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FORCED OSCILLATION EXCITATION IN THE "DISK DIELECTRIC RESONATOR-DIFFRACTION GRATING" SYSTEM

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In this work the strip-like diffraction grating influence on the spectrum of "whispering gallery" modes of the disk dielectric resonator is studied experimentally. Conditions of the single-mode excitation in a wide frequency range are determined.

Keywords: *MICROWAVE RANGE, DISK RESONATOR, "WHISPERING GALLERY" MODES, STRIP-LIKE DIFFRACTION GRATING, OSCILLATION SPECTRUM.*

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1. INTRODUCTION

High Q-factor of "whispering gallery" modes and relatively small dimensions allow us to use widely the quasi-optical dielectric resonators as a stabilizing circuit of microwave solid-state oscillators [1]. The most essential faults are the presence of the field outside the resonator (external component of the electromagnetic field attenuates exponentially along the radial coordinate) and the fact that the spectrum of the disk dielectric resonator has the equidistant behavior. Last years such resonators were used for measuring the electrophysical properties of dielectric materials [2]. The promising direction for dielectric microresonators is their application in laser technique. In this case resonator represents a semi-conductor active medium of the thickness of some nanometers, the disk diameter is chosen to be equal to 2-50 μm at the disk thickness of 50-800 nm [3].

The aim of the present paper is to investigate the oscillation excitation in the disk dielectric resonator with diffraction grating and study the influence of additional dispersion element (which the diffraction grating is) on the rarefaction of the oscillation spectrum.

2. THEORETICAL PREREQUISITES FOR THE INVESTIGATION

Oscillation spectrum of the "whispering gallery" mode is the equidistant frequency set with the interval between adjacent frequencies [1]

$$\Delta f_{m-(m\pm1)} = \frac{c}{2\pi R\sqrt{\varepsilon}}, \qquad (1)$$

where c is the light speed, m is the azimuthal number, R is the disk radius, ε is the dielectric constant of the resonator material. Note that in this work we use the cylindrical coordinate system and marking of the "whispering gallery" modes introduced in [4] such as TM_{mnl} and EH_{mnl} which differ by the polarization. Here m is the azimuthal number (φ-coordinate), n is the radial number (r-coordinate) and l is the axial number (z-coordinate) of the field variations. In the case of thin disk (p-n junction of the semi-conductor laser or disk sputtering from the magnetostrictive material on the substrate) while calculating it is convenient to use the reduced dielectric constant since the phase velocity in such resonator differs from the velocity of the wave propagation in dielectric. As seen from (1) the adjacent "whispering gallery" modes are placed in the frequency domain depending on the relative disk radius R. Instabilities in the "whispering gallery" modes depend on the value of Δf_{m} that, in turn, limits the resonator application. Application of different couplings between the resonator and the radiation source promotes some spectrum rarefaction, but in some cases this selection type is inadequate to the required result.

Computer simulation of the oscillation excitation in the dielectric resonator was carried out by the finite-difference time-domain (FDTD) method [5]. In simulation, we used two-dimensional model of the semi-cylindrical resonator since it is established that the physical processes in cylindrical resonators are the same as those of oscillation excitation in the semi-cylindrical resonators placed on the conducting plane [4]. It is shown that the deposition of a strip-like semi-transparent grating on the lateral surface of the half-disk leads to the substantial change in the "whispering gallery" spectrum. And the spectrum rarefaction depends on the filling factor of the grating

$$\theta = b/p, \tag{2}$$

where b is the width of a grating strip, p is the lattice constant. Computer simulation shows that at $\theta \approx 0{,}3$ the only one response is observed in a wide frequency range [6].

3. THE EXPERIMENT ARRANGEMENT

Investigation of the spectral characteristics of quasi-optical mirror dielectric resonator is performed using the standard measuring device KSVN and the attenuation of R2-61 type in the frequency range 8,2-12,5 GHz. Three cases are considered in the experiment:

- half-disk resonator without metal screen or grating;
- half-disk resonator with a metal screen on the lateral surface;
- half-disk resonator with a diffraction grating on the lateral surface.

Functional diagram of the measuring device with the reflection scheme is represented in Fig. 1.

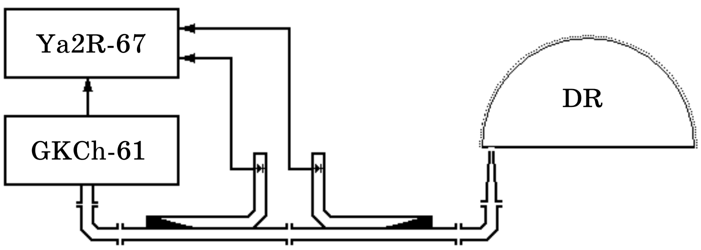

***Fig. 1** – Functional diagram of the measuring device*

A half-disk dielectric resonator made of fluoroplastic with the diameter of 214 mm and the thickness of 20 mm was manufactured for the experimenttal investigation. Resonator was placed in the alignment mechanism, which allowed to change gradually the relative position of the studied resonator and the open aperture of the exciting waveguide with the cross-section of $23 \times 0{,}9$ mm. Resonator was excited through the coupling slot in a plane mirror. Conducting screen or strip-like diffraction grating on a dielectric substrate was deposited on the disk generatrix. It was possible to shift the diffraction grating relative to a plane mirror and change the polarization of the exciting oscillations.

