Frequency dependence of acoustic phonon-assisted tunnelling in semiconductor superlattices

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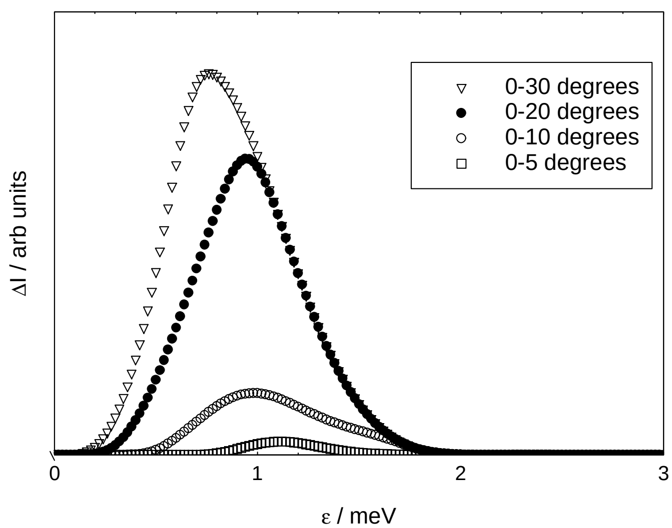
In recent experiments [1,2] we have shown that the change in tunnel current, ΔI(V), through a GaAs/AlAs SL produced by a non-equilibrium acoustic phonon pulse has a maximum at a bias voltage V which varies linearly with the characteristic temperature of the phonon distribution. The form of ΔI(V) is in reasonable agreement with calculations by Glavin et al. [3]. While the experiments clearly show that ΔI(V) is dependent on the dominant phonon frequency, information on the spectral halfwidth Δω (HWHM) of the SL detector is limited by the broad distribution of incident phonons and we can only conclude that $\hbar\Delta\omega \leq k_B T$, where k_BT is the energy halfwidth of the thermal source. A narrower band source would be needed to measure Δω. In the present work we have investigated the halfwidth theoretically by looking at the current changes produced by quasi-monochromatic phonon beams using a model similar to that of ref. [3].

The effect of bias on the SL is to produce an energy separation Δ between the quasi- bound states in neighbouring quantum wells. The frequency, ω_{max}, of the peak in ΔI increases with Δ as expected and is also sensitive to the angular range, $0<\theta<\theta_{max}$, of the incident phonons. Fig. 1 shows ΔI as a function of $\varepsilon = \hbar\omega$ for Δ=2meV and for different values of θ_{max}. $\Delta\omega / \omega_{max}$ increases from ~0.2 to ~0.35 with increasing θ_{max}, and so $q_{\parallel\ max}$ ($q_{\parallel} = q\sin\theta$), while the peak, ω_{max}, moves to lower frequencies. If level broadening can be neglected, $\Delta\omega / \omega_{max}$ should be reduced towards the lower value by quantising magnetic fields, $\infty\omega_c \neq \Delta$, E_F, provided $q_{\parallel\ max} \sim 1/l_B < \Delta/\infty s$ [4] (l_B is the magnetic length and s is the TA sound velocity) both of which are readily achievable. We also note that the dominant assisted tunnelling process contributing to ΔI is stimulated phonon emission [2,3] and, since the sizes of the signals seen in the experiments are approximately thirty times larger than those expected, we believe that phonon amplification may be taking place. This should also result in a significant reduction in the spectral linewidth.

Figure 1.



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