Robust helical edge transport at ν = 0 quantum Hall state in HgTe quantum wells with graphene-like energy spectrum

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Two dimensional massless Dirac fermions in the presence of a strong perpendicular magnetic field show several remarkable features that sharply diverge from conventional behaviour. The energy spectrum is organized in Landau levels (LL) with square root versus linear dependence on the magnetic field and square root dependence on the Landau index n versus n+1/2, in comparison with the parabolic dispersion at the zero field. The most remarkable consequence of this last property is the existence of a zero-energy Landau level (ν = 0). This is not due to the linear spectrum, but is related to the π Berry phase carried by each Dirac point. Therefore, the ν = 0 LL has a magnetic field independent energy, which is quite different from a quantized cyclotron orbit in the conventional quantum Hall effect. The existence of the zeroth Landau level has been examined by measurements of the integer quantum Hall effect (QHE) in graphene with two-valley degenerate spectrum [1]. Application of other materials that posses a single Dirac cone is of particular interest.

Recently a two-dimensional system with a single Dirac cone spectrum, based on HgTe quantum wells, has been discovered. The single spin degenerate Dirac valley allows unambiguous identification of the features resulting from the bulk zeroth Landau level. In addition, the high mobility and giant Lande g-factor favor formation of spin-polarized counter propagating states.

In the present paper, we studied the nonlocal transport in 10-probe devices fabricated from HgTe zero-gap quantum structures. We observe a magnetic field induced, giant, nonlocal resistance peak near the CNP in different configurations of current and voltage probes. The nonlocal response is comparable with local resistance and increases rapidly with B. Simple Kirchhoff based estimations and more complicated model calculations clearly confirm the existence of helical edge states originating from the bulk zeroth LL.

References

[1]. K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, M. I. Katsnelson, I. V. Grigorieva, S. V. Dubonos and A. A. Firsov, Nature, 438, (2005) 197

Figures

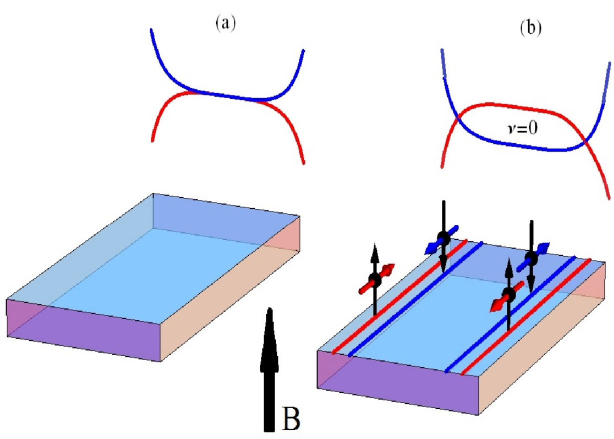

Figure 1 Schematics of band structure (energy spectrum) in low (a) and high (b) magnetic field, showing the zero LL in the middle of the sample and at the sample edge, and counter propagating spin polarized edge states in a slab-shaped sample for the ν=0 LL state.