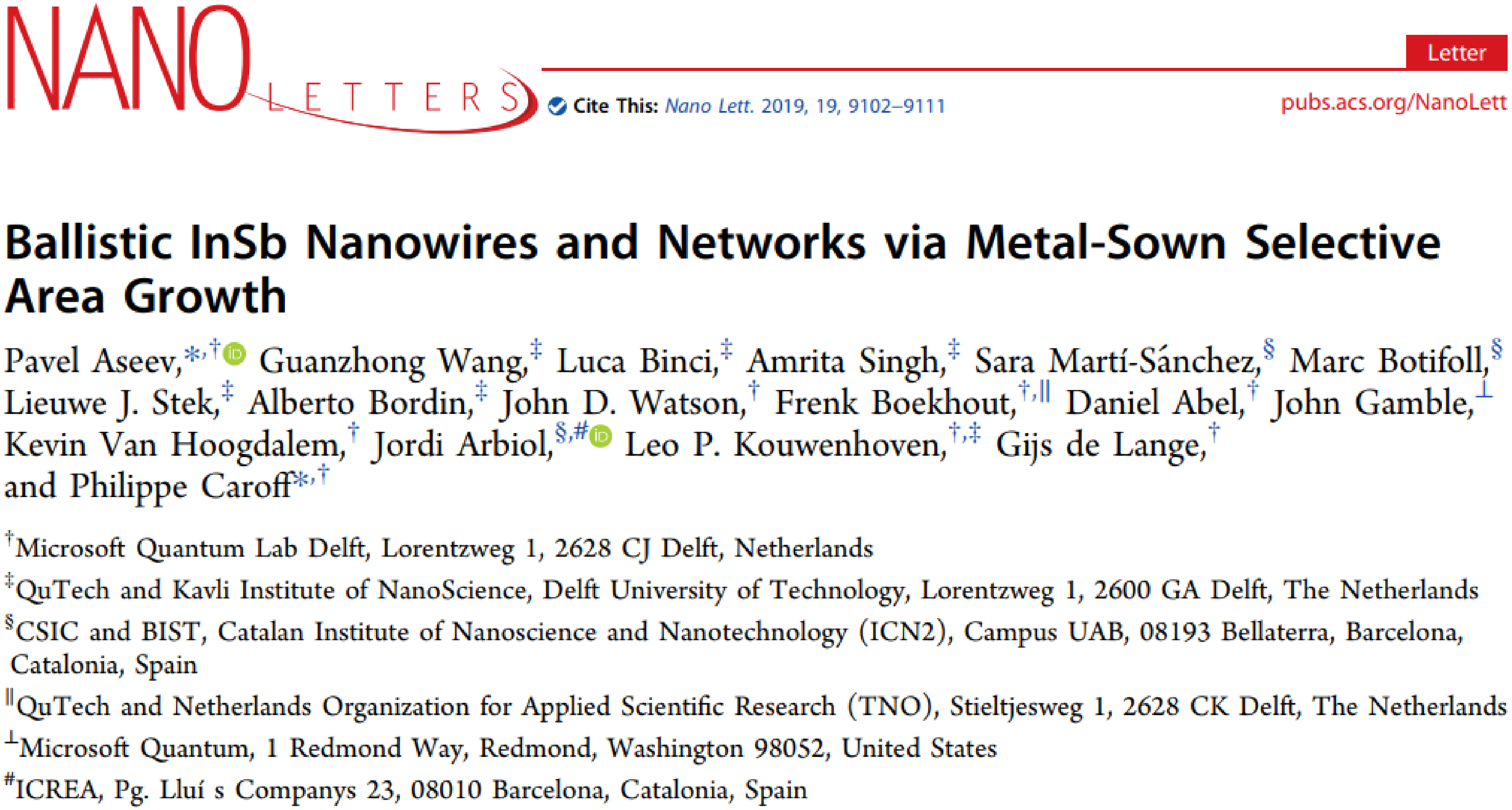

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Ballistic InSb Nanowires and Networks via Metal-Sown Selective Area Growth

