Intersubband Plasmons in InGaAs Quantum Wells

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The excitation of intersubband plasmons (ISP) is a promising new effect for the design of novel THz emission sources. The effect studied in this work is based on the interaction of two resonant plasmon modes. To study this phenomenon a special nanostructure was designed [1], [2]. The core of the structure consists of an RTD and an InGaAs well, providing three energy levels. The idea is to bring the energy difference between the higher energies ΔE_{32} in resonance with the energy difference of the two lower levels ΔE_{21} by tuning the energy levels with occupation differences. As the lowest level is highly populated, the inversion between the levels E_3 and E_2 is achieved by injection of electrons into the third level and the extraction from the second level by the RTD. This way the ISPs can be tuned into resonance by depolarization shifts which depend on the population differences. The coupling between these two ISPs can result in a plasma instability providing growing plasma modes at a resonance frequency $\hbar\omega_r = \Delta E_{31}/2 = (\Delta E_{21}+\Delta E_{32})/2$. This process can be described as a collective electron-electron scattering process [1]. The resonance leads to a very strong extraction of trapped electrons from the lowest level. The lowest level is refilled by an efficient scattering process $3 \rightarrow 1$. The strength of the effect is related to an interplay between the extracting resonant plasmon process and the refilling scattering process. We have grown three samples with varying InGaAs well widths ((a) 31 nm, (b) 28.2 nm, and (c) 26.8 nm) resulting in a variation of E_{31}. Thereby the calculated values for E_{31} ((a) 31 meV, (b) 37 meV, and (c) 40 meV) vary around the LO phonon frequency. Due to the filling of the lowest level, charging leads to a lowering of the energy difference E_{31} resulting in a blocking of the LO phonon process. The resonant plasmon effect is also evident directly in the IV-curves. When the two ISP resonances are tuned to equal values by the injected current a sharp increase of the current is observed.

References

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