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MULTI-BUNCH GENERATOR CAVITY

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Abstract

The system for the linear proton accelerator based on washed-diaphragm loaded structure is proposed and calculated. This structure converts power from six modulated electron beams to accelerating section feeding RF power. Required RF power is 0.8 MW. Different geometries of this compact generator were simulated and also the beam behavior in the cavity was calculated.

INTRODUCTION

For the power supply of the linear accelerators one always uses klystrons [1]. The klystron pulse-operating regime is provided by modulators.

It is possible to simplify such power source using the cavity that transforms the energy from the already modulated electron beam to the input power. In this article we've described the TH_{020}operating mode pillbox cavity with six beam tubes working on frequency 991 MHz.

The injector is the electron gun with six cathodes and with the modulated cathode voltage. Each cathode maximum current is 10 A. So the total injected current is I=(6*10)/2=30 A (because the beam injects only in decelerating wave phase). The cathode voltage is 100 kV, thus the output power should be equal to

$$P_6 = \frac{(100kV * 30A)}{\sqrt{2}} * 0.5 = 1MW ,$$

where 0.5 is the estimated structure performance.

THE MODEL FOR THE DYNAMICS CALCULATIONS

On the Fig. 1 is illustrated the generator cavity 3D model [2].

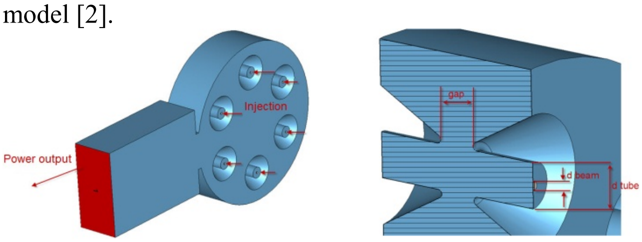

Figure 1: Cavity 3D model.

BEAM SIMULATIONS

The injected bunch parameters are illustrated on the Fig. 2 and Table 1.

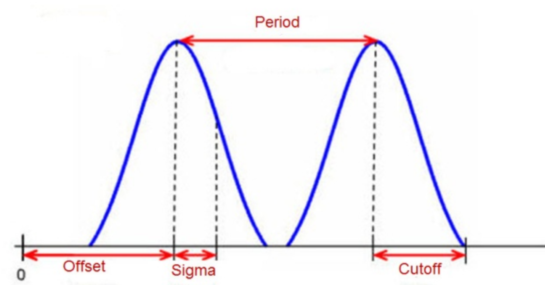

Figure 2: Gaussian bunch.

Table 1: Bunch Parameters

Parameter	Value
diameter d_beam, mm	6
Q, Coulomb	$2.5*10^{-9}$
Sigma, ns	0.3
Cutoff, ns	0.2
Offset, ns	0
Period, ns	1

The output signal strongly depends from the parameter gap, and also from the input energy and beam radius. The injection energy is 100 keV because of 100kV injection voltage, that's why the external magnetic field is not necessary to be included in first calculations. Figure 3 illustrates the dependence of output power from the gap parameter. On the fig. 4 the form of the output signal and its frequency spectrum are shown.

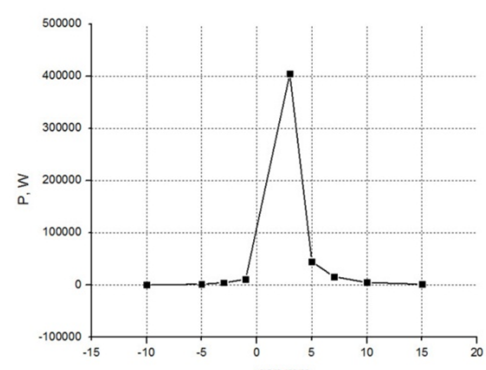

Figure 3: Output power tuning.

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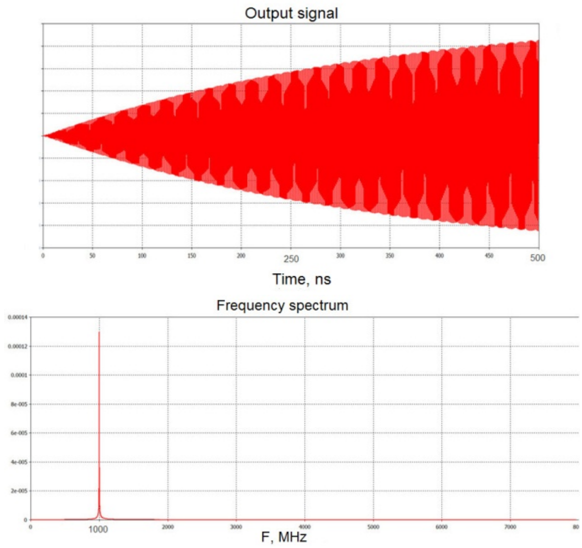

Figure 4: Output signal overview.

