CHARACTERISTICS OF THE CAVITY FOR EXCITATION OF A PARALLEL COUPLED RF ACCELERATOR STRUCTURE

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Abstract

The prototype of the cavity for excitation of the parallel coupled RF structure is a segment of conventional rectangular waveguide with short circuit on one side and coupling aperture on the other side. The oscillation type is TE_{105} with operating frequency of 2450 MHz. The report presents experimental measurement results of the excitation cavity model.

Aspects of connection of the exciting cavity to the accelerating cavities and waveguide tract are considered. The cavity prototype for the parallel coupled accelerating structure for electron energy 5 MeV and frequency 2450 MHz will be developed on the basis of this prototype.

INTRODUCTION

A linear electron accelerator for radiation chemistry researches is being developed by Institute of Nuclear Physics, Institute of Chemical Kinetics and Institute of Catalysis of SB RAS. The energy of accelerator is 3-5 MeV, pulse current is 0.1 A. The parallel coupled accelerating structure [1] is used as accelerating structure. The work frequency is 2450 MHz because of the klystron with just this frequency is available.

The parallel coupled accelerating structure is shown in Figure 1.

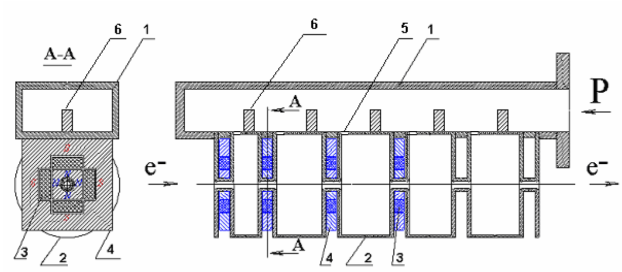

Figure 1: The parallel coupled accelerating structure.

RF power from a klystron feeds the excitation cavity (indicated in Figure 1 as (1)) that excites the accelerating cavities (2). The connection of the excitation cavity with the accelerating cavities is provided by magnetic field through coupling apertures (5). The focusing alternative magnetic field is created along the beam axis by permanent magnets (3) with radial magnetization inserted in the iron yoke (4). This kind of focusing provides large enough magnetic gradient while keeping the weight of the focusing system considerably small. The cupper pins (6) are used to decrease the cavity resonance frequency.

Calculation of particles dynamics in parallel accelerating structure (Figure 2) shows that with the chosen focusing method and RF injection 100% injection efficiency can be achieved.

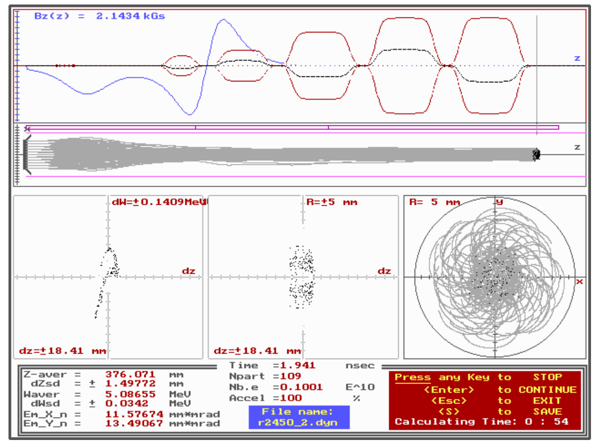

Figure 2: The results of the beam dynamics calculation in the parallel coupled accelerating structure.

EXCITATION CAVITY

The model of excitation cavity was studied in the present report. The excitation cavity is manufactured as a segment of conventional rectangular waveguide with transverse cross section of 72×34 mm^2 (Figure 3) with a short circuit at one side and 3-mm-thick supplying power diaphragm at the other side.

