THE TUNING OF THE ACCELARATING STRUCTURE UTILIZING ELECTROSTATIC UNDULATOR

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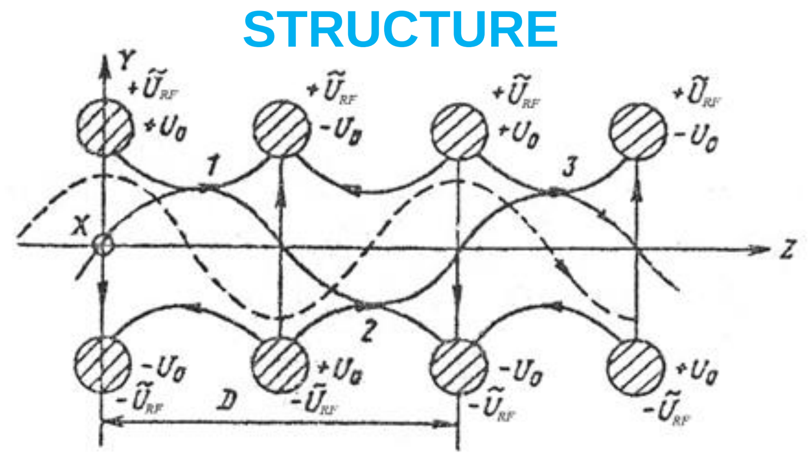
Abstract

The accelerating structure based on an electrostatic undulator is very attractive for bunching and acceleration of ribbon light ion beams with beam current over 1 A. This structure also allows simultaneously accelerating of two ion beams with has positive charged ions and negative charged ions. This article is presenting the ways of tuning of the uniform transverse electrical RF field in this structure. The presented results of the simulation in ANSYS HFSS demonstrated this tuning. The experimental results of the tuning procedures also confirmed the possibility to tune this structure for required field distribution.

THE DESIGN OF THE ACCELERATING STRUCTURE



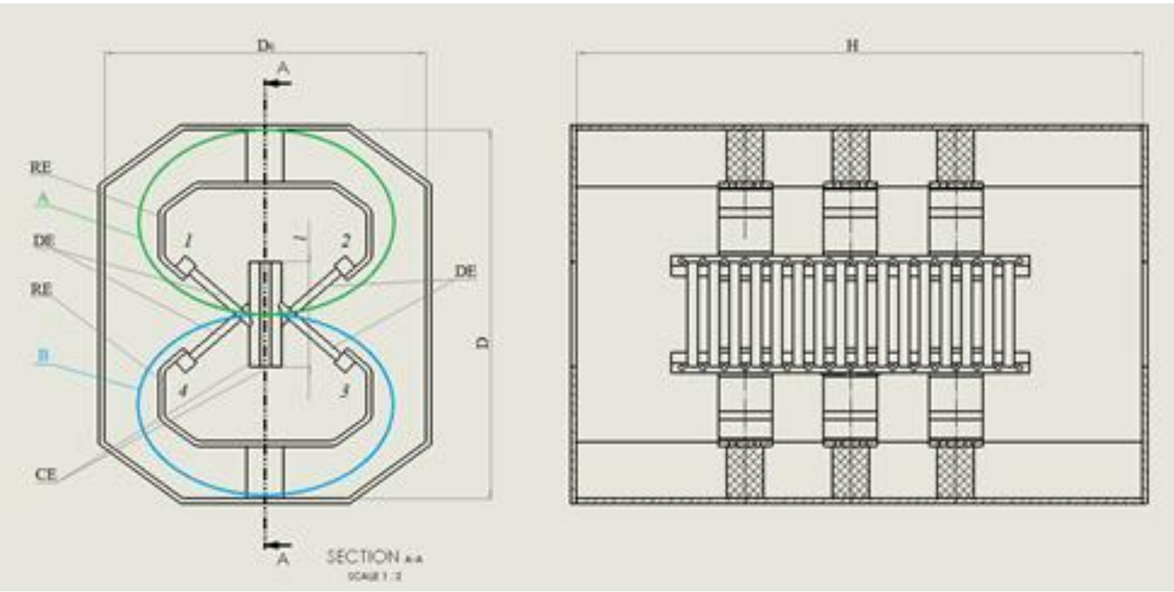


Figure 1. The design of the accelerating structure

THE DEVELOPMENT OF EQUIVALENT CIRCUITS OF THE STRUCTURE

To compose equivalent circuits of structure in the synchronous and non-synchronous type of excitation, present resonance elements as pieces of strip lines and calculate capacitance of accelerating channel. Fig. 2 shows partial capacitances of the accelerating channel calculations.