CAVITY GEOMETRY TUNING

The geometry of the cavity is presented on the Fig. 5. It has been tuned to the operating frequency 991 MHz. Fig. 6 illustrates the TH_{020}field lines in the structure.

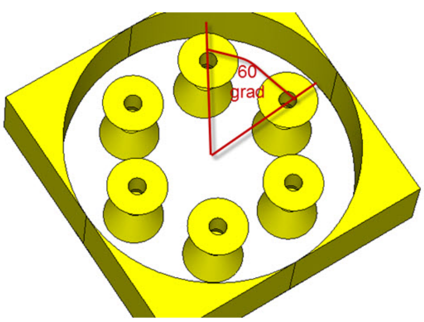

Figure 5: Structure in copper.

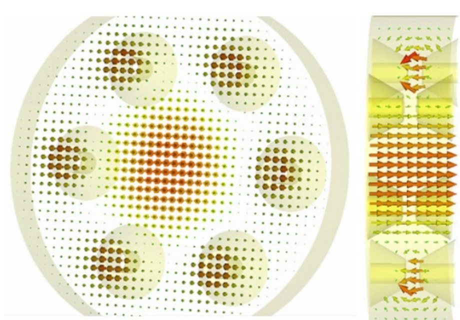

Figure 6: TH_{020} field lines.

Most important electrodynamics parameters are listed in the Table 2.

Table 2: Bunch Parameters

Parameter	Value
Shunt impedance, MOhm/m	1.96
Q_0	32014

This geometry corresponds to the output signal shown on Fig. 4.

CAVITY TO THE ACCELERATING STRUCTURE CONNECTION

The cavity tuned with a critical coupling [3] with a waveguide by changing coupling window width (Fig. 7) and cavity radius. Then it was connected to the accelerating structure (Fig. 8). The difference between accelerating voltages on the cavity beam tube axis and on the accelerating structure axis tuned to 60 (it is bigger on the accelerator axis).

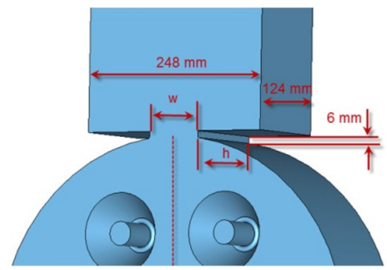

Figure 7: Waveguide coupling.

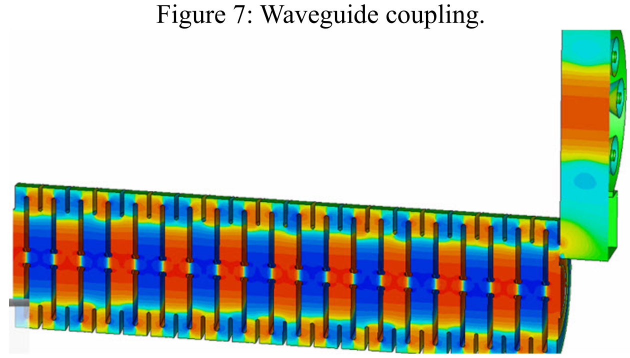

Figure 8: Cavity to the accelerator coupling.

SHUNT IMPEDANCE INCREASING METHOD 1

Figure 3 shows that it is possible to obtain 400kW output power from this structure geometry. That's why the steps has taken to increase shunt impedance in the cavity tube i.e. to increase field with beam interaction.

The first step to increase shunt impedance is the displacement of the useless field in the center of the cavity by putting copper core in the cavity center (Fig. 9) making the coaxial cavity.

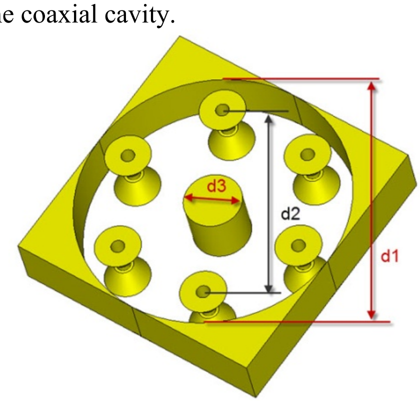

Figure 9: Coaxial cavity.

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The optimal size d3 has been optimized using the graph illustrated on the Fig. 10, where the shunt impedance dependence from this parameter was observed. In the each point of graph the cavity frequency has been tuned to the operating frequency by d1 and beam tubes has been set to the maximum field area (Fig. 11).

The optimal shunt impedance value is equal to 2.79 MOhm/m.

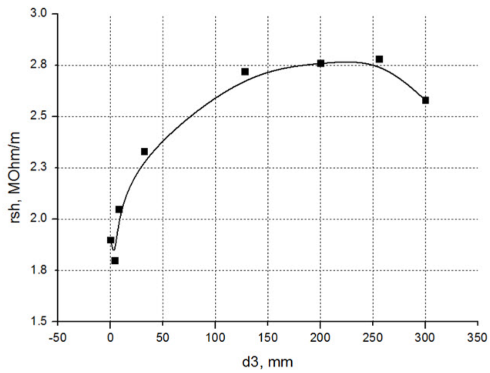

Figure 10: Shunt impedance tuning.

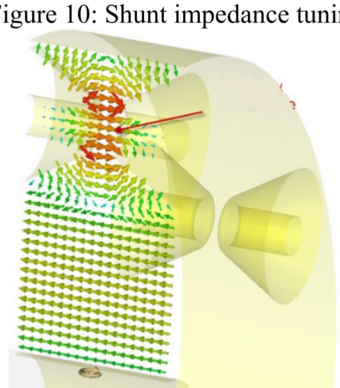
Figure 11: Field lines in the beam tube.

SHUNT IMPEDANCE INCREASING METHOD 2

The second method is to change operating mode from $TH_{020}$to TH_{310} (Fig. 12). The first advantage of this field structure is no useless field in the cavity center, and the second is the 180° field phase changing from peak to peak. It means that 6 electron injectors will not be placed on the one side of the cavity. 3 injectors will be placed from the one side and 3 – from the other.

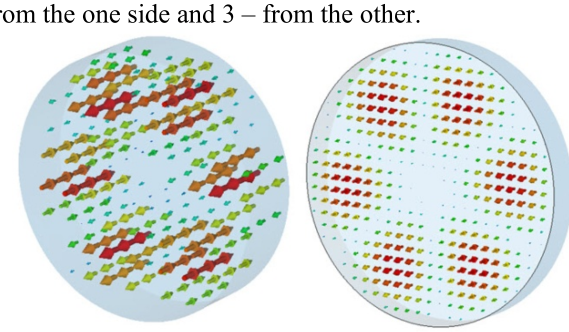
Figure 12: TH_{310} field lines in the pillbox cavity.

Also sizes of the tuned structure with beam tubes (Fig. 13) are smaller that it was on in the first geometry.

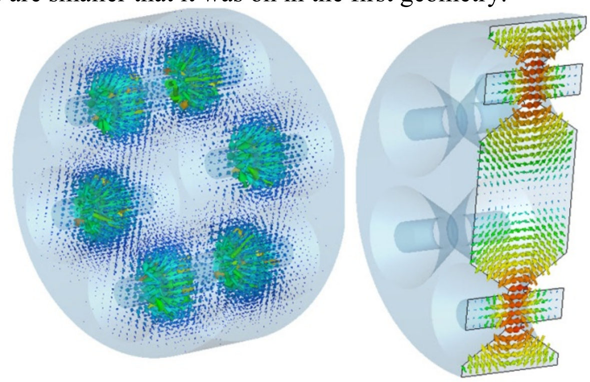
Figure 13: TH_{310} lines in the tuned cavity.

The value of the shunt impedance in the beam tube now equal to 4.74 MOhm/m.

DATA COMPARISON AND SUMMARY

In the Table 3 three types of generator cavity are compared by sizes and shunt impedance value

Table 3: Structures Comparison

Cavity type	**Standard**	**Coaxial**	**TH_{310}**
d1, mm	466	702	341
rsh, MOhm/m	1.96	2.78	4.74

The next step will be optimization of the beam dynamics in the TH_{310}model by variation of the injected beam parameters and the external magnetic field. Because 4.74 MOhm/m shunt impedance causes that the field from some moment starts take the whole bunch energy, that doesn't allow it to fly through the structure.

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[1] L.A. Frejdovich et.al., Multi-Beam Klystrons With Reverse Permanent Magnet Focusing System As The Universal RF Power Sources For The Compact Electron Accelerators, Proceedings of RuPAC 2006, Novosibirsk, Russia.
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