Lossless high-index contrast Distributed Bragg Reflector

Vilson R. Almeida and Michal Lipson
School of Electrical and Computer Engineering, Cornell University, 411 Phillips Hall, Ithaca, NY, 14853
Phone: (607) 255-7877, e-mail: vra2@cornell.edu, lipson@ece.cornell.edu

Abstract: A new approach for achieving nearly lossless high-index contrast planar Distributed Bragg Reflector structures is proposed. It provides means of eliminating diffraction losses, without compromising device performance.

OCIS codes: (230.1480) Bragg reflectors; (130.3120) Integrated optics devices; (140.4780) Optical resonators; (250.5300) Photonic integrated circuits; (260.1960) Diffraction theory; (230.7390) Waveguides, planar

Distributed Bragg Reflectors (DBR) are widely used for photonic devices. Applications include VCSELs, filtering and Wavelength Division Multiplexing (WDM) [1,2]. The performance of DBRs (e.g., bandwidth and reflectivity) improves with the index contrast of the materials. However, losses also increase, as a consequence of light diffraction in the low-index regions. Conventional solutions for reducing losses are usually either reduction of index contrast or an excessive shortening of the low-index region [3,4], both leading to a decrease in device performance.

A schematic 2D description of the new class of DBR is shown in Fig. 1 for a 4-period structure. The structure is embedded in a medium with index n_L and consists of a sectioned waveguide with high index of refraction n_H. It is periodic in $\lambda_0/2$, with each of the sections separated by l_L. Losses are reduced through the insertion of a high index, narrow wire, hereafter called *wire-lens*, in the low-index region. The *wire-lens* width (w_L) of index n_H is much smaller than the waveguide width (w_H). In Fig. 1 we show the electric field distribution for a Si structure (n_H = 3.48) surrounded by air (n_L = 1), with λ_0 = 1.55 µm, w_H = 500 nm, w_L = 50 nm and l_L = 100nm. We calculate the effective indices and find that $n_{H,eff}$ = 3.27 and $n_{L,eff}$ = 1.45 in the high and low index regions, respectively. Simulations are performed employing the finite-difference time-domain (FDTD) method (FullWAVE^{TM} 2.0), for the TE-mode.

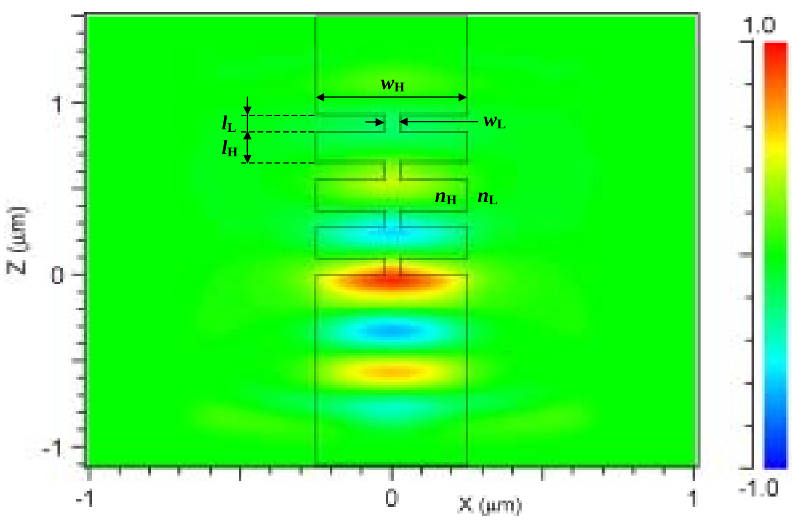

Fig. 1. 2D 4-period DBR with a wire-lens structure together with the electric field distribution for TE-mode. Light is launched next to the first interface (at z = 0) in the z > 0 direction

Fig. 2 shows the dependence of losses and reflectivity on the *wire-lens* width for an 8-period structure. w_L is varied from 0 to w_H. l_L is kept constant (l_L = 100 nm) while l_H is varied as necessary in order to satisfy the condition: $2[n_{H,eff}\, l_H + n_{L,eff}\, l_L] = \lambda_0 = 1.55$ µm.

When w_L = 0 (no bridge), the losses are about 1.6% due to the diffraction of light in the air regions. When w_L ~ 225 nm, losses increase to almost 5%. When w_L = 50 nm, losses are *practically eliminated* (below 0.04%) while reflectivity remains approximately 100%. This is mainly due to the index profile change at the interface between air and Si, leading to strong alterations of the mode profile.

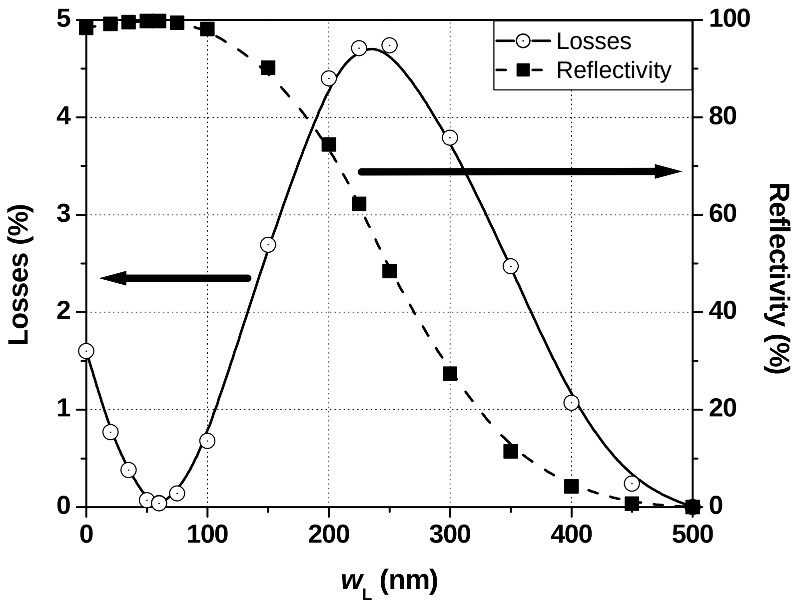

Fig. 2. Dependence of losses and reflectivity on the wire-lens width for a 8-period DBR structure.

In conclusion we show that lossless high index contrast structures *can* be achieved without affecting device performance. This approach can be extended to 3D and to more elaborate photonic structures. It will open the door to a new class of lossless photonic devices for applications in planar all-optical circuits.

1. M. H. Lim, T. E. Murphy, J. Ferrera, J. N. Damask, and H. I. Smith, "Fabrication techniques for grating-based optical devices", J. Vac. Sci. Technol. B 17(6), 3208-3211 (1999).
2. S. Arai, M. M. Raj, and Jörg Wiedmann, "Multiple-reflector Lasers for Photonic Integrations", LEOS 2000, 13^{th} Annual Meeting, p. 2,vol. xxiii+898, 502-503 vol.2 (2000).
3. T. F. Krauss and R. M. De La Rue, "Photonic crystals in the optical regime - past, present and future", Progress in Quantum Electronics 23, 51-96, Elsevier Science Ltd (1999).
4. R. Jambunathan and J. Singh, "Design Studies for Distributed Bragg Reflectors for Short-Cavity Edge-Emitting Lasers", IEEE J Quantum Electron., vol.33, no.7, 1180-1189 (1997).