Diffraction Radiation Oscillator with Asymmetric Open Resonant System. Part 2. Hot Test Results of Diffraction Radiation Oscillator

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The hot test results of diffraction radiation oscillator with asymmetric open resonant system, in which the periodic structure was shifted to the field spot periphery of the operating TEM_{00q}-mode, are presented. It is shown, that displacement of the periodic structure, in double grating form, to field spot periphery of TEM_{00q}-mode allows extending the single-mode frequency tuning range and improves the overall efficiency of diffraction radiation oscillator. The mode competition features in diffraction radiation oscillator with double grating and asymmetric open resonant system are considered. The investigations were carried out in 8-mm waveband.

Keywords: Diffraction radiation oscillator, Open resonant system, Periodic structure, Double grating, Millimeter waves.

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1. INTRODUCTION

Diffraction radiation oscillator (DRO) with periodic structure in double grating form has more higher level of output power and efficiency due to effective using of the ribbon electron beam on its thickness [1, 2]. The significant disadvantage such DRO is relatively narrow frequency tuning range, as a result of the strong double grating influence on resonant field of operating TEM_{00q}-mode into its open resonant system (ORS). To extend DRO frequency tuning range we suggest using of asymmetric ORS, in which the double grating is displaced from longitudinal axis of the system to field spot periphery of operating TEM_{00q}-mode. In the first part of present paper [3] the cold test results of resonant modes properties, existing in the asymmetric ORS with double grating, were shown. It was established, that the double grating shifting to field spot periphery reduces its influence on resonant field of operating TEM_{00q}-mode and decreases ohmic loss in the grating, that contributes to increase of ORS Q-factor and to expand of single-mode frequency tuning range.

In the present paper the hot test results of the DRO-model with asymmetric ORS are presented. The mirrors parameters and the optimal displacement of double grating from resonator longitudinal axis were used according to the cold test results of the resonant modes properties in asymmetric ORS [3]. In order to estimate the advantages of DRO with the asymmetric ORS, the measurements of output characteristics of the DRO-model were carried out in parallel for symmetric and asymmetric location of the double grating in the field spot of operating TEM_{00q}-mode. For the DRO-model with asymmetric and symmetric ORS a comparison of following output parameters were conducted: single-mode frequency tuning range, oscillations starting current, output power level and overall efficiency of the oscillator. Also in the present paper the features of modes competition in DRO-model with symmetric and asymmetric ORS were analyzed. The investigations were carried out in 8-mm waveband.

2. DISMOUNTABLE DRO-MODEL AND HOT TEST EQUIPMENT

For experimental investigations the dismountable model of DRO with symmetric and asymmetric ORS, operating under continuous vacuum pumping, was used (Fig. 1). The DRO-model included: cylindrical vacuum chamber 1 with inner diameter 280 mm; moving spherical mirror unit 2; flat mirror unit 3 with a double grating 4 and electron gun 5. The cylindrical grooves with vacuum rubber at the each mirror units provided coincidence of the longitudinal ORS axis with the vacuum chamber axis. The electron gun formed ribbon electron beam with cross-section 0.12 × 3.8 mm², which was passed in the double grating channel of width 0.30 mm. The electron beam axis was placed at the double grating half-height. The one side of double grating was leveled to the flat mirror surface. The external electromagnet 7 provided focused magnetic field with strength B = 0.5 T. The interception of electron beam by double grating was controlled by isolated collector 8. The flat mirror unit 3 allowed symmetric placement of the double grating relative to ORS axis, and also its shifted location along OX axis to field spot periphery of TEM_{00q}-mode.

The measurements of output parameters had been carried out at pulsed operation, that allowed to decrease thermal heating of DRO-model in ~ 4 times. The accelerating voltage pulses with controlled amplitude (2.5 ÷ 4.0) kV and repetition frequency 50 Hz were fed by power supply without ripple filter. The oscillation pulse length was ~ 2 ms at duty cycle ~ 10 %, that allowed direct measurements of output power by wattmeter with the thermoelastic transducer (P_{max} ≤ 10 W). The oscillation frequency of DRO-model had been controlled by the resonance wavemeter (Fig. 2).

