LOSS MEASUREMENT IN A QUASIOPTICAL RESONATOR WITH SMALL INSTABILITY

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We investigate experimentally the model Q-factor of an asymmetric unstable resonant cavity as a function of a parameter which is equivalent to the Fresnel number for each mirror. Different values of this parameter can be obtained by varying the mirror separation, this is not the case in the method of diaphragming the beam at the exit mirror which has been applied in the past. Our results show that in certain limits one can obtain the required characteristics (size of losses and mode operation) of the resonance system by simply changing its length.

The losses in unstable resonant cavities with circular mirrors have been investigated in the approximation of geometrical optics [1] and on the basis of diffraction theory [2]. As was shown in Refs. [2,3], there is a quasiperiodic dependence of the size of the losses on the parameter N_{eq}, which is introduced on the basis of the geometric analysis in place of the usual Fresnel number. This quasiperiodicity is a characteristic of the modal properties of the cavity, and its physical meaning is that of diffraction on the edges of the mirrors [3]. It was confirmed experimentally in Ref. [4] that the modes alternate in losses as a function of the parameter N_{eq} in the optical region for the special case of a confocal geometry.

In the present paper we report the experimental investigation of the modal Q of an asymmetric, unstable resonator as a function of the parameters N_{eq} for each mirror. Different values of these parameters can be obtained by changing the separation of the mirrors, whereas in Ref. [4] the beam was diaphragmed at the exit mirror. By changing the length of the cavity, one could simultaneously vary both the parameter N_{eq} and the magnification M, which characterizes the degree of instability of the cavity [5]. It should be noted that the predominance of diffraction losses over geometrical losses observed in Ref. [4] for a highly diaphragmed exit mirror would apply in our case to a cavity at the threshold of stability.

The upper part of Fig. 1 shows the layout of the cavity under study, which was found by a concave mirror with radius of curvature R_1 = 266 mm and diameter $2a_1$ = 94 mm and a convex mirror with radius of curvature R_2 = − 140 mm and diameter $2a_2$ = 52 mm. The cavity was excited by a horn, which was fed by a reflection oscillator at a wavelength of λ = 7 mm. This was coupled to the cavity through the central region of the larger mirror, which was covered by a system of transparent slits whose period was less than λ and whose width was of the order of $\lambda/50$. The diameter of the resulting grating was $2a_0 = 2a_1/3$. Excitation was produced by a linearly polarized wave whose plane of polarization was perpendicular to the grating slits. A receiving horn with dimensions 6 × 4 cm^2 was located in the far field and overlapped the central maximum of the output beam.

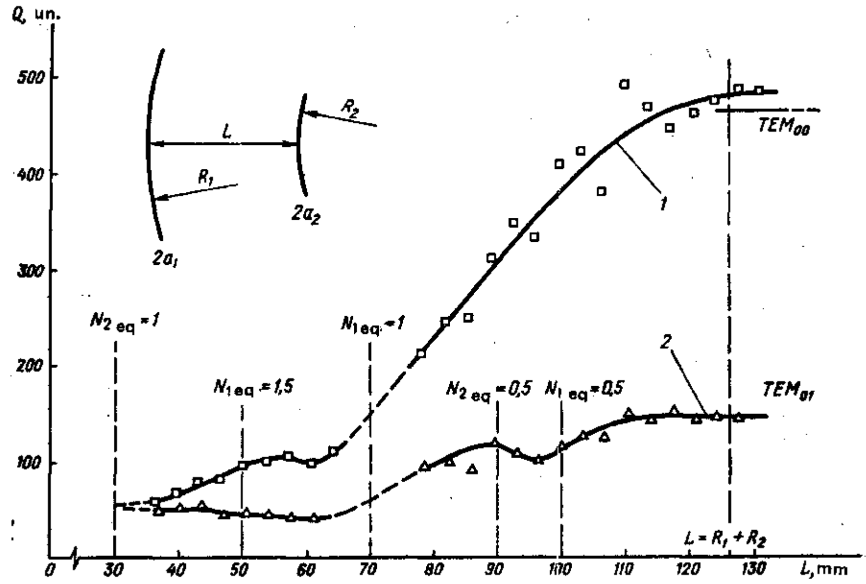

Fig. 1. Schematic diagram of the cavity and Q as a function of the distance between mirrors for the excited modes of oscillation.

The cavity was investigated within the limits of the upper right quadrant of the stability diagram. The region in which the cavity is unstable is determined by the condition $L < R_1 + R_2$, where L is the distance between the centers of the mirrors. For $L = R_1 + R_2$ we obtain a concentric cavity, which is equivalent to a plane-parallel cavity. The equivalence condition can be determined by the integral-equation method [6] and is of the form

$$a = \sqrt{a_1 a_2}, \quad (1)$$

where a is the radius of the mirrors of a plane-parallel cavity having the same losses as a concentric one.

Figure 2 shows individual resonance curves obtained at different values of the length L and, hence, magnification M. The parameter M, which characterizes the degree of instability of the cavity, changes from a maximum value of $M_{max} = 1.90$ for a confocal geometry to unity as L is decreased to L = 0 or increased to $L = R_1 + R_2$. Changing M alters both the degree of separation of the resonance curves and their width. Analysis of the field distribution at the resonances of Fig. 2 implies that near the threshold of stability there are two low-symmetry oscillations, TEM_{00} and TEM_{01}, excited in the cavity. The absence of the antisymmetric mode TEM_{10} from the spectrum can apparently be explained by the fact that its excitation is brought about by means of a broad beam, since the conditions for the excitation of this mode are not satisfied at the large mirror.

