Anomalous acoustoelectric transport in graphene quantum Hall regimes

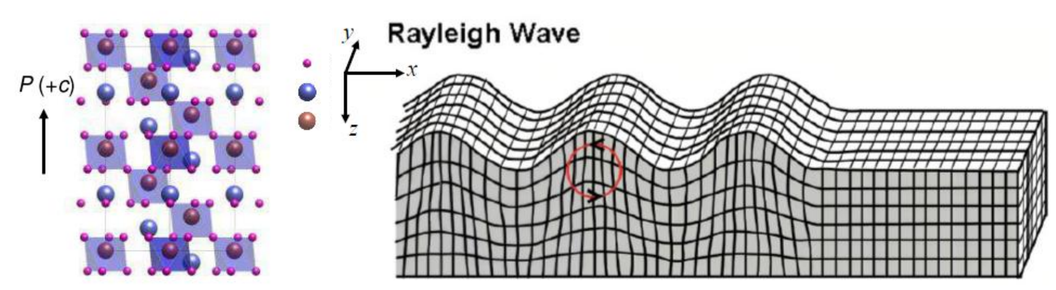
Zixuan Xu[1#], Ziqian Zhou[2#], Yingchao Xia[1], Jiayu Wang[1], Haonan Chen[1], Jiaming Gu[1], Jiaqi Liu[1], Zifan Zhang[1], Pengyu Wan[1], Wu Shi[1,5], Hua Jiang[1,3*], Xincheng Xie[2,3,4*], Cheng Zhang[1,5*]

[1] State Key Laboratory of Surface Physics and Institute for Nanoelectronic Devices and Quantum Computing, Fudan University, Shanghai 200433, China
[2] International Center for Quantum Materials, School of Physics, Peking University, Beijing 100871, China
[3] Interdisciplinary Center for Theoretical Physics and Information Sciences, Fudan University, Shanghai 200433, China
[4] Hefei National Laboratory, Hefei 230088, China
[5] Zhangjiang Fudan International Innovation Center, Fudan University, Shanghai 201210, China

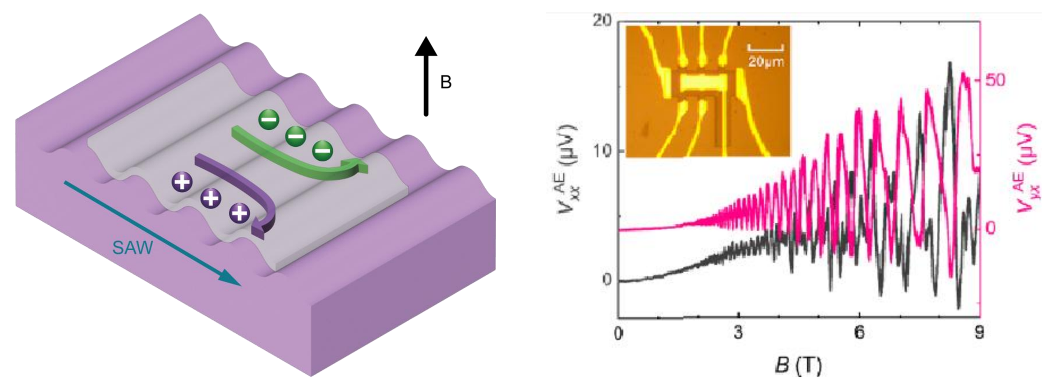
Correspondence:
zhangcheng@fudan.edu.cn
jianghuaphy@fudan.edu.cn

Introduction

Piezoelectrically generated surface acoustic waves (SAWs)

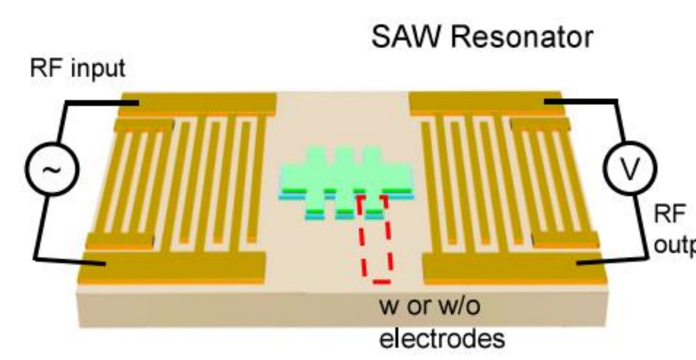


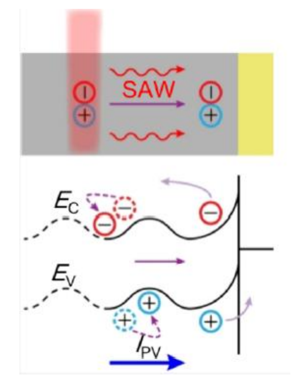
Acoustoelectric (AE) transport probes quantum oscillations



