Microwave spectroscopy of topological quantum states in the quantum Hall bulk

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The quantum Hall effect where the occurrence of the universal quantization in the resistance independent of sample details, indicating its origin in the quantum topology. The formation of the discrete energy states which due to the Fermi level crossing leads to band-bending at the sample edges, resulting in the formation of chiral edge states and localized states in the bulk. Here the current is carried by the chiral current at the edges without backscattering and while the bulk is incompressible where the addition of the electron costs finite energy. This results in the $\rho_{xx} = 0$, $\rho_{xy} = h/ne^2$ where n is an integer in the case of Integer quantum Hall states [1]. Contrary to conventional 2-DEG, graphene is atomically thin, where stronger Coulomb interactions result in the formation of more robust and unconventional quantum states [2]. However, the hard-wall confinement and the non-uniform electrical field distribution at the physical edges of graphene result in the formation of upstream and downstream edge channels. The lattice defects at their physical edges may lead to coupling between upstream and downstream edge channels eventually resulting in the topological breakdown of quantum Hall states [3]. This dissipative phenomenon at the physical edges of graphene make it less attractive for electron quantum optics. An alternative route for this is to manipulate topological states found in graphene bulk. Here we develop the quantum antidot in graphene without physical etching of the graphene and probe the robustness of the topological edge states via microwaves in addition to Hall transport measurement. The microwave resonant spectroscopy developed here will form a potential tool to study non-Abelian quantum Hall states for example $\nu = 5/2$ in confined geometry [4].

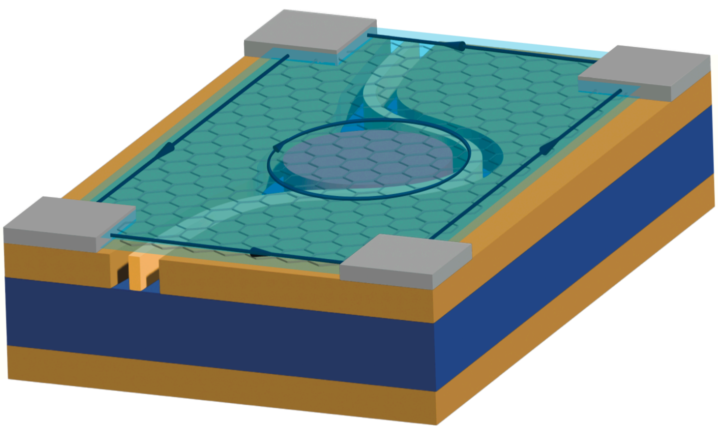

Figure 1: Proposed sample structure: *graphene placed on a transmission line with a superconductor in the middle which will block the magnetic field and form quantum Hall state with different filling factor around its edge. The transmission line will measure the bulk states and the metal contacts measure Hall transport.*

References:

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2. Kumar, M. *et al*. Nature Communication **9**, 2776, 2018
3. Marguerite, A. *et al*. Nature **575**, 628, 2019
4. Willett, R. L. *et al*. Physical Review Letters **111**, 186401, 2013

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