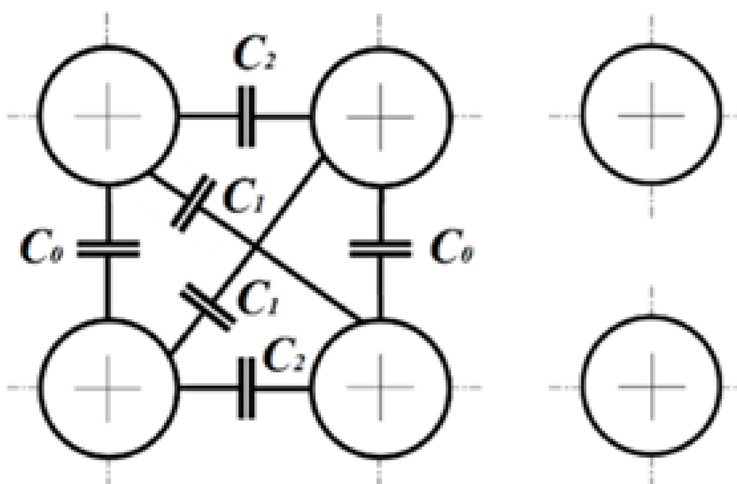


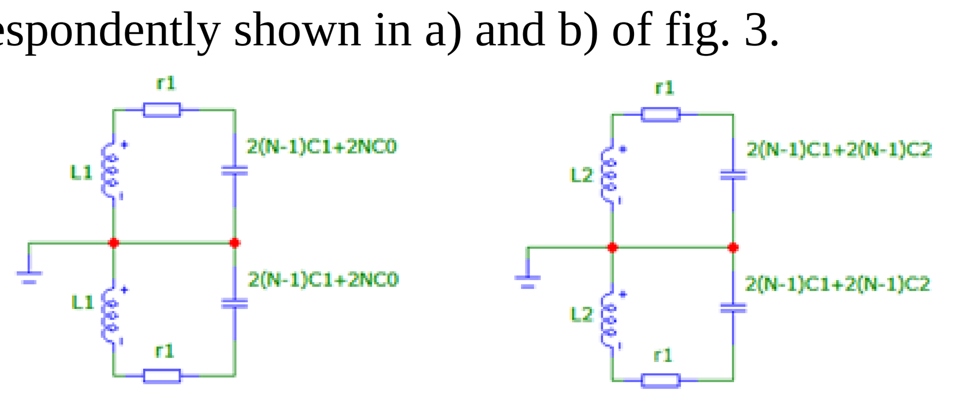
Figure 2. Capacitances of accelerating channel

Calculations of capacitances between bar 1 and 3 allowed calculate NC_0, capacitances between bar 1 and 2 allowed calculate $(N-1)C_1$ and capacitances between bar 1 and 4 allowed calculate $(N-1)\,C_2$. The table 1 contains the results of capacitance calculation, performed in COMSOL.

Table 1. Capacitances of the accelerating channel

C_{13}, пФ	C_{12}, пФ	C_{14}, пФ
7.7	4.2	23.0

The accelerating structure has equivalent circuits for synchronous and non-synchronous type modes correspondently shown in a) and b) of fig. 3.



a) b)

Figure 3. Equivalent circuits of the accelerating structure in synchronous and in non-synchronous modes

Calculation of L_1, L_2 uses formulas (1) and (2) below:

$$L_1 = L_0(1+K) \tag{1}$$

$$L_2 = L_0(1-K) \tag{2}$$

Where L_0 is half of own inductance of three half wave resonance elements in the parallel connection, K is coupling coefficient between two subsystems A and B.

For calculation of L_0 three resonance elements was presented as three strip lines. The input impedance of this line shorted in one end and loaded in the other end by the double of capacitance of the accelerating channel allowed the calculation of this inductance.

In the result of this calculations: $Z_{input} = i46\ \Omega$, $L_0 = 42\ nH$.

