L.7: Impact of interface states on built-in electric field and diamagnetic-Landau energy shifts in InGaAs/GaAs QWs

The modulation-doped quantum structures of InGaAs/GaAs are preferred as efficient channel materials required for optoelectronic and spin photonic devices at the telecommunication window range. However, efficient devices require defect-free heterojunction of InGaAs/GaAs and therefore, intensive research has been performed in recent years to control the kinetics of the adatoms and their influence on the interface quality of one-sided modulation-doped InGaAs/GaAs quantum wells (QWs). In such structures, charge carrier diffusion length, quantum and transport scattering time can be greatly modified by the presence of spatially localized channels associated with point defects. Thus, the impact of interface defect states on the charge carrier's recombination and transport properties in asymmetric modulation-doped InGaAs/GaAs quantum well structures are investigated.

An asymmetric (one-sided) modulation doping results in modification of the energy band bending diagram due to the presence of a built-in electric field. The strength of the electric field is estimated from the Franz Keldysh oscillations (FKOs) observed in the photo-reflectance spectra (Figure L.7.1(a)). The FKOs originate due to the change in dielectric constant values, which is associated with a built-in electric field and the modulated laser light. The period of FKOs is directly related to the electric field (E_e ~ 48.7 ± 0.1 kV/cm at 300 K) present in the structure. The presence of such a high electric field can easily drift the QW charge carriers towards the hetero-interfaces and force them to experience the crystal potential fluctuations associated with the atomic irregularities at the InGaAs/GaAs interfaces. At low temperatures, the charge carriers do not possessed sufficient thermal energy to come out from the localized energy states and get captured. Thus, the consequence of the charge carrier capture and recapture processes at the interface led to reduction of net built-in electric field values under low-temperature conditions as estimated from FKOs. Under such conditions, the magnetic field is used as a probe to reduce the localization effects by re-distribution of the charge carriers among Landau level (LLs depicted as *j* in Figure L.7.1(b)). However, the charge carrier localization states still exist with the lowest ground LL state (*j*=0) for the given magnetic field range (up to 8 T). Thus, the diamagnetic-Landau shift, which is generally used to estimate the fundamental parameters, may lead to ambivalent values for the lowest LL state. Therefore, the effective mass ~ (0.058 ± 0.003) m_0 and binding energy ~ (4.4 ± 0.5) meV for the asymmetric modulation-doped InGaAs/GaAs QW are estimated from the higher LLs that are well separated from low energy defect states in magneto-photoconductivity (PC) spectra (inset of Figure L.7.1(b)). Subsequently, it is proposed that under the presence of large interface defect states, magnetic field-driven diamagnetic-Landau shifts can be used for the estimation of charge carrier's fundamental parameters from the magneto-PC spectra instead of magneto-photoluminescence (PL) spectra.

The present investigation would be beneficial for enhancement of optoelectronic and spin photonic device efficiency in the field of nanotechnology.

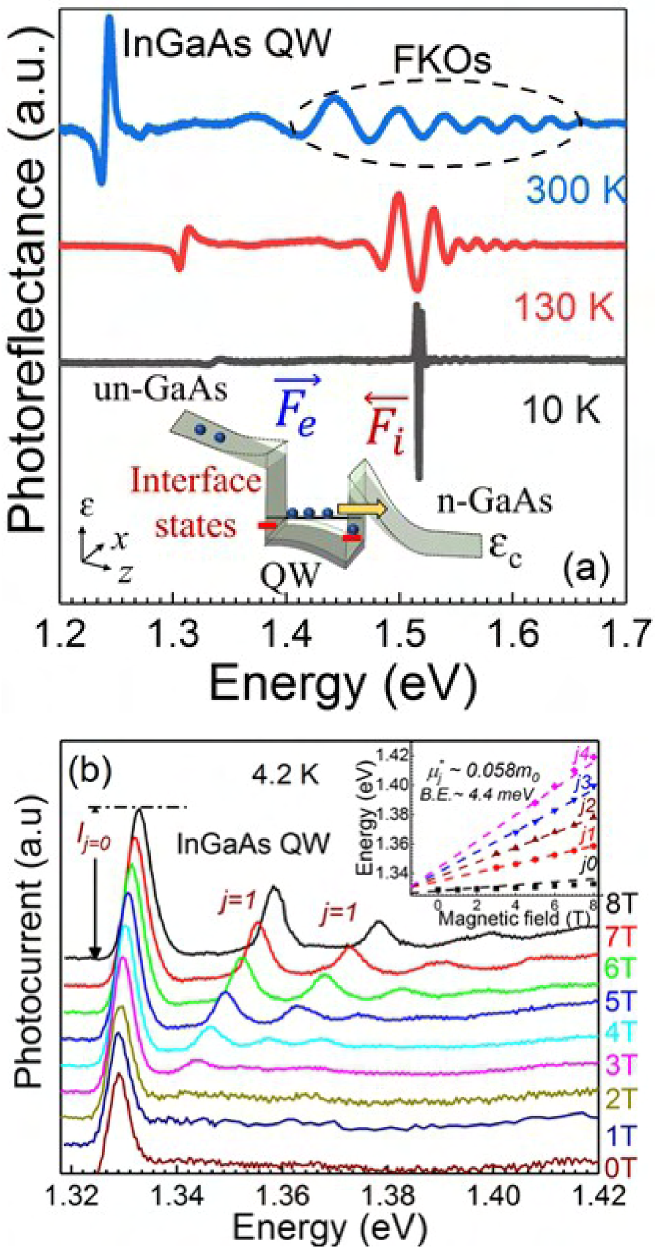

Fig. L.7.1: (a) Photo-reflectance spectra, where inset shows the charge carrier localization at the interface states resulting in change in energy band bending profile and (b) magneto-PC spectra, where the inset shows the Landau–Fan diagram.

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