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Influence of the Frequency Detuning to Electrodynamics Parameters of an Electron Linac

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Abstract. It is very important task to define the tolerances necessary for correct operation of an electron linac. The detuning of linac main parameters as frequency, RF field amplitude and phase can sufficiently influence to the beam parameters. It is highly important for linacs with high brightness beams which are necessary for light sources and colliders. It is also sufficient for industrial linacs. A linac section consists of regular and bunching parts. The influence of one cell detuning on electrodynamics parameters of the whole section was studied. Results of such simulation will discuss in this paper.

1. Introduction

The standing wave biperiodic accelerating structures (BAS) with coupling windows are one of the popular structures for research and industrial electron linacs. Such structures are used in the new industrial 10 MeV/ 20 kW accelerators developed by the joint team of NRNU MEPhI (Moscow) and Corad Ltd. (St. Petersburg) [1-3]. Optimized omega – shape accelerating cells provide the maximum RF field on the structure axis and high shunt impedance in these linacs. New linac has high electrical efficiency, narrow beam energy spectrum within energy range of 5-10 MeV. The high coupling coefficient was obtained also to achieve the maximal efficiency of RF-pulse power usage. The gentle buncher was used to provide high capturing coefficient and narrow energy spectrum in the wide energy band.

The same structure was proposed as the first accelerating section (gentle buncher) for new electron injector of the CERN Future Circular Collider (FCC) [4, 5]. This injector will consist of two e-guns and up to 150 regular sections with output energy up to 14 GeV. One of RF-guns with photo-cathode is proposed to use for injection of short and high-brightness electron bunches in the FCC-ee main booster and the second RF-gun with the thermionic cathode is proposed to use for 6 nC bunches acceleration necessary for e- / e+ conversion.

Starting 2017 the new project of 4th generation synchrotron light source called Specialized Synchrotron Radiation Source (SSRS4) is under development in Russia. Current version of SSRS4 general layout includes 6 GeV main storage ring and top-up injection linac. Free-electron laser will also include in SSRS and top-up linac will used both for injection in the storage ring and for generation of the drive beam for FEL. An additional 1.5 GeV ring is also proposed as an option to generate photons in vacuum UV band. Such layout leads to three linac operation modes: 6 and 1.5 GeV beams for injection and 6-7 GeV high-brilliance bunches for FEL. It leads to the same for-injection scheme as it was used for SuperKEK-B and MAX-IV and is proposed for FCC-ee: two RF-



guns with photocathode and thermionic cathode and one main linac with large number of identical regular sections.

The high-quality manufacturing of the buncher cells and its frequency tuning is one of the main problems for BAS. Investigation of the influence of one cell frequency detuning on the whole structure electrodynamic parameters is very sufficient for e-linac R&D. Results of such effect simulations on the whole structure frequency and RF-field amplitude distribution will be presented below.

2. Results of the detuning simulations

BAS consisting of 28 accelerating and 27 coupling cells was used for simulations [1, 3]. This structure was early proposed for the industrial linac with energy of 10 MeV, the structure total length is 143 cm. The bunching part consists of six accelerating cells with variable phase velocity and RF-field amplitude. One of the middle cells of BAS is used as RF-power coupler. Similar structure is proposed to use in for-injector of SSRS4. The key problem of the development and testing of the linac is the accuracy of bunching cells manufacturing. Frequently some dimensions of one or more bunching cells can be out of tolerance. It can lead to the variation of main electrodynamic parameters of the whole structure as the operating resonant frequency or the phase and the amplitude RF-field. It is very interesting problem to study the influence of the one accelerating cell detuning to electrodynamic parameters of the whole structure.

BAS model was developed to study this effect. As an example, the iris diameter of the sixth bunching cell was varied in the band of $D_6 = D_{opt} \pm 0.1$ mm, where D_{opt} is the optimum 6th cell diameter. The distribution of RF-field amplitudes in centers of bunching and regular cells is presented in Table 1. The distribution for D_{opt} is marked by the green color. Frequencies of the whole structure for the operation mode $\mu = \pi$ ($f\pi/2$) are also presented in Table 1. It is clear that the operation frequency shift is equal only ± 0.6 MHz for the whole structure. Comparatively, the variation parameter $df_{\pi/2} / dD_6 \approx 70$ MHz/mm for separate sixth accelerating cell. The RF-field amplitude distribution on the linac axis is presented in Figure 1 for three different D_6 values. It was found that detuning of one bunching cell leads to the variation of the RF-field amplitudes in other bunching and regular cells. Shown that the error less than 0,1 mm give the error in the RF-field amplitude about 3,6 %. The frequency of the whole structure shifts up and the amplitude of RF field in bunching cells decreases if the diameter of 6th cell is lower than optimal value. In the opposite case, when $D_6 > D_{opt}$ the frequency shifts down and amplitudes for bunching cells increase.