According to the equivalent circuits in the fig. 5 formulas for synchronous and non-synchronous mode are below:

$$f_{syn} = \frac{1}{2\pi}\frac{1}{\sqrt{L_0(1-K)[2(N-1)C_1+2NC_0]}} \tag{3}$$

$$f_{nsy} = \frac{1}{2\pi}\frac{1}{\sqrt{L_0(1+K)[2(N-1)C_1+2(N-1)C_2]}} \tag{4}$$

Find coupling coefficient between subsystems A and B (fig. 1). Eigenmode simulation in ANSYS HFSS gave as the result, $f_{syn} = 174{,}19\ MHz$, $f_{nsy} = 127{,}55\ MHz$.

$$\frac{f_{syn}}{f_{nsy}} = 1{,}377 \tag{5}$$

Development of (3), (4) with utilization of ration (5) gives expression for coupling coefficient K:

$$K = \frac{1-\left\{\left(\frac{f_{syn}}{f_{nsy}}\right)^2\left[\frac{2(N-1)C_1+2NC_0}{2(N-1)C_1+2(N-1)C_2}\right]\right\}}{1+\left\{\left(\frac{f_{syn}}{f_{nsy}}\right)^2\left[\frac{2(N-1)C_1+2NC_0}{2(N-1)C_1+2(N-1)C_2}\right]\right\}} \tag{6}$$

In the result: $K = 0{,}10$.

THE SIMULATION AND THE EXPEREMENTAL STUDY OF TUNING OF FIELD

The specific of accelerating structure with electrostatic undulators that at the edges of these structures capacitance between electrodes of accelerating channel essentially higher than in the rest of part of accelerating channel. This causes non-uniform distribution of RF potential along bars and finally changes RF field in the nearby gaps of the accelerating channel. Fig. 4 shows the distribution of capacitance between left and right rows of the cylindrical electrodes of accelerating channel.

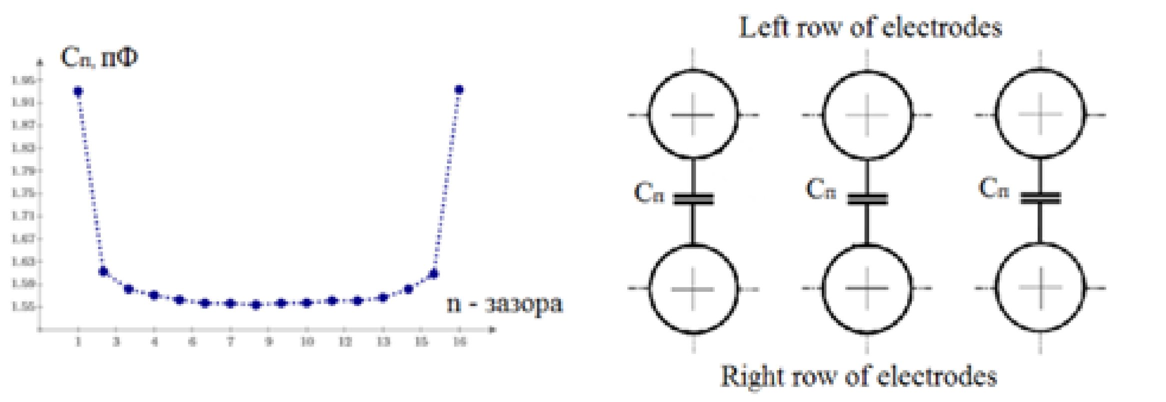


Figure 4. Capacitance distribution in the accelerating channel

The simulation in ANSYS HFSS shows that the reduction of electrical field take place in the pair electrode closer to the first and the last pair of electrodes. The connection of the first pair of electrodes to the different pair of bars than the last pair of electrodes makes the field in the next pair electrode essentially different in magnitude (fig. 5). At the middle of the accelerating channel, the fields are almost the same.

