Contribution ID: **54** Type: **not specified**

Nonlinear Photoelasticity of Crystals and Related Effects of Electromagnetic and Acoustic Wave Interaction

Tuesday 17 June 2025 16:34 (1 minute)

When an electromagnetic wave (EMW) and an acoustic wave (AW) propagate simultaneously in the same region of a crystal, an acousto-optic (AO) interaction arises between them.
As an AW propagates through a crystal, it modulates its dielectric permittivity , which is the primary mechanism responsible for AO interaction, widely used in practical applications.
This study theoretically investigates the nonlinear photoelasticity of crystals and the related effects of electromagnetic and acoustic wave interaction, as well as the resonant properties of the electronic component of the additional value arising under the influence of AW in the frequency range of EMW, where (- the characteristic energy difference of electronic levels in the crystal, - Planck's constant).
When a harmonic AW propagates through a crystal , its dielectric permittivity can generally be expressed as: (1)
where is the permittivity in the absence of sound, and represents certain tensors dependent on the crystal and sound parameters, atc and being the wave vector and frequency of AW, respectively.
Through theoretical analysis and analytical calculations, the following results have been obtained:
• It has been revealed that even under conditions of low modulation depth, where , the value of can be a significantly nonlinear function of the AW amplitude. In this case, expansion (1) includes a considerable number of comparable harmonics. In particular, a stationary additive component appears , leading to changes in the velocity and absorption (or amplification) coefficient of the electromagnetic wave.
• It has been shown that near resonance condition the values of strongly depend on the frequency , reaching a maximum at .
• It has been theoretically predicted that the effect of mutual velocity change of interacting waves may lead (under certain conditions) to the effect of mutual focusing (or defocusing) of electromagnetic and acoustic waves. The characteristic features of this effect have been studied.
The effect of nonlinear photoelasticity may be useful in AO devices operating in the mode of resonant diffraction. In particular, its application may significantly reduce the required AW frequency due to diffraction at higher harmonics .

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Session Classification: Poster Session P17