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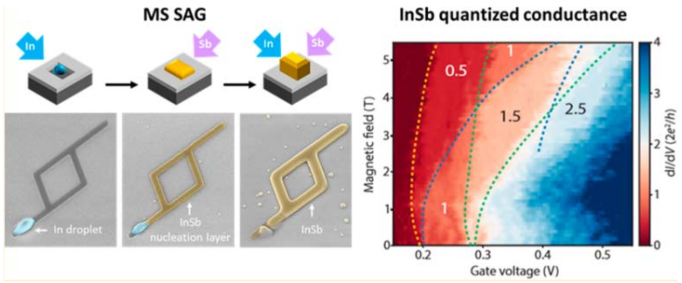
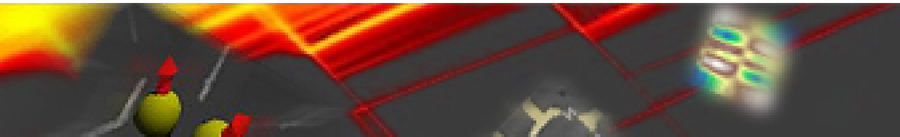


Outline

- The Growth Approach
- Transport Measurements and Analysis
- Outlook



Motivation

InSb

Good:

- Large g-factor (~40) → small B-field needed to drive hybrid device into topological regime
- Small effective mass (0.014 m_0) → leads to large sub-band spacing[1]

Difficult:

- Selective area growth (SAG) difficult by standard MBE techniques (selectivity conditions don’t overlap with preferred nucleation conditions)
    - Can be overcome by hydrogen plasma during growth, but at cost of reduced shape uniformity (not good)

Solution:

- Metal-sown (MS) SAG allows decoupling of nucleation and selective growth conditions

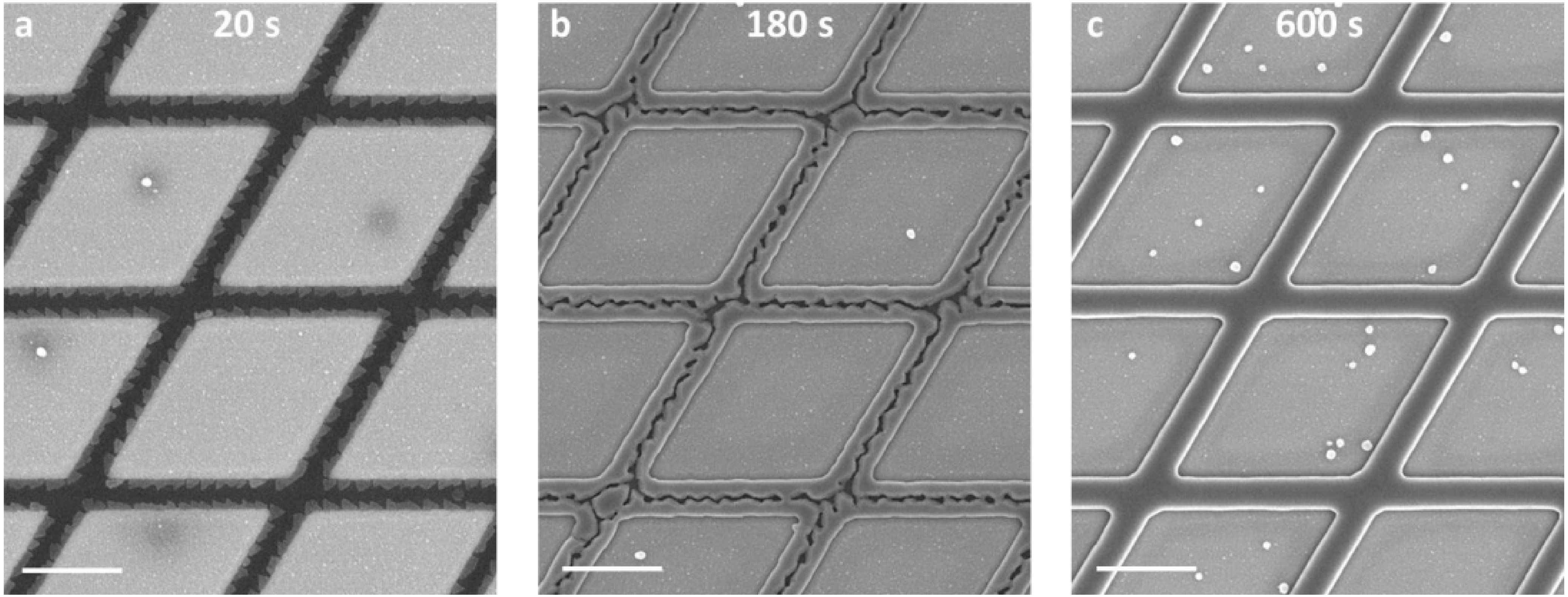
[1]I. van Weperen PRB **91,** (20) 1 (2015)