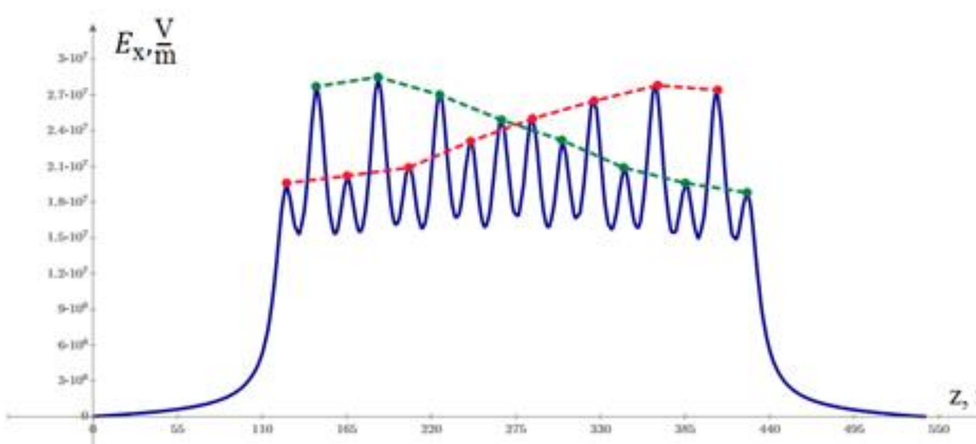


Figure 5. The transverse electrical field of accelerating structure in synchronous mode

The investigation of the distribution of traverse electrical field in the mock-up of the structure showed the same result (fig. 6).

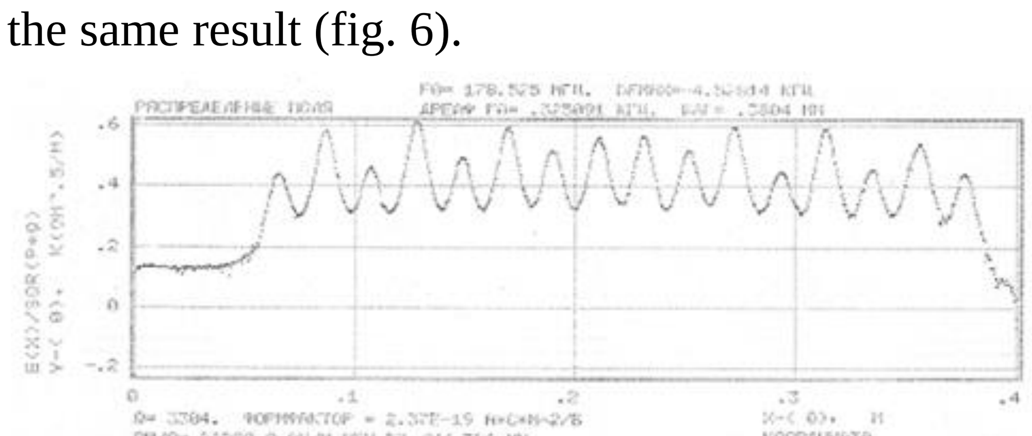


Figure 6. The result of measurements the distribution electrical field in middle of accelerating channel of mock-up

Fig. 7 shows the photo of the mock-up structure used for investigation of the structure that use the electrostatic undulator and study of ways of tuning the structure for the uniform field distribution.

