In situ modification of quantum Hall phases by cavity vacuum fields

Ethan Koskas
Josefine Enkner, Lorenzo Graziotto, Dalin Boriçi, Felice Appugliese, Christian Reichl, Giacomo Scalari, Nicolas Regnault, Werner Wegscheider, Cristiano Ciuti, and Jérôme Faist

ETH Zürich, HPT F10, 8049, Zürich, Switzerland

ekoskas@ethz.ch

Controlling the ground state of solid-state systems with engineered cavity vacuum fields opens new perspectives for the optical control of materials [1,2]. By placing a complementary split ring resonator (CSRR) on top of a GaAs-based heterostructure hosting 2D electrons, ultra-strong coupling between the cavity vacuum fields and Landau levels is achieved. This interaction induces long-range electron scattering, leading to a breakdown of topological protection in the integer quantum Hall regime [1]. Real-time modification of light-matter coupling is achieved by tuning the distance between the CSRR and the Hall bar (Fig. 1). As the coupling increases, the gaps of several fractional states increase (Fig. 2), while the effective g-factor at high odd filling factors decreases [3]. Both effects can be understood as the result of an effective cavity-mediated attractive electron-electron interaction. A recent study also shows a cavity-induced anisotropy in the electronic transport, interpreted as the stabilization of disordered quantum Hall stripes by the vacuum fields [4]. Together, these results provide a demonstration of cavity QED control over electronic phases.

References

[1] F. Appugliese *et al*. *Science* 375, 1030–1034 (2022).
[2] A.Rubio. *Science* 375,976-977(2022)
[3] J . Enkner *et.al. arXiv*:2405.18362 (2024)
[4] L. Graziotto *et al. arXiv* : 2502.15490 (2025)

Figures

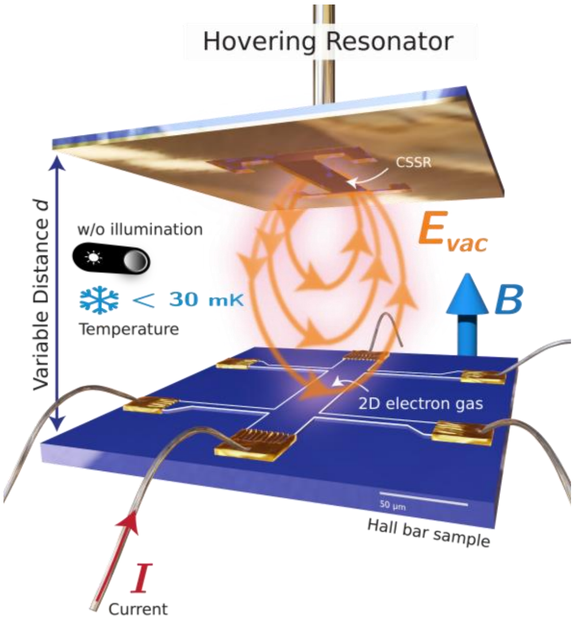

Figure 1: Layout of the experimental setup used to tune the coupling strength between the 2D electrons and the fringing vacuum electromagnetic fields of a CSSR. Magneto-transport measurement are performed in the dark at cryogenics temperature.

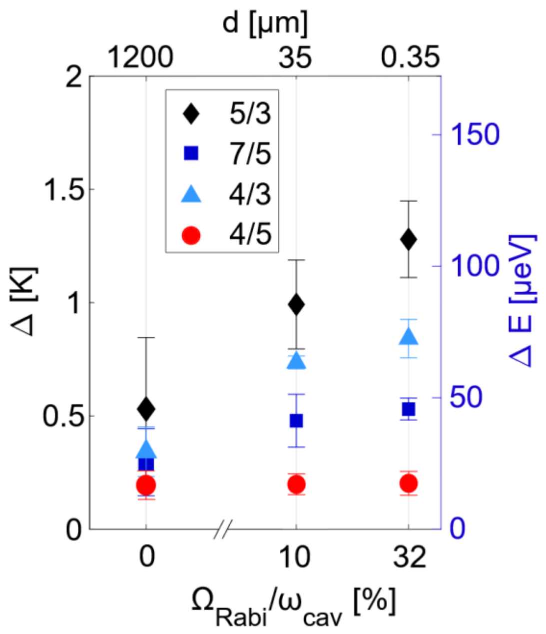

Figure 2: In situ increase of the fractional Hall gaps with the coupling strength.