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The TEM_{00q}\text{-}mode identification, excited in DRO by electron beam at oscillation frequency \( f_o \), was made on accelerating voltage amplitude \( U_o \), which satisfies the synchronism of electron beam velocity \( v_o \) with phase velocity \( v_{ph} \) for 1-st space harmonic of the double grating field:

\[
v_o = v_{ph} = c \frac{l}{\lambda} = 5.93 \cdot 10^5 \sqrt{U_{ph}[\text{Volt}]},
\]

where \( c \) is the speed of light, \( l \) is the grating period, \( \lambda \) is free-space wavelength. Also, for the TEM_{00q}-mode identification we took into account the resonant distance between mirrors \( D_{00}(f) \), which was defined at the cold test of ORS parameters [3]. Note, that for the TEM_{00q}-mode we assumed that longitudinal index \( q \) describes only the number of resonant field variation along \( OZ \) in the intermirror space, as in OR with smooth mirrors. For the higher TEM_{mnq}-modes the transversal indexes \( m, n \) describe the number of field variation along \( OX \) and \( OZ \) axis (Fig. 1).

Let’s designate as \( f_s \) – the frequency for complete matching of “half-wave” double grating with resonant field:

\[
f_s = \frac{c}{2b} \sqrt{1 + \left( \frac{2b}{l_{cr}} \right)^2},
\]

where \( b \) is the double grating height along \( OZ \) axis (Fig. 1), \( l_{cr} \) is a critical wavelength of the H_{10}-mode in the elementary waveguide, formed by opposite slots of double grating [3]. At frequency \( f_s \), the resonant distances \( D_{mnq}(f) \) for TEM_{mnq}-modes can be defined from the resonant condition in semispherical OR with smooth mirrors:

\[
2D_{mnq} = q + \frac{1}{2\pi} (1 + m + n) \arccos \left( 1 - \frac{2D_{mnq}}{R_{ph}} \right).
\]

Initially, in the experiment, to make a correct properties comparison of DRO-model with symmetric and asymmetric ORS, the double grating was placed symmetric to longitudinal ORS axis (\( OZ \) axis), and then it was displaced along \( OX \) axis to the optimal distance \( \xi = 6.0 \text{ mm} \) [3]. The used mirrors in DRO-model had the same parameters, as it was at the cold test of ORS [3]: the spherical mirror had curvature radius \( R_{ph} = 50 \text{ mm} \) and diameter \( \varnothing 55 \text{ mm} \); the flat mirror with double grating had diameter \( \varnothing 58 \text{ mm} \) and was symmetrically truncated on two sides to \( 32 \text{ mm} \) to allocate electron gun and collector in DRO-model.

3. DRO-MODEL WITH DOUBLE GRATINGS OF HEIGHT \( B = 8.0 \text{ MM} \)

The possibility of extending the single-mode frequency tuning range at significant growth of ORS Q-factor was shown by the cold test of resonant modes properties in asymmetric ORS with a double grating. However, many additional factors influence on the output parameters of DRO. So, just carrying out the hot test of DRO with the asymmetric ORS by oscillations operation allows us to estimate the advantage of its using in DRO-modifications.

The oscillation starting current and output power level of DRO throughout frequency tuning range were determined at hot test. The loaded Q-factor and the coupling coefficient of ORS on operating TEM_{00q}-mode were defined at cold test [3]. In DRO-model we used the double grating with length \( L = 25 \text{ mm} \), grating period \( l = 1.00 \text{ mm} \), slots width \( d = 0.50 \text{ mm} \), and slots depth \( h = 2.56 \text{ mm} \). The double grating height along longitudinal ORS axis was \( b = 8.0 \text{ mm} \) (\( OZ \) axis on Fig. 1). The selected parameters of double grating provide the complete phase matching with resonant field at frequency \( f_s = 33.7 \text{ GHz} \).