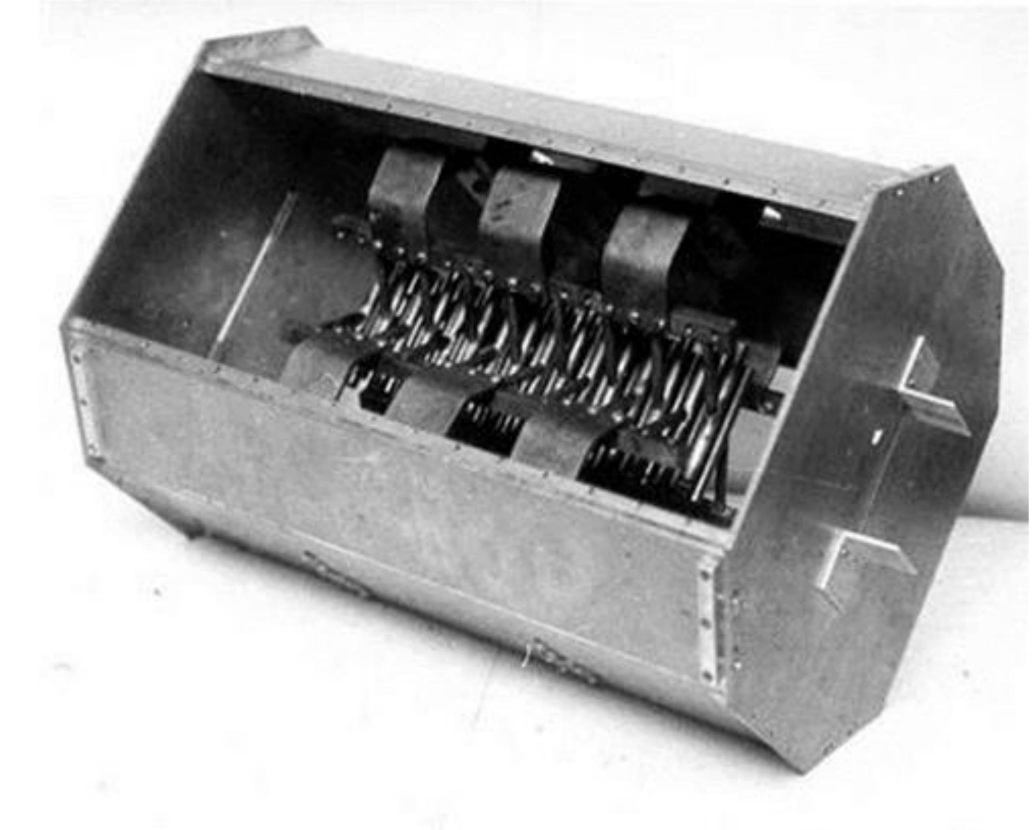


Figure 7. The mock-up of the accelerating structure with the electrostatic undulator

The installation of corrective capacitors between bar 1 and 4; and also the installation the other corrective capacitors between bar 2 and 4 make more uniform distribution of potential along these bars and such way makes field uniform. The simulation in ANSYS HFSS of this way of correction approve that is working. Fig. 8 shows the structure with installed corrective capacitors (pos. 6, 5, 7, 8).

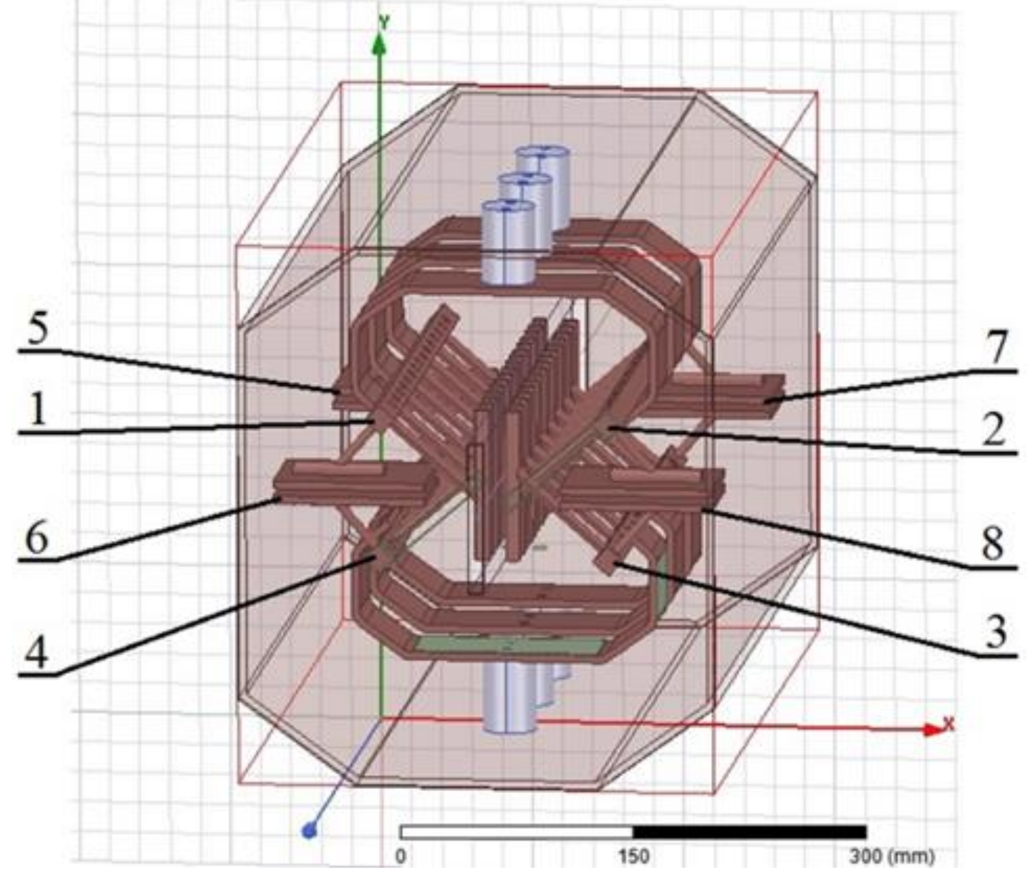


Figure 8. The HFSS model of the accelerating structure with the corrective capacitors

Fig. 9 shows the result simulation after tuning of uniform field distribution.

