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Slow-light (SL) in active photonic crystal (PhC) waveguides enhances the modal gain per unit length [1], with application to shorter lasers [2]. Recently, we have proposed a coupled-Bloch-mode (CBM) approach [4] to analyze active PhC structures. Essentially, the presence of material gain in a line-defect waveguide is viewed as a weak perturbation to a reference structure with purely real refractive index. In the SL regime, the optical gain induces a distributed feedback (DFB) between the counterpropagating Bloch modes of the reference waveguide. The active waveguide is efficiently described by a scattering matrix [5], which accounts for the SL gain enhancement and gain-induced DFB. In particular, this effect reveals that SL semiconductor optical amplifiers may benefit from a smaller linewidth enhancement factor (LEF) [5], as they would experience a weaker backscattering.

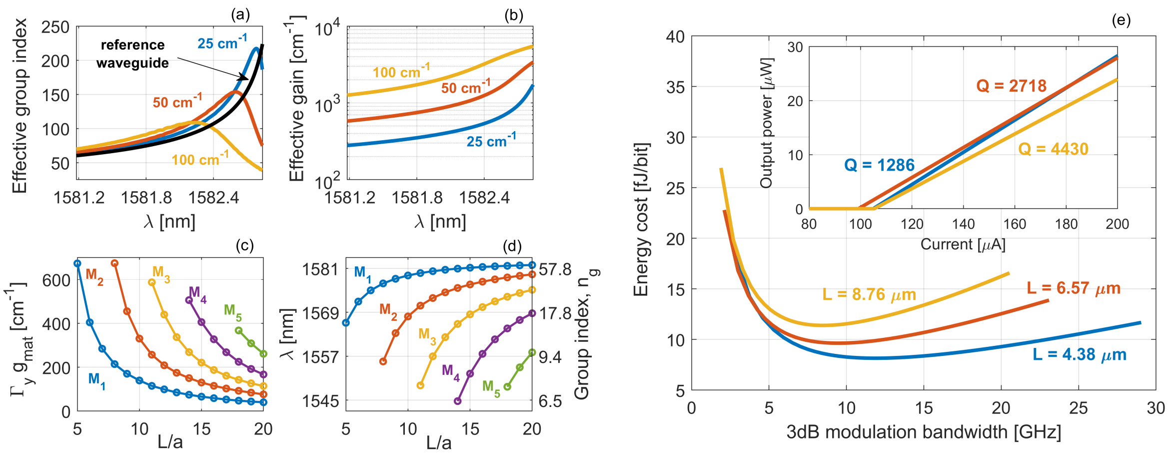

Figure 1: (a) Effective group index and (b) gain of an active PhC waveguide. (c) Threshold modal gain, (d) oscillation wavelength and (e) energy cost of line-defect PhC lasers. Inset: P-I characteristic.

In the active waveguide, the Bloch modes acquire an effective group index which is reduced and spectrally broadened as compared to that of the reference waveguide, n_g, in the proximity of the waveguide band edge [4]. Fig. 1(a) shows this effective group index with the modal gain $\Gamma_y g_{\mathrm{mat}}$ being 25 (blue), 50 (red) and 100 (yellow) cm^{-1}. Here, Γ_y accounts for the vertical optical confinement in the active layers and g_{mat} is the material gain. The parameters of the reference waveguide reflect the lasers in [2], with the LEF being 1.5 and the lattice constant $a = 438\,\mathrm{nm}$, while the active region is a buried heterostructure. Under the same conditions, Fig. 1(b) shows the net effective modal gain in the active waveguide. To analyze lasers, we model the active region via the aforementioned scattering matrix, while additional scattering matrices for the left and right mirror complete the cavity description. By solving the oscillation condition, we find the threshold modal gain (Fig. 1(c)) and corresponding wavelength (Fig. 1(d)) for the various longitudinal modes as a function of the cavity length L. Here, the left and right mirror reflection coefficient are $r_L = 1$ and $r_R = 0.6$ respectively. We focus on the lasing mode M_1. By expanding the oscillation condition around the lasing point [5], we derive a rate equation model which self-consistenstly accounts for SL effects. The inset of Fig. 1(e) shows the output power versus injected current for a cavity made of 10 (blue), 15 (red) and 20 (yellow) lattice constants, with Q being the Q-factor in the absence of optical gain [2]. The main figure shows the energy cost versus 3dB modulation bandwidth for the same laser cavities. The optimum bandwidth diminishes with increasing L, owing to the smaller threhold carrier density and reduced group velocity.

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