Research Article [Saxena, 2(11): Nov., 2011]
ISSN: 0976-7126

INTERNATIONAL JOURNAL OF PHARMACY & LIFE SCIENCES

General theory of Raman and Brillouin instabilities in piezoelectric materials with strain dependent dielectric constant

Shivani Saxena
Physics department, RKDF, Indore, (M.P.) - India

Abstract

In the present communication few problems in the area of Raman and Brillouin instabilities in piezoelectric materials with strain dependent dielectric constant (SDDC) was proposed. The stimulated Brillouin scattering and resulted instability provide a unique tool for the study of acoustic domains since it provide a mean of following the evolution of a particular frequency component propagating in particular directions. The stimulated Raman scattering and consequent instability is used mostly as a tool for studying the vibrations energy level of molecules' and lattice vibrations of the optical branch in the crystals. The intense experimental and theoretical efforts of the past few years in this area have yielded a beautiful return in our basic knowledge but in addition it has opened the way to several classes of new devices with high efficiency and power in different interested frequency regions. The success on both a basic and practical plane offers promise for continuing useful results and increased knowledge from future work in this area. A detail review of the work of wave interactions (linear as well as nonlinear) in solid state plasmas has been made by several workers. A state important advancement in the study of solid v plasmas has brought about the realization that many of the physical characteristics of solid can be explained in terms of the elementary excitations that may be supported by the given solid. One of the most important properties of and electron plasma and or hole plasma is that can support a great variety of collective modes. A number of workers have studied theoretically and experimentally. The excitations of various collective mode in semiconductors. The impetus of `research stems from its relation to the fundamental properties of solids as well as the possibility of its technological utilization in solid state devices. Various types of non linear wave interactions occur in semiconductor plasmas (e.g. parametric modulational, stimulated brillouin and Raman scatterings) under suitable condition s giving rise to appreciable growth rates.

Key-Words: Theory, Raman, Brillouin, Dielectric constant

Introduction

Classically the non linear interactions can broadly be called as those interactions in which lossless (or low loss) non linear energy storage mechanism couples a number of normal modes at different frequency's in a generalized dynamic system. It is possible to feed energy into a system and to excite non linear instabilities. The feeding of energy to the system is called pumping. The non linear interactions can be grouped into three broad categories:-

1. Basically non linearizable problems.
2. Wave particle interactions.
3. Wave wave interactions [1] [2]

It was concentrated that attention towards the non linear wave wave interaction in piezoelectric materials with SDDC.

*** Corresponding Author:**
E-mail: sxn_shvn@yahoo.co.in

Light Scattering Basics

This section is a brief introduction into the basic principles of light scattering. While the derivation of scattering theory on the basis of quantum field theory is possible, herein the scattering medium as well as the light is treated classically, leading to practically the same results within the scope of this thesis. Of course there are light scattering effects, as for example in the well-known Raman scattering technique, which deals with rotational and vibrational transitions of single atoms or molecules, i.e., effects in a quantum length scale, that must be treated (at least partially) quantum mechanically. However, this thesis deals with the investigation of phonons by Brillouin light scattering in condensed Basics and Brillouin Light Scattering matter. Thus the investigated phonons are classical waves with wavelengths in theorder of some nanometer up to micrometer; it is fully justified to apply a classic theory.

Stimulated Brillouin Scattering (SBS)

Classically, the thermally generated density fluctuations of a material medium are responsible for scattering of light. These density fluctuations result in compression and rarefaction regions within th medium, and may be considered as consist of two components, the propagating component and the non-propagating component. When alight wave is incident, scattering from the non-propagating component gives the central Rayleigh line and scattering from the propagating component results in Brillouin lines. There is finite width in Brillouin and Rayleigh lines. The propagating component of density fluctuations

behaves as a sound wave of high frequency. The damping of such a wave in the material medium is responsible for finite width in Brillouin lines while non-zero lifetime of the non-propagating component produces width in Rayleigh lines.

Basic Theory

Brillouin scattering is a nonlinear process that can occur in optical fibers at large intensity. The large intensity produces compression (due to electric field also known as pump field) in core of fiber throughthe process known as electrostriction. This phenomenon produces

Density-fluctuations in fibre medium. It increases the material disorder, which in turn modulates the linear refractive index of medium and results in an electrostrictive-nonlinearity. The modulated refractiveindex behaves as an index grating, which is pump-induced. The scattering of pump light through Bragg diffraction by the pump induced

index grating is called as Brillouin scattering. The disorder is time dependent so the scattered light is shifted (Brillouin shift) in frequency by the frequency of sound wave. For pulses shorter than 500 ps, there is no spatial overlap between the pulse and acoustic wave, which results in negligible electrostrictive nonlinearity .Quantum mechanically the Brillouin shift originates from the photon-phonon interaction, and associated Doppler displacement. In this interaction either a phonon is annihilated (Stokes process-positive Brillouin shift) or created (anti-stokes process-negative Brillouin shift)

Stimulated Raman Scattering (SRS)

The Raman scattering effect is the inelastic scattering of a photon with an optical phonon, which originates from a finite response time of the third order nonlinear polarization of the material. When a monochromatic light beam propagates in an optical fiber, spontaneous Raman scattering occurs. It transfers some of the photons to new frequencies. The scattered photons may lose energy (Stokes shift) or gain energy (anti-Stokes shift). If the pump beam is linearly polarized, the polarization of scattered photon may be the same (parallel scattering) or orthogonal (perpendicular scattering). If photons at other frequencies are already present then the probability of scattering to those frequencies is enhanced. This process is known as stimulated Raman scattering. In stimulated Raman scattering, a coincident photon at the downshifted frequency will receive a gain. This feature of Raman scattering is exploited in Raman amplifiers for signal amplification.

