SUMMARY AND CONCLUSIONS

In the present work we have investigated two - photon absorption (TPA), one of the interesting non - linear optical properties, in quantum wells (QWs) and superlattices (SLs) and thermopower (TP), one of the important transport properties, in heterojunctions (HJs).

TPA is studied in QWs in a quantizing magnetic field considering free electron - hole transitions assuming same polarization for both photons. Two - photon magnetoabsorption (TPMA) coefficient is derived for left and right circular polarized radiation in the plane of the layer. Energy of the incident beam is such that only first heavy hole subband in valence band and first subband in conduction band are involved in the transition. We have found that the selection rules are very much polarization dependent. ΔN = +1 and -1 govern the transitions between the Landau levels for left and right circular polarizations, respectively. TPMA coefficient is numerically evaluated as a function of two - photon energy in a GaAs/GaAlAs QW for the specimen of Fröhlich et al [ Phys.Rev.Lett. 61, 1878 (1988) ]. TPMA shows a series of peaks at two - photon energies matching the separation of Landau levels satisfying the selection rule ΔN = +1 and -1 reflecting the density of states (DOS) of 2D electron gas in a magnetic field. The two - photon energies of the successive peak positions due to left and right circular
polarizations are used to determine the cyclotron masses of electrons (m_e) and holes (m_h) separately and they are found to be m_e = 0.07 m_0 and m_h = 0.22 m_0, where m_0 is the free electron mass. We have compared the calculated TPMA spectrum with the experimental spectrum of Fröhlich et al involving transitions between the Landau levels 2 - 1, 3 - 2 and 1 - 2, 2 - 3. Transitions 1 - 0 and 0 - 1 are due to excitonic absorption. Good fit is obtained for Landau level width of \( \Gamma = 2 \text{ meV} \). Our calculations of resonant photon energy as a function of magnetic field, for the two polarizations, are also in good agreement with the data of Fröhlich et al.

TPMA due to transitions 1 - 0 and 0 - 1 are due to excitonic absorption as evident by the experimental data of Fröhlich et al. We have calculated two - photon magnetoexcitonic absorption (TPMEA) coefficient in GaAs/GaAlAs QW due to 1 - 0 and 0 - 1 transitions for left and right circular polarizations, respectively. We have found from the selection rules that TPMEA is due to 2P excitons (unresolved) as is observed in the experiment of Fröhlich et al. There is a peak in a TPMEA spectrum at a resonant two - photon energy which is equal to effective band gap of QW in a magnetic field minus the binding energy of 2P exciton. This forms the threshold energy for TPMEA spectrum. We have found that the threshold energy shifts to higher energy side as magnetic field increases. This is due to increase in effective effective band gap. We have presented numerical calculations of
two-photon threshold energy for different magnetic fields for 1-0 and 0-1 transitions for left and right circular polarizations, respectively. It is fitted to the experimental data of Fröhlich et al treating BE of 2P exciton, appearing in Dirac delta function, as a parameter. Thus BE of 2P excitons (~2 meV) at different magnetic fields is extracted and it is found to increase with increase in magnetic field. This is expected because increasing magnetic field reduces the cyclotron radius and compresses the exciton wave function leading to increase in BE.

TPMEA coefficient is evaluated as a function of two-photon energy for 1-0 and 0-1 transitions and is in good agreement with experimental data of Fröhlich et al for Landau level width of \(\Gamma = 2 \text{ meV}\). The peak value of the TPMEA coefficient is found to increase with increasing magnetic field due to increase in oscillator strength.

We have calculated the BE of the unresolved 2P excitons, as a function of magnetic field for the specimen of Fröhlich et al, by variational method and perturbation method. BE values calculated from perturbation method are closer to the values extracted from the experimental data of Fröhlich et al.

Further, we have studied TPA in SLs in zero and non-zero magnetic field, neglecting excitonic effects, for the radiation polarized in the plane of the layer. TPA coefficient is evaluated
for GaAs/GaAlAs SLs. Zero field TPA coefficient is found to increase non-linearly with two-photon energy in miniband region and linearly in the miniband gap region. The behaviour of TPA coefficient in miniband gap region is attributed to the linear $k$ (electron wave vector) dependence of the interband matrix element and constant DOS. This is similar to zero field TPA in QWs. The non-linear behaviour of TPA coefficient in miniband region is due to gradual increase of DOS in this region although intraband matrix element remains proportional to $k$. This range of two-photon energy for which TPA coefficient varies non-linearly is the measure of miniband width. The effect of miniband width on absorption coefficient is also investigated by varying the period of SL. The threshold energy for TPA to occur shifts to lower energy side as the period of the SL decreases since the SL of smaller period has larger miniband width.

