BEAM DYNAMICS CALCULATION OF ELECTRON BUNCH SEQUENCE PASSING THROUGH DIELECTRIC *

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Abstract

The present work involves modelling the electron beams dynamics for development of new THz source based on cylindrical dielectric waveguide. The sequence of relativistic electron bunch generates Cherenkov radiation, which is a superposition of the TM and HEM-modes. The distances between bunches is selected for creating of monochromatic THz radiation. We made calculation of beam dynamics considering the Space Charge and focusing field with help of original BBU 3000 code. The main parameter of radiation was investigated: length of wave pocket, monochromaticity and frequency.

INTRODUCTION

This work was initiated by the experimental works [1-4] aimed at exploring new sources THz sources based on dielectric waveguide. Numerical calculations of the sources are made in previous works [5].

The THz Cherenkov radiation is generated in dielectric waveguide by electron beam. Spectrum of radiation is defined by parameters of waveguide (outer and inner radius, dielectric constant). Charge profile of electron beam can be used for selecting and damping of TM-modes in Cherenkov radiation. We are considering a new method of frequency selecting based on using of bunch sequence as source of radiation, figure 1. Variation of distances between bunches allow to select radiation frequency. The main disadvantage of this method is inability of frequency variation.

The main point of present work is beam dynamics which limits way passed by bunches. This parameter limits wave pocket of radiation.

Transverse dynamics caused by influence of asymmetric HEM–modes and focusing system. The value of transverse field grows with offset increasing from the axis of waveguide. In this paper, we study the dynamics of bunch sequence and influence of the focusing system to control of the transverse instability.

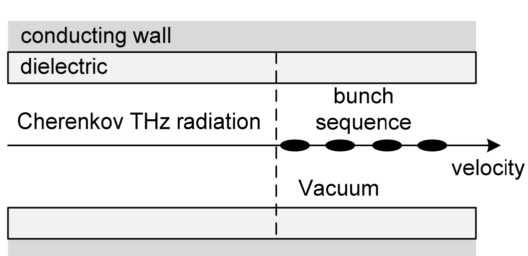

Figure 1: Longitudinal section of cylindrical dielectric waveguide with sequence of bunches.

The radiation (wakefield) with strong Ez component behind single bunch consist principally set of TM modes. One mode regime with frequency of TM_{01} mode can be realized by increasing of bunch length. The sequence of bunches permits to excite one mode radiation based on high order TM modes. This monochromatic radiation can be realized by fine tuning of distances between bunches. The sequence with founded distances allow to damp all TM mode except selected one.

INITIAL PARAMETERS

The dielectric waveguide presented in this work (Table 1) can be used as THz source for next frequencies: 142 GHz (TM_{01}-mode), 439 GHz (TM_{02}-mode), 765 GHz (TM_{03}-mode).

Parameters of bunch sequence are presented in Table 2. All bunches have same radial offset, which caused strong transverse instability particularly for low energy (15 MeV).

It is very important to consider the attenuation of the wakefield (loss tangent of dielectric and conductivity of metal wall in Table1), as well as the effect of group velocity. The group velocity grows with order of TM modes. It is means the wave pocket for high frequency will be shortest.

Table 1: Dielectric Waveguide Parameters

Waveguide	Value
Inner radius (um)	600
Outer radius (um)	850
Epsilon	3.8
Length (cm)	10
Loss tangent	0.001
Wall conductivity (S/m)	5.7E+07

Table 2: The Bunch Sequence Parameters

Bunch sequence	Value
Transverse beam size (um)	120
Longitudinal bunch length (um)	~ 100
Beam energy (MeV)	~ 15
Offset (um)	~ 100
Number of bunches	6-8
First frequency (GHz)	439
Second frequency (GHz)	765

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BEAM DYNAMICS CALCULATION

We used original BBU 3000 code [5,6] for beam dynamics calculation. This code is based on Green function knowledge for different types of dielectric waveguides. Numerical calculation of dynamics is realized according to macroparticle method.

First, we used Green function for "Multibunch" module which allow to create and edit different types of sequences and calculate result wakefield. Figure 2 show example for THz radiation on frequency 765 GHz created by 8 bunches. In the next step, all founded parameters transmitted to "3D Beam Dynamics" module. The focusing system also is created before final simulation. Focusing and defocusing quadrupole sections are edited per next parameters: number of sections, values of magnetic field, lengths.

Beam dynamics calculation is based on interaction between particles and consider 4 axial monopole TM modes and four asymmetric dipole HEM modes. For each mode attenuation coefficient and group velocity are calculated.

First numerical experiment was made without focusing system. This fact led to the destruction of sequence after 3.5 cm pass. The strongest radial force experienced by bunches in middle of sequence: "head" and "tail" of bunches are displaced in opposite directions in transverse coordinate.

We suggest FDFD (Focusing-Defocusing) system to increase the way of sequence up waveguide length. Figure 3 show tracking of bunch sequence and structure of focusing system. Each quadrupole section focus bunches in one direction and defocus it in perpendicular direction. This fact causes increasing of transverse size of sequence which leads to the bunch collision with dielectric tube, figure 4. Presence of focusing system allow to pass bunch sequence up to 9.5 cm.

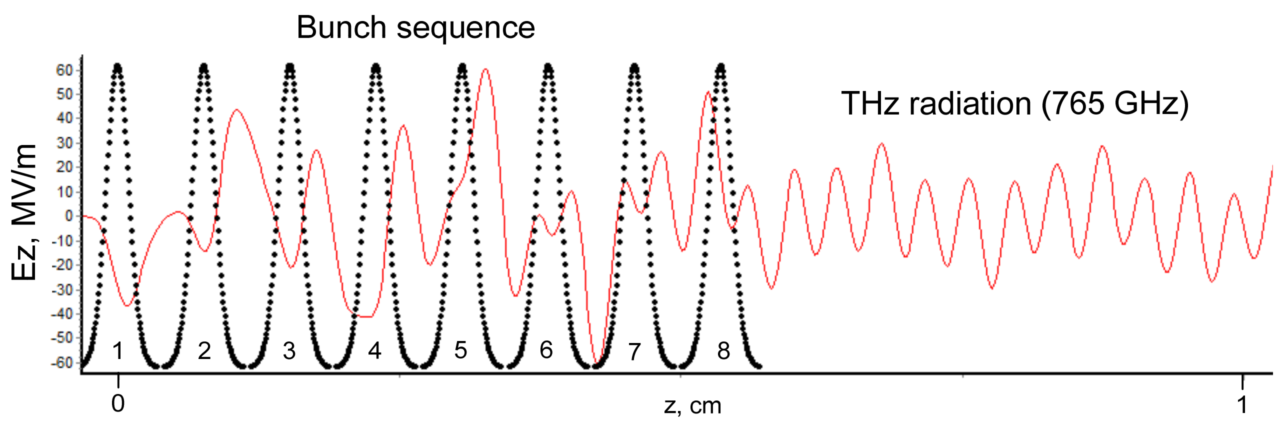

Figure 2: THz radiation inside and behind bunch sequence passing in waveguide from right to left.

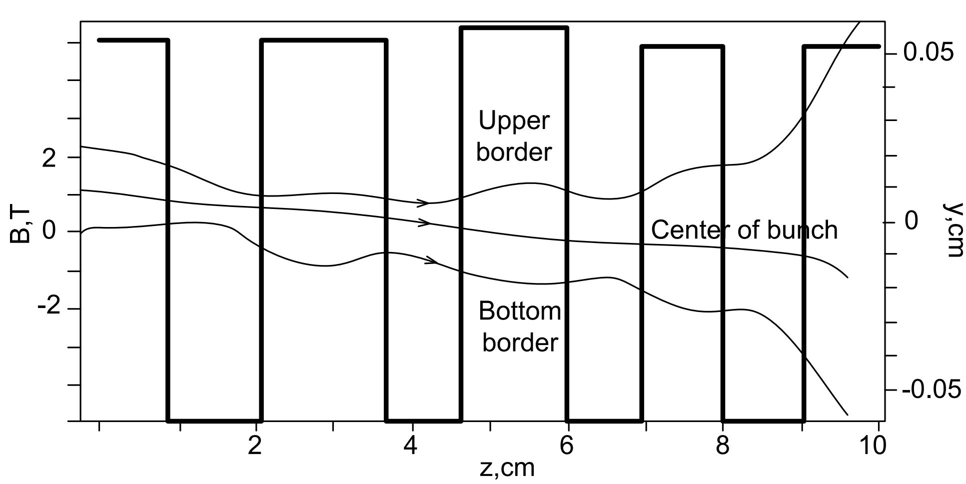

Figure 3: Results of dynamics calculation presented as dependence of sequence's borders (transverse coordinate – right axis) from passed way. Bunches are moving from left to right in presence of FDFD focusing system (left axis)

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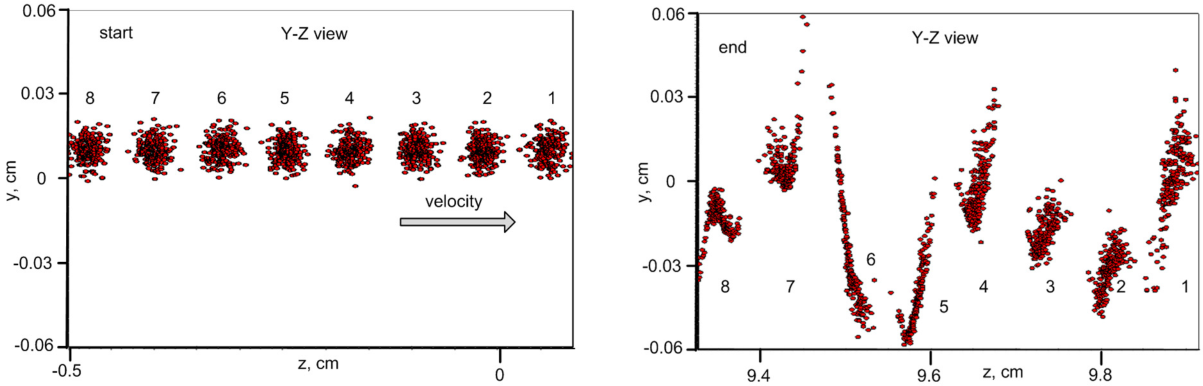

Figure 4: Results of dynamics calculation presented as image of start longitudinal view (left plot) and final longitudinal view after 9.5 cm passing inside waveguide (right view). Bunches are moving from left to right in presence of FDFD focusing system, figure 3.

CONCLUSION

We plan to develop algorithm for optimisation of focusing system parameters. Focusing system must provide of bunch sequence passing in dielectric waveguide for permissible ranges of offsets and number of bunches.

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