# Spin-orbit vs. Zitterbewegung in 2D Kane and Dirac-like semiconductors

**P. E. Kunavin, E. L. Rumyantsev**

*Institute of Natural Sciences, Ural Federal University, 620000 Ekaterinburg, Russia*

The effect of Zitterbewegung being of great theoretical interest in recent years [1, 2] is considered within second quantized method in intrinsic 2D Kane semiconductors with normal and inverted band ordering. The 2D Dirac-like Hamiltonian was subjected to the same transformation in order to verify the proposed approach. It was shown in this "classical" situation that the unambiguous expression for single particle position operator can be obtained if we define it in accordance with the expression for spin-orbit (SO) term induced by linear potential (constant force): $\hat{V} = -F \cdot \hat{x}$. This particular SO term so as general expression (coinciding with classical one as it must be) were obtained within the same approximation as was used during investigation of Zitterbewegung effect, namely, the vacuum (Dirac sea, filled valence band) was considered to be stable under application of external potential. The obtained expression for position operator in momentum representation contains curl-like terms which contrary to considered by Dirac gradient terms cannot be excluded by the redefinition of Eigen functions phases [3]. In Kane problem the expressions for position operators of electron, light (LH) and heavy holes (HH) were obtained along the same way of derivation within the same approximation neglecting electron-hole pair-production. It was shown that as the introduced position operators in Kane problem demonstrates non local behavior as in classical paper [4], the interconnected with them SO terms are in general also non-local. It is shown that along with common expressions for SO terms of the second order of parameter $Pk/E_g$ ($P$ - Kane velocity) the additional "topological" terms of the zeroth order in this parameter emerges in proposed approach. Their arising is due to the degeneracy between LH and HH for direct ordering, or to the degeneracy between electron band and HH in the inverted case at the $\Gamma$ point. This fact is confirmed while considering Dirac problem where the same type of terms are obtained in "graphene case" at $E_g = 0$ (Dirac point). Contrary to Dirac problem where symmetry between electron and hole SO terms exists, in Kane problem the SO terms for electrons and LH demonstrate different behavior.

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