SIMULATION OF THE ELECTRON BEAM DYNAMICS IN THE BIPERIODICAL STRUCTURE

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Abstract

A biperiodical accelerating structure (BAS) with operating frequency 27 GHz for the 6 MeV compact radiotherapy electron accelerator is considered. The operating frequency 27 GHz allows to significantly reducing the facility sizes, unlike the S-, X- and C-band operating linacs. The optimal geometrical parameters of BAS necessary for $\pi/2$ mode were defined by means of accelerating and coupling cell tuning. The BAS coupler was also simulated. Results of the electron beam dynamics analysis in designed structure are also discussed.

INTRODUCTION

Electron accelerators are becoming more widely used in the fundamental and applied scientific researches, in the medicine, industry and ecology. Compact electron accelerators uses for industrial and medical purposes [1]. The possibility of compact electron accelerator energy of about 6 MeV design is, suitable for use in medical therapy system and operating at the high frequency of 27 GHz. The beam dynamics simulation was conducted for accelerating structure based on biperiodical accelerating system (BAS) with all disk loaded waveguide (DLW) and beam dynamics in such structure. High operating frequency 27 GHz is the feature of such facility development which is much higher than the standard frequency used for the applied purpose accelerators (2856, 2898 or 5712 MHz). It makes possible to sufficiently reduce the size of the accelerator. Compact size of such accelerators allows using it for medical application. The main part of the installation is a biperiodical accelerating structure based on disk loaded waveguide (DLW) at the frequency of 27 GHz.

The beam dynamics analysis in the designed models of structures was carried out using BEAMDULAC-BL code [2].

BEAM DYNAMICS IN THE BAS

The beam dynamics will be investigated in the buncher and in the main section, the optimal parameters will choose. Optimization was conduct by varying of different parameters such as the amplitude of the accelerating RF field and the length of the bunching section.

It is offered to divide structure into two sub-sections (bunching and main accelerating section). In a buncher the continuant bunch reduces to rather short bunches, which also more accelerates to the energy, allowing injecting them in the main section without losses. In a buncher the phase velocity and amplitude of an electric field monotonically increase and in the main accelerating section they are constant.

It was shown that the electron beam can be effectively bunched and accelerated to the energy of 6 MeV in a BAS operating at 27 GHz. The total current transmission coefficient for the full structure reaches 72 %. The beam envelope can be effectively controlled. Energy spectrum, beam envelope and transverse velocity distribution, beam cross-section, longitudinal emittance for the buncher and the main section are shown in the Fig. 1-4.

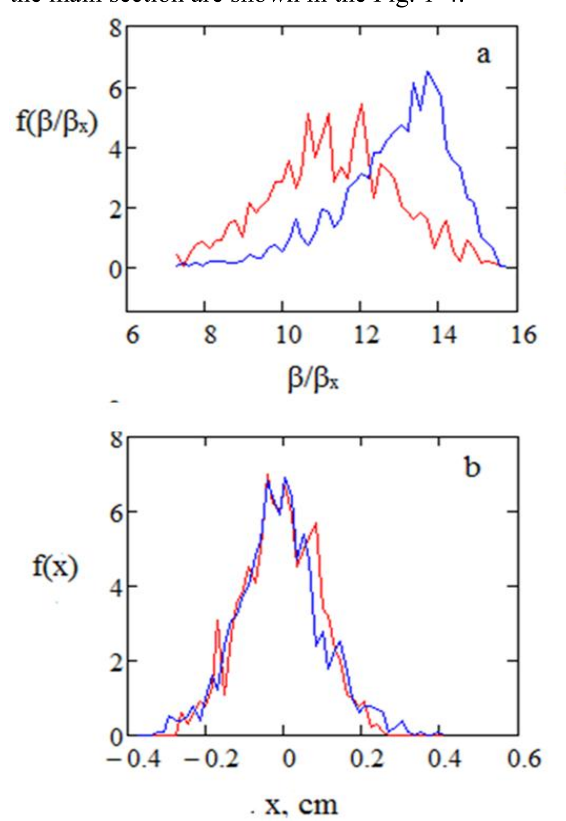

Figure 1: Energy spectrum (a) and (b).

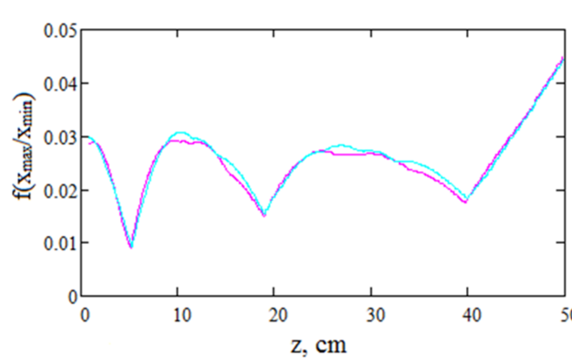

Figure 2: Beam envelope.

