Microwave-induced resistance oscillations and zero-resistance states in 2D bilayer systems

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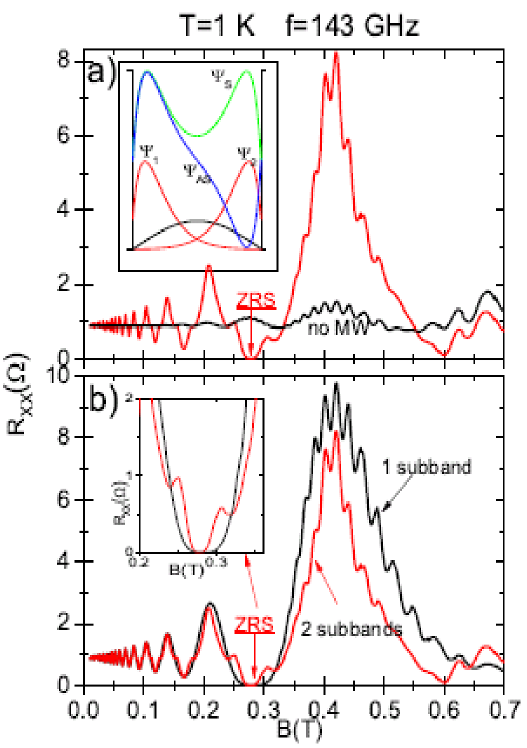
In the last decade it was discovered that when a Hall bar (a 2DES with a uniform and perpendicular magnetic field (*B*)) is irradiated with microwaves, some unexpected effects are revealed, deserving special attention from the condensed matter community: microwave-induced (MW) resistance oscillations (MIRO) and zero resistance states (ZRS) [1]. These remarkable effects show up at low *B* and high mobility samples, especially ZRS where ultraclean samples are needed. Different theories have been proposed to explain these striking effects but the physical origin is still being questioned. To shed some light on the physics behind them, a great effort has been made, especially from the experimental side, growing better samples, adding new features and different probes to the basic experimental setup, etc. One of the most interesting setups, carried out recently, consists in using samples with two or three occupied subbands [2]. These samples are either based in a double quantum well structure or just one single but wide quantum well. The main difference in the longitudinal magneto-resistance (*Rxx*) of a two-subband sample is the presence of magneto-intersubband oscillations (MISO).



In this work, we theoretically study magneto-resistance of a Hall bar being illuminated with MW radiation when two electronic subbands participate in the transport. We apply the theory developed by the authors, the MW-driven electron orbits model [3], which we extend to a two-subband scenario. According to this theory, when a Hall bar is illuminated, the electron orbit centers of the Landau states perform a classical trajectory consisting in a harmonic motion along the direction of the current. Thus, the whole 2DES moves periodically at the MW frequency altering dramatically the scattering conditions and giving rise eventually to MIRO and ZRS. In a double subband scenario the situation gets more complicated but with a richer physics. On the one hand, due to the presence of MW, we have two 2DES (two subbands) moving harmonically at the MW-frequency. On the other hand, we have two possible scattering processes with charged impurities: intra and inter-subband. We then calculate the two corresponding elastic impurity scattering rates, obtaining that the intra one is, approximately, three times larger than the inter-subband. This means first, that the current is mainly
supported by intra-subband scattering processes. Secondly and more important, the competition between intra and inter-subband scattering events under the presence of radiation alters significantly the transport properties of the sample. This is reflected in the magneto-resistance profile through a strong and peculiar interference effect. As in experiments, our calculated results recover the presence of new features regularly spaced through the whole MIRO's profile, mainly two shoulders at minima and narrower peaks (see Fig.). Within the same theory, we have obtained also ZRS in same position of experiments and with the same MW-frequency dependence. Finally, we have studied the influence of MW-power (*P*) and temperature (*T*) on MIRO's of the two subband sample and the obtained results are also in reasonable agreement with experimental result.

References

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