L.10: Ultrafast carrier dynamics of 2-D electron gas in AlGaAs -GaAs structure

Ultrafast carrier dynamics studies in metals, semiconductors and their nanostructures are being carried out in Ultrafast Spectroscopy Lab, Laser Physics Applications Section, RRCAT using pump probe technique. Recently we have studied the carrier dynamics of two-dimensional electron gas (2DEG) formed near the interface of an $Al_{0.7}Ga_{0.3}As$-GaAs heterostructure. Determination of room temperature carrier dynamics of the 2DEG in such heterostructures is challenging due to two reasons. First, the photoluminescence is totally quenched at room temperature. Second, transient reflectivity measurements show the net effect of carriers in both the 2DEG layer as well as the underlying GaAs substrate. Till now, it was not possible to directly determine the separate contributions from different layers. We have demonstrated a new, general technique in which the transient changes in reflectivity of a particular layer can be isolated by appropriate selection of the exciting wavelength. This utilizes the wavelength dependence of linear reflectivity due to etalon effects in the multilayer structure.

The heterostructure consists of the top AlGaAs layer, the 2DEG layer and the GaAs substrate. Fig. L.10.1 shows the different layer thicknesses and their refractive indices. The transient reflectivity measurements are performed in standard degenerate pump-probe geometry with the excitation wavelengths in the region 760- 850 nm. In this wavelength region AlGaAs does not absorb, hence the reflectivity of only the 2DEG layer and the GaAs substrate will change with time. It can be shown that the transient change in reflectivity can be given by the equation,

$$(\lambda,t)\geq\Re_2(\lambda)\Delta n_2(\lambda,t)+\Re_3(\lambda)\Delta n_3(\lambda,t)$$

where $\Re_2$ and $\Re_3$ are the respective contributions from 2DEG region and GaAs.

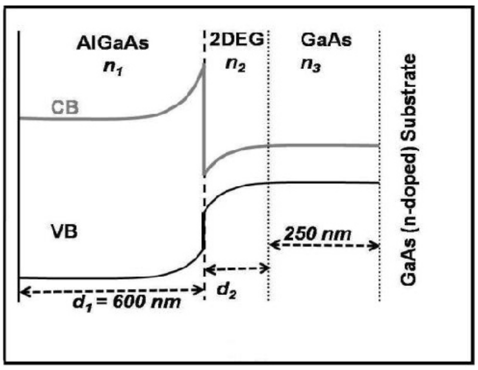

Fig. L.10.1: Band bending diagram. n_1, n_2 and n_3 are refractive indices for AlGaAs, 2DEG region and GaAs respectively. d_1 and d_2 are thickness of AlGaAs and 2DEG layer respectively.

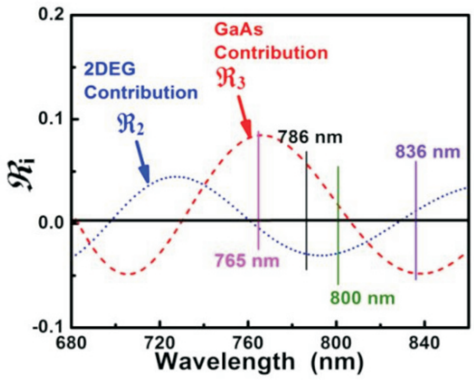

Fig. L.10.2: Calculated wavelength dependence of the contribution to the linear reflectivity from the GaAs and 2DEG layers of the heterostructure.

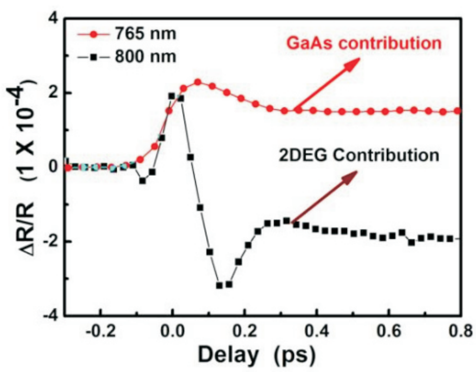

Fig. L.10.3: Room temperature TR curves for the $Al_{0.7}Ga_{0.3}As$-GaAs heterostructure showing the individual contributions from the GaAs and 2DEG layers obtained by selecting appropriate wavelengths as per Fig L.10.2.

The calculated wavelength dependence of $\Re_2$ and $\Re_3$ is shown in Fig L.10.2. It is clear that at certain wavelengths the predominant contribution to the transient reflectivity is from one specific layer and thus, transient reflectivity measurements at such wavelengths would directly measure the carrier dynamics in that layer. Using this, we have been able to isolate the dynamics of the carriers in the GaAs and 2DEG layers of the heterostructure (Fig. L.10.3). The decay time of the 2DEG at room temperature is determined to be 60 ps at an excited carrier density of ~10^{15} cm^{-3}.

Thus, we have demonstrated that, by choosing the appropriate working wavelength, transient reflectivity can be used to measure carrier dynamics in multilayer structures. For details please see App. Phys. Lett.,107,121905.

Reported by:
Salahuddin Khan (skhan@rrcat.gov.in)