Acoustic attenuation unveils quantum oscillations

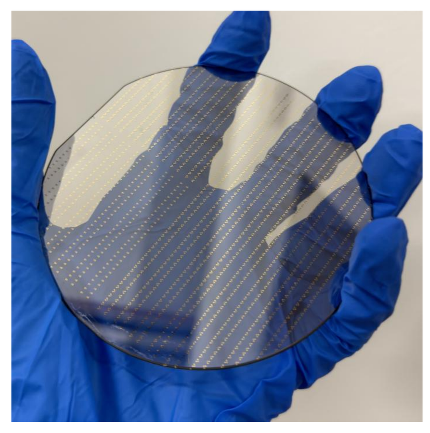
Acousto-drag photovoltaic effect



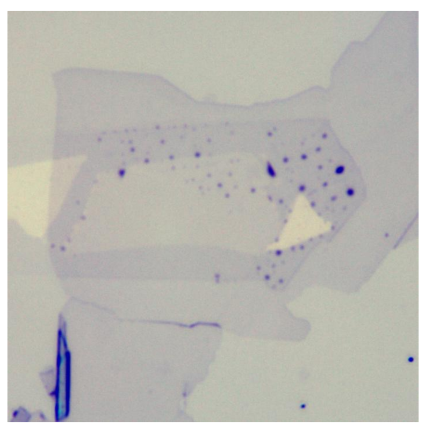


Methods

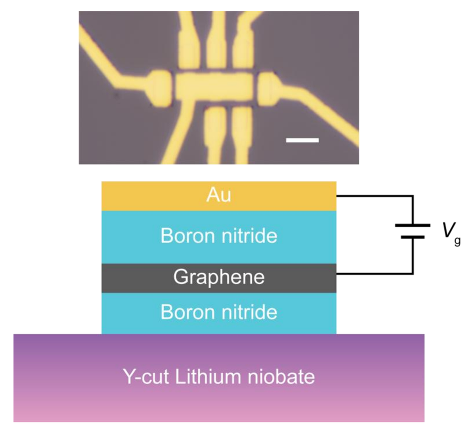
Device fabrication

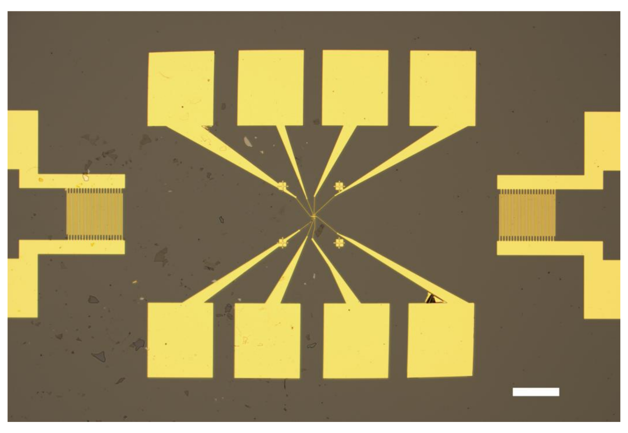


Delay-line IDTs on Y-cut $LiNbO_3$



Standard dry-transfer technique
hBN/graphene/hBN heterostructures