MS SAG Process

1. Selective definition of channels
2. Selective metal sowing (indium only, high temp, get seeds)
3. InSb nucleation layer (antimony only, get InSb layer)
4. Homoepitaxy of InSb on nucleation layer, growth continues with InSb in conditions favoring high crystal quality and desired dimensions

This has been done on InP and GaAs substrates. The paper focuses on InP (111)B, done at or below 500 C (CMOS compatible)

Very Cool

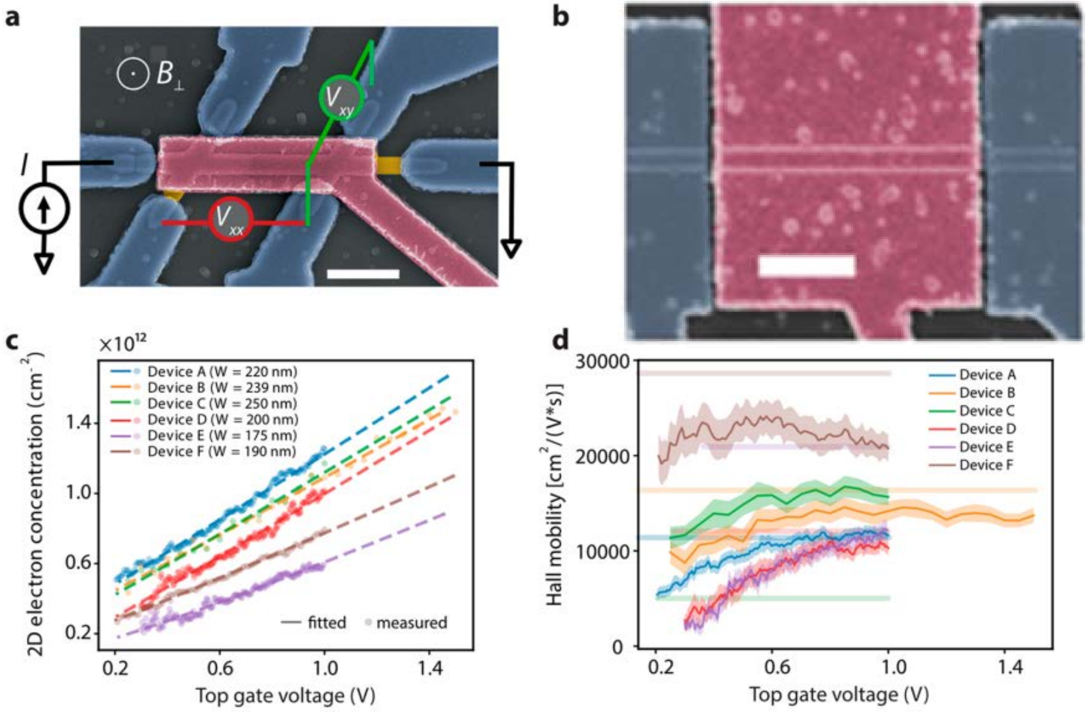


Nucleation layer growth halted at different times. Scale bar 500 nm

Mobility Measurements

- Assuming Drude model $\mu = {}^{\sigma}/_{ne}$
- Through Hall and field-effect measurements
  - Hall gives direct measurement of density, doesn't rely on an accurate model for capacitance, which can be non-trivial
  - $V_{xy} = {}^{I_{bias} B_\perp}/_{(n_{i,2D} e)}$
  - $\sigma_{xx} = \frac{I_{bias}}{V_{xx}} L_{xx}/(Wt)$
    - Obtain $l_e \sim 330\ nm$ (assuming $\mu = 20k$)
- Field Effect measurements on single wires + Hall bars
  - Contact spacing 2 or 3 μm
  - Straight lines in (d) are mobilities obtained from Hall bars in this way
  - Claim the discrepancies are due to not reflecting transport properties in same regions of the devices
    - All in same range, suggesting that the junctions don't disproportionately add more scattering
- They stress the high mobility across the junctions as key for this approach to create multi-terminal devices for topological quantum computation

$$G(V_g) = \left[R_s + \frac{L^2}{\mu_{FE} Q_c(V_g)} \right]^{-1}$$ [2]



Scale bar 1 μm

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[2] Ö. Gül, Nanotechnology **26,** (21) 215202 (2015)

