Reflectance Enhancement Distributed Bragg Reflector on $LiNbO_3$ Waveguide by Corrugated High Index Overlay Configuration

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Abstract

A corrugated high index overlay configuration is used to greatly enhance the reflectance of the distributed Bragg reflector. The optimized structural parameters have been derived by considering both coupling coefficient and insertion loss.

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Surface-relief distributed Bragg reflector (DBR) on $LiNbO_3$ waveguide has been well investigated both theoretically and experimentally [1-2]. It can be employed as the cavity mirror of a waveguide laser, or the spectral filter of a WDM communication system. Whereas, producing grooves on the $LiNbO_3$ surface by the dry etching technique [2] is complex and expensive. Besides, the induced mode index modulation is fairly weak, and the achievable reflectivity is thus limited.

Significant improvements could be carried out if the Si-on-$LiNbO_3$ structure is used, and the periodic corrugations are then introduced on the surface of silicon overlay (Fig. 1) [3-4]. In this way, many well-developed etching processes for silicon can be directly applied. Moreover, the guiding nature of the Si-layer caused by the relatively higher index of refraction than that of $LiNbO_3$ will attract more optical energy of the normal modes from the underlying $LiNbO_3$ waveguide region, which results in more efficient contradirectional coupling.

The concept is numerically verified by the coupled-mode approach. From which, the maximum reflectivity supported by a uniform DBR with length L is expressed as

$$R_{\max} = \tanh^2\left(|\kappa|L\right), \tag{1}$$

where κ represents the coupling coefficient. Let us take the TE_2 mode as an example. Dramatically different features of mode profile are presented for distinct Si-layer thickness values (Fig. 2). Since the periodic perturbation is made on the silicon-air interface, a more obvious energy concentration within the Si-layer like (Fig. 2b) will introduce a larger coupling strength $|\kappa|$. The resultant reflectivity, however, is deteriorated by the serious insertion loss due to the mode profile mismatch (Fig. 3). After the two principle mechanisms have been taken into account, the optimum Si-layer thickness for the largest effective reflectivity can be numerically determined (Fig. 4). According to the same strategy, we may retrieve the optimum groove depth as well (Fig. 5). Using these optimized structural parameters, the maximum reflectivity calculated from Eq. (1) is as large as 99.5% (with L=3*mm*). Meanwhile, a similar traditional surface-relief DBR without silicon overlay only predicts a value of 3.69%. The reflectance enhancement is so apparent that the corrugated high index overlay configuration will be useful in various practical applications.

[1] Amnon Yariv, *Optical Waves in Crystals*, John Wiley & Sons, 1984.

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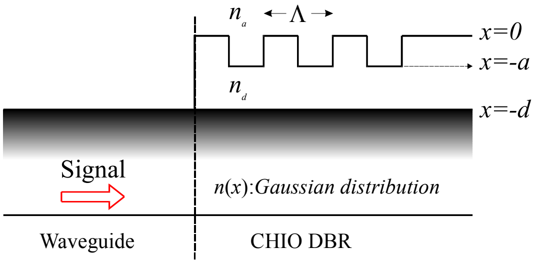
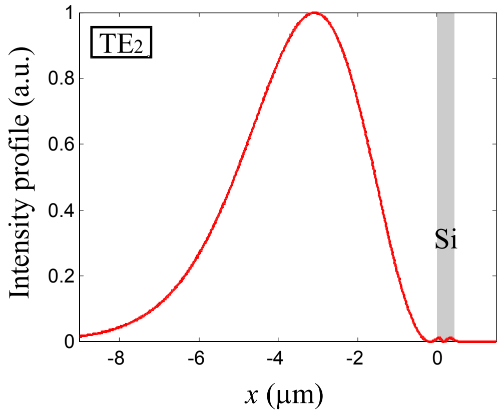
[3] C. P. Hussell, "High-index overlay for high reflectance DBR gratings in $LiNbO_3$ channel waveguides," *IEEE Photonics Technology Letters*, vol. 9, no. 5, pp.636-638, 1997.

