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Berry phase and extraordinary Landau levels shift

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CgHgTe / HgTe / CdHgTe quantum wells due to large Hg mass, resulting in strong relativistic effects and thus to inverted spectrum of 3D HgTe, are rather different from other known quantum wells based on semiconductor heterostructures. Thus HgTe quantum wells have different energy spectra and so different interesting properties depending on a well width [1]. It is an ordinary insulator at width $d < 6.3$ nm; it has linear spectrum of so called Dirac fermions at $d \approx 6.3$ nm; inverted spectrum being 2D topological insulator at $d > 6.3$ nm; semimetallic spectrum with a small overlap between the conduction and vallence bands at $d \approx 20$ nm; finally at width $d > 70$ nm it is 3D topological insulator [2].

The work is devoted to the experimental investigation of Shubnikov - de Haas oscillations (ShdHO) in wide (20 - 22 nm) HgTe quantum wells. Previously for these wells it was indirectly shown by study of roughness scattering that electrons in a conduction band at large energy start to locate near well surfaces [3]. Together with calculated spin polarization of the states these wells look similar to 3D topological insulator with quantum well instead 3D volume. The present work was first directed to study more detailed obtained surface states. Experimentally we indeed obsereved appearance of beatings in oscillations with applying external gate voltage. This can be well described in model of two types of carriers (electrons on two well surfaces) which at nonzero gate voltage, due to screeneng the gate by the top surface towards the bottom one, have different electron concentrations and thus different ShdHO frequencies.

Besides observing what was expected we found an interesting Landau levels (LLs) behavior with mangnetic field increase. Landau levels degenerated at low magnetic field split at large magnetic field but instead separating also with naighbor LLs they come closer to them and degenerate causing period doubling of Shubnikov - de Haas oscillation. Such a behavior can be explained by mixing of the first conduction band states with total momentum 3/2 (due to inverted band structure) with states of second band which has momentum 1/2. This mixing causes changing of Berry phase and thus Landau levels energy.

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