Laser operation in Rounded Isosceles Triangular Cavity

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Abstract

We report directional laser operation in a rounded isosceles triangular shape cavity. The laser exhibits bidirectional laser output in numerical simulation. The operating laser modes are analyzed with a boundary element method.

Key words: microdisk laser; Maxwell-Bloch equation; Boundary element method

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1. Introduction

Recently, microcavity lasers have attracted much attention for the application to hybrid optoelectronic circuits and optical communication. The early works in this field were concentrated on the simple geometrical shape such as sphere, cylinder, and circular because these geometries have extremely high-Q lasing modes, so-called whispering gallery modes (WGM), resulting from a complete confinement of rays by the total internal reflection (1). The advantage of WGM is the small losses only due to evanescent leakage. Although the threshold of these lasers is low, their output powers are weak and their emissions are isotropic. This drawbacks have been resolved by deforming the boundary shape (2). However, the number of output beams are at least two because of the discrete symmetry of the boundary geometry. Recently it was reported that a small size of the rounded isosceles triangular (RIT) cavity in the range $28 < \mathrm{Re}(nkD) < 36$, where n is the refractive index and k is the wave number, exhibits a unidirectional laser operation (3).

In previous study for RIT cavity, since the cavity size is too small to fabricate a laser, the lasing characteristics should be studied for larger size cavity. In microcavity, as the cavity size increases, the directionality can be changed because of the change of the curvature. In this paper, we study a larger size RIT microcavity in the range of $63 < \mathrm{Re}(nkD) < 65$ with $n = 2$. We find that the laser still operates almost unidirectionally in numerical simulation of the two-dimensional Maxwell-Bloch (TDMB) equation. The directional emission is confirmed by using the boundary element method (BEM) (4).

2. Numerical Results

The RIT microcavity is shown in Fig. 1. We take the characteristic linear size D as a length between the bottom and the center of the circle A. The lengths of the bottom b and height h are chosen as $b = 1.2D$ and $h = 2.4D$, respectively. We also set the radius of circle B as $r_B = 0.3D$, and the radius of the circle A is then $r_A \simeq 0.34D$. The details of these dimensions of the cavity are unimportant as far as the basic structure of the microcavity is

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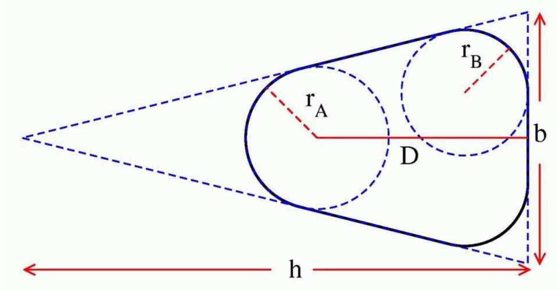

Fig. 1. The rounded isosceles triangular cavity.

The classical ray dynamics of the RIT is totally chaotic, i.e., a trajectory starting from arbitrary initial position (s_0, p_0) fills uniformly the whole phase space in the Birkhoff coordinates (s, p) where s is the boundary length and its conjugate momentum p is $\sin \chi$, χ is the incident angle. To obtain the laser emission in this chaotic cavity, we apply the TDMB equation, which is developed by Harayama *et al.* (5). The equation takes into consideration of the nonlinear interaction between the light field and the lasing medium. The validity of this model has been checked by Harayama *et al.* for the microstadium. In our simulations, we choose the dimensionless length of the cavity for $nkD \sim 65$, which is the maximum size in the limit of the computer power. All of the parameters are the same as those in Ref. (5). The lasing pattern for this geometry is shown in Fig. 2(a). We note that the quality factors $Q \simeq 35$ of the modes are considered of the same order as those of the microstadium (6) and more than ten times lower than those of slightly deformed disks (2). The RIT cavity laser operates almost unidirectionally. The figure shows strong emission beams from the bottom part. On the rounded part, the opposite part of the bottom, we can see the weak laser emission in comparison with the bottom part. It means that the rounded boundary prevents emission by forming a whispering gallery type pattern.

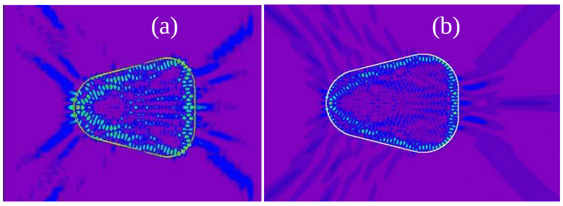

Fig. 2. (Color Online) The stationary lasing pattern obtained from (a) TDMB equation and (b) BEM analysis.

To confirm the laser emission, we obtain various resonance modes for the same size as the above by using BEM. One of the resonance modes is given in Fig. 2(b), which has the lowest loss factor in the even symmetry. The pattern of the resonance is very similar to the result shown in Fig. 2(a). The laser emission on the bottom part is stronger than the rounded part. These results shows that the RIT microcavity generates almost unidirectional emission even the size is increased.

3. Summary

In summary, we have shown that, through the numerical simulation with the TDMB equation and BEM analysis, the RIT microcavity laser, whose size is in the range $63 < \mathrm{Re}(nkD) < 65$, also generates directional lasing emission. It has been found that these dirctional lasing modes correspond to the high-Q resonance modes. We expect that this microcavity of directional property could make useful contribution to the future application.

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