The investigations of DRO output power level along the frequency tuning range were measured at electron beam current \( I_e = 120 \text{ mA} \). The output power maximum on the operating TEM_{001}-mode in DRO with the symmetric ORS was observed on frequencies near \( f_s = 33.7 \text{ GHz} \), and was \( P_{\text{max}} = 39 \text{ W} \). The frequency tuning range at the output power level \( P \geq 0.5 P_{\text{max}} \) was \( \Delta f/f_s = 6.3 \% \). In DRO with the asymmetric ORS, when the double grating was shifted on \( \xi = 6.0 \text{ mm} \), the output power maximum on the operating TEM_{004}-mode was observed on frequency \( f = 32.8 \text{ GHz} \) and was
The resonant effect of the radiation loss on the frequency tuning range was more clearly demonstrated, when DRO operated on TEM_006-mode. Thus, the maximal output power of DRO was observed near \( f_\pi \) independently from the type of used ORS and was \( P_{\text{max}} = 34 \text{ W} \) (Fig. 4a). In DRO with asymmetric ORS, the frequency tuning range extended to \( \Delta f/f_\pi = 8.5\% \) and the drops of the output power reduced at frequency tuning.

The increase of loaded Q-factor in asymmetric ORS on TEM_004-mode was not significant (Fig. 3c), therefore the starting current growth probably due to resonant field amplitude decrease in double grating by its displacement to field spot periphery of TEM_004-mode. In the same time, the significant growth of coupling coefficient \( \beta \) in asymmetric ORS (Fig. 3c) promoted the growth of overall efficiency of DRO and the growth of output power level at low-frequency region.

\[ P_{\text{max}} = 34 \text{ W}. \]  

The frequency tuning range extended to low-frequency region and was: \( \Delta f/f_\pi = 9.4\% \) (Fig. 3a). The oscillation starting current in DRO with the asymmetric ORS increased in \( 1.5 \div 2 \) times in comparison with starting current in DRO with symmetric placement of double grating and was \( I_{\text{st}} = (45 \div 60) \text{ mA} \) at frequencies near \( f_\pi \) (Fig. 3b).

**Fig. 3** – The characteristics of DRO-model with symmetric and asymmetric ORS at operation on TEM_004-mode

**Fig. 4** – The characteristics of the DRO-model with symmetric and asymmetric ORS at operation on TEM_006-mode
of asymmetric ORS reached the maximum \( \beta = 1.6 \) on frequencies near \( f_s \).

A comparison of the beam-field interaction efficiency in DRO with symmetric and asymmetric ORS had been carried out on frequencies near \( f_s \), where DRO had maximal output power throughout frequency tuning range. The first investigations of efficiency on beam-field interaction were realized in DRO with double grating length \( L = 25 \text{ mm} \approx 3w_0y \) (\( w_0y \) is the field spot radius on flat mirror along \( OY \) axis). For DRO-operation on TEM\(_{00}\)-mode the linear growth of output power at beam current increase was observed in DRO with symmetric and asymmetric ORS (Fig. 5a). The overall efficiency \( N \) in DRO with symmetric ORS reached saturation \( N_{\text{max}} = 8.4 \% \) at beam current \( I_a \geq 120 \text{ mA} \). In DRO with asymmetric ORS overall efficiency reached saturation \( N_{\text{max}} = 7.9 \% \) at beam current \( I_a \geq 140 \text{ mA} \).

![Efficiency and output power of DRO with symmetric ORS and asymmetric ORS for double grating length \( L = 25 \text{ mm} \) (a) and \( L = 17 \text{ mm} \) (b)](image)

When we shortened the double grating length to \( L = 17 \text{ mm} \approx 2w_0y \) the saturation of overall efficiency wasn’t observed up to beam current \( I_a = 150 \text{ mA} \) both in DRO with symmetric ORS and with asymmetric ORS (Fig. 5b). In DRO with asymmetric ORS at beam current \( I_a > 90 \text{ mA} \) the output power and overall efficiency of DRO exceeded the same parameters for DRO with symmetric ORS. The maximal output power and overall efficiency of DRO with the asymmetric ORS were obtained at beam current \( I_a = 153 \text{ mA} \) and were: \( N_{\text{max}} = 11 \% ; P_{\text{max}} = 60 \text{ W} \). For DRO with symmetric ORS the maximal output power and overall efficiency at beam current \( I_a = 150 \text{ mA} \) were: \( N_{\text{max}} = 9.4 \%; P_{\text{max}} = 50 \text{ W} \).

