INTERACTION OF ELECTROMAGNETIC FIELDS WITH SEMICONDUCTORS

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ABSTRACT

generation for simple model semiconductors in the presence of a DC field to many-valley non-degenerate semiconductors and applied his analysis to germanium. It is concluded that for i.r. frequencies the magnitude of second harmonic is proportional to DC field, which is in contrast to Kaw's prediction[1] of an optimum DC field for maximum second harmonic generation in the microwave range of frequencies.

The author has also investigated propagation of electromagnetic waves in non-degenerate semiconductors in the presence of magnetic field. This includes hot electron Faraday effect in non-polar and piezoelectric semiconductors.

The amplification of coupled magnetoelastic mode in ferromagnetic semiconductors due to its interaction with the drifting carriers has also been investigated.

The emission of electromagnetic radiation is studied from a semiconductor due to spin inversion of the carriers on application of small DC field.

The following is the chapterwise summary of the thesis:

In Chapter I the author has derived the collision integrals in Boltzmann transfer equation explicitely for various modes of the lattice scattering in parabolic degenerate semiconductors. Using these collision integrals

the carrier energy distribution functions are derived for arbitrary degeneracy of the charge carriers and for various cases of interest of mixed scattering in degenerate semiconductors subjected to DC field. These carrier energy distribution functions are shown to reduce to those derived by earlier workers for the case of non-degenerate semiconductors.

In Chapter II the author has derived the collision integrals explicitely for various modes of lattice scattering in non-parabolic degenerate semiconductors. These collision integrals are used in the Boltzmann transfer equation to obtain carrier energy distribution function in the presence of a DC field. An important conclusion drawn in the case of piezoelectric semiconductors is that the corresponding distribution function in the presence of DC field can be normalized for high values of DC fields only when the non-parabolicity of energy bands is taken into account. Leikhtman[2] has concluded for the case of simple model non-degenerate piezoelectric semiconductors that the corresponding distribution function can be normalized for applied DC fields smaller than some critical value determined by the parameters of the semiconductor. On the other hand it is experimentally observed that DC fields much greater than this critical value are required to obtain supersonic carrier drift velocities and consequent acoustic wave amplification which implies that carriers do not escape out of the semiconductor for applied DC fields greater than the critical value predicted by Laikhtman[2]. The existing kinetic theories[3] of acoustic wave amplification in piezoelectric semiconductors assume the distribution function of charge carriers to be Maxwellian at an elevated temperature higher than that of the lattice which as pointed out before is not at all justified, the difficulty disappears when non-parabolicity of the energy bands is taken into account.

In Chapter III author has extended the theory of nonlinear harmonic generation in the following case of interest. It has been shown by Kaw[1] that there exists an optimum value of DC field for maximum microwave second harmonic generation in simple model non-degenerate semiconductors subjected to strong microwave and DC field; the acoustic mode of lattice scattering was taken into account. The author has shown that in the infrared range of frequencies the amplitude of second harmonic increases in proportion with the strength of applied DC field and there exists no optimum DC field for maximum second harmonic generation in contrast to the case of microwave frequencies discussed by Kaw[1]. The analysis was applied to many-valley non-polar semiconductor, Ge; the anisotropy in the magnitude of generated second harmonic is also investigated for different directions of DC field.

Faraday effect measurements are one of the powerful magneto-optical methods used for probing the semiconductors. In Chapter V the author has investigated the hot electron Faraday rotation and ellipticity in the cases of interest pointed below for obtaining information about either the energy dependence of relaxation time or the effective mass of the carriers in non-degenerate semiconductors.

In Chapter IV the importance of the oscillatory perturbation in the distribution function is emphasized in the investigations of hot electron microwave magneto-optical effects. It is shown that the consideration of oscillatory perturbation in distribution function in the presence of DC field leads to the change in the sign of Faraday ellipticity and to the significant decrease in the magnitude of Faraday rotation towards the higher DC fields in the case of non-polar semiconductors like Ge.

It is further shown in Chapter V that the anisotropy of hot electron Faraday ellipticity in the infrared range of frequencies for Ge is independent of the magnitude and direction of the applied static magnetic field in the linear approximation. It is also shown that the Faraday ellipticity in the infrared range of frequencies increases with the DC field in contrast to its decrease in the micro-wave range of frequencies.

It is pointed out in Chapter VI that the Faraday rotation measurements are far easier to conduct as compared to cyclotron resonance measurements conducted in piezo-electric semiconductors to obtain information about the parameters of the semiconductor. The necessary theory is developed and the variation of Faraday rotation and ellipticity are discussed as the function of scattering parameter and the DC field applied to obtain information about the hot electron effects.

In Chapter VII the author has investigated the amplification of coupled magneto-elastic mode in ferro-magnetic semiconductors due to its interaction with the drifting carriers. It is suggested that an analysis of the hypersound generated can be used to draw information about the spectrum of spin waves for wider range of the static magnetic field. An information about the inter-action of magneto-elastic waves with the drifting carriers is also obtained.

In Chapter VIII the author has developed theory of the emission of radiation due to spin population inversion. This absorption is caused by the difference in the rates of energy absorption from the heating field by differently aligned electrons and non-thermalising spin-flip scattering of the electrons. This theory explains the low field microwave emission at low temperatures from non-degenerate samples placed in a moderate magnetic field.

The work reported here has resulted in the following publications:

1. High field effects in degenerate semiconductors: Collision integral and isotropic distribution function, Phys. Rev. B, 1, 3993 (1970).

2. High field effects in non-parabolic degenerate semiconductors: Collision integral and isotropic distributions function, Phys. Rev. B, 2, 3249 (1970).

3. Second harmonic generation in anisotropic semiconductors using DC electric fields, Phys. Status Sol. 37, 311 (1970).

4. Hot electron Faraday effect in non-polar semiconductors, Brit. J. Appl. Phys. (J. Phys. D.), 2, Ser. 2, 1527 (1969).

5. Faraday ellipticity of hot electrons in many-valley semiconductors, Phys. Status Sol. 37, 115 (1969).

6. Microwave free-carrier Faraday effect in piezoelectric semiconductors, Brit. J. Appl. Phys. (J. Phys. D.) 1, Ser. 2, 1603 (1968).

7. Amplification of coupled spin-acoustic waves in ferromagnetic semiconductors, Brit. J. Appl. Phys. (J. Phys. D.) 3, 54 (1970).

8. Emission of radiation due to spin inversion, Phys. Status Sol. 35, K51 (1969).

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