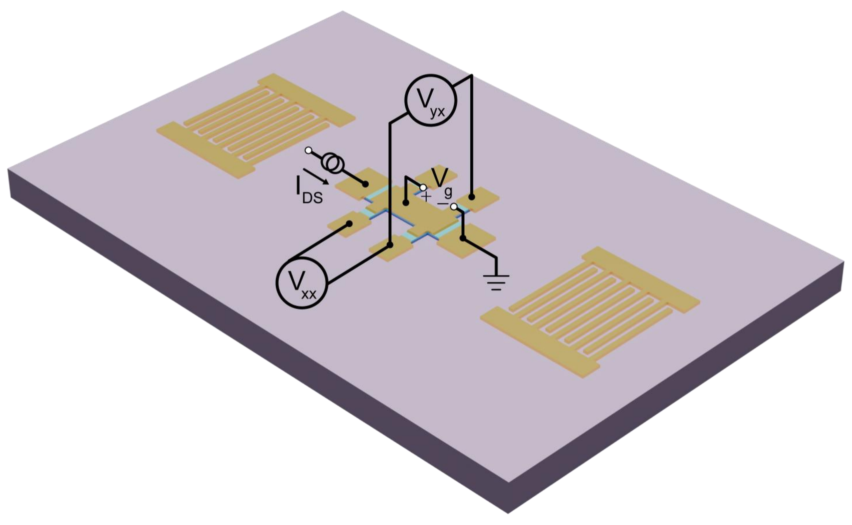




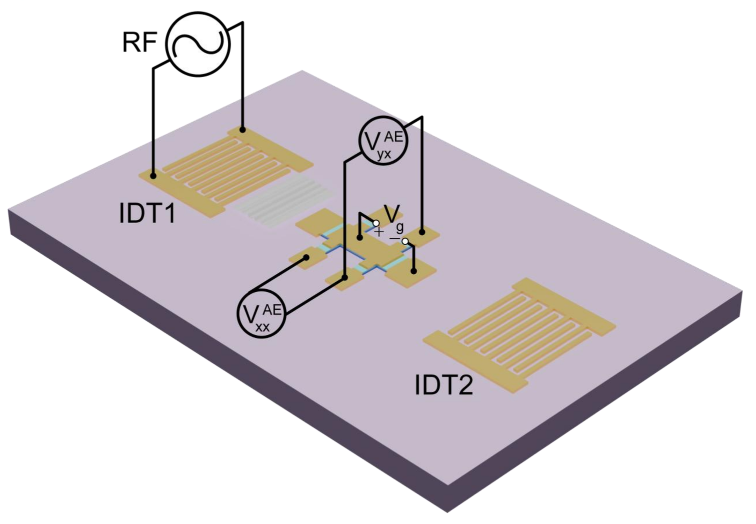
Electron beam lithography (EBL) - Electron beam evaporation (EBE) – EBL- Reactive ion beam etching (RIE) - EBL - RIE - EBE

Electrical transport & AE transport measurements

Cryogenic Superconducting Magnet System
2 K, 12 T



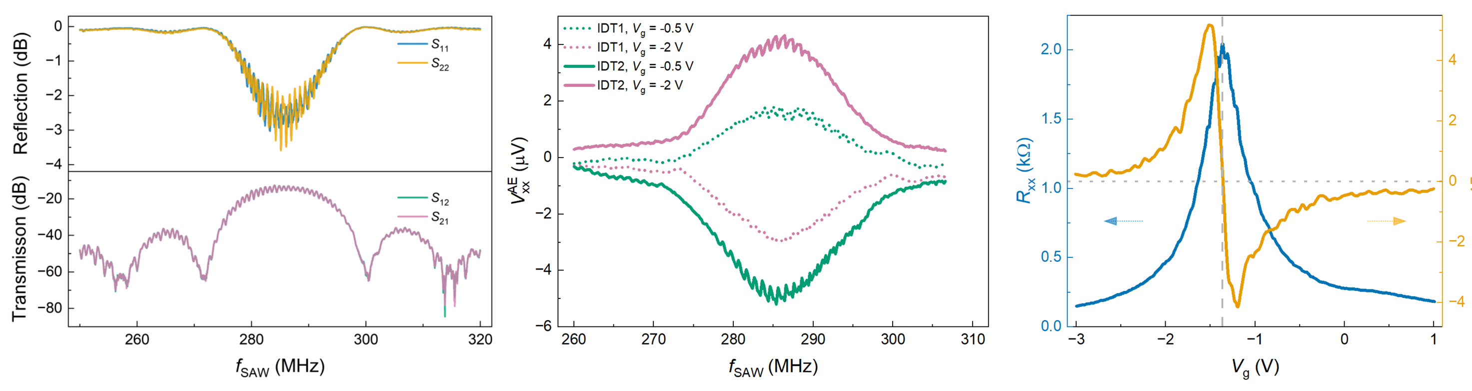
Standard four-probe configuration
AC lock-in techniques