4. DRO-MODEL WITH DOUBLE GRATING OF HEIGHT \( B = 10.0 \text{ MM} \)

For DRO with double grating the significant elongation of H\(_{10}\)-mode in elementary waveguides, formed by opposite slots of double grating, is typical. This fact allows using in DRO the broader electron beam, that is especially important at operating in short millimeter waves [2]. On the other hand, selection of double grating parameters, which provides high elongation of H\(_{10}\)-mode in its cell, is conducted by narrowing of DRO frequency tuning range and decreasing of ORS Q-factor due to ohmic loss growth in double grating. The problems can be overcome by using in DRO an asymmetric OR with the double grating, shifted to field spot periphery of operating TEM\(_{00}\)-mode.

The verification of asymmetric ORS influence on output characteristics of DRO at double grating height increasing was conducted on DRO-model with double grating of height \( b = 10.0 \text{ mm} \). The used ORS was in semispherical OR form (focusing mirror with curvature \( R_{\text{ord}} = 50 \text{ mm} \) and aperture \( 255 \text{ mm} \)). The other double grating parameters were: grating length \( L = 32 \text{ mm} \); grating period \( – l = 1.00 \text{ mm} \); slots width \( d = 0.50 \text{ mm} \), and slots depth \( h = 2.67 \text{ mm} \). The estimated frequency of the complete phase matching of double grating with resonant field was: \( f_s = 31.0 \text{ GHz} \).

The output power maximum of DRO-model with symmetric ORS at operating on TEM\(_{00}\)-mode was observed near \( f_s = 31.0 \text{ GHz} \) and was \( P_{\text{max}} = 25 \text{ W} \), the frequency tuning range at the output power level \( P \geq 0.5 P_{\text{max}} \) was \( \Delta f / f_s = 5.2 \% \). When the double grating was shifted on \( \xi = 6.0 \text{ mm} \) from ORS longitudinal axis, the oscillation output power maximum increased to \( P_{\text{max}} = 32 \text{ W} \), and the frequency tuning range extended to \( \Delta f / f_s = 6.8 \% \) (Fig. 6a). Due to increasing of the interaction space length to \( L = 32 \text{ mm} \approx 3.6 w_0y \), the oscillation starting current in DRO with symmetric ORS was only \( I_a \approx 15 \text{ mA} \). The oscillation starting current in DRO with asymmetric ORS increased in ~ 2 times and was \( I_a = (24-33) \text{ mA} \) at frequencies \( f = (29.5-31.0) \text{ GHz} \) (Fig. 6b).

A comparison of efficiency on beam-field interaction in DRO-model with the double grating of height \( b = 10.0 \text{ mm} \) had been carried out at frequency \( f = 31.0 \text{ GHz} \). It was established, that overall efficiency in DRO with symmetric ORS reached saturation \( N_{\text{max}} = 7.5 \% \) at beam current \( I_a \geq 100 \text{ mA} \), and when we used asymmetric ORS the overall efficiency increased without saturation to \( N_{\text{max}} = 8.8 \% \) at beam current \( I_a = 144 \text{ mA} \) (Fig. 6c).

5. MODE COMPETITION FEATURES IN DRO WITH SYMMETRIC AND ASYMMETRIC ORS

Mode competition, excited by electron beam in ORS, significantly influences on DRO output parameters. Especially strong mode competition phenomenon observed when symmetric ORS was used in DRO. Thus, for DRO with symmetric OR in hemispherical form,
Diffraction Radiation Oscillator with...

The output characteristics of DRO-model with double grating of height \( b = 10 \) mm at operating on \( \text{TEM}_{00q} \)-mode the spectrum crashing of resonant modes is observed near semiconfocal geometry at \( D \approx 0.5R_{\text{ph}} \). In this case, according to the dispersion equation (3) the resonance frequencies placed closely for the fundamental \( \text{TEM}_{00q} \)-mode and higher transversal \( \text{TEM}_{m0q} \)-\( n \)-modes with transversal indexes \( m + n = 4 \).

