$\lambda/4$-SHIFTED NONLINEAR PERIODIC STRUCTURE: THEORY OF LOW-INTENSITY SWITCHING

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INTRODUCTION

It is difficult to overemphasize the role that the $\lambda/4$-shifted periodic structure has played in the design of linear distributed feedback (DFB) waveguides. First proposed by Haus and Shank[1], such structures have been used extensively in the fabrication of single-mode semiconductor lasers[2,3] and narrow-bandpass filters[4,5]. Most recently, $\lambda/4$-shifted DFB devices have been succesfully used for highly discriminative waveguide coupling[6] leading to an entire new class of waveguide filters.[7]

In a view of the considerable interest that nonlinear DFB (NLDFB) structures have attracted over the past decade,[8-12] it is rather surprising that, to our knowledge, no explicit treatment of the $\lambda/4$-shifted NLDFB device exists. Since the pioneering work of Okuda[8] and Winful,[9] a wide variety of applications using NLDFB structures have been studied in detail.[10-12] The change of the local refractive index due to a nonlinear medium response coupled with the strong dispersion of the DFB structure, gives rise to the novel phenomena such as slow energy transport in form of Bragg solitons and all optical switching and limiting. Unfortunately, in most cases of practical interest, the required input intensities are extremely high, rendering the proposed configurations difficult to realize. Designed nonuniformities[13,14] in NLDFB proved to be moderately succesful in lowering the field intensity requirements.

We propose the use of $\lambda/4$-shifted NLDFB as a means to significantly reduce the intensities necessary to achieve all optical switching and limiting behavior. A linear $\lambda/4$-shifted device is characterized by exceptionally strong electric fields in its center (phase shifting location) - a feature that should readily facilitate significant changes in local refractive index even for a moderate input intensities.

NONLINEAR COUPLED MODE METHOD

Consider the structure shown in Fig. 1. We assume that the waveguide allows only a single TE mode to propagate, neglecting any longitudinal field components (weakly guiding structure). The polarization of the field remains unchanged throughout the entire waveguide structure. Nonlinear response of the optical medium is given by Kerr-type nonlinearity: $n_{NL} \sim n^{(2)}|E|^2$. The variation of the effective linear index is given by:

$$n_{eff}(z) = n_0 + \Delta n \cos(2\beta_B z + \Omega); \qquad \Omega = \begin{cases} \Omega_1, & z < 0 \\ \Omega_2, & z \geq 0 \end{cases} \quad (1)$$

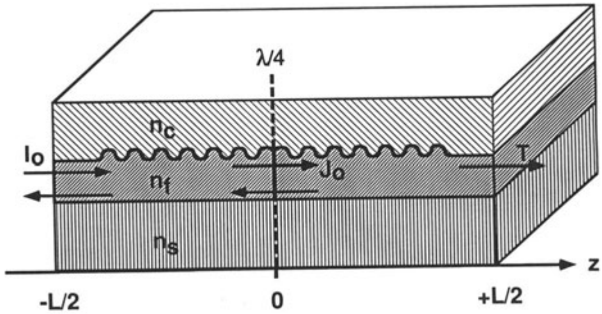

Figure 1. Geometry of λ/4-shifted planar waveguide DFB device.

The transmission of the linear λ/4-shifted DFB device is shown in Fig. 2, exibiting nearly full transparency at the middle of the photonic stop-band. The central transmissive peak is characterized by a very narrow linewidth, a feature arising from the resonant nature of the λ/4-shifted structure. A nonlinear device with an identical geometry should have the same transmission characteristics in the low-intensity limit when its nonlinearity can be neglected. However, as the input intensity of the device is increased, one would expect a change in the band structure, particularly at the zero-detuning position ($\Delta\beta L = 0$).

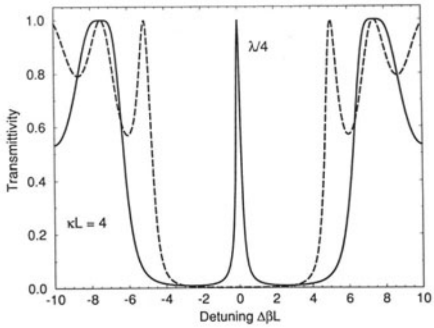

Figure 2. Transmission characteristics of linear λ/4-shifted DFB device with κL = 4.

In order to describe such a behavior, we start with the standard coupled-mode approach, by separating the field into its forward and backward propagating components: