Transport Studies on Double Period Superlattices Utilizing Hot Electron Spectroscopy

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The transmission properties of double period superlattices were studied using hot electron spectroscopy. In superlattices with two different alternating well widths each miniband splits into two subminibands [1]. Figure 1 shows the conduction band of the two investigated superlattice structures. The barrier width (b) and well widths (w_1, w_2) are identical in both structures, the only difference is the sequence of the wells. The coherent transmission of these structures was calculated using a transfer matrix method taking nonparabolicity into account.

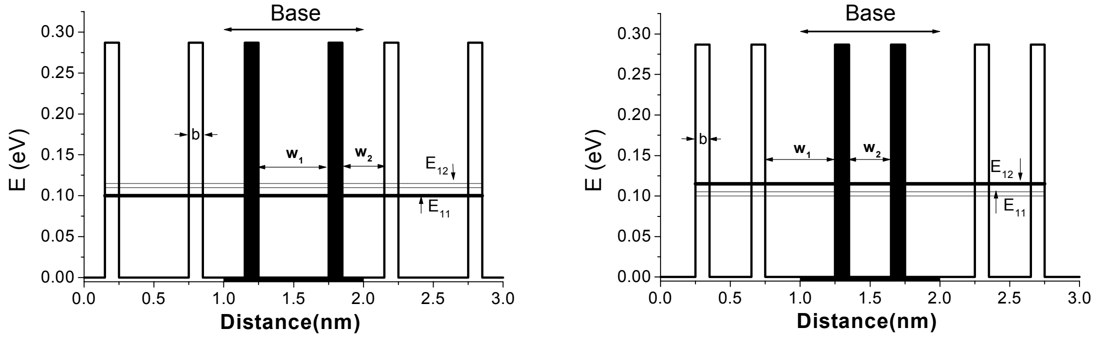
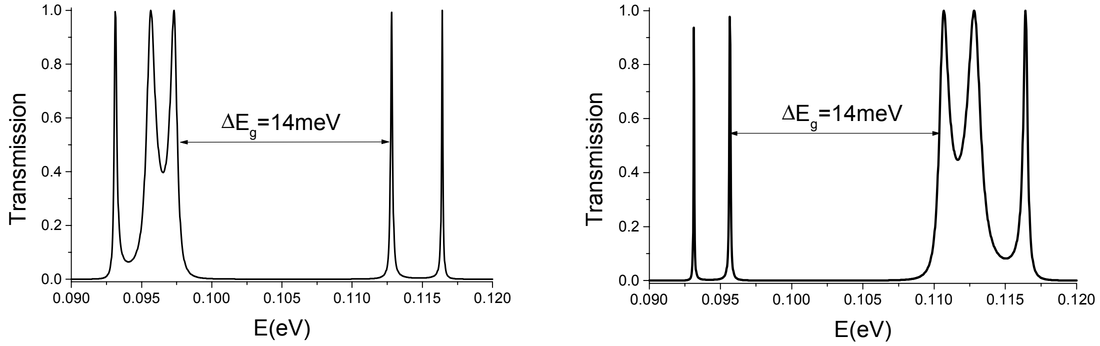


Fig. 1: Conduction band of the investigated double period superlattices.



(a) (b)

Fig. 2: Transmission functions of the investigated double period superlattices.

The structure where narrow wells (w_2) encapsulate the superlattice show two narrow resonances at lower energies and broad resonances at higher energies (Fig. 2 (b)). The superlattice encapsulated by broad wells (w_1) shows an exciting difference in the transmission: the narrow energy resonances are formed at higher energies, and the broad resonances build up at lower energies. This leads to a long lifetime of the resonant electrons at higher energies while the lower resonances provide a channel where electrons can effectively be extracted (Fig. 2 (a)). Thus this system is ideally suited to achieve inversion.

The chosen width of the barriers (b = 4.3 nm) and the wells (w_1 = 4.3nm, w_2 = 3.8nm) shall lead to two clearly separated subminibands with an energy gap $\Delta E_{gap} < 36$ meV, to exclude energy relaxation by LO-phonons in the superlattice. The experiments have been performed with a three terminal device (3TD, Fig. 3) at a temperature T = 4.2 K. In a 3TD hot electrons are injected through a tunnel barrier between two contacts (emitter and base) into a drift region. The energy of these hot electrons is tunable by the applied voltage between the emitter contact and the base contact. After traversing the drift region, the hot electrons reach the double period superlattice structure. In a third contact the electrons, which have been transmitted through the superlattice, are detected as collector current. From the ratio $\alpha=I_C/I_E$ of the measured currents the transmission function is obtained energy-resolved. The high resolution (ΔE = 10meV) [2] of the spectrometer allows it to resolve the two subminibands and to obtain the transmission amplitudes.