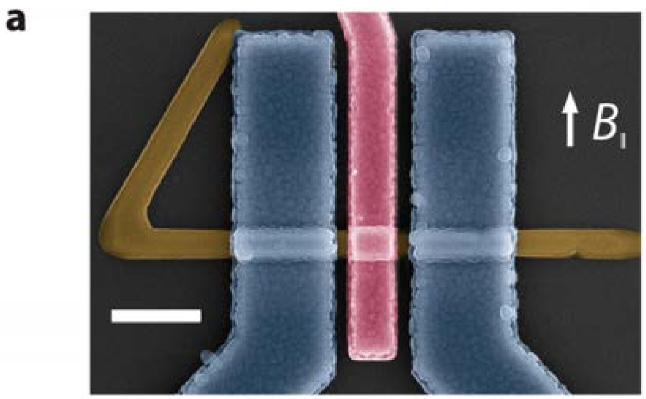
Measurements done at 20 mK

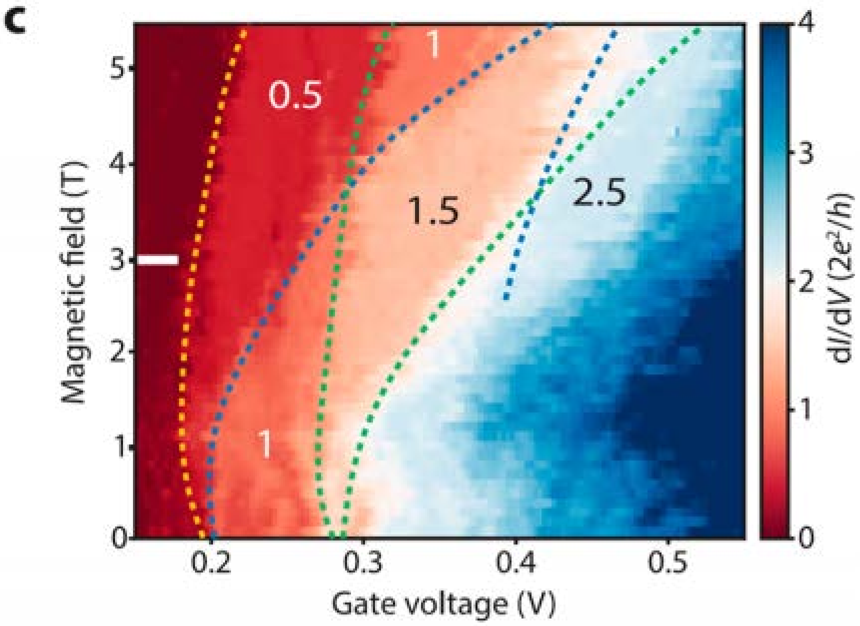
QPC Measurements

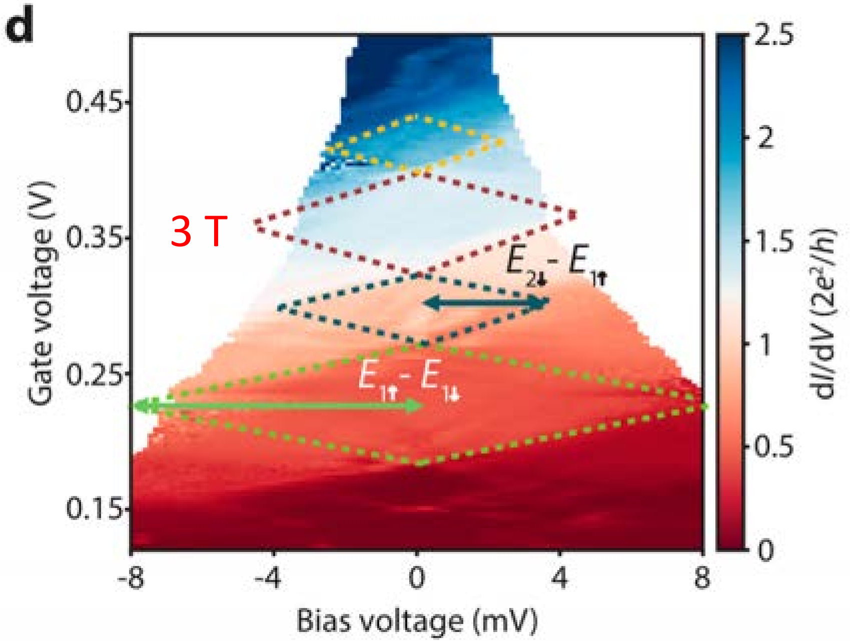
Scale bar 1 μm

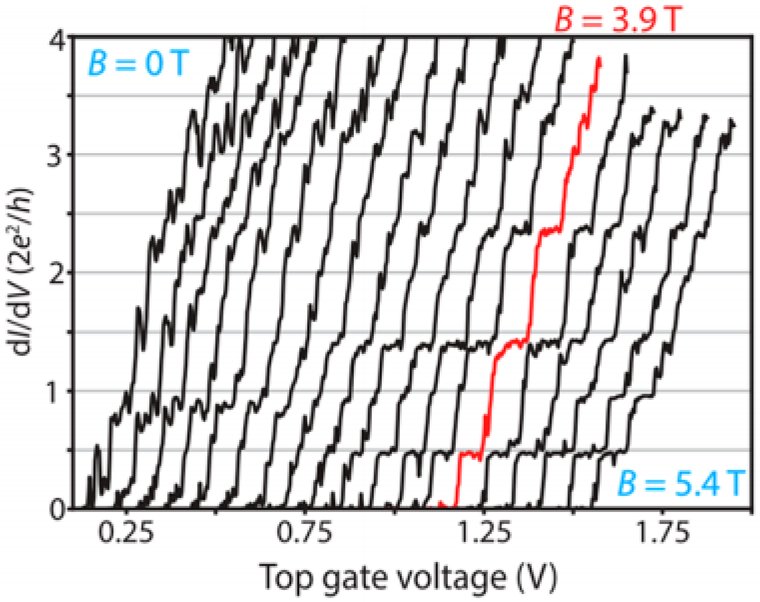
- Ballistic over 440 nm (+ other devices up to 700 nm)
- B applied parallel to substrate, perpendicular to wire
- At ~ 3.9 T the higher-energy spin sub-band of lowest orbital ($E_{1\uparrow}$) crosses the lower-energy sub-band of second orbital ($E_{2\downarrow}$)

