COMPARISON OF PRISMATIC AND CIRCULAR BIPERIODICAL ACCELERATING STRUCTURES ON 27 GHz OPERATING FREQUENCY

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Abstract

As known a biperiodical accelerating structure (BAS) represents as a system based on disk loaded waveguide (DLW) operating on π/2 mode and is widely used for the compact electron linacs. Earlier such structure with operating frequency of 27 GHz was proposed for medical application and beam dynamics simulations and electrodynamics modeling were done [1-2]. It was shown that such structure manufacturing should have very high accuracy and can be manufactured using electro erosive technology only. It is very complex for axi-symmetrical geometry to use such technology. Interesting option will to use a prismatic geometry BAS. In this report the design of a prismatic and disk-loaded BAS will discus, simulation results and analysis will presented.

INTRODUCTION

Many medical applications need to design of compact and low RF power consumption electron accelerators. At the present day many manufactures of linacs for 2D, 3D conformal radiotherapy or IMRT use s-band accelerating structures on travelling and standing wave. But there are a number of applications which demand more compact accelerators, such as intro-operational radiotherapy and cyber-knifes with the beam energy about 6 MeV.

Accelerator length shortening can be achieved at the increasing of accelerator field frequency (6 or 10 GHz today and 17 or 30 GHz frequency band is possible for the future). Also these accelerating structures demand less RF power due to higher shunt impedance. Effective medical accelerators in S- and X-band are sufficiently known [3-5] and 17 GHz linear accelerator construction also was discussed [6].

The idea to use the linear accelerator with operating frequency of 30 GHz band isn't new. It was proposed to use 26 GHz structure in the one of earlier version of CLIC project as an example [7]. But usage of such band for medical application was suggested few years ago [1-2] and can leads to a number of advantages as compact size and low power needs.

We considered an opportunity of using a disk-loaded waveguide on standing wave and π/2 mode (biperiodical accelerating structure, BAS) and rectangular–loaded structure (prismatic accelerator biperiodical structure, PBAS) with operating frequency of 27 GHz. Also we discussed the possibility of the BAS thermal stabilization problem solving with acceptable requirements for water flow [8]. The variant of cooling system with double cover should be recommended for use is a simplest constructional solution.

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The analyses of variation characteristics were also done and it was shown that it is needed to produce the structure with tolerances of 10 µm. These tolerances can be reached by the application of electroerosion technology [8]. But such technology can not be easily used for axi-symmetrical structures. We propose to discuss a prismatic accelerator biperiodical structure to do the manufacturing much easy.

One of possible power source types in 30 GHz band is a high power pulse gyrotron. Such generators can produce the long pulses (hundreds of µs) with low repetition rate, thus the power system of proposed linac will differs from conventional C-band medical linac due to [9].

BIPERIODICAL STRUCTURE ON 27 GHz

The standard biperiodical accelerating structure based on the disk–loaded waveguide operating on the standing wave is proposed to use for the accelerator as it was noted above [1-2]. The operating frequency of 27 GHz allows significant reduction of the accelerating structure size comparatively the presently used S-band and C-band structures. The general view of the BAS cell is illustrated in Figure 1.

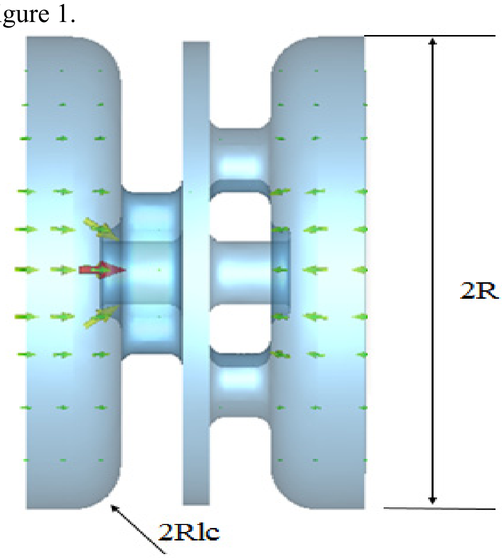

Figure 1: General view of the disk-loaded BAS cell and electric field in cell, where R=4.4 mm, R_{lc}=1 mm, f=27 GHz.

Optimal sizes of the biperiodical structure were defined by means of parameter tuning of accelerating and coupling cells for the π/2 mode at frequency 27 GHz and alignment of the field's amplitude distribution. As the result of simulations the cell geometry with optimal parameters was designed and electrodynamics parameters of structure are specified in Table 1. The biperiodical accelerating structure model consisting of 9 accelerating and 8 coupling cells with magnetic coupling windows was used for simulation after tuning of the one-period model. All accelerating and coupling cells were tuned to the operating frequency. The 27 GHz coupler was also designed and tuned. The general view of structure with coupler and power feeding waveguide is shown in Figures 2-3 [1].

