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Gregersen, Niels

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Modeling of optical fields in laser microcavities using a modal method

Niels Gregersen(1)

(1) DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Ørsteds Plads, Building 343, DK-2800 Kongens Lyngby, Denmark

e-mail: `ngre@fotonik.dtu.dk`

A compact microlaser featuring a high-Q cavity with a low mode volume V is of interest as it allows for a near-unity β factor, thresholdless lasing and reduced energy consumption. However, whereas a high Q and a low V are easily achieved separately, combining the two poses a challenge. Furthermore, the cavity should allow for efficient out-coupling of light, which in low-V systems represents an additional design challenge.

Engineering a microcavity meeting these demands requires a in-depth physical understanding of the governing physical mechanisms of the system. In the low-V cavity, a central mechanism limiting the Q factor is the poor modal overlap between the cavity Bloch mode and the mirror Bloch mode. Also, the strong confinement will generally lead to highly divergent far field patterns and thus low collection efficiency. In this scenario, Bloch-wave engineering [1] and the introduction of adiabatic transitions emerge as powerful design tools to control the optical mode.

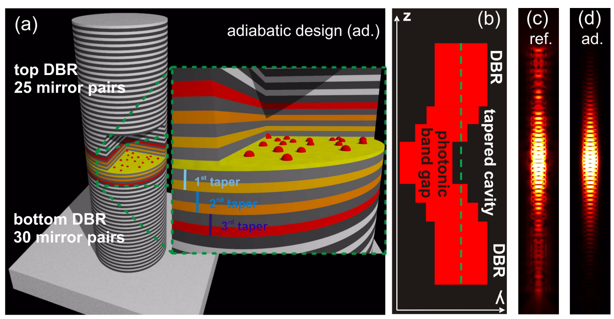

FIGURE 1. Adiabatic micropillar cavity design (a) based on a central 3 taper region (inset). (b) The photonic bandgap (b) and mode profiles for a reference design (c) and for the adiabatic design (d).

In the modal method, the field is expanded on the eigenmodes of z-invariant layers and on the Bloch modes of periodic sections. Using mode matching at the interfaces, the method gives direct access to reflection and transmission coefficients describing the scattering of the optical modes, and the method is thus highly suitable for Bloch-wave engineering of the low-V cavity.

As example we have used the modal method to propose the high-Q submicron-diameter micropillar geometry implementing an adiabatic cavity design as illustrated in Fig. 1, which recently lead to the experimental demonstration of high-β lasing in fabricated devices with β factors exceeding 0.5. [2]

References

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