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Electron transmission in symmetric and asymmetric double-barrier structures controlled by laser fields

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ABSTRACT

The potential profiles of symmetric and asymmetric rectangular double-barrier structures made of (Ga, Al)As/GaAs and the transmission coefficient of an electron in these systems have been investigated under intense laser field. The results show that the field alters the potential profile, and the transmission coefficient can thus be controlled. The transmission at the first resonance energy for the symmetric structure is higher than that of the asymmetric structure. Therefore, the symmetric design is feasible. The properties exhibited in this work may establish guidance to device applications.

1. Introduction

Recent progress in fabricating low-dimensional semiconductor structures has created new opportunities for controlling the transmission of electrons which can be important in determination of the characteristics of electronic devices. In this respect, the electron transmission and resonant tunneling in one dimensional structures is a current problem in theoretical and experimental investigations [1–4]. Based on resonant tunneling phenomenon, experimental research on resonant tunneling diodes [5–7] and resonant tunneling transistors [8–10] have been carried out. Double-barrier resonant tunneling quantum structures have been extensively investigated due to their potential device

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applications [11–14]. Theoretical studies on tunneling phenomena in asymmetric rectangular double-barrier structures [11,12] have been performed. In those studies, the transmission coefficient of an electron and the dwell time is calculated for the specified resonant conditions. Furthermore, the resonant tunneling transmission characteristics have been theoretically studied for asymmetrical rectangular triple-barrier structures [1,15]. It is found that unity resonant tunneling can occur at two independent desired energy levels simultaneously. The resonant states and the oscillations of transmission coefficient for the specific well potentials and barrier potentials have been reported by Uma Maheswari et al. [16,17]. They demonstrate that the maxima in transmission coefficient are correlated with the broad resonances generated by these potentials. Also, the effects of interfacial roughness on transmission probability through GaAs/$Al_xGa_{1-x}As$ double barrier diodes are studied [18].

In recent years, the investigations on interaction of intense laser fields with the electrons in semiconductors have been increased by the advent of high-power tunable laser sources, for example free electron lasers (FEL). The effect of intense high-frequency laser field on the physical properties in low-dimensional structures has been investigated [19–23]. Dynamical behavior of electron transport in a (Ga, Al)As/GaAs double-barrier under high-frequency radiation field has been studied and found that the structures can function as a THz photoelectric switch [24]. The effect of laser field intensity on the polarizability in a quantum well has been studied and it is observed that the polarizability increases as intensity of the laser field increases [25]. The response of the two-dimensional electron density to a laser field in modulation-doped quantum wells has been studied for various field strengths [26]. Theoretical investigations on the effect of laser field intensity on the exciton binding energies have been discussed earlier in double-quantum wells and the results show that the exciton binding energy and the photoionization cross-section depend strongly on the well width and the laser field intensity [27]. The effect of intense laser field on the symmetric and asymmetric Pöschl–Teller potentials has been studied. It has been observed that the laser dressing parameter effectively narrows the well width as the boundaries of the well go to infinity [28]. A study on resonant tunneling tunable by long-wavelength radiation in a double-barrier heterostructure reports only the effects of the laser field on the well between the barriers [29].

In this study, we are focused on the calculation of the transmission coefficient of an electron in the symmetric double rectangular barrier (SDRB) and the asymmetric double rectangular barrier (ASDRB) structures under an intense laser field. We consider the effect on the whole structure. The organization of this article is as follows: the details of the calculation procedures are described in Section 2. In Section 3, the numerical results are given together with their discussion. Section 4 sums up the conclusions.

2. Theory

We show a double barrier structure which cannot be expressed by linear functions in Fig. 1. To obtain transmission coefficient, T, of an electron in this structure, the system is divided to N parts

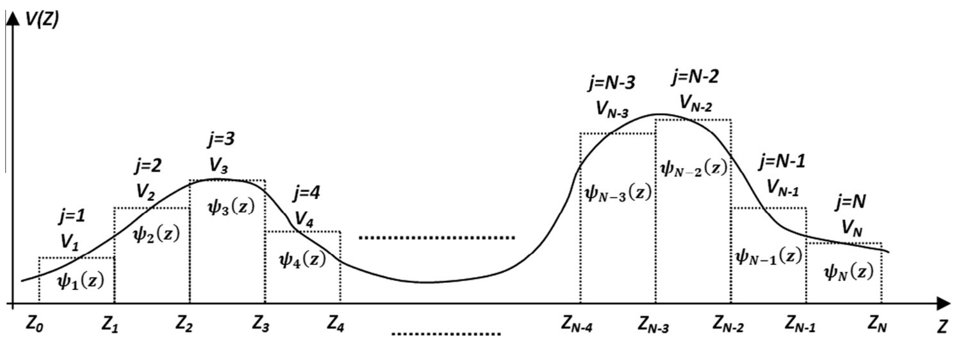

Fig. 1. Potential profile model of a double-barrier.