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A Modified Single Defect Cavity Study for Coherent Coupling in Photonic Crystal VCSELs

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Abstract: A modified single defect cavity study was conducted to determine if a calibrated simplified model could be use to predict and subsequently design for coherent coupling in PhC VCSELs. Modeled and fabricated devices are compared.

OCIS codes: (250.7260) Vertical cavity surface emitting lasers; (140.2010) Diode laser arrays.

Coherent evanescent coupling has been reported in arrays of defect cavities in photonic crystal (PhC) vertical cavity surface emitting lasers (VCSELs) [1]. Results of a parametric study varying the coupling region hole diameter, *b'*, in PhC VCSEL devices with 2x1 arrangements of defect cavities showed a transition point delineating uncoupled and coupled devices. Devices with *b'* above a threshold value tended to be uncoupled, while devices with *b'* below that threshold value tended to be coupled [2]. In the work reported here, a modified single defect cavity study was conducted to determine if a calibrated simplified model could be use to predict and subsequently design for coherent coupling in a PhC VCSEL. Single defect devices with varied *b'* were both modeled and fabricated.

A simplified model of the PhC VCSEL structure was used to facilitate a two-dimensional plane wave expansion method calculation. PhC air holes were placed in a background of effective index chosen to recreate the fundamental mode far field intensity pattern obtained from a fabricated single defect cavity device with unmodified *b'*. This calibrated model was then used to calculate near and far fields for devices with successively decreasing *b'*, which were then compared to measured data. Figure 1 shows the PhC designs, calculated, and measured results for the first and last devices in a series of 10, where the single defect is the omitted PhC hole to the left of the coupling region hole (shown in red). Analogous calculations with the single defect created by omitting the hole to the right of the coupling region were also performed, and overlap integrals between the left and right modes were calculated.

The overlap integral calculations showed increasing modal intensity in the coupling region with reduction in *b'* and were in general agreement with the observed experimental coupling in PhC VCSEL devices with 2x1 arrangements of defect cavities. However, this approach was not able to differentiate between devices fabricated in VCSEL material of different epitaxial growths, indicating a more detailed model is necessary. A full three-dimensional treatment of the PhC VCSEL devices utilizing a 200-node Beowulf cluster will be pursued.

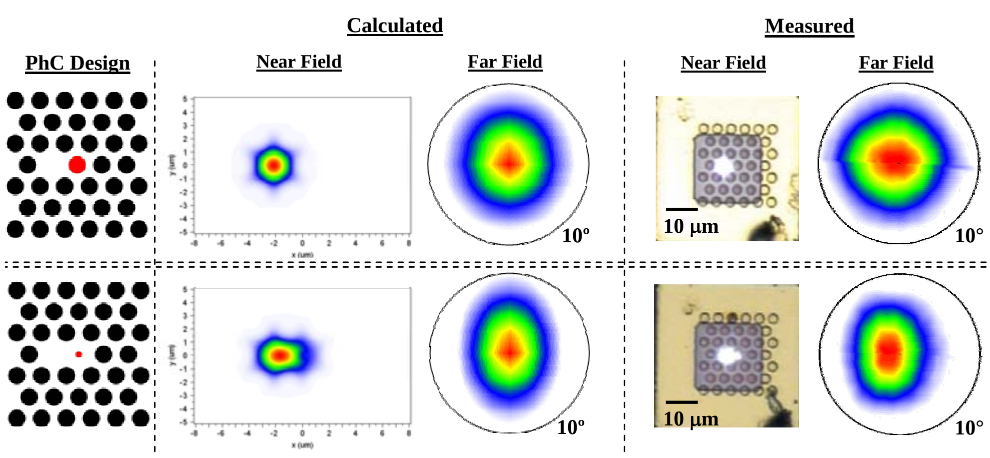

Fig 1. Calculated and measured near and far field intensity patterns for the two PhC designs shown. PhC lattice constant, *a*, is 4.0 μm and the PhC hole-diameter-to-lattice-constant-ratio, *b/a*, is 0.7; *b'/a* = 0.7 (top design), *b'/a* = 0.25 (bottom design).

[1] A. J. Danner, J. C. Lee, J. J. Raftery, Jr., N. Yokouchi, and K. D. Choquette, "Coupled-Defect Photonic Crystal Vertical Cavity Surface Emitting Lasers," *Electron. Lett.* **39**, 1323 (2003).
[2] J. J. Raftery, Jr., A. J. Danner, A. C. Lehman, P. O. Leisher, A. V. Giannopoulos, and K. D. Choquette, "A Parametric Study of Coherent Coupling in Photonic Crystal VCSELs with 2x1 Arrangements of Defect Cavities," CLEO (Conference on Lasers and Electro Optics) **CWO3**, Long Beach, CA, USA (May 2006).