THz generation in one dimensional photonic crystal structures

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Abstract: We propose a device based on a one-dimensional photonic band gap structure that is optimized for the generation of coherent, THz radiation tunable up to 10 THz.

OCIS codes: (190.2620) Frequency conversion; (999.9999) Photonic Band Gap Materials;

Recently great attention has been devoted to the problem of the generation of coherent THz radiation [1]. In this work we study a $\chi^{(2)}$ –doped photonic crystal that is able to generate coherent THz radiation in a region that ranges up to ~10 THz. The THz radiation comes out from a difference-frequency generation (DFG) process, where two, nearly-degenerate optical pumps of frequencies ω_1 and ω_2 generate $\omega_3=\omega_1-\omega_2$ which falls in the THz range. In order to have an efficient device two condition should be satisfied: (i) the two pumps should be tuned near the band edge , preferably inside the same transmission resonance peak, in order to take advantage of the enhancement of the nonlinear process due to high field localization, slow group velocities, and field overlap [2]; (ii) the $\chi^{(2)}$ photonic crystal should allow only the DFG process and inhibit all other second-order processes, such as sum-frequency (SF) and second harmonic (SH) generation. SF and SH processes can be inhibited by designing a structure having a large band gap centered around the SH frequency, as shown in figure 1.

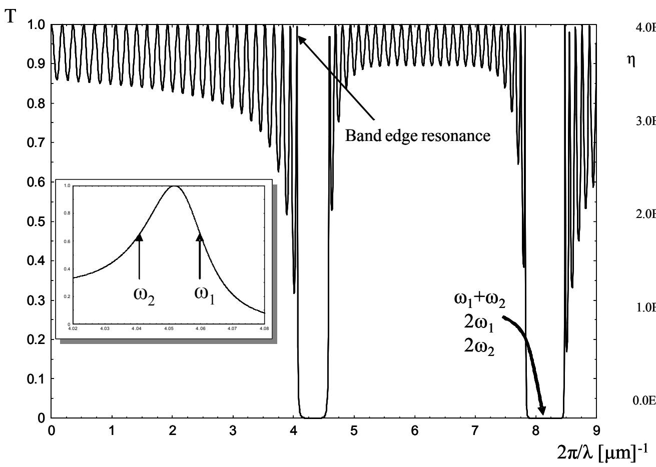

Figure 1: Transmittance vs. wave vector for a half/quarter-wave stack. The structure is composed of 51 alternating layers of high and low refractive index. The indices of refraction of the layers are respectively: $n_1=1.8$ and $n_2=1.4$. The high index layers have a normal dispersion of 15%, and a $d^{(2)}$of 100pm/V. The layers have thicknesses $a=\lambda_0/(2n_1)$ and $b=\lambda_0/(4n_2)$ where $\lambda_0 =1\mu m$. The total length of the structure is approximately 12 μm.

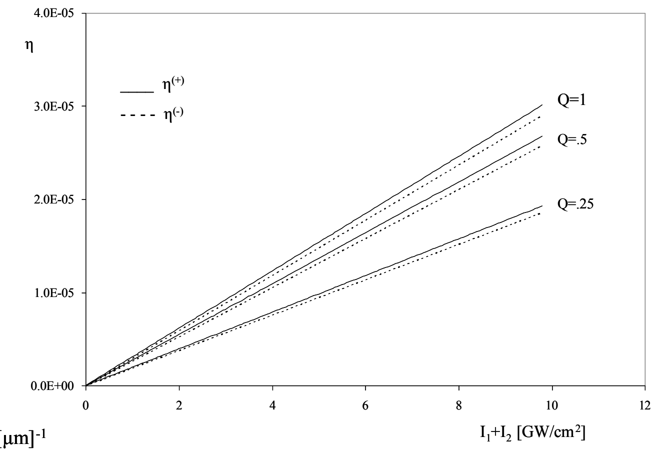

Figure 2: Predicted forward and backward conversion efficiencies as a function of the total intensity of the pumps, for different values of the intensity ratio $Q= I_1/I_2$.

For the structure that satisfies these conditions, in the undepleted pump regime, THz total conversion efficiency ($\eta=\eta^{(+)}+\eta^{(-)}$) is calculated using the Green function approach, as:

$$\eta = \frac{8\pi^2}{\varepsilon_0 c}\left(d^{(2)}\right)^2 \frac{I_1 I_2}{I_1+I_2}\frac{L^2}{\lambda_{THz}^2}\left[F_1+F_2\right], \text{ where } F_{1/2}=\frac{1}{L^2}\int_0^L \Phi_{THz}^{(-/+)} f(z)\Phi_1^{(+)}\left(\Phi_2^{(+)}\right)^* dz$$

I_1 and I_2 are the intensities of the input pumps, $d^{(2)}$ is the nonlinear coupling coefficient, f(z) is the nonlinear grating , $\Phi^{(+/-)}$ are the linear, right-to-left and left-to-right field modes inside the structure [2]. In figure 2 we plot the predicted THz conversion efficiency as a function of the relative intensity of two collinear input pumps, at normal incidence. We note that the frequency of the outgoing THz radiation can be tuned by varying the frequency and the angular incidence of at least one of the pumps.

Reference:

[1] R.A. Cheville, D. Grischkowsky, Appl. Phys. Lett. **67**, 1960 (1995)
[2] G. D'Aguanno et al, J.Opt.Soc.Am.B **19**, .2111 (2002)