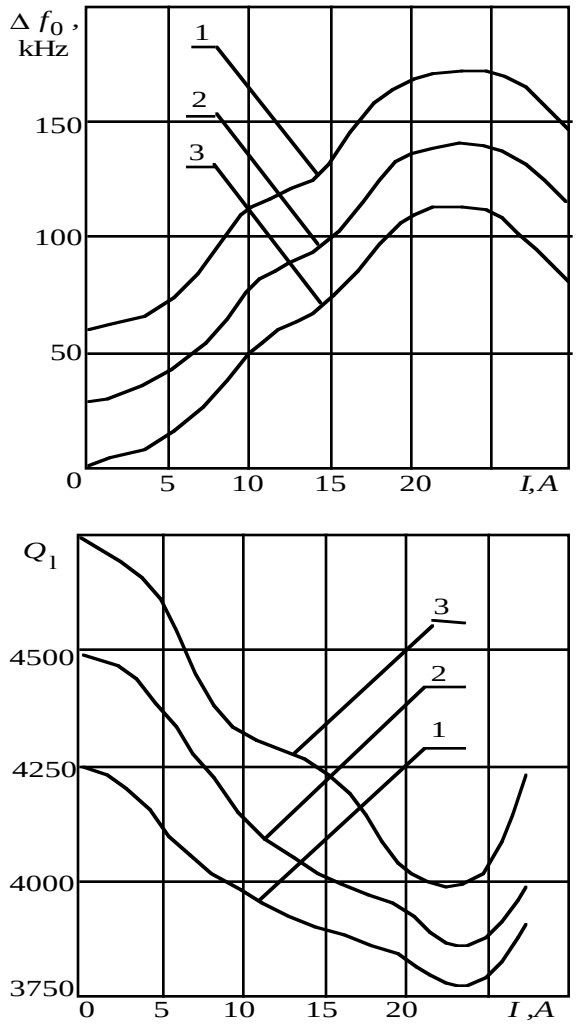

Fig. 1. The dependencies Δf_0 and Q_l on the current I for various source power (1. P_{in}=60 kW, 2. P_{in}=40 kW, 3. P_{in}=20 kW).

Conducted researches have shown also, that the working pressure increase in accelerating structure results in decreasing of magnetic field influence on the RF-discharge development conditions. It is explained by that collisions number, tested of the RF-discharge plasma electrons during their movement, at low pressure it is not enough and their elimination from volume, engaged by a plasma, occurs preliminary at the

expense of them diffusion to walls with subsequent recombination.

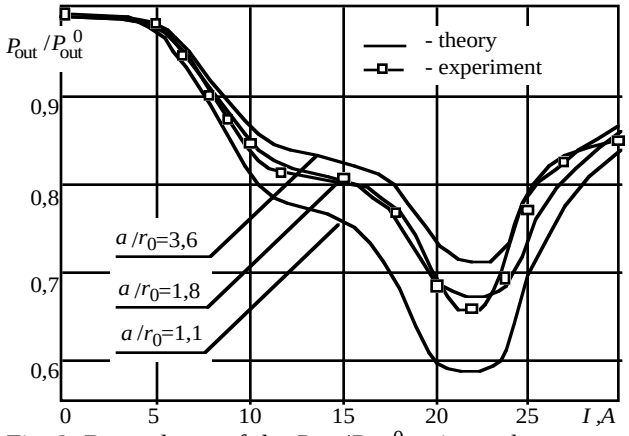

Fig. 2. Dependence of the P_{out}/P_{out}^0 ratio on the current I at the buncher output.

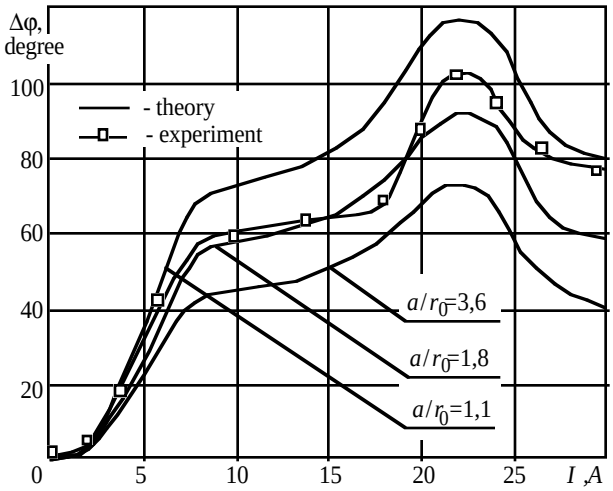

Fig. 3. Phase shift dependence on the current I at the buncher output.

