ADVANCED MODELLING OF SINGLE AND PERIODIC ACTIVE DIELECTRIC RESONATORS FOR MICROLASERS

Accurate mathematical and numerical modelling of arbitrary-shape microcavities and their arrays is a major trend in today's research into microlasers. We address a hard nut in the electromagnetic analysis of optical fields in microcavity lasers - the point that the lasing phenomenon is not characterised directly through the usually studied Q-factor. Indeed, the specific value of the pump or gain that is needed to force a mode to become lasing is not included in this formulation. As a practical consequence, the Q-factor theory fails to explain why photopumping with a hollow beam reduces the threshold power for a microdisk and why in the stadium-shape cavity the lasing occurs on the "bow-tie" modes whose Q-factors are much lower than those of the WG-like modes. Trying to answer these questions, researchers resorted to complicated non-linear descriptions of the lasing.

Realising such a gap in the linear characterisation of lasers, we propose to make it more adequate to the nature of lasing as a physical phenomenon. This will be done by introducing active regions into the cavities and studying specific eigenvalue problems for the Maxwell equations, able to deliver the thresholds in addition to the natural frequencies. Open resonators will be considered as single arbitrary-shaped cavities with active regions and also as periodic arrays of small-size quantum wires of circular and strip-like shape sandwiched between layered mirrors. Numerical study will be concentrated on the effects of cavity and active-region shape, Bragg-type reflectors composition, layer number, periodicity, etc., on the Q-factors and light-emission thresholds of the lasing electromagnetic modes.

We will consider the problems of determining the natural frequencies and lasing thresholds as eigenvalue problems, i.e. as source-free boundary-value problems for the set of Maxwell's equations with exact boundary, edge, and radiation conditions. For periodic resonators, we will use the theory of Floquet modes and associated series representations. In each case we will elaborate economic boundary integral equations (IEs), which do not imply small-contrast or high frequency approximations and lead to convergent, stable, and efficient numerical algorithms. Besides of the frequencies and thresholds, we will study modal field patterns in the near and far zones and systematically look for the ways to improve these characteristics. Most of the research will be done within 2-D models however we foresee that this experience will serve for the further investigation of 3-D resonators and double-periodic gratings of quantum dots.

It is expected to be able to clarify the effects of the shape of resonator and active region - for a single resonator, and of their periodicity - for a periodic resonator, on the lasing frequencies, thresholds, and modal optical fields in the near and far zones. Such an accurate analysis and quantification is a challenging task, however the proposed approach and advanced numerical methods are adequate to the problem and will lead to the goal.

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IJP - 2007/R1