

Donor electron in a quantum well under the influence of an electric field

B SUKUMAR and K NAVANEETHAKRISHNAN

School of Physics, Madurai Kamaraj University, Madurai 625 021, India

MS received 9 April 1990

Abstract. The ionization energies and the polarizabilities of a donor in an isolated well of a quasi two dimensional (Q2D) GaAs/Ga_{1-x}Al_xAs heterostructure have been obtained for different well widths including electron-lattice coupling. A wave function that properly reduces to the hydrogenic function in the limiting case has been used. For fields of the order of 10⁵ V/m, the ionization energies decrease slightly with electric fields for all well widths (10 nm to 50 nm) studied. Also for a given electric field, as the well width increases, the ionization energy decreases. For fields of the order of 10⁷ V/m and for smaller well widths (< 10 nm), the ionization energy generally increases with electric field. The results also show that for electric fields of this order, no donor bound state associated with the lowest subband is possible for well widths greater than 20 nm. The polarizabilities estimated using the expression for the dipole operator show that as the well width increases, the polarizability values also increase and do not show any abnormal behaviour.

Keywords. Quantum well; Q2D system; donor energy; polarizability; electron-lattice coupling.

PACS Nos 71-55; 71-38

1. Introduction

Among the low dimensional systems, GaAs/Ga_{1-x}Al_xAs superlattice system has been subjected to vigorous experimental and theoretical analysis. The interest in these Q2D and Q1D systems stem from the fact that these systems exhibit several novel phenomena (Berggren 1988; Ando *et al* 1982). Donor states in these Q2D and Q1D systems have also been studied theoretically (Bastard 1981; Brown and Spector 1986) and experimentally (Delalande 1987; Meseguer *et al* 1987). Donor states under external perturbations like electric (Brum *et al* 1985) and magnetic fields (Greene and Bajaj 1985) have also been pursued with great interest. It has also been shown that no bound states are possible in a quantum well of a 2QD system with a finite barrier, separating the GaAs well and the GaAlAs regions under a strong electric field applied along the superlattice growth axis (Bastard *et al* 1983). Recently, the present authors worked out the polarizabilities of a quantum confined charge carrier in such a quantum well (Sukumar and Navaneethakrishnan 1989). The pressure dependence of the diamagnetic susceptibility of a donor has also been worked out recently (Sukumar and Navaneethakrishnan 1990). In the present work, we would like to report the results of our investigations on the ionization energies and the polarizabilities of a donor in a quantum well. The present work differs from the other calculations on the donor binding energies in the sense that we have used a wave function that correctly reduces to the hydrogenic form, in the limit $L \rightarrow \infty$ (L — is the well width)