Integer and Fractional Helical States in the Quantum Hall Effect regime

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In recent years, efforts to observe helical edge states in materials with large spin-orbit coupling have accelerated. These material, once in proximity to an s-wave superconductor may, under certain conditions, manifest a topological superconductive (TS) phase [1]. Consequently, Majorana fermions, allusive quasiparticles with a non-Abelian exchange statistic, are expected to emerge. Even more interesting are the fractional helical states, previously not observed, which manifest the more exotic para-fermion anyons. Though evidence for the presence of Majorana fermions accumulates, observations of helical edge transport, being a prerequisite for the formation of Majorana quasiparticles, are scarce. Encouraged by proposals that induce topological superconductivity in 2DEG at the quantum Hall effect (QHE) regime [2, 3], we succeeded to form such, the sought after, robust chiral helical edge modes in GaAs-AlGaAs heterostructures.

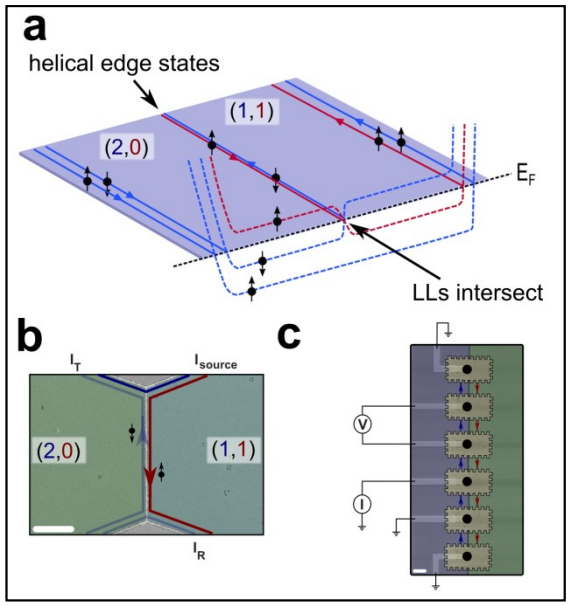

Fig: a. Schematic illustration demonstrating helical edge states formation when the Fermi energy is tuned to LLs intersection point. **b.** Colored SEM: Interface region with two counter-propagating helical modes (scale-2μm). Reflected and transmitted current are measured, confirming absence of tunneling between the modes. **c**. Colored SEM: Contacts along the interface region (scale-10μm).

In order to have two adjacent **counter-propagating** edge modes with **opposite spin**, the 2DEG is embedded in a unique quantum well structure, which hosts two weakly interacting electronic sub-bands. Gating the 2DEG with two half-plain gates, enable a scenario where two different filling factors (ν_{down}, ν_{up}) are applied to the lower and upper sub-bands. Landau levels of different sub-bands cross at the interface between the two gates; thus forming overlapping, counter-propagating, chiral edge modes. Two counter-propagating edges with opposite spins, both in the integer and fractional regime were observed, propagating for more than 300 microns without mixing. In addition, spin protected tunneling was observed depending on spin orientation.

[1] L. Fu and C. Kane, PRL **100**, 096407 (2008).
[2] N.H. Lindner, E. Berg, G. Refael and A. Stern, PRX **2**, 041002 (2012).
[3] D.J. Clarke, J. Alicea and K. Shtengel, Nature. Communication **4**, 1348 (2013).