Stimulated Raman and Brillouin scattering (SRS and SBS) phenomena have been investigated analytically with use of density-matrix formulations and assuming parity indefiniteness for the eigenfunctions of the energy eigenstates of a two-level system in noncentrosymmetric (NCS) crystals. In crystals, when a molecule is excited, the disturbance travels through the crystal as a vibrational wave (phonon mode). We have considered the scattering of the incident electromagnetic wave by phonon modes on a common footing, assuming that vibrations should correspond to optical phonons for SRS and to acoustic phonons for SBS. The retardation effect due to finite $\chi^{(2)}$ in NCS crystals is found to play a more significant role in the case of SRS than for SBS. The classical differential polarizability $(\partial\alpha/\partial u)_0$ that causes SRS has been determined from the present formulations in terms of the material constants of the crystal and the photon pump energy. Applying Heisenberg's uncertainty relation, we have also obtained a general formula for the determination of the electrostrictive coefficient γ that is responsible for SBS in crystals. We find $(\partial\alpha/\partial u)_0/\gamma \sim 10^{-8}$ with $\gamma \sim 10^{-10}–10^{-11}$ mks units for important III-V semiconductors. Both Raman and Brillouin gain constants are studied over a wide frequency spectrum in the semiconductors. The ratio between the two gain constants indicates that for the same pump intensity SBS exhibits higher gain than SRS by a magnitude $\sim\omega_{OP/\omega AP}$. .AE

Raman instability of the Stokes component of the scattered electromagnetic wave has been investigated in an *n*-type piezoelectric semiconductor in the presence of a large transverse magnetostatic field. The general dispersion relation has been obtained following the coupled-mode theory and considering that the scattering results not only from the molecular vibrations produced owing to the pump wave at a frequency equal to that of the transverse-optical phonons but also from the electron plasma wave. The analysis has been applied to both cases of isotropic (B_0=0) and magnetoactive (B_0≠0) plasmas. The threshold value of the pump amplitude necessary for the onset of instability and the growth rate of the unstable mode well above the threshold have been obtained analytically for B_0=0 and B_0≠0. It is observed that a large transverse magnetostatic field can reduce the threshold value of the pump amplitude and increase the growth rate of the unstable Raman mode at electric field amplitude greater than the threshold value. Numerical estimates have been made for *n*-InSb crystal at 77 K. The crystal has been irradiated with a pulsed 10.6-μm CO_2 laser to obtain the necessary electric field. The analytical as well as the numerical results have been compared with those of Seen while studying Brillouin instability in *n*-type magnetoactive piezoelectric semiconductors.

Methodology

In the proposed work, it was aimed at the detailed analytical investigation of Raman and Brillouin instabilities in piezoelectric materials with SDDC under a variety of configurations of electric and magnetic fields and the wave vectors. The general dispersion relations will be derived for different type of waves. The general dispersion relations will be derived for different type of waves in the medium using hydrodynamic model of plasmas, Maxwell's equations and coupled mode theory. The electro kinetic branches of the dispersion relation will be examined. The propagation characteristics and the possibility of instabilities will be investigated.

When a crystal is irradiated by any pump field its dielectric constant does not remain constant but does, in fact depends upon the deformation of the material; this is true for both piezoelectrically active as well as inactive crystals.

Thus Simple analysis of the modulational instability of a laser beam in material with strain dependent dielectric constants is given in this thesis. The analysis is based on the hydrodynamic model of the plasma in the collision dominated regime. Using coupled mode theory the acoustic instability in the medium is investigated and the threshold value of the pump electric field and the conditions for the initial growth rates are deduced. It is found that the large value of growth rate can be achieved for materials having an anomalously large dielectric and /or Deformation potential interactions.

Results and Conclusion

The results of the analysis for specific piezoelectric materials with SDDC to demonstrate the practical utility of the theoretical investigations proposed to be made we also aim to complete to compare our analytical results with the available experimental results.

Briefly therefore We wish to study some important aspects of nonlinear wave instabilities especially Raman and Brillouin instabilities and the excitation mechanisms under different configurations of general scientific interest we hope that the proposed work shall be able to contribute to the better understanding of the mechanisms of Raman and Brillouin instability in piezoelectric materials with SDDC and used in the development of semiconductor devices.

The consideration of crystals with strain dependent dielectric constant thus possibly offers an area of promises for pursuit's non linear interactions and one expects the experimental studies on nonlinear interactions to open a potential tool for energy conversion and solid state diagnostics in crystals with high dielectric constant.

Acknowledgements

The author is very thankful to Dr. Sanjay Dixit for encouragement.

References

1. Ghosh S. and Dixit S. (1984). Parametric decay of a high power helicon wave. *Phys State.* Sol (b) 124: 395.
2. Guha S., Sen P.K. and Ghosh S. (1979). *Phys. Letter*, 71A:149.
3. Ghosh S. and Dixit S. (1985). *Phys State* Sol (b) 130:260.
4. Ghosh S., Aptes N. and Agarwal V. K. (1981). *Phys. State*. Sol (b) 107:75.
5. Ghosh S. Sen P. K. and Guha S. (1979). *Pramana*, 13: 599.
6. Guha S. and Apte N. (1980). *J. Appl. Phys.* 51:5267.
7. Ghosh S. and Khan S. (1983). Phys. Stat. Sol. (b): 119
8. Sallimullah Md. and Alan. M. N. (1982). *J. Appl. Phys.* 53: 4534.
9. Sallimullah Md. and Singh T. J. (1982). *Phys. Chem. Solids*, 43:1087.