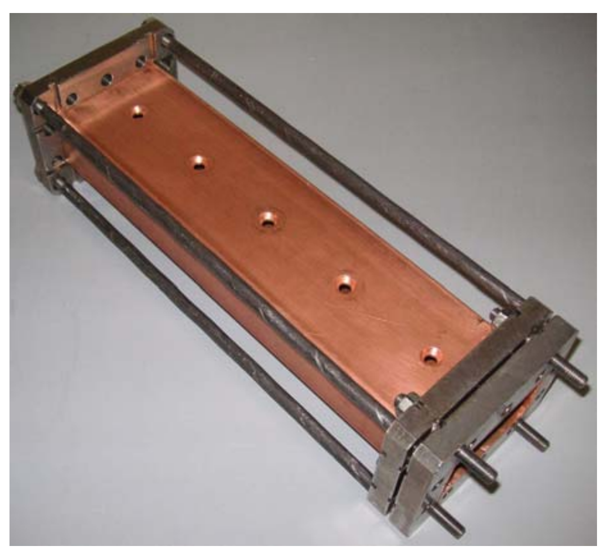

Figure 3: The excitation cavity model. The holes at the upper wall are used to fix the cupper pins.

The diaphragm has coupling aperture with initial sizes 33×10 mm^2. The length of the cavity (313 mm) is determined by accelerator geometry. The excitation cavity operates with the TE_{105} oscillation mode. The calculated frequency of the cavity is 3.15 GHz. To tune the cavity to the working frequency 2.45 GHz and to achieve a required distribution of electromagnetic field, cupper pins are placed equidistantly along the cavity in the region of electric field maximum. The coupling apertures of the accelerating cavities and the excitation cavity are placed in the region of magnetic field maximum.

The diameter of the pins was chosen from the design consideration and equals to 16 mm. The height of the pins was calculated initially by the HFSS computer code in such a way to obtain the resonant frequency of the excitation cavity lower than the working frequency 24.5 GHz. Later the influence of the pins characteristics to the cavity resonance frequency and quality factor was investigated experimentally with the help of the vector spectrum analyzer ROHD&SCHWARZ, VSWR detector and attenuator.

EXPERIMENTAL RESULTS

For 17 mm pins height, the calculated resonance frequency of the excitation cavity is equal to 2.3 GHz. To obtain the dependence of the cavity resonance frequency on the pins height, the pins were cut step-by-step. The resonance frequency, loaded quality factor and coupling factor were measured by passing scheme.

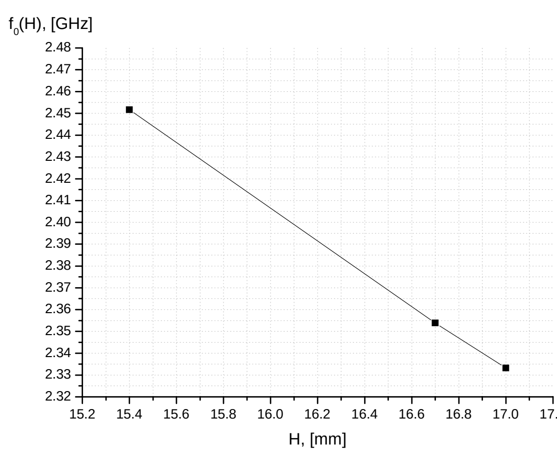

Figure 4: Resonance frequency of the cavity as a function of the pins height

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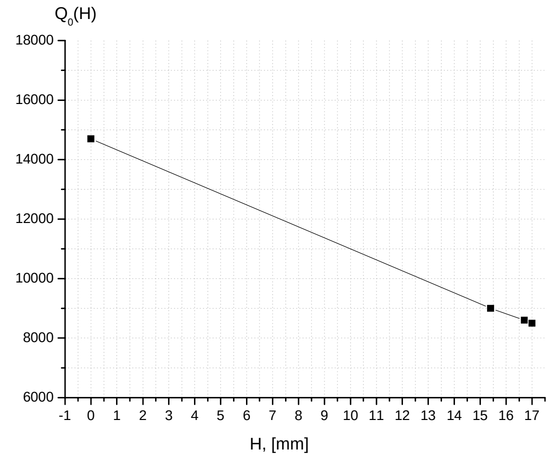

Figure 5: The cavity quality factor vs. the pins height.

The size of coupling aperture between the cavity and the waveguide kept constant (33×10 mm^2). The measured results are shown in Figures 4 and 5.

One can see from Figure 4 that there is almost linear dependence between the resonant frequency and the pins height, and the slope is equal to 74 MHz/mm. For the pins height 15.4 mm, the resonance frequency is 2.45171 GHz that is very close to the working frequency. The experimental data allow us to choose the pins height for given geometry of the excitation cavity and coupling aperture of diaphragm.

The parameters of excitation cavity without pins and with pins are written in Table 1.

Table 1: Parameters of the excitation cavity (pins height is 15.4 mm).

