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Analytical Determination of Degeneracies in an 8-Band Solid with Zincblende Structure under Intrinsic and Extrinsic Spin-Orbit Interaction

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Extended Abstract

In the field of condensed matter physics, zincblende-type semiconductors, such as GaAs and InAs, are fundamental due to their high symmetry and unique electronic properties, positioning them as key materials for applications in spintronics and optoelectronics [1]. This work analyzes the behavior of spin-orbit interaction (SOI) in the bulk, a coupling between the spin and orbital momentum of electrons, within the band structure of a zincblende solid modeled using an 8-band, with the $\mathrm{k} \cdot \mathrm{p}$ approximation [2].

Two main contributions to the SOI are considered: the intrinsic Dresselhaus interaction, derived from the crystal asymmetry, and the extrinsic or Rashba interaction, generated by external fields, asymmetric interfaces, impurities, or lattice distortions [3]. The objective is to analytically derive the system's energies and observe how these interactions affect the system's degeneracies.

This work includes the complete Hamiltonian, calculating each matrix element corresponding to the additional Hamiltonian terms: the term describing kinetic energy and the hydrogenoid impurity potential H_0, the intrinsic spin-orbit interaction $H_{SO_{int}}$, the extrinsic spin-orbit interaction $H_{SO_{ext}}$, and the additional $\mathrm{k} \cdot \mathrm{p}$ term $H_{k \cdot p}$, to obtain the energies and provide a qualitative and quantitative analysis of the contributions from Rashba and Dresselhaus.

The results include corrections to the energies and breaking of degeneracies, depending on the specific conditions of the system, where the extrinsic interaction produces non-zero corrections to the energy level, while the intrinsic interaction does not contribute energy due to the cancellation of the term caused by the symmetry of the material and the parity of the wave functions. This study has direct implications for spintronic devices by facilitating spin control. Finally, this analysis provides a detailed understanding of the intrinsic and extrinsic contributions to the SOI, consolidating a robust theoretical foundation for designing new materials and advanced devices [4].

References

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