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Nonlinear Dynamical Simulation of the Universal Single-Mode Lasing in Fully-Chaotic Microcavity Lasers

Mengyu You[1], Susumu Shinohara[2], Satoshi Sunada[3], and Takahisa Harayama[1]

[1] Department of Pure and Applied Physics, School of Advanced Science and Engineering, Waseda University
3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555, Japan
[2] Department of Production Systems Engineering and Sciences,Komatsu University
Nu 1-3 Shicho-machi, Komatsu, Ishikawa 923-8511, Japan
[3] Faculty of Mechanical Engineering, Institute of Science and Engineering, Kanazawa University
Kakuma-machi Kanazawa, Ishikawa 920-1192, Japan
Email: mengyuyou@akane.waseda.jp

Abstract—We numerically simulate the lasing of the D-shaped microcavity laser, and show that lasing occurs in single mode, even when the pumping power is so high that many resonance modes have positive gain. Our numerical results support the universal single-mode lasing conjecture for fully-chaotic microcavity lasers.

1. Introduction

Stable lasing in fully-chaotic microcavity lasers have been demonstrated by numerical simulations and experiments [1]. Unlike conventional one-dimensional lasers, for microcavity lasers, the morphological effect of a resonant cavity plays a nontrivial role both in lasing properties and spectral properties. It was theoretically shown that, for fully chaotic microcavity lasers, single-mode lasing states are stable under continuous-wave pumping condition as long as the pumping power is sufficiently high, and the longitudinal relaxation rate is larger than the difference between adjacent lasing modes [2]. In this study, we numerically demonstrate that even many resonance modes have the potential to be lased, single-mode lasing can still be achieved in certain parameter regimes for the D-shaped microcavity laser (the white curve and line in Fig. 1(b) defines the D-shaped cavity).

2. Results

In this study, we use the Schrödinger-Bloch (SB) model for numerically simulating lasing states for the D-shaped microcavity laser. The SB model is an approximate model of the Maxwell-Bloch model, describing the slowly varying envelope of the electric field $\tilde{E}$, the polarization field $\tilde{\rho}$, and the population inversion component W with a two-level active medium.

By numerically solving the SB model, we found that single-mode lasing occurred even when many resonant modes have positive gain. A typical lasing spectrum is shown in Fig. 1(a). The spatial intensity pattern of this single-mode lasing state is shown in Fig.1(b), which is asymmetrical and turns out to be different from all the spatial patterns of the resonance modes with positive gain. However, we found that the superposition of two low-loss resonance modes with frequencies close the gain center, as shown in Fig. 1(c), can well reproduce the spatial pattern of the lasing state shown in Fig. 1(b). Hence, in this case, the single-mode lasing state can be explained by the locking of the two resonance modes.

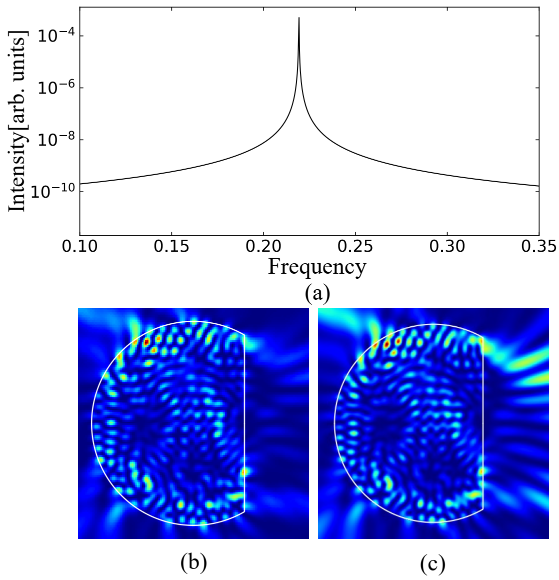

Figure 1: (a) Numerically simulated lasing spectrum for the D-shaped microcavity laser. (b) Spatial intensity pattern of a stationary lasing mode. (c) Superposition of the wavefunctions for two resonance modes.

In addition, we investigated the lasing states for various pumping powers and longitudinal relaxation rates. The resulting phase diagram revealed the conditions for the occurrence of the single-mode lasing, which turned out to be consistent with the conditions assumed for a theoretical justification of the universal single-mode lasing in Ref. [2].

ORCID iDs Mengyu You: 0000-0002-8690-0418

References

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