Pulse Orotron with Double - Row Periodic Structure of 150…400 GHz Frequency Range

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***Abstract*— The experimental results on the generation study of the orotron with double - row periodic structure in frequency tuning region of 150…400 GHz and their discussion will be represented. On the basis of the obtaining results, conclusion about outlook of the advancement upwards in frequency will be made.**

The goal of this paper is the investigation of orotron construction with double-row periodic structure (DRPS) in submillimeter wavelength region. The origin of this work was based on authors' results obtained earlier for the first time in the world and shown in Table [1].

Table

Year	f, GHz	P, kW	η %	Q_l	U_o, kV	I_o, A	j, A/cm^2
1984	10	53	35	800	13	11.6	50
1986	37.5	40	17	2000	19	12	90
1987	90	1.2	6	5000	20	1	100

Here: f – frequency, P – output pulse power, η – orotron efficiency, Q_l – load quality factor of open resonator (OR), U_o – voltage, I_o – pulse beam current, j – cathode current density. In the second line of the Table results of the three-beam device are presented.

Experimental results presented hereafter were obtained on the new-made setup with permanent vacuum pumping. This setup permits the operative changing of device electrodynamics and electron-optical system configuration and as a consequence to get some conclusions about submillimeter orotron's construction.

First of all this concerns the possibility of providing the main DRPS orotron's effective operation condition that allowed to obtain results shown in Table. Namely, in orotron with DRPS and semispherical OR it is necessary to provide the structure period l to interaction space height $2H$ ratio $l/2H \geq 3$ and the cathode width $2C$ @ r_{c}, where r_c – caustic radius of TEM_{00q} oscillation mode on plane mirror [2]. The fulfilling of these conditions allows to ignore the no uniformity of high frequency (HF) field distribution along the width and height of plane electron beam. This is the basic advantage of DRPS over others orotron open periodic structures as it allows potentially the use of thick high power electron beams and consequently to generate high levels of HF output power. However, from these conditions is evident that when structure period and caustic radius diminish the cathode area diminishes too. In consequence maximum values of beam current and output power diminish as the cathode emission capability is limited. So we can reduce structure period till we can create electron-optical system providing realization of condition $l/2H \geq 3$. If this condition can not be realized, as in our case, it is necessary to increase the interaction length and to use wide electron beams [3]. The realization of the condition $2C$ @ r_c, may be significantly facilitated by using complicated multifocal mirrors [4]. In actual work we optimized device parameters to achieve the maximum value of upper frequency of tuning boundary.

On Figure 1 the experimental device with DRPS scheme is presented. Here: 1 – focusing mirror, 2 – cathode, 3 – collector, 4 – electron beam, 5 – DRPS.

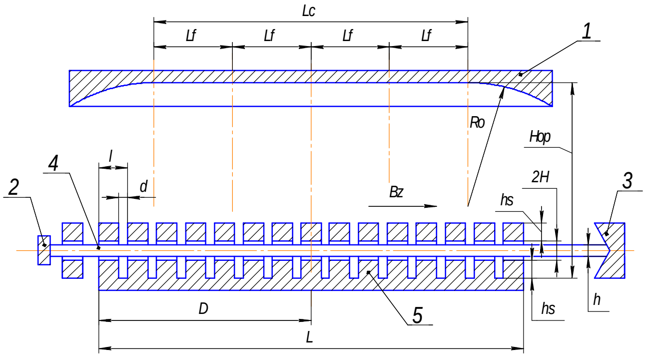

Fig. 1

To decrease the no uniformity of transverse HF field distribution, we use the double focuses sphere-cylindrical mirror (1) («double sphere-cylinder») with the cylinder axis, directed along the DRPS (5) axis, and with curvature radius of cylindrical and spherical parts R_{cyl} = R_{sph} = 32 mm, distance between focal axis is 3mm, length of cylindrical part of mirror L_c= 21 mm and transverse mirror aperture - 18 mm. The transverse HF field distribution of double sphere-cylinder for l_1=1mm, l_2 = 0.9mm, l_3= 0.8mm is presented on Fig. 2 (curvatures 1, 2, 3). The transverse HF field distribution for one focus sphere-cylindrical mirror and for the same l_1, l_2, l_3 is presented on Fig. 2 also (curvatures 4, 5, 6).

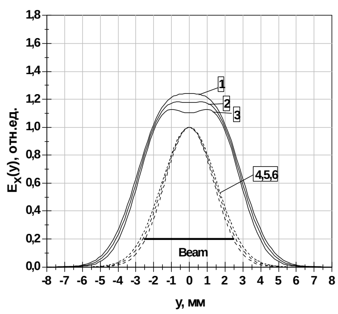

Fig. 2

It is shown on Fig. 2 that effective caustic radius is ~3.5mm for double sphere-cylinder and, besides, one can not take into account the no uniformity of HF field on width ~ 3mm. As result ratio of the width «remainder» $2C$ – 3mm (5.3mm-3mm) of electron beam to the caustic radius is 1.06, 1.12, 1.18 instead 2.44, 2.57, 2.7 at complete width $2C$ for l_1=1mm, l_2 = 0.9mm, l_3= 0.8mm accordingly.

Another parameters of device presented below. DRPS: period l = 0.182 mm, length 33 mm, width 13mm, height of the first from plane mirror row b_1 =0.16mm, that of the second b_2 = 0.15 mm, height of the interaction space channel $2H$ = 0.1mm. So the whole DRPS height is b_1+2H+b_2=0.41 mm and $l/2H$ ratio is 1.82.

The plane mirror of OR had length of 33 mm and width of 13 mm. The power output was effectuated by the 0.8 x 2.4mm^2 orifice in plane mirror [5]. Such construction allows changing the value of OR – loading coupling by displacement of focusing mirror along the DRPS longitudinal axis.

The focusing mirror must provide the optimal HF field distribution along the interaction space and simultaneously an optimal OR – loading coupling. The intermirror distance H_{OR} may be changed from 10 to 7.5 mm.

To form the plane electron beam we used diode electron gun immersed in 7kGs magnetic field produced by an electromagnet with 58 mm interpole gap. Anode slit had 0.1 x 10 mm^2 cross-section. The impregnated cathode had the emitting surface of 2C = 5.3 mm in width and h = 0.098 mm in height. As we couldn't fabricate cathodes with lower height the maximum collector beam current was not more than 60% of whole cathode emitting current that limited maximum beam current on higher frequency tuning boundary.

On Figure 3 the experimental results of the orotron with double-row periodic structure frequency tuning with double sphere - cylindrical focusing mirror of OR are presented. Here: U - pulse voltage, I – beam current, P – output power.

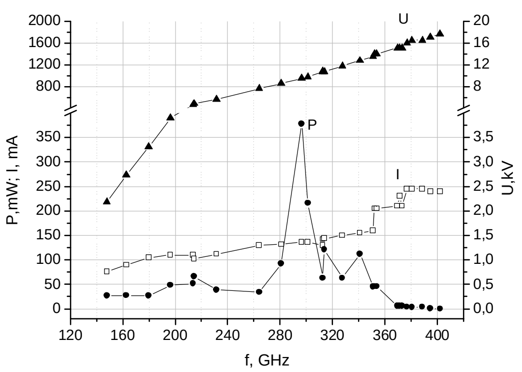

Fig. 3

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