Pulsed-amplitude-modulated SAWs
Open-circuit conditions

Results

Zero-field characterization

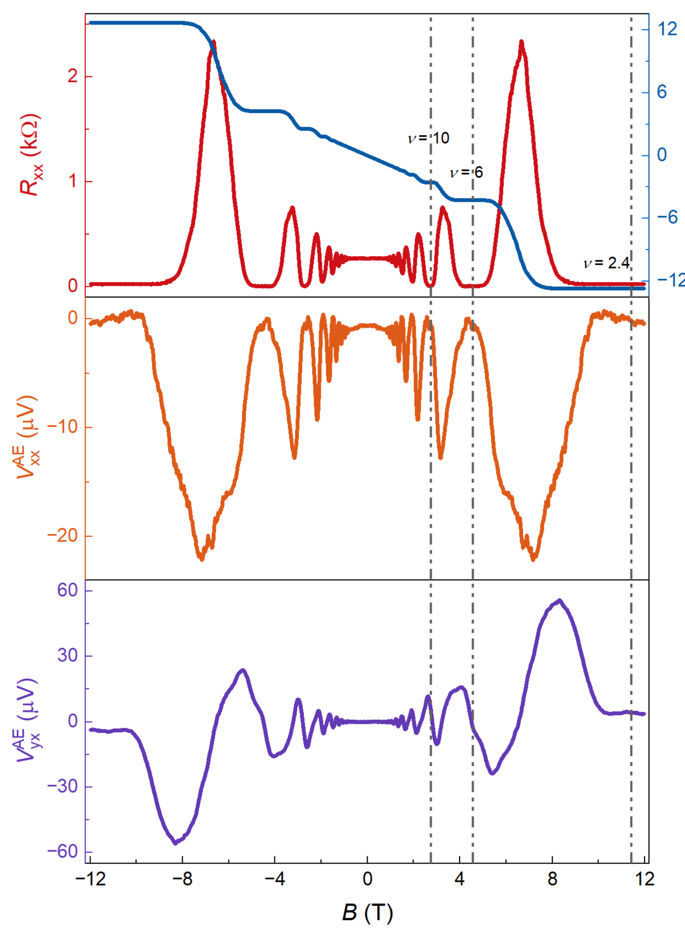


Center frequency ~285.5 MHz

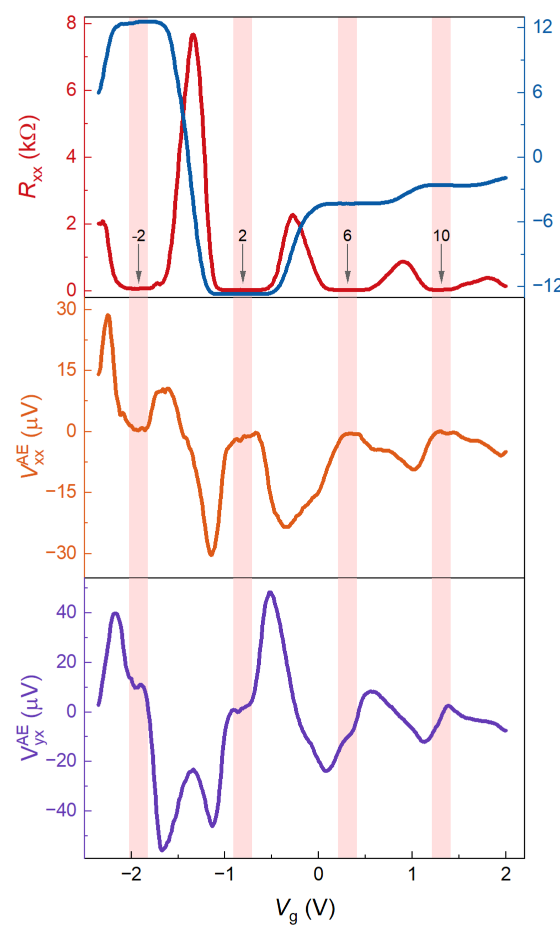
SAW relaxation model

$$J_{xx}^{AE} = -\frac{\pi K^2 I \sigma_m}{e \lambda v} \frac{(n_e - n_h)}{(n_e + n_h)^2}$$

