Band Edge Lasing in Metal-Clad Multimode Photonic Crystal Slabs

J. Van Campenhout, P. Bienstman and R. Baets
Ghent University – IMEC, Department of Information Technology
Sint-Pietersnieuwstraat 41, 9000 Ghent, BELGIUM
joris.vancampenhout@intec.ugent.be

We present a novel approach to achieve electrically pumped lasing action in a PhC with a footprint of less than 20 µm in diameter. Current state-of-the-art membrane photonic-crystal (PhC) lasers consist of a patterned III-V membrane, suspended in air or bonded to a carrier wafer, for instance silica on silicon. The membrane optical thickness is around half the operational wavelength and vertical light confinement is provided by the high refractive index of the core with respect to air and/or the low index carrier. Lateral light confinement is achieved by etching a 2D photonic crystal through this slab structure. Generally, there are two options: one can define a defect-based cavity – for instance by leaving out some holes – which in fact acts as a micron-sized Fabry-Pérot cavity. Another approach is in tailoring the dispersion characteristics of the PhC to realize propagating Bloch modes with a very low group velocity (i.e. band edge Bloch modes). This is in fact a 2D DFB laser type, and can easily be designed for in-plane or surface emission. Examples of both types can be found in [1]-[3]. Although these microlasers show very good properties in terms of confinement quality factors and lasing threshold powers when pumped optically, no electrically pumped micron-sized devices have yet been made. The concept of an electrically pumped 2D PhC DFB surface-emitting laser has been experimentally elaborated in [4]. However, the concerning PhC laser has a footprint of more than 350 µm in diameter due to its weak grating structure.

In our approach metal contact layers are added on top and bottom of a PhC membrane. The presence of these metals in the vicinity of the optical field will cause a considerable absorption loss that prevents lasing action. However, by increasing the membrane thickness and choosing the appropriate contact metal, absorption losses can be reduced to an acceptable level. The resulting slab structure is multimodal and the metal-semiconductor interface causes several effects that don't appear in index guided waveguides such as particular cut-off frequencies and surface plasmon modes.

The possibility to achieve band edge lasing action in this type of structures is studied using the eigenmode expansion tool CAMFR [5]. Simulations are performed for a 2D cross-section of the metallized 1D PhC slab. It is shown that an appropriate PhC design can support TE-polarized band edge lasing modes with an acceptable material gain threshold. The device can be easily designed for surface emission, which can be tuned by varying the metal thickness. The simulation results will be discussed as well as their relevance to real 3D PhC laser devices.

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