The usage in DRO an asymmetric ORS allows significant decrease the influence of mode degeneracy near semiconfocal geometry, that was confirmed at experimental investigations of DRO-model with double grating of height \( b = 8.0 \) mm and interaction space length \( L = 25 \) mm \( (R_{\text{ph}} = 50 \) mm\). So, when DRO operated on \( \text{TEM}_{00q} \)-mode near the semiconfocal geometry \( (D \approx 25 \) mm\), the asymmetric ORS usage allowed significant the frequency tuning range extension without decreasing of DRO output power level. Also, for DRO with symmetric ORS, operated on \( \text{TEM}_{00q} \)-mode, the frequency tuning range was \( \Delta f/f_s = 3.8 \% \) due to modes degeneracy. For DRO with asymmetric ORS the frequency tuning range on \( \text{TEM}_{00q} \)-mode extended to \( \Delta f/f_s = 6.2 \% \) (Fig. 7).

![Fig. 6](image1.jpg)  
![Fig. 7](image2.jpg)

**Fig. 6** – The output characteristics of DRO-model with double grating of height \( b = 10 \) mm at operating on \( \text{TEM}_{00q} \)-mode

**Fig. 7** – The frequency tuning range of DRO with symmetric and asymmetric ORS at operating on \( \text{TEM}_{00q} \)-mode near semiconfocal geometry at \( D = R_{\text{ph}} = 25 \) mm

Significant elongation of H\( 10 \)-mode in the elementary waveguides, formed by opposite slots of double grating [3] leads to slope increasing of dispersion curve \( D_{\text{mnq}}(f) \) for fundamental \( \text{TEM}_{00q} \)-mode, especially at the low-frequency tuning range of DRO at \( \lambda \to 2\pi \). For higher \( \text{TEM}_{00q} \)-modes the influence of double grating on resonant field is negligible and their dispersion curves \( D_{\text{mnq}}(f) \) have a smaller slope and can be defined according to the resonance condition in OR with smooth mirrors (3). The difference in slope of dispersion curves \( D(f) \) for operating \( \text{TEM}_{00q} \)-mode and higher \( \text{TEM}_{00q} \)-modes may leads to mode degeneracy and their competition at low-frequencies of DRO tuning range [4]. Besides, owing to small asymmetry in DRO-model, caused by mirrors distortion, a competition of operating \( \text{TEM}_{00q} \)-mode occurs both with even and odd higher \( \text{TEM}_{00q} \)-modes.

For example, consider the modes degeneracy features in DRO-model with symmetric and asymmetric ORS \( (R_{\text{ph}} = 50 \) mm; \( b = 8.0 \) mm; \( f_s = 33.7 \) GHz) at operating on \( \text{TEM}_{00q} \)-mode. The output characteristics of DRO-operating on \( \text{TEM}_{001} \)-mode are shown on Fig. 3. The experimental dispersion curves \( D_{\text{mnq}}(f) \) for DRO-operating on \( \text{TEM}_{001} \)-mode with symmetric and asymmetric ORS are shown on Fig. 8. Here the dispersion curves for nearest resonant modes in hemispherical OR with smooth mirrors are shown by solid lines: \( \text{TEM}_{003} \)-mode (Fig. 8, curve 1); \( \text{TEM}_{001} \)-mode (Fig. 8, curve 2) and \( \text{TEM}_{003} \)-mode (Fig. 8, curve 3).