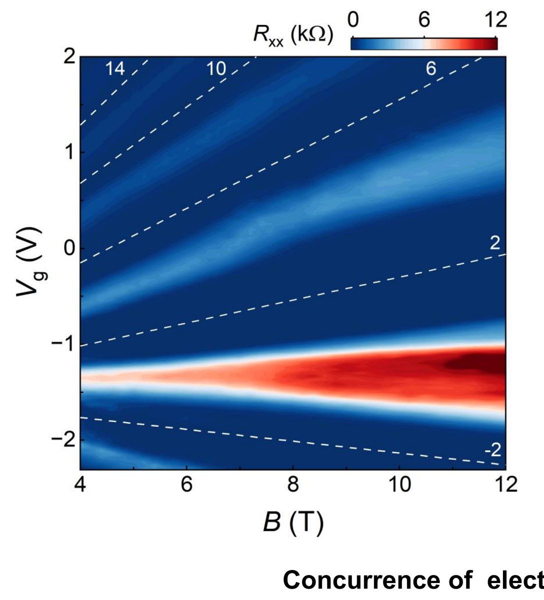
Comparing Electrical and AE Transport

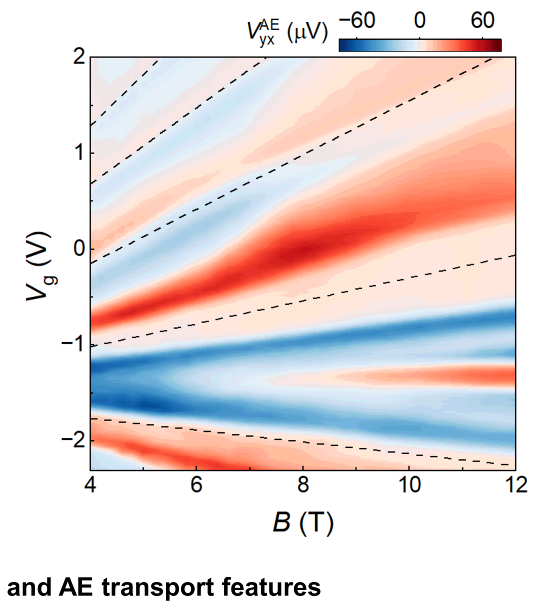


Magnetic field dependence



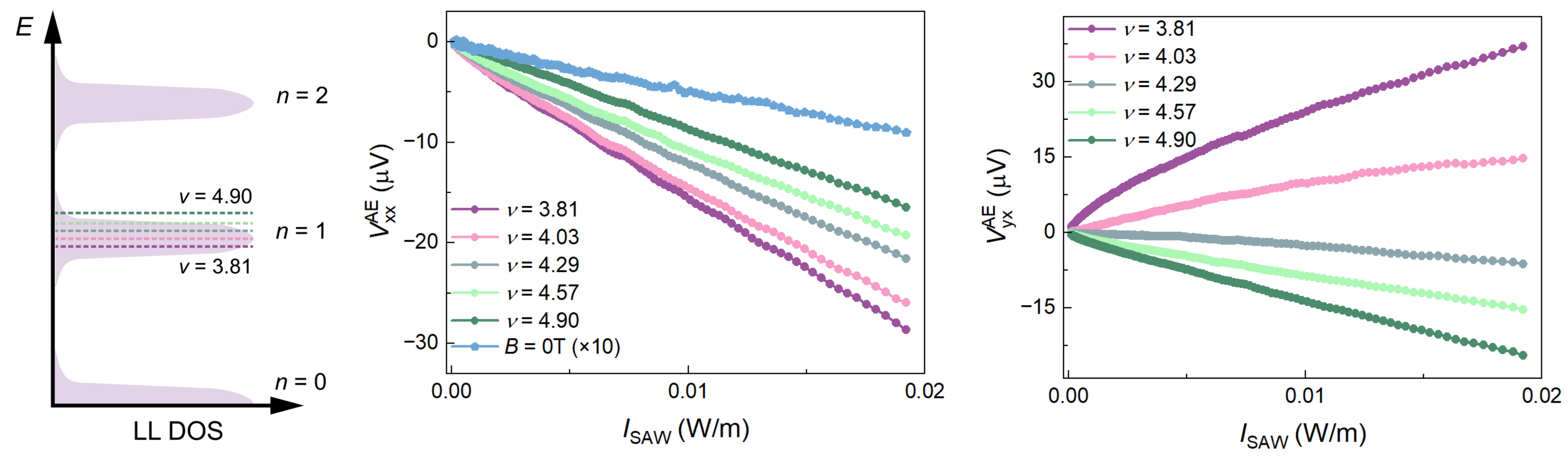
Gate voltage dependence



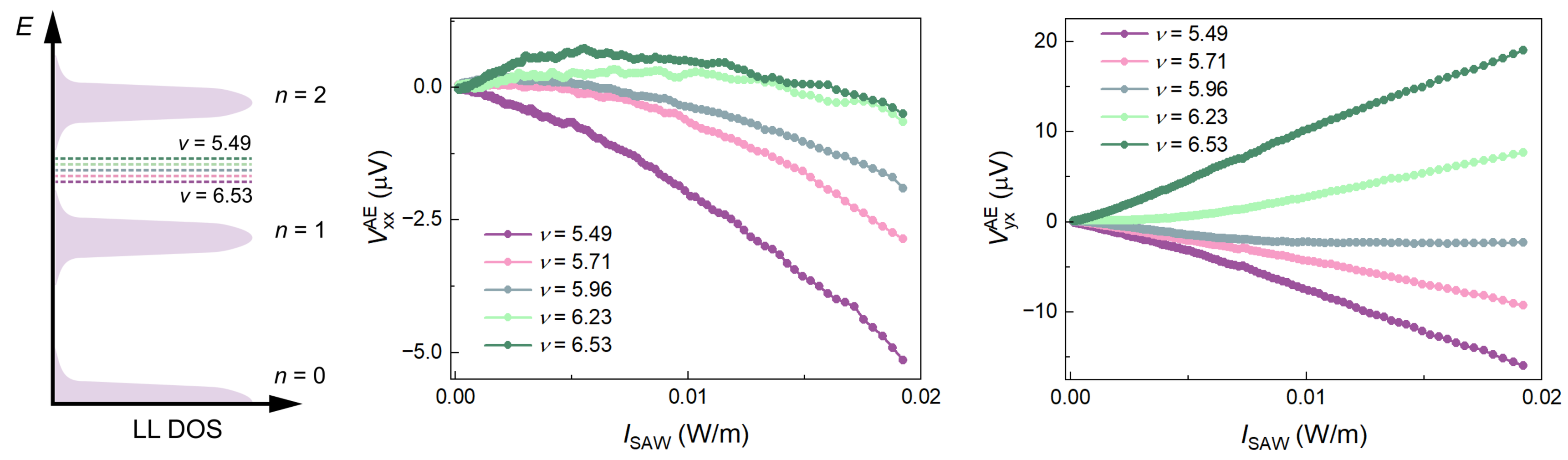


Concurrence of electrical and AE transport features

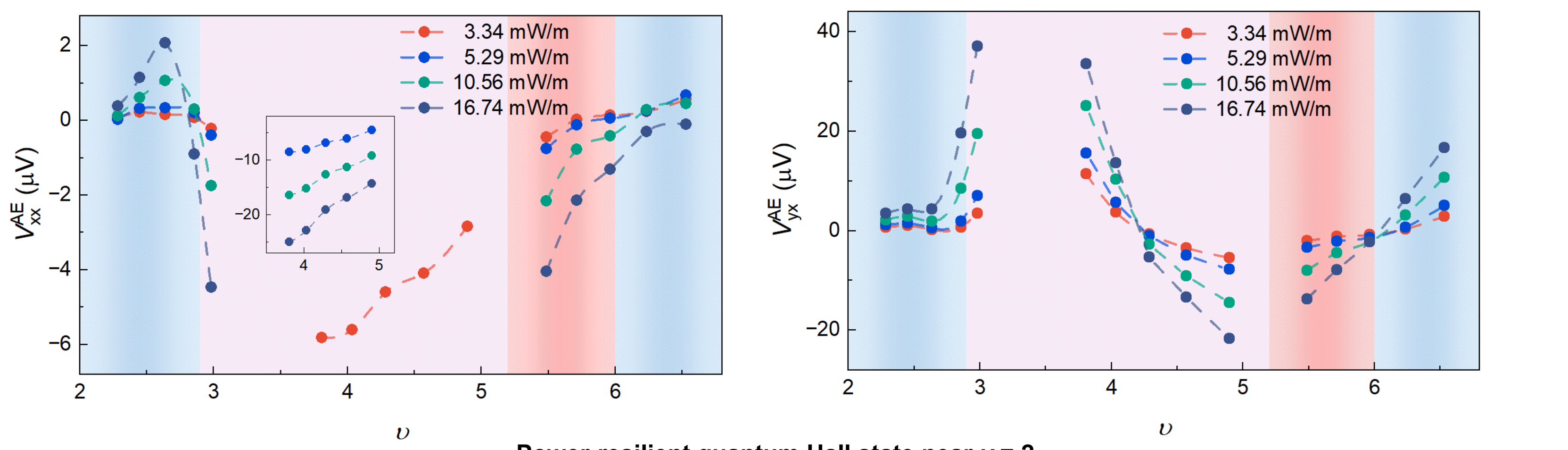
Power-dependent AE transport in metallic and QH regimes



Linear scaling of AE voltages with SAW intensity in the metallic regime confirms the classical acoustic-drag model.