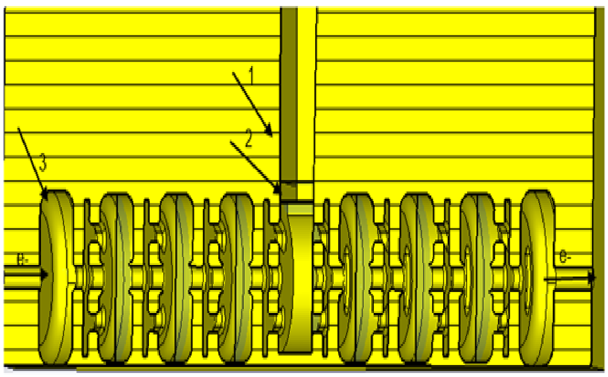

Figure 2: General view of the BAS: 1 – coupler, 2 – power feeding waveguide, 3 – regular accelerating cell.

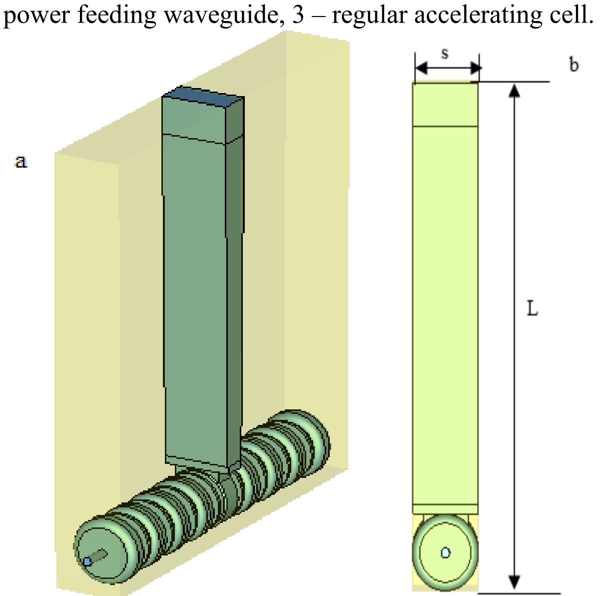

Figure 3: Accelerating system with waveguide: general view (a), front view (b), where $L = 50$ mm, $s = 3$ mm.

Table1: Electrodynamics Characteristics of the DLW BAS.

Parameter	Value
Operating mode	π/2
Radius of the accelerating cell, *R*, mm	4.4
Radius of blending sidewall, R_{lc}, mm	1.0
Frequency, GHz	27.0
Shunt impedance, MΩ	170
Field amplitude, MV/m	382
Coupling coefficient, %	9.0
Q – factor	4680

The central accelerating cell is used as the power coupler and has the high the coupling coefficient with the structure [10]. Figure 4 illustrates the S11 parameter vs. the operating frequency.

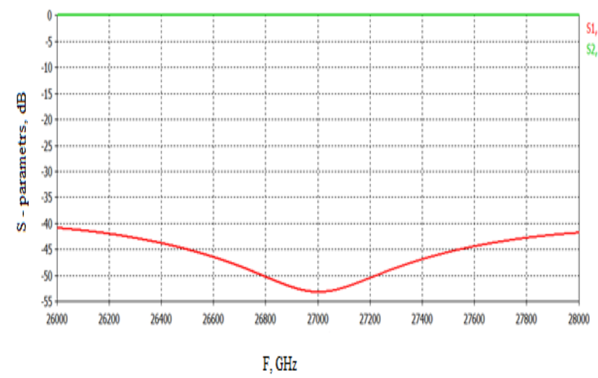

Figure 4: S11 parameters of the biperiodical accelerating structure.

PRISMATIC BIPERIODICAL ACCELERATING STRUCTURE ON 27 GHz

The prismatic biperiodical accelerating structure is based on the rectangular–loaded structure and operates on the standing wave also**.** The general view of the PBAS cell is illustrated in Figure 5.

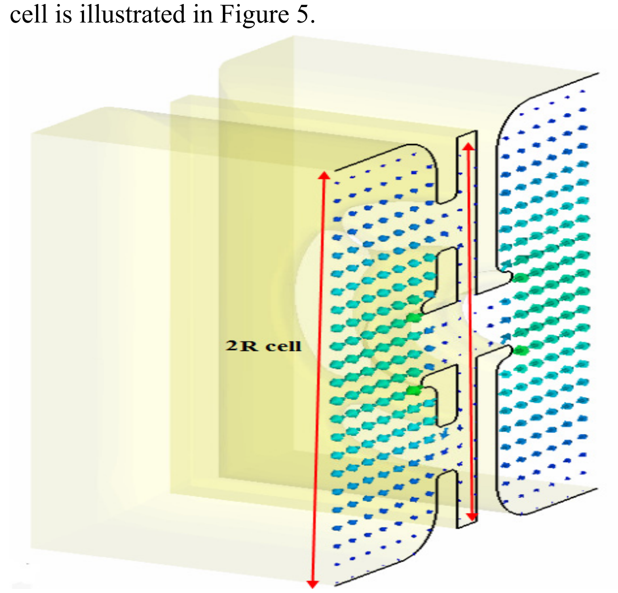

Figure 5: General view of the prismatic biperiodical structure cell and electric field in cell, where R_{cell}=4.1 mm.

