AN EFFECT OF LINEAR LOSSES ON THE EFFICIENCY OF HIGHER HARMONICS GENERATION IN MEDIUM

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The high harmonics generation in the prescribed intensity approximation, taking into account the harmonics reverse reaction on the basic wave phase in this paper is analysed. This approximation allows to take into account the simultaneously effect of both phase mismatching and losses in medium on the proceeding of the nonlinear-optical processes. The results of the prescribed intensity approximation are shown to be use in dissipative medium.

The process of higher harmonics generation is widely used in order to convert the frequency of coherency optical radiation. The basic radiation frequency may be convert to harmonics by using both the medium with high order nonlinear susceptibilities [1,2] and cascade process [3-5].

A theoretical analysis of higher harmonics generation has been carried out in the constant pump field approximation, which doesn't take into account an effect of linear losses of interacting waves in medium to the harmonics generation efficiency.

The results of analysis of optical frequency conversion in the constant pump intensity approximation are presented in this paper. This approximation takes into account the reverse reaction of the excited wave to the phase of the exciting one in contrast to the constant pump field approximation. The constant intensity approximation can be used for the analysis of nonlinear conversion of optical frequencies in a dissipative medium. This approximation allows to take into account the simultaneously effect of the phase mismatch and losses to occurring of the nonlinear process in medium.

We shall consider higher harmonics generation in the constant intensity approximation. The system of reduced equations for q-th harmonics [1] has the form

$$\frac{dA_1}{dz}+\delta_1 A_1 = i\gamma_1 A_q (A_1^*)^{q-1}\cdot exp(i\Delta_q z)$$
$$\frac{dA_q}{dz}+\delta_q A_q = i\gamma_q A_q (A_1^q)^{?}\cdot exp(i\Delta_q z) \qquad (1)$$

where index "1" corresponds to the wave with the frequency and "q"-to the harmonics with the frequency $\omega_q=q\omega_1$ $(q=3,5,7,\ldots)$; A_j - are the complex amplitudes of the interacting waves; δ_j - are the absorption coefficients; γ_j - nonlinear coupling coefficients between the waves; $\Delta_q=k_q-qk$ is the phase mismatch.

Solution of system of equations (1) in the constant intensity approximation subject to the boundary conditions $A_1(z=0)=A_{10}$; $A_2(z=0)=0$ for the intensity of q-th harmonics is given by

$$I_q=\gamma_q^2 I_{10}^q \rho_q^{-1}(sin^2\alpha_q+sh^2\beta_q)\,e^{-(\delta_q+q\delta_1)z} \qquad (2)$$

where

$$\rho_q^2=a_q^2+b_q^2;\quad a_q=q\Gamma_q^2+[\Delta_q^2-(\delta_q-q\delta_1)^2]/4$$

$$b_q=\Delta_q(\delta_q-q\delta_1)/2;\quad \alpha_q=\rho_q^{1/2}z\cos\frac{\theta}{2};$$

$$\beta_q=\rho_q^{1/2}z\sin\frac{\theta}{2}$$

$$\theta=arctg(b_q/a_q);\quad \Gamma_q^2=\gamma_1\gamma_2 I_{10}$$

Further we shall consider the case of third harmonics generation ($q=3$). Under phase matching conditions the efficiency η_3 $(\eta_3=I_3/I_{10})$ is expressed by simpler formula $(\delta_1=\delta_3\equiv\delta)$

$$\eta_3=\frac{\Gamma^2}{3\Gamma^2-\delta^2}sin^2(\sqrt{3\Gamma^2-\delta^2}z)\,e^{-4\delta z} \qquad (3)$$

When the losses in medium are equal, the results of the constant intensity approximation can be compared with the results of both accurate calculations [1]

$$\eta_{3,a.c.}=\frac{\frac{\Gamma^2}{4\delta^2}(1-e^{-2\delta z})^2}{1+\frac{\Gamma^2}{4\delta^2}(1-e^{-2\delta z})^2}e^{-2\delta z} \qquad (4)$$

and constant pump field approximation

$$\eta_{3,c.f.a.}=\frac{\Gamma^2}{\delta^2}sh^2z\cdot e^{-4\delta z} \qquad (5)$$

The dependence of the third harmonic generation efficiency on the losses in medium is shown in fig.1 (curve 1). The results of the accurate calculation (curve 2) and the results of the constant field approximation (curve 3) are also plotted here for comparison. It can be seen that the results of the constant intensity approximation are almost same with the results of the accurate calculation. However the result of the constant field approximation differs greatly from that obtained in the accurate calculation. From the comparison it follows, that an account the losses in medium leads to decrease of third harmonic efficiency.