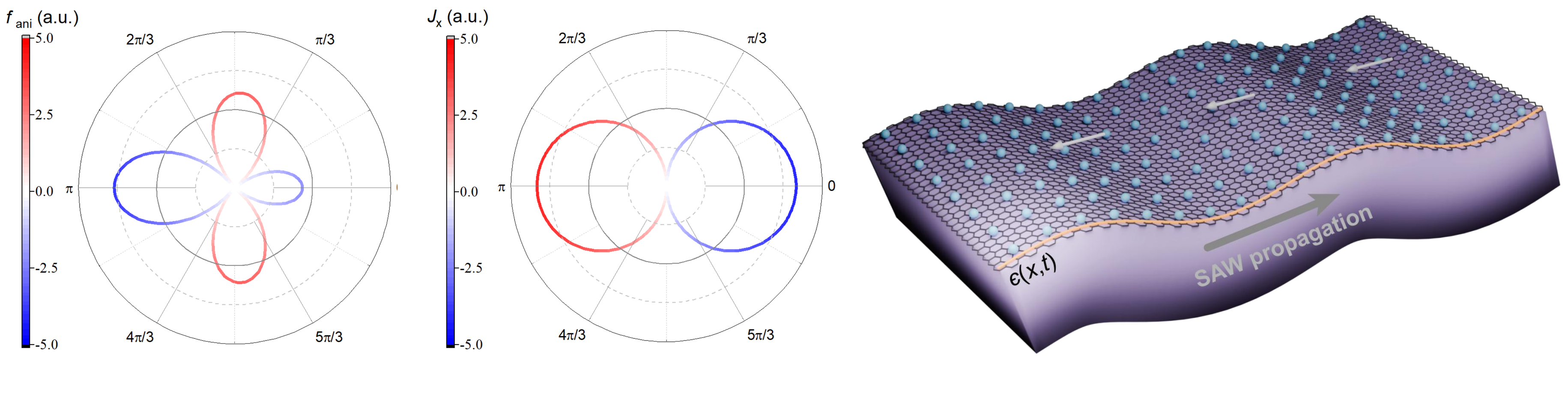


Quasi-electron states exhibit an anomalous polarity reversal at low power, reverting to normal electron-like transport at high power.



Power-resilient quantum Hall state near $\nu = 2$.

Quadrupole-Driven Reverse AE Transport



Quadrupole mode coupling ($l = 2$) takes over once bulk incompressibility suppresses conventional density modulation.

Conclusion

1. Effective Landau Level Tracking: The AE response precisely maps the evolution of quantum Hall states.
2. Unveiling Quasiparticle Dynamics: The AE response effectively captures the underlying quasiparticle dynamics within quantum Hall liquids.
3. Angular Momentum Mode Coupling: In the quantum Hall liquid, bulk incompressibility blocks conventional acoustic drag, enabling angular momentum mode coupling to drive the counter-propagating transport.

References

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