PHYSICS AND MATHS

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THE IMPACT OF THE PHASES OF THREE INTERACTING WAVES ON FREQUENCY DOWN-CONVERSION AT SEQUENTIAL INTERACTION

Current methods of nonlinear optics allow us to control and monitor the flow of photons which is crucial in achievements of photonics. Processing of informations in optical systems is closely associated with photons as information carriers. The process of simultaneous generation of coherent radiation during interaction of several frequencies was analyzed in an optical superlattice [1].

Up to now the process of sequential quasi-phase-matched interaction has been numerically analyzed in terms of couple mode equations [2]. Quasi-phase matched interaction in a regular domain structure for the generation of second [3],[4] and third harmonics, parametric interaction and intracavity frequency transformation in RDS crystals in the constant-intensity approximation was done by us in [5],[6],[7] ,[8].

The presented paper is a continuation researches of sequential interaction of passing and counterpropagating waves in an RDS crystal. The main purpose is studying of high -frequency pumping with a sequential three wave interaction in case of a counter-propagation geometry of waves.

Interaction of three waves such as $3\omega, 2\omega$ with multiple frequencies and with high frequency pumping wave of 3ω is considered to be within a periodically poled crystal with a quadratic nonlinearity. From the energy point of view, with high-frequency pumping, each pump photon provides a three-fold higher energy value compared to the case of low-frequency pumping at a frequency ω. We assume that two co-directed waves at frequencies $\omega_1 = \omega$, $\omega_3 = 3\omega$, propagating along the positive axis, are distributed from the left entrance of the optical superlattice, and the wave at the frequency $\omega_2 = 2\omega$ is reverse. The system of coupled mode equations are given by [2]

$$\frac{dA_1}{dz} + \delta_1 A_1 = -i\beta_3 g_3^* A_3 A_2^* - i\beta_2 g_2^* A_2 A_1^*,$$
$$\frac{dA_2}{dz} + \delta_2 A_2 = +i2\beta_3 g_3^* A_3 A_1^* + i\beta_2 g_2 A_1^2, \qquad (1)$$
$$\frac{dA_3}{dz} + \delta_3 A_3 = -i3\beta_3 g_3 A_1 A_2,$$

where $A_{1,3}$ are the complex amplitudes of two direct waves carrying energy in the positive direction of z axis, A_2 is the complex amplitude of the backward wave transporting energy in the opposite direction, δ_j are the absorption coefficients at the respective frequencies ω_j,$j = 1 \div 3$,

Geometry of the interactional process (1) is described by following boundary conditions:

$$A_{1,3}(z=0) = A_{10,30} \cdot \exp(i\varphi_{10,30})$$
$$A_2(z=L) = A_{21} \cdot \exp(i\varphi_{21}) \qquad (2)$$

Where z=0 corresponds to the left of the crystal, $A_{10,30}, \varphi_{10,30}$ are the initial amplitudes and phases of the waves when entering the nonlinear medium on the left, A_{2l}, φ_{2l} are the initial amplitude and phase of the wave at the doubled frequency when entering the nonlinear medium to the right z=L.

Prior to this work, the quasi-phase-matching conditions in scientific papers were analyzed by the method of constant- field approximation. These conditions differ in the constant-intensity approximation. The change occurs in the phase of the interacting waves, where it is necessary to take into account the additional termunder square root $2\Gamma^2$.

The backward wave efficiency has been obtained by us like

$$\eta_2^{CIA}(z) = \Big[\frac{A_{2l}}{A_{30}}\frac{cos\lambda z}{cos\lambda L}cos\varphi_{2l} +$$

$$+\frac{C}{\lambda}\Big(2g_3^*\,\Gamma_{13}sin\varphi_{10} - g_2\Gamma_{12}\frac{A_{10}}{A_{30}}sin2\varphi_{10}\Big)\Big]^2 +$$

$$+\Big[\frac{A_{2l}}{A_{30}}\frac{cos\lambda z}{cos\lambda L}sin\varphi_{2l} + \frac{C}{\lambda}\Big(2g_3^*\Gamma_{13}\cos\varphi_{10} + g_2\Gamma_{12}\frac{A_{10}}{A_{30}}cos2\varphi_0)\Big]^2 \qquad (5)$$

$Where\ C = sin\lambda z - tan\lambda z \cdot cos\lambda z.$

Presented calculations has been done due to method of constant intensity approximation. It is shown that the initial phases of the waves significantly affect the efficiency of frequency conversion. By choosing the optimal initial phases, it is possible to significantly increase the conversion efficiency. The results may deliver practical interest for the development of backward second harmonic devices.

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