Theoretical research on two-dimensional microcavity lasers

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In this thesis, we study the mode-interaction in two-dimensional microcavity lasers and the morphological effect of the cavity-shape on the lasing property. Two-dimensional cavities can be characterized by the resonance structure. However, when the two-dimensional cavity is used as a laser-device, the nonlinear-interaction between the resonant modes occurs through an active (laser-) medium inside the cavity. Therefore, the lasing properties of the two-dimensional cavity show non-trivial physical properties that can't be realized in the case of conventional one-dimensional lasers, because they strongly depend on the structure of frequency-space, the spatial patterns, and the symmetry of the resonant modes.

This thesis are mainly, (1) the derivation of the Schreodinger-Bloch equations which describe the time-evolution of two-dimensional microcavity lasers, and the relation between the resonant modes and the single-lasing modes (Section. 2 and 3), (2) the method of numerical simulations for the Schreodinger-Bloch equations (Section. 4-1), and (3) the morphological effects on the lasing properties (Section 4-2 -4). Here, we study circular cavity lasers (Section 4-2), and two-kinds of deformed cavity lasers from a circular cavity.

First, the lasing-modes in elliptic cavities are studied in order to reveal the deformation effect on the laser-operation (Section. 4-3). The resonance structure of a circular cavity is unstable with respect to the change of the symmetry of the cavity-shape, and then the deformation split degenerate resonant frequencies of the resonance in a circular cavity.

However, on the laser action, it is shown that the lasing frequencies become same again due to the mode-locking interaction. Moreover, it is also shown that the mode-locking interaction leads to the lasing mode of an asymmetric spatial pattern even in the cavity of a symmetrical shape such as an ellipse. This is universal phenomenon for the two-dimensional cavity lasers of symmetrical shapes.

Next, in order to reveal the difference in lasing properties between an "integrable" cavity where all of ray trajectories are regular, such as a circular or elliptic cavity, and "fully chaotic cavity" where all ray-trajectories show chaos, we study a stadium-cavity laser (Section 4-4). In a stadium-cavity laser, it can be observed that the number of effective lasing modes decreases even when a pumping power increases. Then, it is discussed that this phenomenon can't be observed in the case of "an integrable cavity" such as a circular cavity. Finally, Section 5 shows the summary of the results obtained by the numerical simulations and open questions.