4. INVESTIGATION RESULTS AND DISCUSSION

The equidistant spectrum of the "whispering gallery" modes corresponding to the different azimuthal mode numbers (Fig. 2) [4] is observed in resonator without screen or grating. In the case of the lateral surface shielding by the continuous screen the spectrum of the "whispering gallery" modes is slightly shifted (Fig. 3a) that can be explained by the shift of the field maximum to the resonator center and, as a result, the decrease in the optical length of the resonator. Moreover, the responses of a lesser intensity (position of the amplitude maximum of such mode probably does not coincide with the coupling aperture position) are observed in the spectrum.

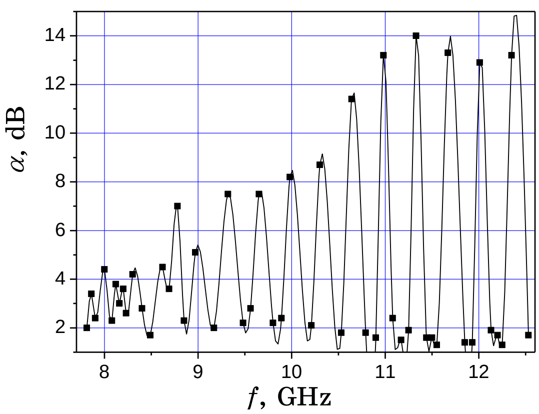

***Fig. 2** – The spectrum of the resonator without screen*

In Fig. 3b we present the spectrum of the semi-cylindrical disk resonator with a strip-like grating on the lateral surface. In the investigation we used gratings with different grating constant and filling factor. The maximal degree of selection was achieved at the filling factor $\theta = 0{,}3$. As seen from Fig. 3 resonator has the rarefied spectrum. Resonator is excited on the frequency corresponding to that of the surface wave propagating along the grating under the condition that the optical length of the resonator contains a whole number of half-waves. For frequencies higher than the surface wave one the strip-like grating acts as the scattering element. Some ill-defined oscillation modes are present in the spectrum. In this case the condition of the azimuthal resonance in the dielectric resonator holds on the frequencies lower than the surface wave frequency, and the grating acts as the screen since $\lambda > p$ [7]. Arrangement of the diffraction grating with respect to the half-disk edge plays a very important role in formation of the practically single-frequency excitation of the resonator. Thus, when the first grating strip was shifted by 0,4p, the excitation conditions held on other frequencies (10 and 10,7 GHz).

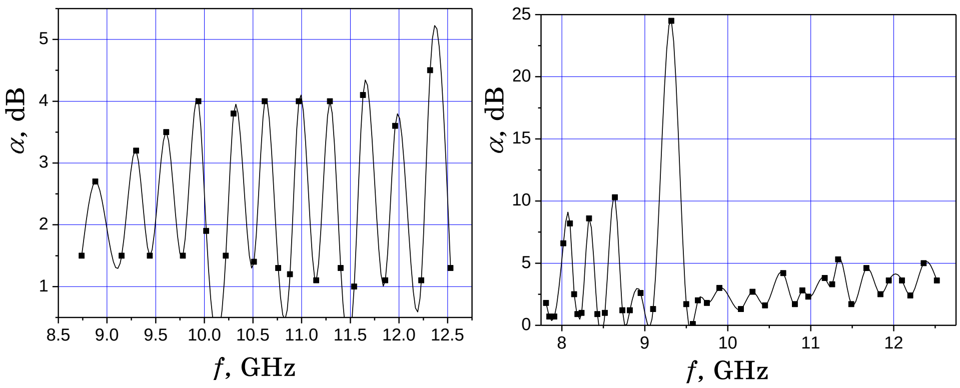

Fig. 3 *– Spectrum of the resonator with a metal screen on the lateral surface (a). Spectrum of the forced oscillations of the resonator with the grating at* $\theta = 0{,}3$ *(b)*

5. CONCLUSIONS

Possibility of the single-mode excitation of the "whispering gallery" modes in disk dielectric resonator is experimentally studied in the present work. It is shown that the positioning of the strip-like diffraction gratings on the generatrix of the disk dielectric resonator allows to efficiently rarefy its oscillation spectrum. The experiment is performed using the fluoroplastic half-disk dielectric resonator in 3-cm wavelength range. Application of dielectrics with large ε (for example, sapphire) and film deposition technique directly on the disk generatrix enables to solve the problem of the creation of compact single-frequency elements for circuits of the microwave range with high integration level.

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