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TUNNELING EFFECT ON THE INTERSUBBAND OPTICAL ABSORPTION IN QUANTUM WELL STRUCTURES

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The tunneling effect on the intersubband optical absorption in a quantum well structure subjected to an external electric field perpendicular to the layers has been investigated theoretically. The analysis is based on the calculation of the intersubband transition rate by means of Fermi's golden rule using expressions for the density of states, and the wave functions of the quasi-stationary energy levels inside the quantum well obtained considering the tunneling of electrons. We find that the density of states consists of peaks with asymmetrical broadening, which increase with the electric field and their positions correspond to the quasistationary levels inside the quantum well, and an expression is obtained for the intersubband absorption coefficient as a function of the photon energy. We applied these results to calculate the responsivity spectrum for a multiple quantum well infrared photodetector. The theoretical results are compared with experimental data.

Keywords: A. quantum wells, A. semiconductors, D. tunneling.

1. INTRODUCTION

THE QUANTUM well Stark effect and intersubband optical properties have attracted a great deal of interest because of their potential applications in optical devices [1]. By engineering the well width and barrier height, quantum well devices with desirable properties may be fabricated.

For detector applications, attempts have been made to improve its responsivity since the first GaAs/AlGaAs superlattice infrared detector was reported [2]. Subsequent work has shown that the responsivity of a two-level square well detector can be increased by enhancing the tunneling process of photoexcited states. Recently Levine *et al.* [3, 4] have measured the continuous infrared photoconductivity spectrum for an intersubband absorption photoexcited tunneling quantum well detector. The line shape is broadened and asymmetrical with respect to the zero-bias Lorentzian absorption spectrum. They qualitatively showed that this is a result of the uncertainty principle lifetime broadening due to the rapid tunneling escape of the photoexcited electrons.

The resonance peak width and shift of a quantum well under applied electric field has already been extensively studied by many authors [5, 6]. Ahn and Chuang [7] also calculated the electric field dependence of the intersubband optical absorption in a quantum well. They used an infinite-potential-barrier to calculate the optical matrix element and choose an effective well width to give the same ground state energy of the finite quantum well. Further, the tunneling of the quasibound states of the finite quantum well with an applied electric field is taken into account in the linewidth broadening of the absorption coefficient phenomenologically. Li and Wang [8], on the other hand, pointed out that when an electric field is applied, the excited state wave function tunnels out of the quantum well, leading to an unconfined wave function over a half space. In other words, the overlap integral which gives the transition probability from the ground state decreases since the excited state wave function is no longer strictly confined in the well as in the case of an infinite well. However, they only considered the tunnel effect on the absorption spectrum in the optical matrix element and neglected completely the tunneling effect in the linewidth broadening of the excited state in the presence of an applied electric field.