To evaluate the Q of the oscillations we used the formula

$$Q = \frac{L}{\Delta L},$$

where ΔL is the half-width of the resonance curve in units of length. The behavior of Q as a function of the length of the cavity L for two types of excited oscillations is shown in Fig. 1 (curves 1 and 2). Near the point L = 126 mm, which corresponds to a concentric geometry, the experimental value of Q (the horizontal segment in Fig. 1) was obtained according to the results of Ref. [6] with

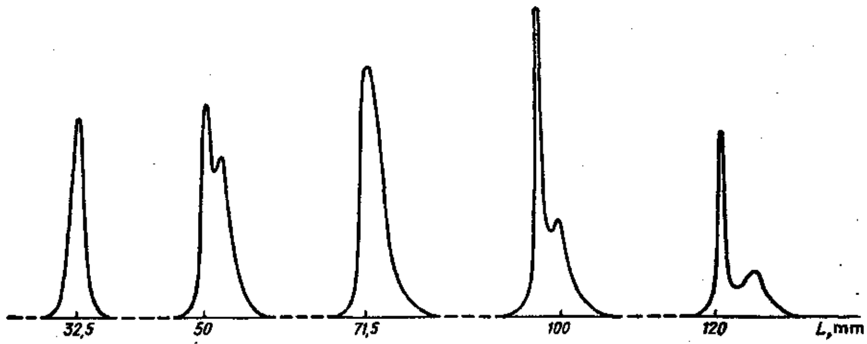

Fig. 2. Individual resonance curves from the spectrum of the cavity.

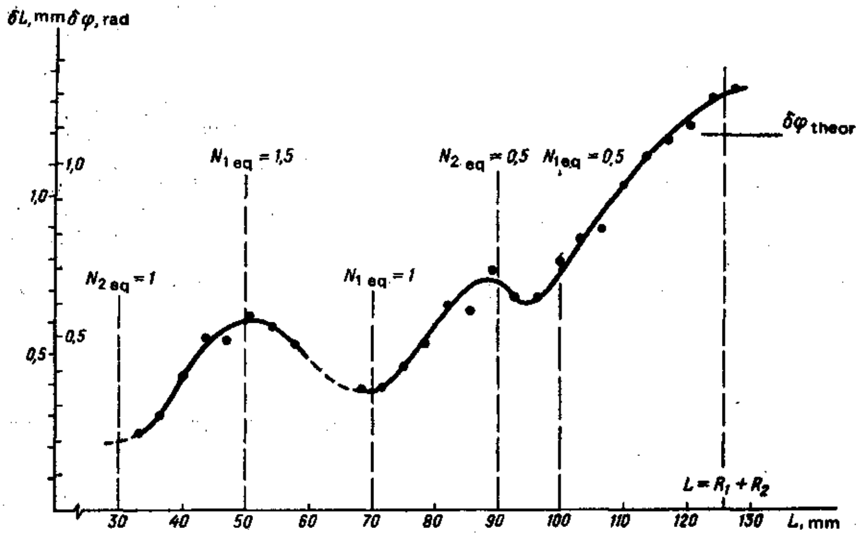

Fig. 3. Difference between phase shifts δφ for excited modes of oscillation as a function of the length of the cavity. The experimentally measured quantity is $\delta L = \lambda/2\pi\delta\varphi$.

allowance for the equivalence condition (1) and the relation between the Q and the loss per complete pass

$$Q = \frac{2\pi L\sqrt{1-\delta}}{\lambda\delta}.$$

We will define parameters N_{1eq} and N_{2eq} for each of the mirrors as follows:

$$N_{1eq} = \frac{a_1^2}{\lambda L} \sqrt{\frac{g_2}{g_1}(g_1 g_2 - 1)},$$
$$N_{2eq} = \frac{a_2^2}{\lambda L} \sqrt{\frac{g_1}{g_2}(g_1 g_2 - 1)}, \quad (2)$$

where $g_i = 1 - L/R_i$; $i = 1, 2$ are the mirror indices. Writing these parameters in the form (2) is equivalent to defining them in terms of the coordinates of imaginary centers on the basis of a spherical-wave analysis [3], but in a more convenient form for calculations. Integral and half-integral values of N_{1eq} and N_{2eq} are indicated on the graph of Fig. 1; one can see some increase in Q for half-integral values of N_{eq}, in qualitative agreement with the theory of Ref. [2]. As L is decreased from the threshold of stability, the Q of the lower mode (curve 1) decreases, approaching the value of Q for the second mode, and becomes equal to it at $N_{eq} = 1$. Consequently, by changing L one can smoothly vary the size of the losses of the operating mode.

The difference between the phase shifts of the excited modes (see Fig. 3) is maximum at the stability threshold of the cavity at $L = R_1 + R_2$. The experimental value of the mode separation at this point is in satisfactory agreement with the result of a calculation based on Ref. [6] (the horizontal line). As L decreases, the mode separation is maximum for half-integral values of the parameters N_{eq} and minimum for integral values. Such a result agrees qualitatively with the results of computer calculations [2], but quantitative comparison is complicated by the fact that in Ref. [2] the characteristics of unstable resonators were examined as functions of N_{eq} for fixed values of the g parameters.

The results presented here could be useful for doing calculations on resonance systems or for working with them, it being possible within certain limits to obtain or preserve the desired characteristics of the cavity by simply changing its length.

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