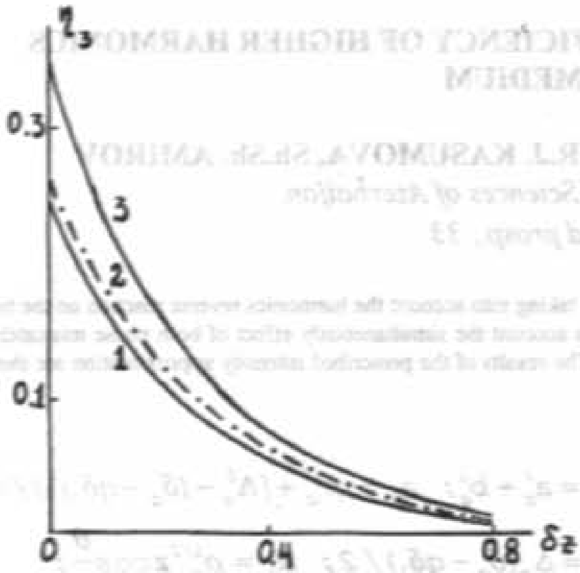

Fig. 1. Dependence of the third harmonic generation efficiency on the losses in medium: 1 - in the constant intensity approximation; 2 - for the accurate calculation; 3 - in the constant pump field approximation.

As in the case of third harmonic generation it is also possible to make a comparison for the second harmonic generation. In the constant intensity approximation the second harmonic efficiency is given by

$$\eta_2 = \Gamma^2 z^2 \cdot sinc^2 \frac{\sqrt{8\Gamma^2 - \delta^2}\, z}{2} \cdot e^{-3\delta z} \qquad (6)$$

and is shown in fig.2 (curve 1). As can be seen from this figure the results of both accurate consideration (curve 2)

$$\eta_{2\,a.c.} = e^{-2\delta z} \cdot th^2\left[\frac{\Gamma}{\delta}(1 - e^{-\delta z})\right] \qquad (7)$$

and the constant field approximation (curve 3)

$$\eta_{2\,c.f.} = \Gamma^2 z^2 \cdot sinc^2 \frac{\delta z}{2} \cdot e^{-3\delta z} \qquad (8)$$

are presented.

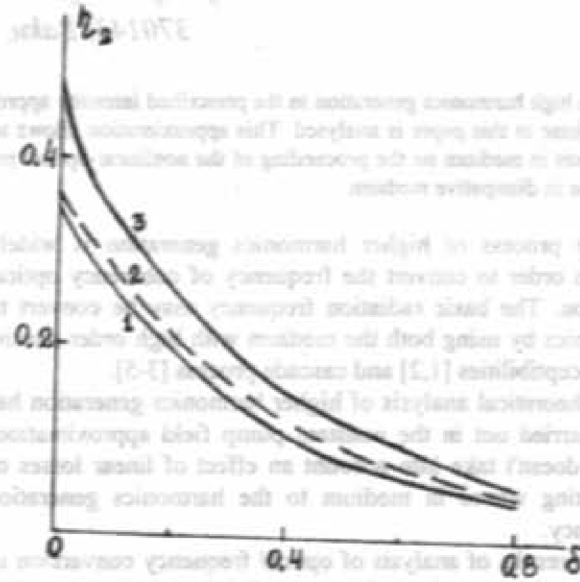

Fig. 2. Dependence of the second harmonic generation efficiency on the losses in medium: 1 - in the constant intensity approximation; 2 - for the accurate calculation; 3 - in the constant pump field approximation.

The comparison of these curves shows, that unlike the results of the constant field approximation the results of the constant intensity approximation are in good agreement with the results of accurate calculations.

Thus, to analyse the higher harmonic generation in medium with the losses it can be used the results of the constant intensity approximation.

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YÜKSƏK HARMONİYA GENERASİYASININ EFFEKTİVLİYİNƏ MÜHİTDƏKİ XƏTTİ İTKİLƏRİN TƏ'SİRİ

İşdə harmoniya dalğasının əsas dalğanın fazasına tə'sirini nəzərə alan sabit intensivlik yaxınlaşmasında yüksək tərtibli harmoniya dalğalarının generasiyası təhlil edilir. Bu yaxınlaşma eyni zamanda həm faza pozulmasının, həm də mühitdəki itkilərin qeyri-xətti prosesin gedişinə tə'sirini nəzərə almağa imkan verir. Göstərilmişdir ki, dissipativ mühitlərdə sabit intensivlik yaxın-laşmasının nəticələrindən istifadə etmək olar.

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ВЛИЯНИЕ ЛИНЕЙНЫХ ПОТЕРЬ В СРЕДЕ НА ЭФФЕКТИВНОСТЬ ГЕНЕРАЦИИ ВЫСШИХ ГАРМОНИК

Анализируется генерация высших гармоник в приближении заданной интенсивности, учитывающим обратное воздействие гармоник на фазу возбуждающих волн. Данное приближение позволяет учесть одновременное влияние фазовой расстройки и потерь в среде на протекание нелинейного процесса. Показано, что в случае диссипативных сред можно пользоваться результатами приближения заданной интенсивности.

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