The experimental research of the magnetic field influence for accelerating structure EDC as cylindrical iris loaded waveguide (IW) was conducted on installation, formed on linac buncher base [4]. Buncher represents IW with variable phase speed and frequency f_0=2800 MHz. As a result dependencies of the output buncher power P_{out}/P_{out}^0 for various current magnitudes in the focusing solenoids I (fig.2) were received. Here P_{out} - RF-power at a buncher output at a zero current in focusing solenoids. Theoretical curves were received by technique described above. Experimental data were obtained on model cavity, similar to cells of given IW. The account was conducted for various values of the output buncher power P_{out}^0 and the RF-discharge radius in waveguide a/r_0, where and a - aperture radius in waveguide iris. The similar experimental and theoretical dependencies were received for à phase shift in the buncher accelerated structure, stipulated by the RF-discharge plasma availability in it (fig.3).

Conducted researches of reflected power dependence on the value I in buncher proved a hypothesis about the RF-discharge arising in IW power absorption, as far as the maximum reflected power magnitude at change of a current in focusing solenoids did not exceed 5% from the output power level, and the qualitative character of received dependencies was close to submitted in fig.2,3 curves. Transients study, arising at RF-discharge formation in IW has shown, that the time, during which RF-discharge will be formed in waveguide, does not exceed 0,3÷0,4 μs. Hence, the experimental results submitted in fig.2,3 are received in conditions completely created plasma.

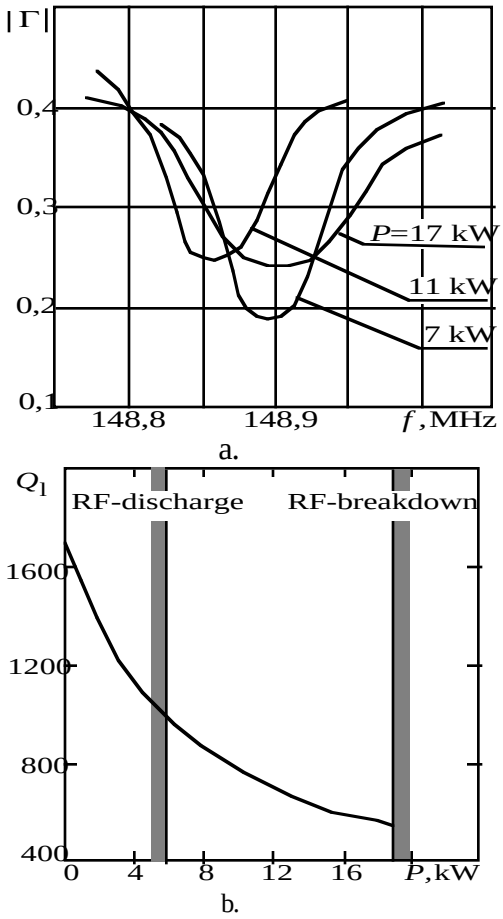

Fig. 4. Frequency and quality Q_l dependencies for various source power magnitudes.

To research RF-discharge influence on L-band accelerating structures EDC a series of experiments was conducted on the double-gap cavity with drift tube, installed on quarter wave vibrator. Experimental dependencies of reflection coefficient Γ on frequency for various magnitudes of RF-powers are shown in fig.4,a. The given dependencies feature is various resonance curve size that shows a cavity loaded quality value decrease with an arriving in a cavity power increase (fig.4,b).

The following part of experimental researches was devoted the electrons MI issuing in the artificial created autoemission centres area. As measurement object the described above S-band cylindrical capacity was chosen. The determination of

the magnetic field amplitude, created in the cavity by special two types solenoids, and optimum time of RF-pulse delay concerning the modulator pulse was executed with the help of a calibrated induction gauge [4].

