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Surface Normal Photonic Crystal Waveguide Coupling for N^3 Distributed Optoelectronic Crossbar

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The realization of the N^3 distributed optoelectronic crossbar [1,2] requires the incorporation of bidirectional transceiver modules. The current design philosophy of these modules in their single wavelength configuration consist of the integration of VCSEL and RCE detection devices monolithically integrated with a bidirectional common waveguide. Coupling into this common waveguide is currently under investigation utilizing two methods 1.) surface normal coupling using a buried grating coupler as shown in Figure 1, and 2.) external but monolithic surface normal coupling utilizing photonic crystal as shown in Figure 2. This paper will briefly discuss the first method and its drawbacks which motivate the second photonic crystal implementation method. In addition, initial results will be presented.

The key motivation for this work is investigate the potential to eliminate the epitaxial regrowth requirement for the surface normal grating coupled internal waveguide in the current design of Fig. 1. As shown by Noda, photonic crystal structures enable surface normal coupling. [3,4] By utilizing the structure at the edge of the VCSEL and photodetector, yet monolithically

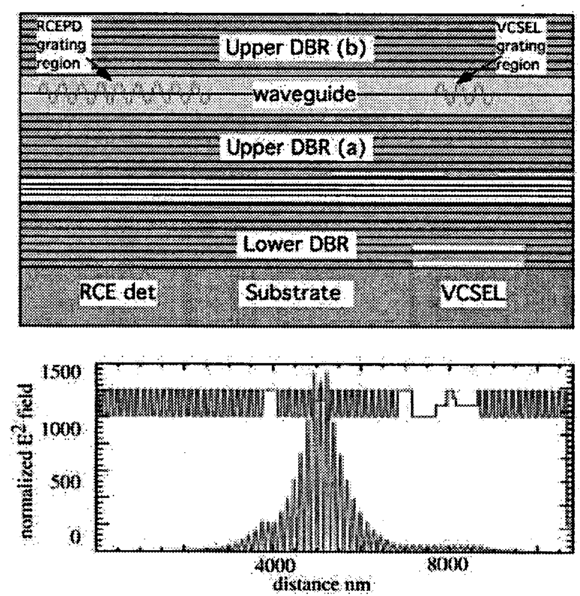

Figure 1: Bidirectional transceiver implemented with internal surface normal grating coupling.

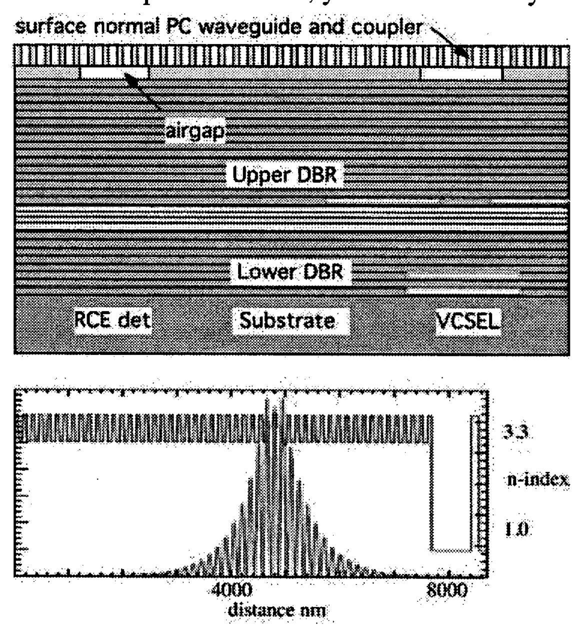

Figure 2: Bidirectional transceiver implemented with surface normal photonic crystal waveguide coupler at the surface of the epitaxy.

integrated as shown in Fig.2, this effect may be utilized to provide an efficient waveguide coupling solution at the surface the structure, yet still within its epitaxy. By comparison the grating coupler must be used within the cavity due to its low diffraction efficiency. By providing intra-cavity coupling, the diffraction efficiency of the grating coupled approach is enhanced by the resonant cavity effect, thereby increasing its effective diffraction efficiency into the waveguide.

However what is desired is a solution which may be potentially utilized at the surface such that epitaxial regrowth may be eliminated, and the coupling process structured such that it is fabricated post growth. However a coupler with high diffraction efficiency must be designed.

By providing a solution for waveguide coupling without regrowth, potentially the bidirectional transceiver costs may be reduced. In addition, the photonic crystal solution promises to provide potential the required improvement in single pass diffraction efficiency required for surface epitaxy designs.

In addition, the photonic crystal solution may provide for increased design flexibility, as well as extension to wavelengths where internal waveguide designs are difficult in a given material system, such as the extension 850 nm when operating in the AlGaAs system. The photonic crystal solution may also provide for polarization and mode selection, selective WDM mux/demux and directional coupling, as well as a means for temperature insensitive wavelength control.

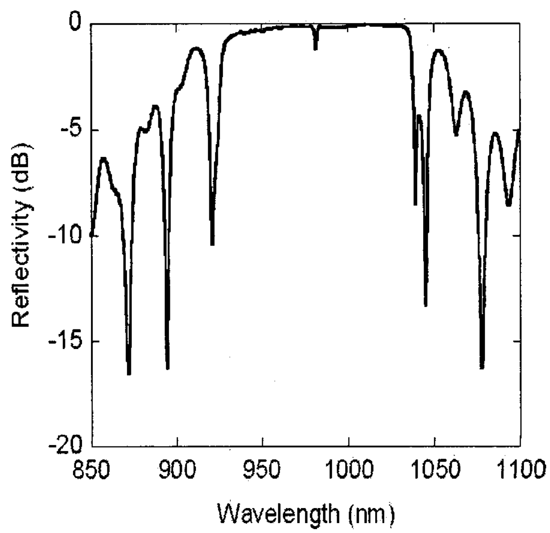

Figure 3: Reflectance spectrum for AlGaAs VCSEL wafer grown for the PC waveguide experiment.

Our initial design work has been accomplished at 980 nm. Shown in Figure 3 is the measured reflectance spectrum of the VCSEL/PD epitaxy structure prior to the fabrication of the photonic crystal coupler and waveguide layer. The structure is designed for top emission with an 18 period top DBR. Previous VCSEL structures fabricated with this design have yielded threshold currents as low as 200 μA with threshold voltages as low as 1.45 V. The epitaxy deviates from convention design through the incorporation of two additional epitaxy layers at the surface. The lower AlGaAs layer is selectively under etched to provide an air gap which increases the index contrast between it and the overlapping GaAs waveguide layer, where the photonic crystal is then fabricated.

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[1] Guilfoyle, Louderback, et.al., Waveguide Coupled VCSEL/Detector Array Module and Architecture for Distributed Switching, SPIE 2942-30, Oct. 2002.
[2] Morozov, Guilfoyle, Louderback, Emerging Technology for Backplanes and Chip-to-Chip Interconnects, IEEE LEOS 20003 annual Meeting, Nov. 2003.
[3] S. Noda, Teaching Light New Tricks, SPIE OE magazine, Oct. 2001.
[3] S. Noda, M. Yokoyana, et.al., Science, 10 Aug. 2001.