Investigation of third order nonlinearity in propagation of cylindrical waves in homogeneous nonlinear media

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A B S T R A C T
Four-wave mixing in propagation of cylindrical waves in a homogeneous nonlinear optical media has been investigated theoretically. An explicit analytical expression which contains all the main nonlinear optical effects, including third harmonic generation, sum and difference frequency generation has been obtained. A comparison between sum frequency efficiency for exact and approximation expression in a homogeneous nonlinear medium has been done. The effect of increasing the nonlinear optical coefficient $\chi^{(3)}$ and increasing the frequency difference between two adjacent waves $\Delta \omega$, on the efficiency of sum frequency generation in homogeneous media has been investigated.

1. Introduction

Optical nonlinearity of the third order is a universal property, found in any material regardless of its spatial symmetry. This nonlinearity is the lowest order nonvanishing nonlinearity for a broad class of centrosymmetric materials, where all the even-order nonlinear susceptibilities are identically equal to zero for symmetry reasons. Third-order nonlinear processes include a vast variety of four-wave mixing processes, which are extensively used for frequency conversion of laser radiation and as powerful methods of nonlinear spectroscopy. Frequency-degenerate, four-wave mixing, Kerr-effect-type phenomena constitute another important class of third-order nonlinear processes [1]. Four-wave mixing is a nonlinear effect arising from a third-order optical nonlinearity and can take place in any kind of material. It is one of the nonlinear phenomena in which three input electromagnetic waves at $\omega_1$, $\omega_2$ and $\omega_3$ frequencies are mixed and generate output wave at $\omega_4$ frequency which is different from input frequencies.

The propagation of intense waves in a nonlinear medium generates many nonlinear phenomena in output of medium such as harmonics generation, self-focusing and sum and difference-frequency generation. The cylindrical electromagnetic wave propagation in nonlinear media is of interest for theory and experiment in fundamental problems in physics [2–6] and can be investigated by two ways, coupled-wave equations and the Maxwell equations which remain poorly studied because of associating with extreme mathematical difficulties but obtain many achievements up to now and has been put forward [3]. Propagation of cylindrical electromagnetic waves has been investigated in different media such as nonlinear nondispersive inhomogeneous media [7] and nondispersive homogeneous media [8]. In [9] second-harmonic generation of cylindrical electromagnetic waves propagating in an inhomogeneous nonlinear medium has been investigated. They have used two different methods for description of SHG by the coupled-wave equations and the exact solutions. The second-order nonlinear phenomena in nonlinear homogeneous media are investigated by Xiong et al. [10,11] in which the exact solutions of the Maxwell equations and coupled-wave equations are compared. In [12] an exact axisymmetric solution has been obtained, by using the corresponding solution of linear field equations in an inhomogeneous medium and they found that the amplitude and frequency of the electromagnetic wave can be controlled with different inhomogeneous factors.

In this paper the propagation of cylindrical four-wave mixing in homogeneous nonlinear media has been investigated. In Section 2 the theoretical model to obtain an explicit expression for the electric field in homogeneous nonlinear media has been done. In Section 3 the numerical results for the efficiency of the sum frequency amplitude have been reported. In the last section a brief summary of the result has been presented.

2. Theoretical model

In general, third-order nonlinear processes are much weaker than their second-order counterparts. If the medium have the center of inversion, the third-order nonlinearity makes the dominant contribution to the nonlinear polarization. As most isotropic nonlinear media fall into this category, the third-order nonlinear