The first series of experiments on RF-fields limiting amplitude dependence research from magnetic field induction in the cavity was conducted with solenoids, working in continuous mode. At achievement of power level, as it is visible from fig.5, order $0{,}3 \cdot P_0$ (where P_0 - the RF-power limiting value at magnetic field absence) was observed RF-pulse breakage. Thus, the pulse envelope form in input waveguide and pressure in a system did not change. The average current density in the winding j_s varied within the limits of 10^6 A/m^2. The received RF-discharge area top border dependence on the magnetic field induction permits to assume, that the pulse breakage occurrence gear is connected to RF-fluctuations excitation at the electron cyclotron resonance (ECR) frequency. At achievement of some RF-power limiting significance the pulseform in the capacity was strongly deformed, and the pressure in a system was increased at the order. The reduction of the RF-power maximum value entered without capacity breakdown was observed as at counter, as at agree solenoids inclusion in accordance with the power supply current increase (fig.5). As ECR arises under condition of $f = e\gamma B/mc$, where γ - the relativistic factor, for exit from the resonance band the magnetic induction B increasing is required.

As far as the limiting current value in focusing solenoids by work in a continuous mode was limited their essential heating and made 10 A, the second series of experiments was conducted with solenoids, working in pulse regime. We shall note also, that after the cavity training the maximum power level P_0 was increased up to 100 kW at a duration pulse 2,5 μs and the repetition frequency 1 Hz. During measurement the RF-power limiting value reduction P_{br} was marked at the average current density in the solenoids up to 10^8 A/m^2. However, for higher current density the value P_{br} was sharply increased up to a level $(1{,}7 \div 2{,}0) \cdot P_0$ (fig.5), that it is possible to interpret as transition from a regime of power absorption by the RF-discharge to the regime of MI (continuous line in fig. 5). At agree solenoids inclusion or connection only one solenoids took place essential (in 3÷4 times) reduction of P_{br} in comparison with P_0 in all significance j_s changes range (a dashed line in fig.5).

The cavity internal surface research after a series of experiments has shown, that cylindrical surface heaviest degradation was subjected. It can be explained by electrons bombardment, driven along magnetic field force lines, normal to a cylindrical surface. The similar character and arrangement of emitted from the cathode electrons flow bombardment traces was marked in [6].

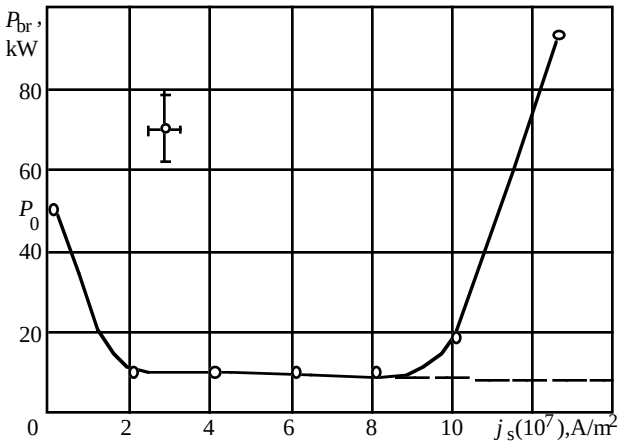

Fig. 5. The dependence P_{br} on the current density.

Thus, the conducted researches have shown, that conventional theoretical account models use in the assumption of ideal vacuum at devices designing with the RF-discharge is not always reasonable from the reliability point of view. The experimental results comparison with calculating has confirmed serviceability by the developed authors technique of the modelling processes, occurring in accelerating structures filled by RF-discharge plasma [4]. The conducted researches, besides have confirmed a opportunity of essential accelerating structures with MI sharking limit increase, in particular, cylindrical cavity. At the expense of focusing solenoids counter inclusion the magnetic field in such structures has casp configuration, and at this fields sufficient intensity effective MI of emission electrons occur. However, for positive effect reception from MI use it is necessary to exclude the power absorption conditions by the RF-discharge in a residual gas, in particular, to leave a occurrence ECR band.

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