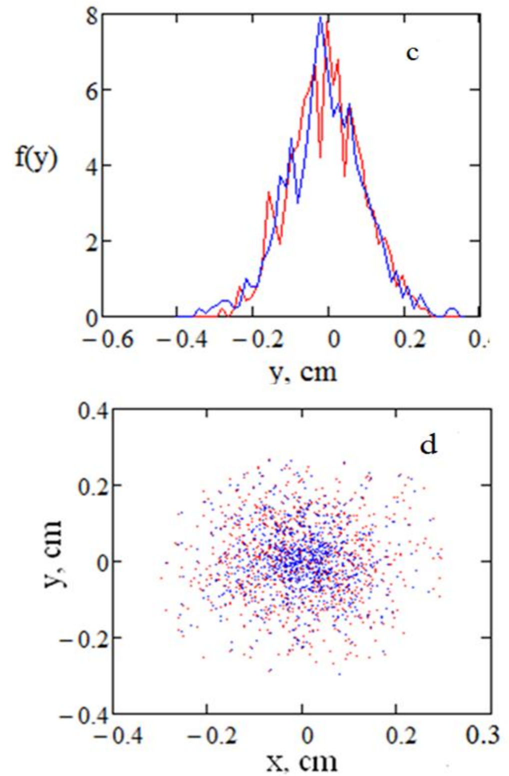

Figure 3: Transverse velocity distribution (c), beam cross-section (d).

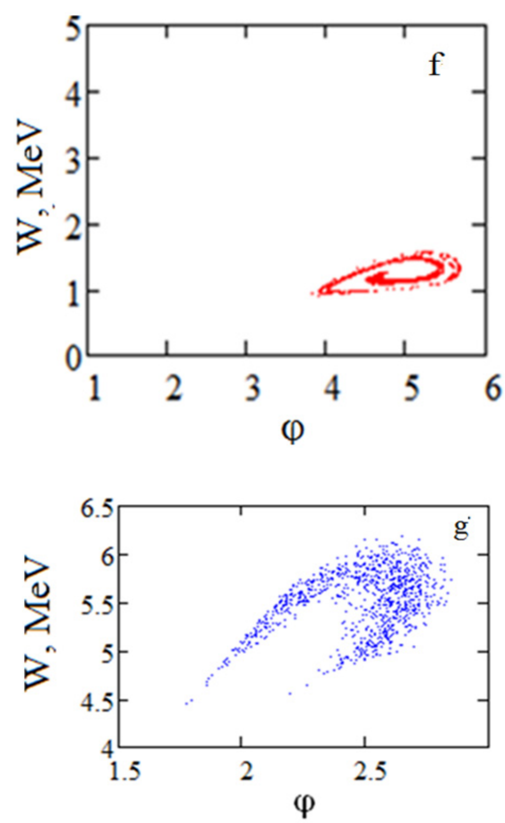

Figure 4: Longitudinal emittance for the buncher and the main section, red and blue points correspond to initial and output values, respectively.

BIPERIODICAL STRUCTURE AT 27 GHz

The simulation was performed using the three-dimensional electrodynamics modeling code CST STUDIO SUITE [3]. The purpose of the modeling was to determine the geometry that provides the operating frequency of 27 GHz. As a result of simulations was found geometry of the cell with the optimal parameters listed in Table 1, as well as the electrodynamics parameters of the structure.

Magnetic coupling windows were added into DLW structure to increase the coupling. The rotation of the windows of adjacent cells by 90 degrees excludes the appearance of dipole components of the electric field. The one period of the BAS and the type of electric field lines, the operation oscillation mode π/2 and BAS, front view with windows communication shown in Fig. 5.

The structure is characterized by negative normal dispersion.

Resonance frequency of the structure was tuned to the desired value by means of cell radius variation.

Table 1: Main characteristics of the accelerating structure

Parameters	**Value**
Frequency, GHz	27
Structure length, mm	55
Operating mode	π/2
Radius of the accelerating cell, R_{cell}, mm	8,8
Radius of sidewall blending, R_{lc}, mm	1
Shunt impedance, MΩ	170
Field amplitude, MV/m	382
Coupling coefficient	0.09
Q – factor	4684

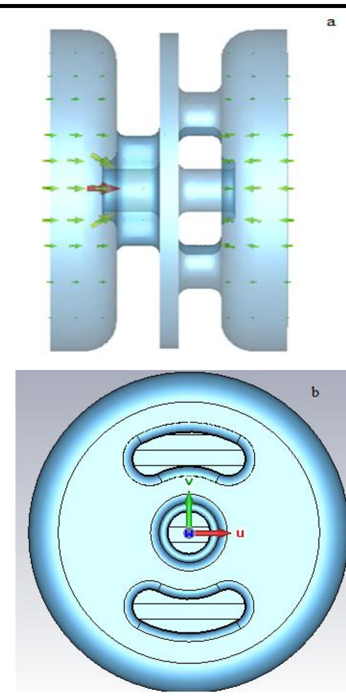

Figure 5: One period of the BAS and the type of electric field lines (a), the operating oscillation mode π/2; BAS, front view with windows communication (b).

