Interaction Of Electromagnetic Field With Nano Opticals

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Abstract:

This paper shows with the study of interaction of intense electromagnetic field with materials creating modified fields. As a result, the phase, frequency and amplitude of modified field can be different from that of the input field. In a nonlinear medium, the dielectric polarization *P* responds nonlinearly to the electric field *E* of the light [1-3]. Generally the nonlinear behavior of light is only observed at very high intensities of light, generating electric field of about 10^8 V/m. This huge intensity is produced only by lasers.

Keywords: electromagnetic, nonlinear and linear, nano optical, etc.

Introduction:

In quantum electrodynamics (QED), the Schwinger limit is a scale above which the electromagnetic field is expected to become nonlinear. Nonlinear optical processes are of various types and are briefly explained below. The second harmonic generation (SHG) is a nonlinear optical process which results in the production of light with doubled frequency of input light [4-8]. In SHG, two photons are employed to create a single photon with frequency two times the frequency of incident photons. Third harmonic generation (THG) is the generation of light with a tripled frequency of input light. In THG, three photons are employed to create a single photon with frequency three times that of the incident photons. High harmonic generation (HHG) is the creation of light with frequencies of 100 to 1000 times greater than the input light. Sum frequency generation (SFG) is the makeup of light with sum of frequencies of input lights of two different frequencies [8-13].

Since the invention of laser lights particularly, pulsed lasers, the studies of nonlinear optical properties of materials have attained wide accessibility. The pulsed lasers are mainly used for creating intense electromagnetic field. The intense lasers are harmful to optical sensors like range finders, highly equipped military accessories, night vision equipments and human eye [1-3]. Therefore, it is necessary to find suitable materials for limiting the harmful laser light intensity. The materials that are used for limiting harmful laser light are known as optical limiters. In an optical limiter, the intensity of transmitted light decreases over the increment of incident light intensity, and at particular intensity the material becomes opaque [4-7].

The Linear absorption

Generally the absorption of electromagnetic radiation means the way in which the energy of a photon is absorbed into a material that the electromagnetic energy becomes part of the internal energy of an absorber. Each portion of the electromagnetic spectrum contains quanta of energies which is appropriate for the excitation of certain types of physical processes.

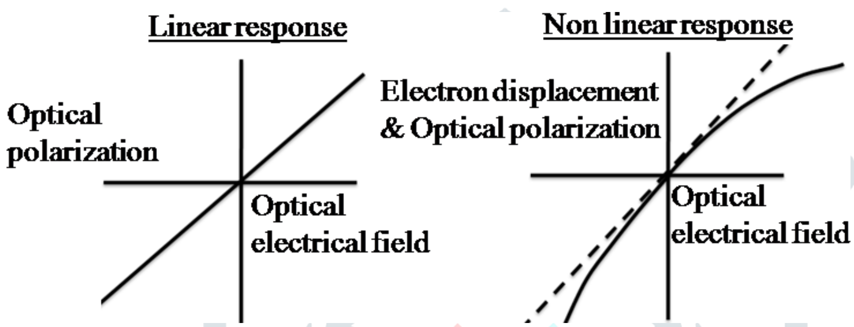

Fig. 1 Linear and nonlinear response

The energy levels associated with physical processes at the atomic and molecular levels are also quantized. If the quantized energy levels of a material match well with the quantum energy o f the incident radiation then the material can absorb this quantum energy. If there are no matched quantized energy levels corresponding to the incident photons, the material becomes transparent to photons. In a linear process the absorption of radiation does not depend on incident intensity. For a nonlinear process the absorption of radiation is strongly dependent on the intensity of incident light. For linear absorption, the intensity (I) is given by the Beer-Lambert's law [14-16],

$$I(z) = I_0 e^{-\alpha(\omega)l} \quad (1)$$

where I_0 is the incident intensity, $\alpha(\omega)$ is the linear absorption coefficient (fraction of electromagnetic rays absorbed per unit area of the absorber), l is the propagation depth of the absorbing medium.

The Nonlinear Nano Optics

The electromagnetic radiations can primarily interact with matter through the valence electrons of the outer most orbital. This interaction creates electric dipoles and the medium becomes polarized. For small field strength, these polarizations are proportional to applied electric field [17]. The electric displacement originated due to the propagations of electromagnetic radiation through a dielectric medium is written as

$$D=\varepsilon_0 E+P \quad (2)$$

where P is the polarization of the medium. For small electric field P is given by

$$P = \varepsilon_0 (\varepsilon_r - 1)E = \varepsilon_0 \chi E \quad (3)$$

where $\chi = \varepsilon_r - 1$ is the linear susceptibility of the material, *E* is the electric field vector, ε_0 is the permittivity of free space.

For a nonlinear medium the induced polarization at higher electric field is a nonlinear function of the applied electric field. Here, the expression for the induced polarization is a power series [18]

$$P = \varepsilon_0 ((\chi)E + (\chi)^2 E^2 + (\chi)^3 E^3 + \dots\dots\dots) \quad (4)$$

The terms $(\chi)^1$, $(\chi)^2$ and $(\chi)^3$ are the linear, quadratic (second order) and cubic (third order) susceptibilities respectively and *E* is the electric field vector.

The Second order and third order nonlinearity of nano optical:

Generally the second-order nonlinear effects are second harmonic generation, sum and difference frequency generation and optical parametric amplification. The second order susceptibility $(\chi)^2$ is responsible for the origin of all second order nonlinear effects [18]. Typically the second order nonlinear effects are produced by the interaction of two waves to produce a third wave. Momentum conservation and sufficient photon energy are the required parameters for these processes [19]. By the help of second order susceptibility, the optical fields of these waves are coupled to one another. The coupling can be made as the mechanism of exchanging of energy among the interacting fields [20]. In second harmonic generation (SHG), the frequency mixing can be attributed by the initial two waves of same frequency, $\omega = \omega_1 = \omega_2$ which interacts nonlinearly to produce a third wave of frequency $\omega_3 = 2\omega$. According to eqn 4.4, with $E = E_0 \sin(\omega t)$, the induced polarization in SHG is written as

$$P = \varepsilon_0 ((\chi)^1 E\sin(\omega t) + (\chi)^2 E^2 (1 - \cos 2\omega t) + \dots\dots\dots) \quad (5)$$

In sum and difference frequency generation, the two initial waves of frequencies ω_1 and ω_2 interact nonlinearly to produce a third wave at a frequency ω_3. The polarization in this case can be written as [19, 20]

$$P(\omega_3) = \varepsilon_0 ((\chi)^2 E(\omega_1)E(\omega_2)) \quad (6)$$

where $\omega_3 = \omega_1 + \omega_2$ (for sum frequency generation) and $\omega_3 = \omega_1 - \omega_2$ (for the difference frequency generation). In third order nonlinearity, the initial three fields of frequencies interact to produce a fourth field. The polarization in this case is [20],

$$P(\omega_4) = \varepsilon_0 ((\chi)^3 E(\omega_1)E(\omega_2)E(\omega_3)) \quad (7)$$

Conclusion:

When a light of suitable frequency is transmitted through a medium, the transmitted light gets distorted by various factors such as scattering, refraction, reflection, absorption, etc depending on the characteristic behavior of the medium. When a medium/material is irradiated with high intensities of light such as lasers, there is a probability to absorb more than one photon from the incident radiation by the medium.

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