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Enhancement of Second Harmonic Generation in Layered Media out of Phase Matching conditions.

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Abstract: We show that, under particular conditions, second harmonic generation efficiency in layered structures may be hugely enhanced maximizing field's overlap at the expenses of phase matching conditions.

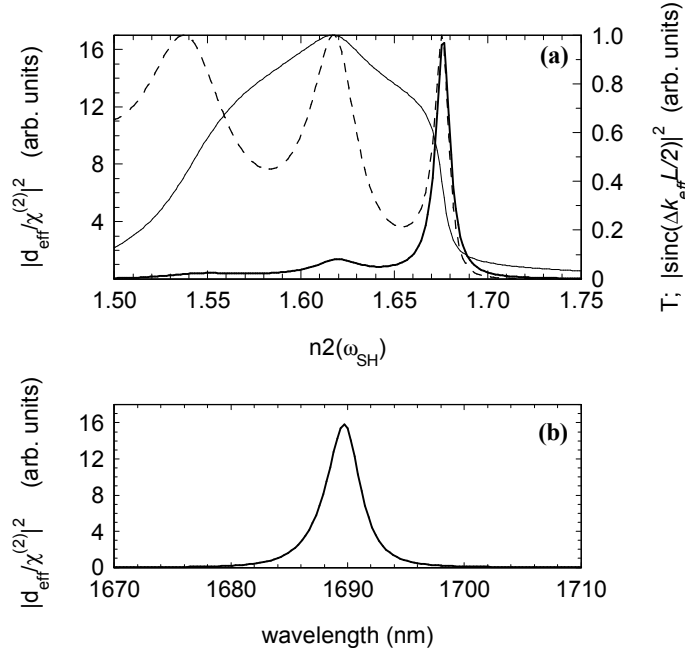
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In the presence of enhanced local fields resulting from multiple internal reflections, there are terms in the nonlinear polarization that do not conserve momentum [1]. Those terms are generally neglected in the analysis of nonlinear optical effects because their contribution averages to zero on a length scale of the order of a wavelength. We show that under proper conditions the contributions of fast varying terms can dramatically change the dynamics in spite of phase matching conditions. In reference [2] a multiple scale approach was used to derive an analytic expression for the conversion efficiency for a generic layered structure of finite length composed of non-absorbing media. It was found that the conversion efficiency is proportional to the square modulus of an effective coupling coefficient, defined as:

$$\tilde{d}_{eff} = \frac{1}{L} \int_0^L c^{(2)}(z) \Phi_w^2(z) \Phi_{2w}^*(z) dz \quad (1)$$

Here L is the length of the structure, and $\Phi_w(z)$ and $\Phi_{2w}(z)$ are the complex, linear field profiles normalized with respect to a unitary input field. To evaluate the weight of the overlapping integral over phase matching conditions we consider as an example a structure with mixed quarter-wave/half-wave geometry and 20 periods.



The nonlinear material ($\lambda/4$ optical thickness) has a refractive index $n_2(\omega_{FF})=1.428$ at the FF frequency. The linear material ($\lambda/2$ optical thickness) is assumed to be air, with $n_1=1$. The reference wavelength used to calculate the optical paths of the layers is $1\ \mu\text{m}$. Assuming normal incidence, we tune the FF at the first order band edge resonance ($\lambda_{FF}=1.69\ \mu\text{m}$). Once layer thicknesses have been chosen, one may add dispersion by varying the index of refraction at the SH frequency ($\lambda_{SH}=0.845\ \mu\text{m}$) to tune the field to any desired frequency near the band edge. In Fig.(1a) we depict the value of the square modulus of $\tilde{d}_{eff}/C^{(2)}$ as a function of the refractive index $n_2(\omega_{SH})$ when the pump field remains tuned at the band edge resonance (thick solid line). Changing the refractive index at the frequency ω_{SH} is equivalent to changing the tuning conditions only for the field at ω_{SH} (see transmission spectrum for SH in fig.1a –dashed line). Using only *effective index* considerations, maximum conversion efficiency is expected to be achieved when the second harmonic field is tuned at the second resonance as described by the function $|\text{sinc}(\Delta k_{eff}L/2)|^2$ (Fig. 1a -thin line). Comparing the two curves we note that we have only a relative maximum of $|\tilde{d}_{eff}/C^{(2)}|^2$ when effective PM is fulfilled. On the other hand, maximum enhancement is achieved when the second harmonic field is tuned to the first band edge resonance, where the effective mismatch is $\Delta n_{eff}=0.06$. Finally we plot $|\tilde{d}_{eff}/C^{(2)}|^2$ vs. FF wavelength for our optimized structure (Fig 1b). Here, when $\lambda_{FF}=1.69\ \mu\text{m}$, the enhancement factor is more than 3 orders of magnitude larger compared to the out-of-resonance case, with a usable bandwidth of approximately 4nm.

- [1] M. Botey, J. Martorell, J. Trull, R. Vilaseca, “Suppression of radiation in a momentum-nonconserving nonlinear interaction” Opt. lett 25, 1177 (2000)
- [2] G. D’Aguanno, M. Centini, M. Scalora, C. Sibilia, M. Bertolotti, M. J. Bloemer, C. M. Bowden, “Generalized coupled-mode theory for $\chi^{(2)}$ interactions in finite multilayered structures”, JOSA B **19**, 2111-2121 (2002)