The competition of operating \( \text{TEM}_{001} \)-mode with the higher ones should be expected in DRO near the intersection points of the dispersion curves. Thus, for DRO-model with symmetric ORS the intersection point of the dispersion curves for the \( \text{TEM}_{004} \)-mode and higher \( \text{TEM}_{00q} \)-mode is on frequency \( f = 31.6 \) GHz (Fig. 8, point A). In DRO-model with asymmetric ORS the influence of double grating on resonant field decreases, and dispersion curve slope for operating \( \text{TEM}_{00q} \)-mode is diminished. As a result, the intersection point of dispersion curves for \( \text{TEM}_{004} \)- and \( \text{TEM}_{003} \)-modes shifts to the low-frequency region (Fig. 8, point B), and this fact leads to extension of DRO frequency tuning range on \( \text{TEM}_{001} \)-mode without mode competition (Fig. 3a).
The shown above cases of modes competition influence on DRO output characteristics by means of energy exchange between modes at resonant field. But DRO operating can be affected by the ORS modes, which don’t interact through resonant field, but directly interact with electron beam. We’ll call this case, as mode competition on beam accelerating voltage. For DRO with double grating, operated on \( \text{TEM}_{004} \)-mode, the potential competitor on accelerating voltage is the \( \text{TEM}_{014} \)-mode with two antiphase field spots along interaction space [5, 6]. The suppression of DRO excitation on \( \text{TEM}_{014} \)-mode is realized by reduction of ORS mirrors aperture along \( OY \) axis (Fig. 1) and truncation of interaction space length. A more radical way is the DRO-operating only on \( \text{TEM}_{014} \)-mode, using the shifting of grating slots periodicity in the center of interaction space [7].

For DRO with asymmetric ORS, operated on \( \text{TEM}_{004} \)-mode, except the \( \text{TEM}_{004} \)-mode a potential competitor on accelerating voltage is the \( \text{TEM}_{004} \)-mode with two field spots along \( OX \) axis (Fig. 9a). The DRO excitation on \( \text{TEM}_{004} \)-mode isn’t observed when we use the symmetric ORS, due to symmetric location of double grating in anti-phase field spots of this mode. In DRO with asymmetric ORS the double grating is placed on flat mirror near the field maximum of \( \text{TEM}_{004} \)-mode (Fig. 9a), that promotes the effective energy exchange between electron beam and resonant field of \( \text{TEM}_{004} \)-mode. The resonant frequencies of these modes at fixed distance between ORS mirrors satisfies the inequality \( f_{004} > f_{003} \), and DRO electronic tuning zone of \( \text{TEM}_{004} \)-mode is placed above on DRO electronic tuning zone of \( \text{TEM}_{004} \)-mode (Fig. 9b). This leads to hard condition of DRO-operating on \( \text{TEM}_{004} \)-mode near the output power maximum and to failure of oscillations at the increase of beam current value.

The experimental studies of the competition features by accelerating voltage between \( \text{TEM}_{004} \) and \( \text{TEM}_{014} \)-modes had been carried out in DRO-model with asymmetric ORS and double grating of height \( 2 \delta = 10.0 \) mm. The output characteristics of such DRO at the tuning on \( \text{TEM}_{004} \)-mode are shown on Fig. 6. The resonant frequencies separation of \( \text{TEM}_{004} \) and \( \text{TEM}_{001} \)-modes at the equal distance \( D \) between ORS mirrors was \( f_{004} - f_{003} \approx 1.3 \) GHz throughout the all tuning range (Fig. 10a), i.e. the direct mode competition on resonant field wasn’t observed. The excitation of oscillation in DRO-model on \( \text{TEM}_{004} \)-mode was observed at starting current, comparable to the oscillation starting current on \( \text{TEM}_{004} \)-mode. At the DRO-operating on \( \text{TEM}_{004} \)-mode the resonant increase of starting current was observed near the frequency \( f_{004} \approx f_c = 31.0 \) GHz at \( D = 21.5 \) mm (Fig. 10a), caused by the degeneracy of the \( \text{TEM}_{004} \) and \( \text{TEM}_{004} \)-modes in ORS at complete phase matching of double grating with resonant field.
TEM_004-mode \((U_{\text{max},004})\) exceeded the synchronous voltage for TEM_{104}-mode \((U_{\text{ph},104})\) practically throughout the frequency tuning range of DRO (Fig. 10b). Only on the upper frequency tuning area at the distance between mirrors \(D = (19.5-19.9)\) mm, where the DRO operated at low level of output power, the overlapping of electronic tuning zone for TEM_{004} and TEM_{104}-modes wasn’t observed.

The next case of mode competition on accelerating voltage in DRO is the interaction of electron beam with slow backward wave in periodic structure (so called the BWO-mode of operation) \([8-10]\). The starting current growth in DRO with asymmetric ORS can lead to hard competition of DRO-mode and BWO-mode. To suppress the excitation of DRO-model on BWO-mode it is necessary to reduce the length of periodic structure, or to use the periodicity failure in the centre of grating.