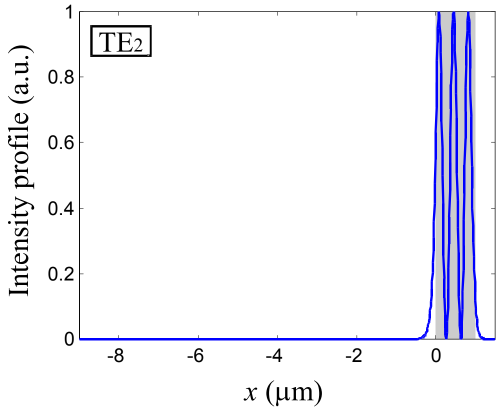
[4] T. Conese, "Finite element analysis of $LiNbO_3$ waveguides with Is or Si/SiO_2 overlay," *Journal of Lightwave Technology*, vol. 16, no. 6, pp. 1113-1122, 1998.



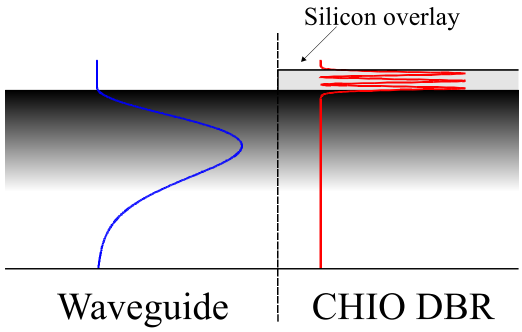
(Fig. 1) Schematic diagram of a corrugated high index overlay (CHIO) DBR on a waveguide with Gaussian index profile: $n(x)=n_s+\Delta n\cdot\exp[-(x+d)^2/T^2]$, for $x<-d$.



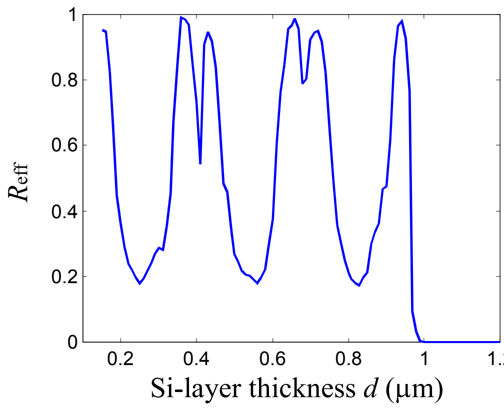
(Fig. 2a) Intensity profile of TE_2 mode. d=0.44μm, N_{eff}=2.2046, n_a=1, n_d=3.5, n_s=2.2, Δn=0.01, T=6μm, λ=1.546μm, a=0.1μm.



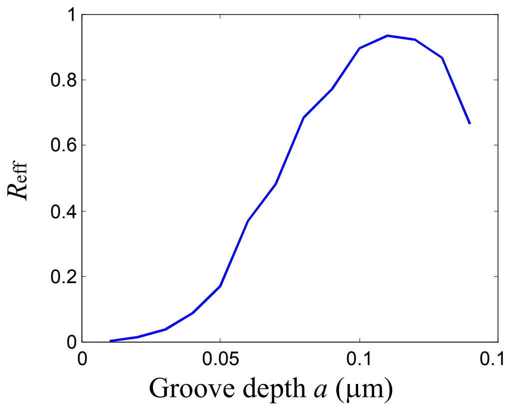
(Fig. 2b) Intensity profile of TE_2 mode. d=1μm, N_{eff}=2.8128, n_a=1, n_d=3.5, n_s=2.2, Δn=0.01, T=6μm, λ=1.546μm, a=0.1μm.



(Fig. 3) Serious mode mismatch caused by concentrating optical energy within Si-layer, which introduces large insertion loss.



(Fig. 4) Optimization curve for Si-layer thickness.



(Fig. 5) Optimization curve for groove depth.