Two-photon magnetoabsorption (TPMA) is studied in SL for left and right circular polarizations. The allowed transitions between Landau levels are governed by the selection rules $\Delta N = +1$ and $\Delta N = -1$ in left and right circular polarizations, respectively, as in QW. TPMA shows series of peaks at resonant two-photon energies. Overall TPMA coefficient increases with increase in two-photon energy, unlike in case of QW, in miniband region reflecting behaviour of DOS of SL in magnetic field. In miniband gap region TPMA behaviour is similar to that in QW case. Experimental TPA and TPMA observations in SL are
required to test our predictions. In absence of the data our calculations in SL are compared with those in QW case and are consistent in the miniband gap region as expected.

In the second part of the thesis we have studied thermopower (TP) of a 2D electron gas in GaAs/GaAlAs heterojunction (HJ), in particular.

We have investigated phonon - drag thermopower and diffusion thermopower in zero magnetic field. Our formulations and calculations are suitable for wide range of temperature (1 to 300 K), unlike the earlier works. We have modified the Cantrell and Butcher basic formula of phonon - drag thermopower ($S_g$) so that it is suitable for temperature higher than liquid helium temperature. We have taken into account of i) the inelasticity of the scattering mechanisms ii) proper degeneracy of electron distribution function, (iii) temperature dependent screening of electron - phonon interaction and iv) phonon scattering due to other phonons and impurities, besides the boundary scattering. For temperatures at and below liquid helium temperatures, phonon mean free path is governed by boundary scattering. At higher temperatures it is also governed by phonon - phonon and phonon - impurity scattering. $S_g$ variation as a function of temperature shows that $S_g$ increases ($\sim T^3$) with increase of T and reaches a maximum at $T \sim 10$ K. Above $T > 10$ K, $S_g$ decreases rapidly with further increase of T. Appearance of maximum in $S_g$ and a rapid
fall thereafter is attributed to the phonon scattering due to other phonons and impurities at higher temperatures. For the first time we have calculated zero field diffusion thermopower $S_d$ by variational method, unlike the earlier works which use relaxation time approximation. For temperatures $T > 50$ K polar optical modes play a dominant role in electron scattering and scattering is no longer elastic. As a result of this relaxation time cannot be defined. Use of variational method makes our $S_d$ calculations suitable for large range of temperature. Electrons are assumed to be scattered due to acoustic phonons, polar optical phonons, interface roughness and remote impurities. $S_d$ variation as a function of temperature shows linear behaviour, as expected from Mott formula, at very low temperatures. and is almost constant at higher temperatures. ($T > 100$ K ). $S_d$ dependence on $T$ over the entire range of temperature (1 to 300 K) is $T^{1/2}$. Total TP, $S = S_g + S_d$ is studied as a function of temperature and is compared with recent experimental data of Cyca et al [ J.Phys. : Condens.Matter, 4, 4491 (1992) ]. Our calculations are in excellent agreement with the experimental data over the large range of temperature 1 to 200 K. For $1 K < T < 50$ K, $S_g$ dominates $S$ and for $50 K < T < 200$ K, $S_d$ dominates $S$.

We have presented the calculation of phonon drag magnetothermopower $S_g$ for temperatures at and above liquid helium temperature. In the basic formula for $S_g$ given by Kubakaddi et al
we have incorporated screening of electron-phonon interaction and phonon-phonon and phonon-impurity scattering in phonon relaxation time. These additional phonon scattering mechanisms reduce $S_g$ at higher temperatures. The strength of the phonon-phonon and phonon-impurity scatterings is varied to fit the data. Inclusion of phonon-phonon and phonon-impurity scattering in phonon relaxation time gives excellent agreement with experimental data of Fletcher et al. [Phys. Rev. B 33, 7122 (1986)] accounts for rapid decrease of $S_g$ for $T > 6$ K. Phonon scattering due to boundary alone cannot explain the data in this temperature range. In the $S_g$ versus $T$ curve the maximum is observed at $T \sim 6$ K. The appearance of maximum and its position and further decrease of $S_g$ at higher temperatures is partly due to the width of the Landau level which limits the energy of the acoustic phonons involved.