Direct Measurement of Intersubband Population Dynamics

T. Müller, R. Bratschitsch, G. Strasser, K. Unterrainer

We have studied the time-resolved photo-induced intersubband absorption in an undoped GaAs/AlGaAs coupled-well. We apply a novel interband pump/intersubband probe technique that directly allows us to measure the temporal evolution of the intersubband absorption spectrum after optical excitation.

In the experiment an interband pump pulse injects electrons into the first and second subband of an asymmetric double quantum well with a level spacing smaller than the optical phonon energy. The time evolution of the electron population in these two subbands is monitored by probing the mid-infrared (MIR) transition to the empty subbands 3 and 4. Ultrashort MIR pulses are generated by phase-matched difference-frequency mixing in GaSe, and the spectrum of the transmitted MIR pulses through the sample (T = 5 K) is recorded by performing an interferometric correlation technique.

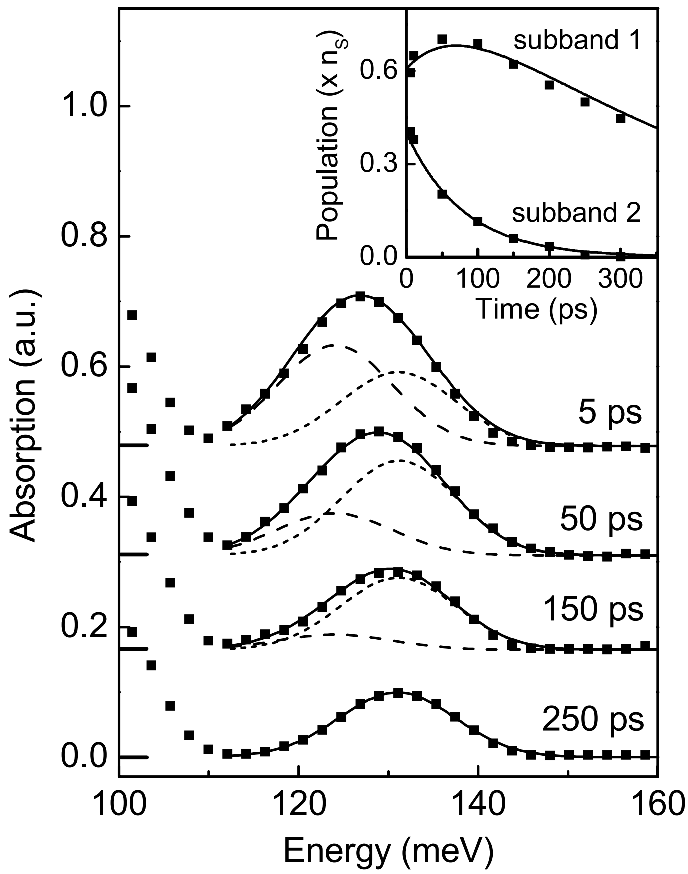

Fig. 1: Intersubband absorption at different time delays with Gaussian fits. Inset: Subband population of level 1 and 2.

Figure 1 shows the intersubband absorption spectrum recorded at different time-delays after the pump pulse. We observe an absorption peak, corresponding to the transitions 1-4 and 2-4, that clearly shifts to higher energies over time.

In addition we observe the onset of a second peak at lower energies, which we attribute to the transitions 1-3 and 2-3, that cannot be resolved due to the cut-off of our detector. We explain the blue shift of the absorption by relaxation of carriers from the second to the first subband. In Fig. 1 we have fitted two Gaussian peaks to the measured data: one at 124 meV, corresponding to the transition 2-4, and another one at 131 meV, corresponding to the transition 1-4. Since the area under the peak (i-4) (i = 1, 2) is directly proportional to the subband population $n_i(t)$, we are able to determine the population dynamics in the quantum well on the basis of the time-resolved absorption spectra. The inset of Fig. 1 shows the electron population of the first and second subband as a function of time delay after optical excitation (symbols). About 40% of the photo-excited carriers are injected into the second subband, while the remaining 60% are injected into the first subband at higher k-value. The population in the second subband (squares) shows an exponential decay. The carriers relaxing down from the second subband add to the population in the ground level. Subsequently, the population in the ground level drops due to carrier recombination. The lines are the results obtained from a simple rate equation model.