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Threshold pump strain for parametric amplification in n-indium antimonide

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Abstract. Phenomenological approach has been used to determine the threshold pump strain by assuming that at this strain the pump generates an electric field for which the drift velocity of the carriers equals the sound velocity. Numerical values obtained for n-InSb have been compared with similar studies which are based on Boltzmann transport approach.

Keywords. Threshold pump strain; parametric amplification; indium antimonide.

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1. Introduction

When more than one wave propagates through a piezoelectric crystal, they affect one another because each wave gives rise to its own bunching of carriers as a result of which the carrier distribution of one interacts with the field distribution of the other. The coupling due to this interaction is known as parametric coupling. In this case the nonlinear interaction between the carriers and the electric field results in the generation of new electrical and acoustical signal (Kroger 1964; Tell 1964; Elbaum and Truell 1964; Mauro and Wang 1967). In addition, the parametric interaction between a large and a small amplitude wave results in the amplification of the latter (Komar and Timan 1970; Dyakonov and Lisavskii 1970). The large amplitude wave, usually referred to as the pump, can produce amplification only above a certain fixed strain known as the threshold pump strain. Johri and Spector (1977) employed the Boltzmann transport approach to derive an expression for the threshold pump strain. However, studies based on the phenomenological approach are not available in literature. In the phenomenological approach one first derives an expression for the second order field acting on a given wave due to acoustoelectric interaction with the other wave. The wave equations are than set up for the coupled waves and solved for subharmonic and second harmonic generation. We have employed this approach to derive an expression for the threshold pump strain by assuming that at this strain the pump generates an electric field for which the drift velocity of the carriers equals the sound velocity. Under such a situation the carriers will remain in phase with the wave and will impart their energy to the signal which will, therefore, be amplified.

2. Theory

We consider an acoustic wave propagating in the x-direction of an n-type piezoelectric semiconducting medium and define a strain S, a stress T, and a displacement u such that

$$S = \partial u/\partial x \tag{1}$$