### 6. Conclusion

1. The hot tests of DRO-model confirm the advantages of using asymmetric ORS for frequency tuning range extension. Thus, in DRO-model with double grating of height \(b = 8.0\) mm the frequency tuning range extended in 1.5 times and for the output power level \(P \geq 0.5\) \(P_{\text{max}}\) was \(\Delta f/f_s = 9.4\%\) at \(P_{\text{max}} = 35\) W. The usage of asymmetric ORS for DRO-model with double grating of height \(b = 10.0\) mm allowed to extend the frequency tuning range in 1.3 times: \(\Delta f/f_s = 6.8\%\) at \(P_{\text{max}} = 32\) W.

2. The displacement of double grating to field spot periphery in asymmetric ORS led to increasing of oscillation starting current in 1.5-2 times, but also reduced the influence of electron beam regrouping on output power level of DRO at beam current increasing. Also, DRO with asymmetric ORS had the advantage in output power and overall efficiency at beam currents \(I_e > 90\) mA. Thus, at beam current \(I_e = 150\) mA the overall efficiency in DRO with asymmetric ORS was \(N = 11\\%\) and maximum output power level was \(P_{\text{max}} = 60\) W, but when we used symmetric ORS in DRO at the same beam current the output parameters of DRO were: \(N = 9.4\%\) and \(P_{\text{max}} = 50\) W.

3. It is shown, that in DRO with asymmetric ORS it is possible to avoid traditional mode degeneracy near semiconfocal ORS-geometry. Also, in such DRO it is possible to shift zone of modes competition for operating TEM_{00\perp}-mode and higher TEM_{n0q -1} modes in region of lower frequencies, and it contributes to extend the DRO single-mode tuning range.

4. The disadvantage of DRO with asymmetric ORS is the presence of additional competition by accelerating voltage between operating TEM_{00\perp}-mode and TEM_{104}-mode, one of two field spots of which falls on the double grating, shifted from the longitudinal axis of ORS.
Генератор дифракційного випромінювання з асиметричною відкритою резонансною системою. Частина 2. Результати “гарячих” досліджень генератора дифракційного випромінювання

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Представлені результати “гарячих” досліджень генератора дифракційного випромінювання з асиметричною відкритою резонансною системою, в який періодична структура зміщена на периферію плама поля робочої TEM\textsubscript{00q}-моди. Показано, що розміщення періодичної структури у вигляді здвоєної гребінки на периферії плама поля TEM\textsubscript{00q}-моди дає можливість розширити одномодовий діапазон перестройки по частоті та підвищити загальний ККД генератора дифракційного випромінювання. Розглянуто особливості конкуренції мод в генераторі дифракційного випромінювання з асиметричною гребінкою та асиметричною відкритою резонансною системою. Дослідження виконані у 8-мм діапазоні довжин хвиль.

Ключові слова: Генератор дифракційного випромінювання, Відкрита резонансна система Періодична структура, Здвоєна гребінка, Міліметрові хвилі.

Генератор дифракційного випромінювання з асиметричною відкритою резонансною системою. Частина 2. Результати “горячих” досліджень генератора дифракційного випромінювання

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Представлены результаты “горячих” исследований генератора дифракционного излучения с асимметричной открытой резонансной системой, в которой периодическая структура смещена на периферию пятна поля рабочей TEM\textsubscript{00q}-моды. Показано, что размещение периодической структуры в виде сдвоенной гребенки на периферии пятна поля TEM\textsubscript{00q}-моды дает возможность расширить одномодовый диапазон перестройки по частоте и улучшить общий КПД генератора дифракционного излучения. Рассмотрены особенности конкуренции мод в генераторе дифракционного излучения со сдвоенной гребенкой и асимметричной открытой резонансной системой. Исследования выполнены в 8-мм диапазоне длины волн.

Ключевые слова: Генератор дифракционного излучения, Открытая резонансная система, Периодическая структура, Сдвоенная гребенка, Миллиметровые волны.

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