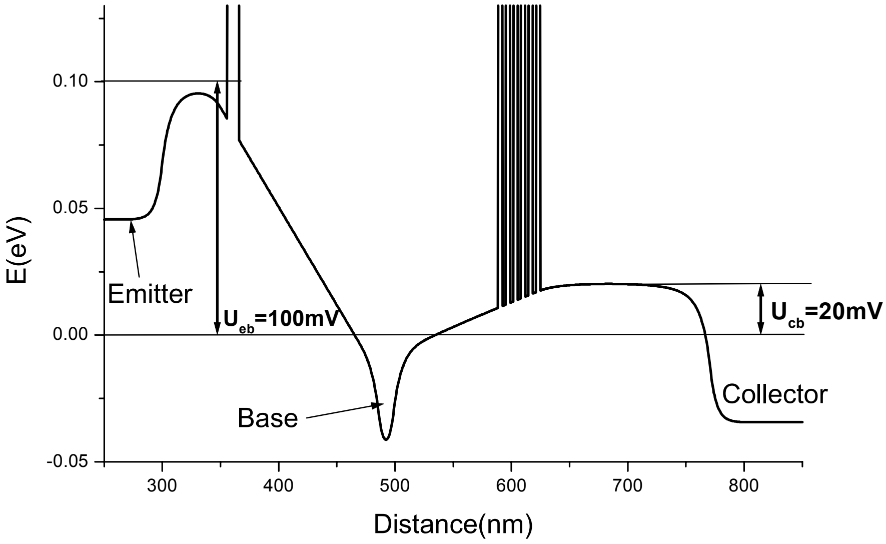
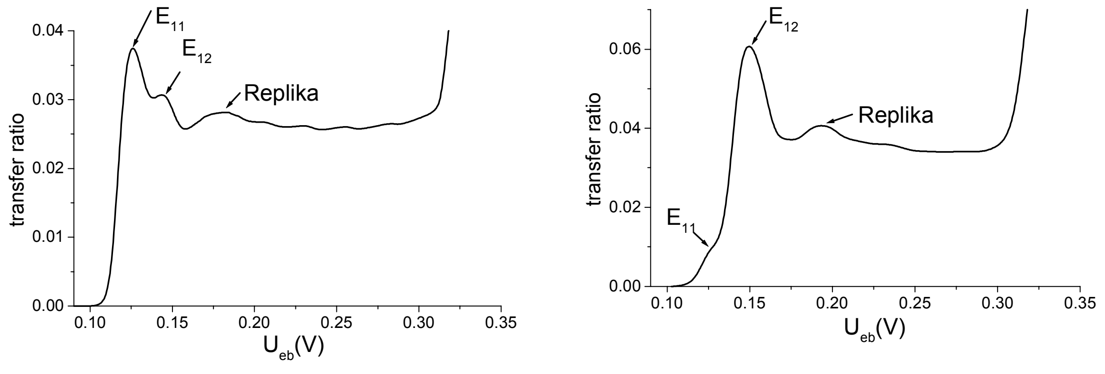


Fig. 3: Conduction band structure of the 3 terminal device.

The experimental results are shown in Fig. 4. The transfer ratio is plotted versus the voltage between emitter and base (U_{be}). The two peaks of both subminibands are indicated by E_{11} and E_{12}. Due to scattering at LO-phonons the transfer ratio stays finite. The peak positions obtained from the transfer ratio show good agreement with the calculated energies of the transmission resonances. Deconvoluting the transfer ratio with the injected energy distribution [2] gives the amplitudes of the low and high energy transmission channels, also in very good agreement with our calculations.



(a) (b)

Fig. 4: Measured transfer ratio of the investigated double period superlattices.

In summary we have shown that double period superlattices can be constructed in a manner that they are perfect systems to achieve inversion.

References

[1] E. H. Boudouti et al., *Phys. Rev. B*, 56, 9603 (1997).

[2] M. Kast, C. Pacher, G. Strasser, and E. Gornik, *Appl. Phys. Lett.* 78, 3639 (2001).