Parameter	No pins	Pins
Res. frequency (GHz)	3.15785	2.45171
VSWR	10.3	1.3
Loaded quality factor	1300	5100
Coupling factor	10.3	0.75
Unloaded quality factor (Calculated value)	14700 (17000)	9000

Data from Table 1 show that the unloaded quality factor of the excitation cavity with pins decreases about twice, the loss power increases about twice and the coupling factor decreases about 10 times in comparison with the case when the pins are removed from the cavity. A considerable decrease of the coupling factor is due to the dependence of the power transfer coefficient $T^2 = P_{tran} / P_g$ (here P_{tran} and P_g are the transferred and the generated power respectively) on frequency.

The dependence of the power transfer factor on frequency is shown in Figure 6 for the 3-mm-thick diaphragm with 33×10 mm^2 coupling aperture. A narrow peak around 2.38 GHz may be explained by resonance behavior of the diaphragm. Above this peak the power transfer factor depends almost linearly on the frequency, so the ratio of the power transfer factor at 2.45 GHz and 3.16 GHz is four.

For a segment of conventional rectangular waveguide with short circuit at one side and supplying power diaphragm at the other side the relation between the power transfer factor T^2 and the coupling factor β is described by

$$T^2 = \frac{2\pi}{Q_0}\beta \cdot \left(\frac{\lambda_g}{\lambda_0}\right) \cdot n, \qquad (1)$$

where Q_0 is the cavity unloaded quality factor, λ_g and λ_0 are the waveguide and generator wave length and n is the number of half-waves in the waveguide. From (1) the ratio of the cavity coupling factor β for the frequencies of 3.16 GHz and 2.45 GHz is equal to:

$$\frac{\beta_{3.16}}{\beta_{2.45}} = \frac{Q_0^{3.16}}{Q_0^{2.45}} \cdot \left(\frac{T_{3.16}}{T_{2.45}} \cdot \frac{\lambda_0^{3.16}}{\lambda_0^{2.45}} \cdot \frac{\lambda_g^{2.45}}{\lambda_g^{3.16}}\right)^2 \cong 11.8. \qquad (2)$$

The measured ratio $\beta_{3.16}/\beta_{2.45}$ reasonably corresponds to that calculated with the help of (2). Some discrepancy may be explained by the pins in the waveguide, which is difficult to consider in the calculated model.

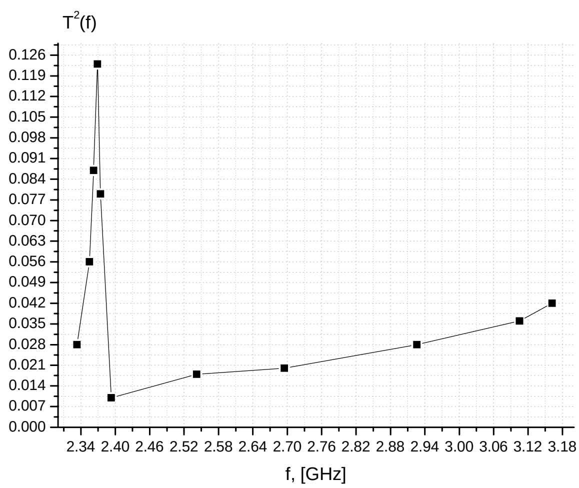

Figure 6: The dependence of power transfer factor on the frequency for 33×10 mm^2 diaphragm coupling aperture.

CONCLUSION

A linear electron accelerator based on the parallel coupled accelerating structure is now under development. The model of the excitation cavity was manufactured and tested. Cupper pins were considered experimentally as a tool for the structure tuning. The measurement results show that in spite of cavity power loss increases twice due to the pins insertion, the coupling factor reduces more than 10 times due to the dependence of the diaphragm transfer power factor on frequency.

These experimental results, which describe parameters of the excitation cavity as a function of the pins height will be used later for developing of the parallel coupled accelerating structure linac prototype.

REFERENCES

[1] O. N. Brezhnev, P. V. Logatchev, V. M. Pavlov, O. V. Pirogov, S. V. Shiyankov, Ju. D. Chernousov, V. I. Ivannikov, I. V. Shebolaev. PARALLEL-COUPLED ACCELERATING STRUCTURES. Proceedings of LINAC 2002, p.213.