Breakdown of the topological protection by cavity vacuum fields in the integer quantum Hall effect

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At mK temperatures we measure electron transport, Shubnikov de Haas (SdH) oscillations and Hall resistance. The platform consists of an etched GaAs two-dimensional electron gas heterostructure, forming a Hall bar geometry, combined with a 2-D metamaterial split ring resonator. Amplified vacuum fields are confined in its gap, i.e. at the position of the Hall bar (fig.1). On a chip we measure multiple samples sharing source and drain. Like this, we can directly compare effects of the cavity on longitudinal and transverse resistances with respect to the unperturbed system. In the diffusive transport regime, we observe an amplitude reduction in the SdH when coupling the electrons to amplified vacuum fields [1]. Shifting our focus to the quantized states of the integer quantum hall regime, in our latest study [2] we draw out the effect of vacuum fields breaking the topological protection of edge states: the hall quantization is lost (fig. 2), while in the very same sample much more fragile states, the fractional states, persist due to their inability to couple to optical modes as postulated by Kohn's theorem. The accompanying picture to this effect is introduced as cavity-mediated electron hopping. Conceptually it describes how electrons scatter from topologically protected edge states into bulk disordered states [3]. With a current theoretical work predicting modifications to the quantized Hall conductance as a function of the light matter coupling [4] this platform can be of major interest in studying the fundamental physics of matter coupled to vacuum fields.

References

[1] G.L. Paravicini-Bagliani et al., Nat. Phys, 15.2 (2019) 186-190
[2] F. Appugliese, J. Enkner et al., Arxiv, 2107.14145 (2021)
[3] C. Ciuti Arxiv 2107.09435v1 (2021)
[4] V.Rokaj et al., Arxiv, 2109.15075v1 (2021)

Figures

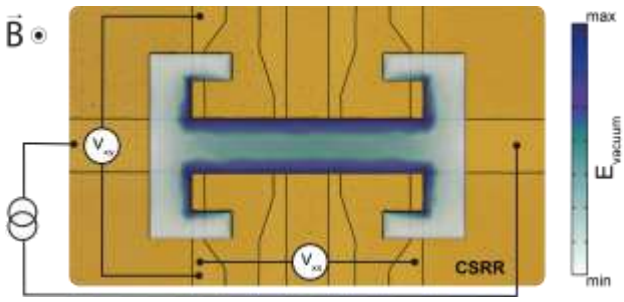

Figure 1: Visualization of cavity field distribution penetrating the Hall bar located in its gap. V_{xx} and V_{xy} indicate voltage probes for longitudinal and transverse resistivity measurements

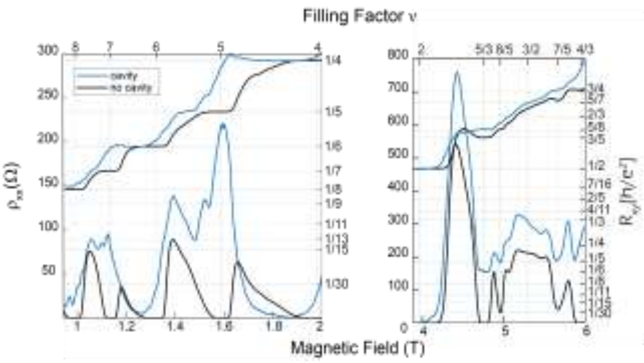

Figure 2: longitudinal and transverse resistance are shown for a cavity embedded Hall bar (blue) and a cavity-less reference Hall bar (black). The reference is well quantized, the cavity shows a collapse at filling factors 5 and 7 (left). The fractional states around 3/2 are still visible for both samples (right).