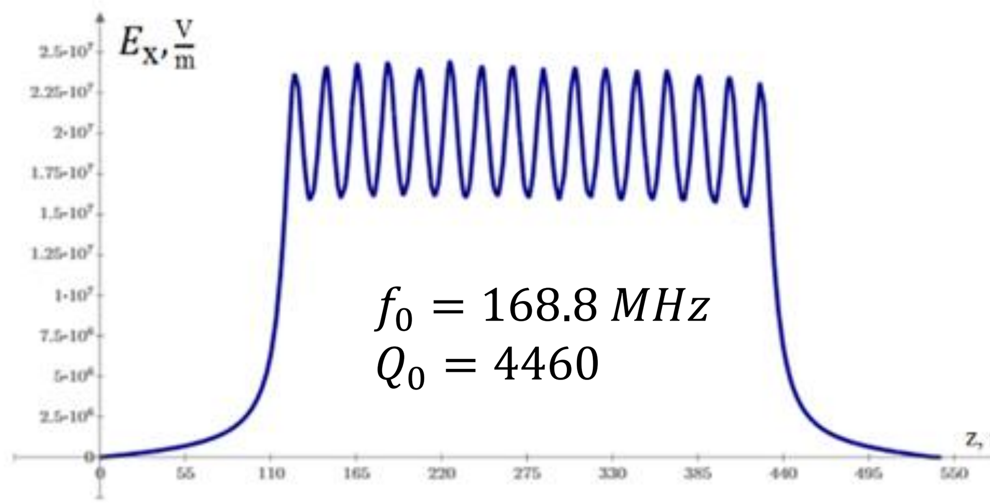


Figure 9. The distribution of electrical component of RF field after installation of corrective capacitors

The utilization of the corrective capacitor in the mock-up of structure also allowed reach uniform distribution of field. Figure 10 shows the result of the measurements after tuning.

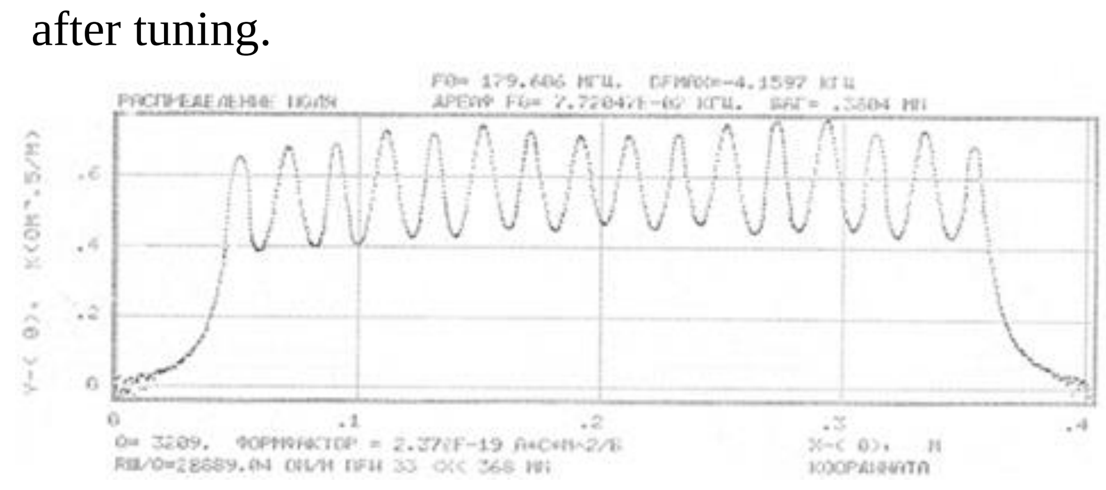


Figure 10: The field distribution after the tuning of uniform filed

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