As it was done for disk-loaded BAS early, all accelerating and coupling cells of the PBAS were tuned to the operating frequency of 27 GHz. As the result of parameters optimization the optimal sizes of the accelerating cell and the coupling cell of the prismatic structure were founded and alignment of the RF field amplitude distribution in the accelerating cells was done. The result of simulation and optimized electrodynamics characteristics of the PBAS are shown in Table 2.

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Table2: Electrodynamics Characteristics for the Prismatic Biperiodical Structure.

Parameter	Value
Operating mode	π/2
Transverse size of the accelerating cell, R_{cell}, mm	4.1
Radius of blending sidewall, R_{lc}, mm	1.0
Frequency, GHz	27
Shunt impedance, MΩ	135
Field amplitude, MV/m	374
Coupling coefficient, %	9.0
Q – factor	3460

PBAS with power coupler (Fig 6) was also simulated and tuned. Input power coupler is organized in to the central cell by use of the matching diaphragm. Such RF power load is organized by standard K-band rectangular waveguide of 8.6x4.3 mm size, which corresponds to the frequency range of 22.0-33.0 GHz [11]. The input of power into the central accelerating cell through a waveguide enlarges the coupling coefficient of the structure.

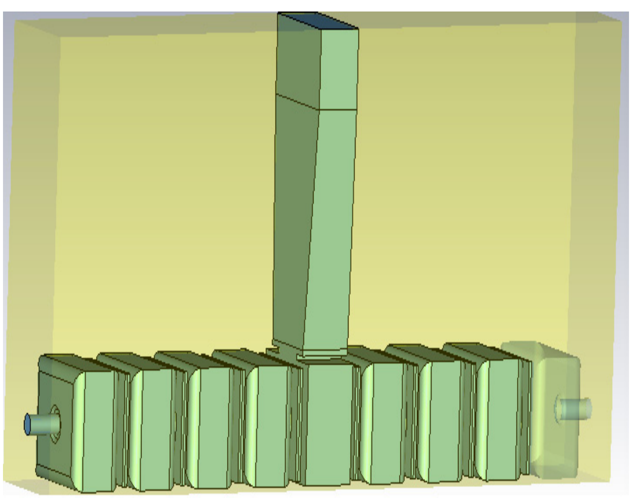

Figure 6: General view of the prismatic biperiodical accelerating structure.

COMPARISON OF BAS AND PBAS

As it is clear from Tables 1 and 2, analysis of electrodynamics characteristics for BAS and PBAS shows that Q-factors and effective shunt impedances are very close for both structures.

The distribution of the RF field amplitude on axis of the BAS and PBAS are shown in Figure 7. As it is clear, they differ not sufficiently and we can to expect that the beam dynamics results will very close to results discussed for disk-loaded BAS in [12].

These results give us possible to use PBAS which manufacturing will much easier.

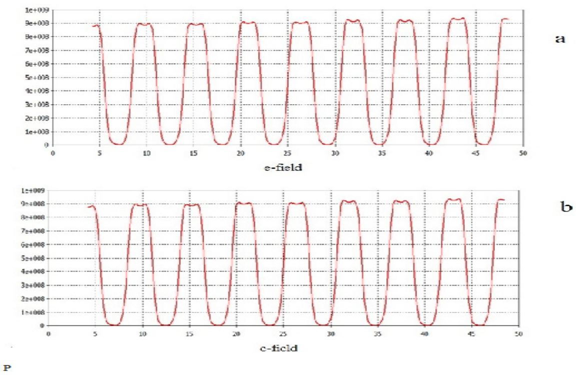

Figure 7: RF field amplitude distribution along the longitudinal axis for BAS (a) and PBAS (b).

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CONCLUSION

The conceptual design of the compact 27 GHz and 6 MeV accelerating structure was discussed. The biperiodical and prismatic biperiodical accelerating structures were designed, tuned and compared. It was shown for both structures that they have higher shunt impedance (170 MΩ for BAS and 135 MΩ for PBAS) but lower Q-factor (4680 and 3460 correspondingly) comparatively with C- or S-band structures. It was also shown that the RF field amplitude distribution is the same than for disk-loaded BAS. It says that the beam dynamics simulation results for BAS and PBAS will identical.

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