Table 1. Results of the sixth cell detuning simulation

$f_{\pi/2}$, MHz	$A_{regular}$	A_6	A_5	A_4	A_3	A_2	A_1
$D_6 = D_{opt} - 0.1$ mm							
2859.32	1	0.94	0.78	0.63	0.64	0.52	0.58
$D_6 = D_{opt} - 0.05$ mm							
2859.15	1	0.94	0.78	0.63	0.63	0.51	0.57
$D_6 = D_{opt}$							
2858.98	1	0.94	0.78	0.63	0.63	0.50	0.56
$D_6 = D_{opt} + 0.05$ mm							
2858.82	1	0.93	0.78	0.62	0.62	0.49	0.55
$D_6 = D_{opt} + 0.1$ mm							
2858.66	1	0.93	0.78	0.62	0.61	0.48	0.54

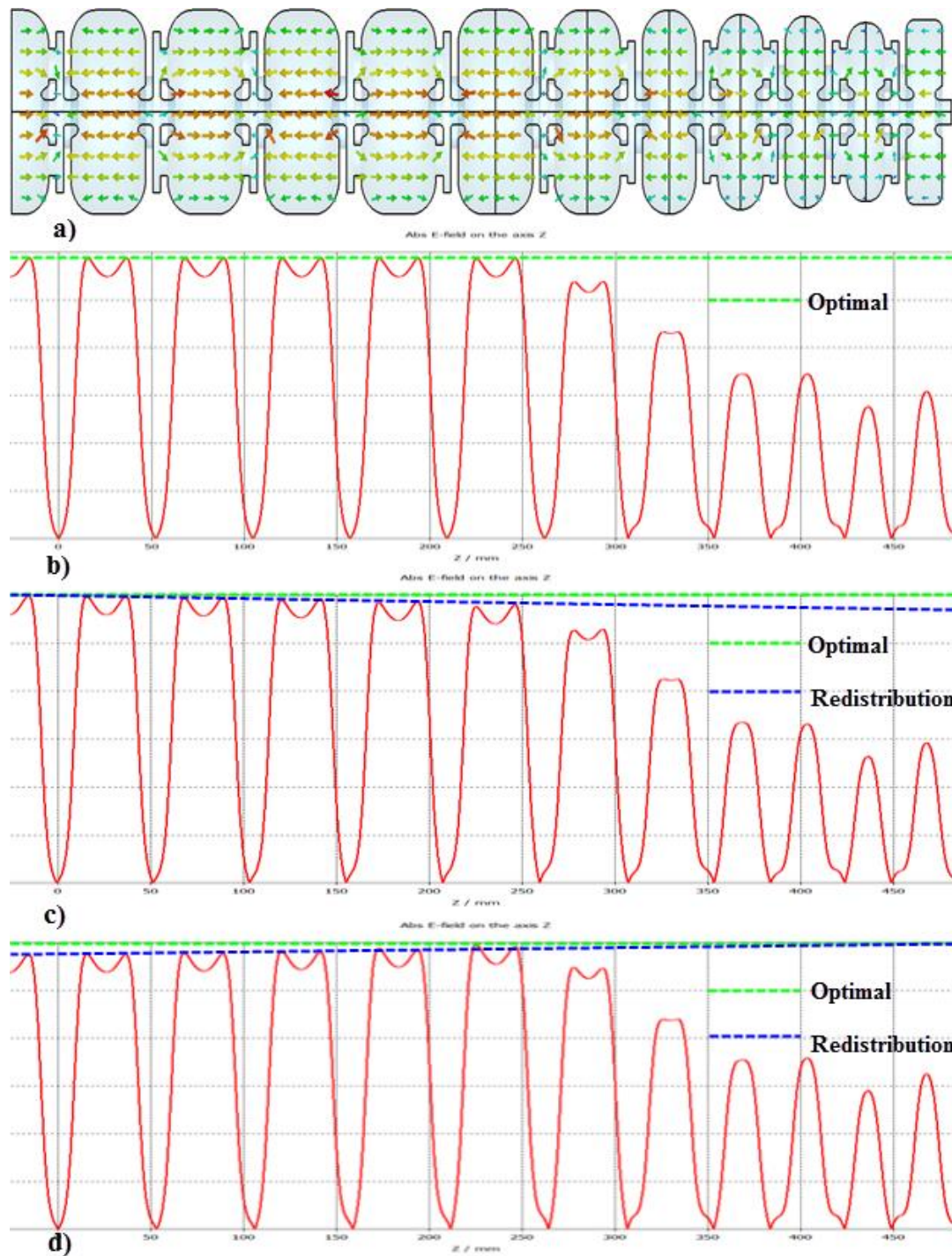


Figure 1. The RF-field amplitude distribution (a) on the linac axis for three different D_6 values: $D_6 = D_{opt} = 0$ mm (b), $+0.1$ mm (c) and -0.1 mm (d)

3. Conclusions

Results of the one cell detuning simulation in the accelerating structure of an electron linac were studied in the frame of its effect on electrodynamics parameters of the whole section. The operation frequency shift is equal to ± 0.6 MHz for the whole structure with the one bunching cell diameter error of 0.1 mm. The detuning of one bunching cell leads to the variation of the RF-field amplitudes in other

bunching and regular cells but in the RF-field amplitude is about 3.6 % for the diameter error noted above. The coupling coefficient is not depends of the error.

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