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The rounding radius was chosen to provide the highest possible shunt impedance and Q-factor. Structure parameters are tuned accurately (for an example in the structure shown in Fig. 5 has operating frequency 27000,01 MHz).

ACCELERATING SYSTEM

Biperiodical accelerating structure with input power was design during the simulation. Input power is carried out in the central cell via the matching diaphragm. Structure RF power input in organized by K-band standard rectangular waveguide 8.6x4.3 mm with the coaxial coupler, which correspond to the frequency range 22,0-33,0 GHz [4] external view is shown in Fig. 6-7. The structure is working on the μ=π/2 RF mode. The input of power into the middle accelerating cell through a waveguide enlarges the coupling coefficient of the structure [5]. Figure 8 illustrates the S_{11} (reflection coefficient from the structure) parameter versus operating frequency.

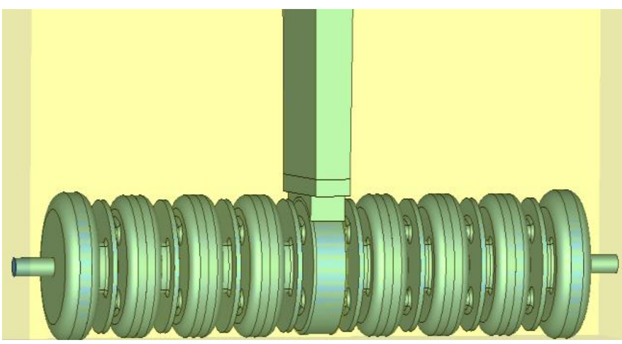

Figure 6: General view of accelerating system.

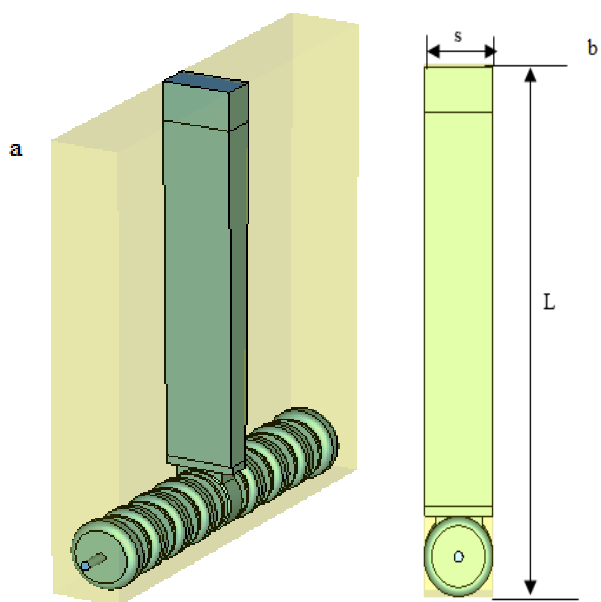

Figure 7: Accelerating system with waveguide: general view (a), front view (b), where L = 50 mm, s = 3 mm.

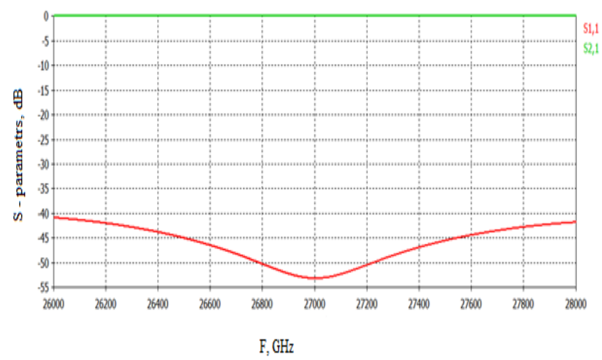

Figure 8: S_{11} parameters of the biperiodical accelerating structure.

CONCLUSION

R&D of the biperiodical 27 GHz accelerating structure was discussed. Obtained electrodynamics characteristics of the accelerating structure are discussed. The BAS was designed and tuned. Structure has high values of shunt impedance – 170 MΩ. Held power input matching structure, setting it at the resonance frequency and the reflection coefficient at the desired power S = – 50 dB, which is accomplished by varying the outer radius of the cell radius. Also the beam dynamics analyzes. By results of optimization the value of energy equal to 6 MeV and the current capturing coefficient 72 %, was reached with a length of the main section 50 cm.

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