  → plateau at G_0 vanishes until higher field
- $eV_{bias} = E_{1\uparrow} - E_{1\downarrow} = g\mu_B B_{\parallel}$ → $g \sim 46$
- Sub-band spacing between first two spin-degenerate orbitals found by summing width of first two diamonds → 12 meV









Cuts every 0.3 T

Aharonov-Bohm

- Conductance probed while applying out of plane B-field through area of loop A

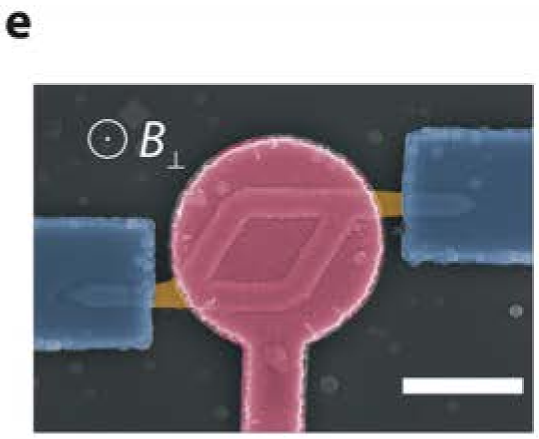
$\Phi = B_{\perp}A$

- Probing phase coherence of wire through periodicity of conductance fluctuations resulting from quantum interference between electron trajectories around loop

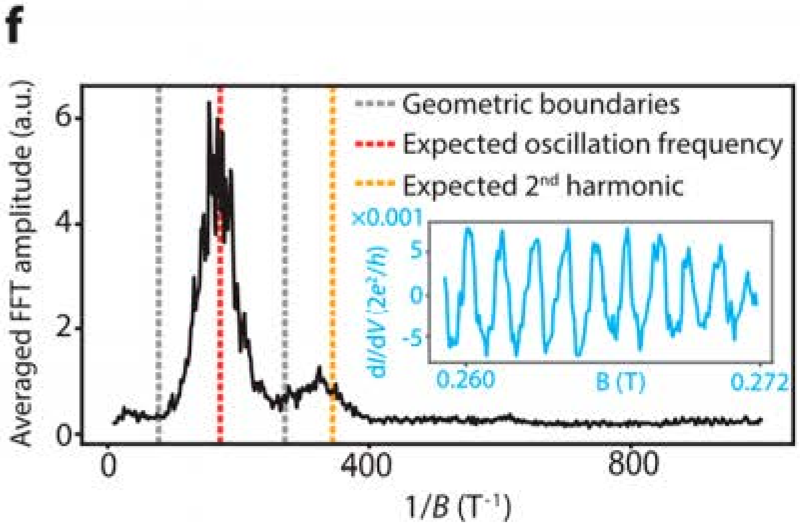
$\phi_0 = {}^{h}\!/_{e}$

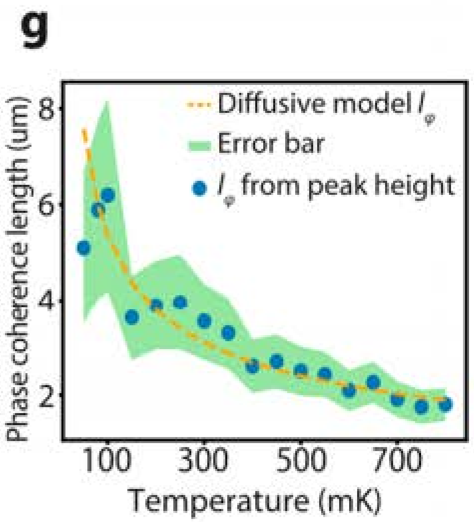
- Periodicity depends on loop area and magnetic flux quantum ϕ_0 as $\Delta B_{\perp} = \frac{\phi_0}{A}$
- Coherence length l_{ϕ} extracted via peak amplitude $A_{h/e} = A_0 \exp(-a\sqrt{T})$

$l_{\phi} = \frac{L}{a\sqrt{T}}$



Scale bar 800 nm





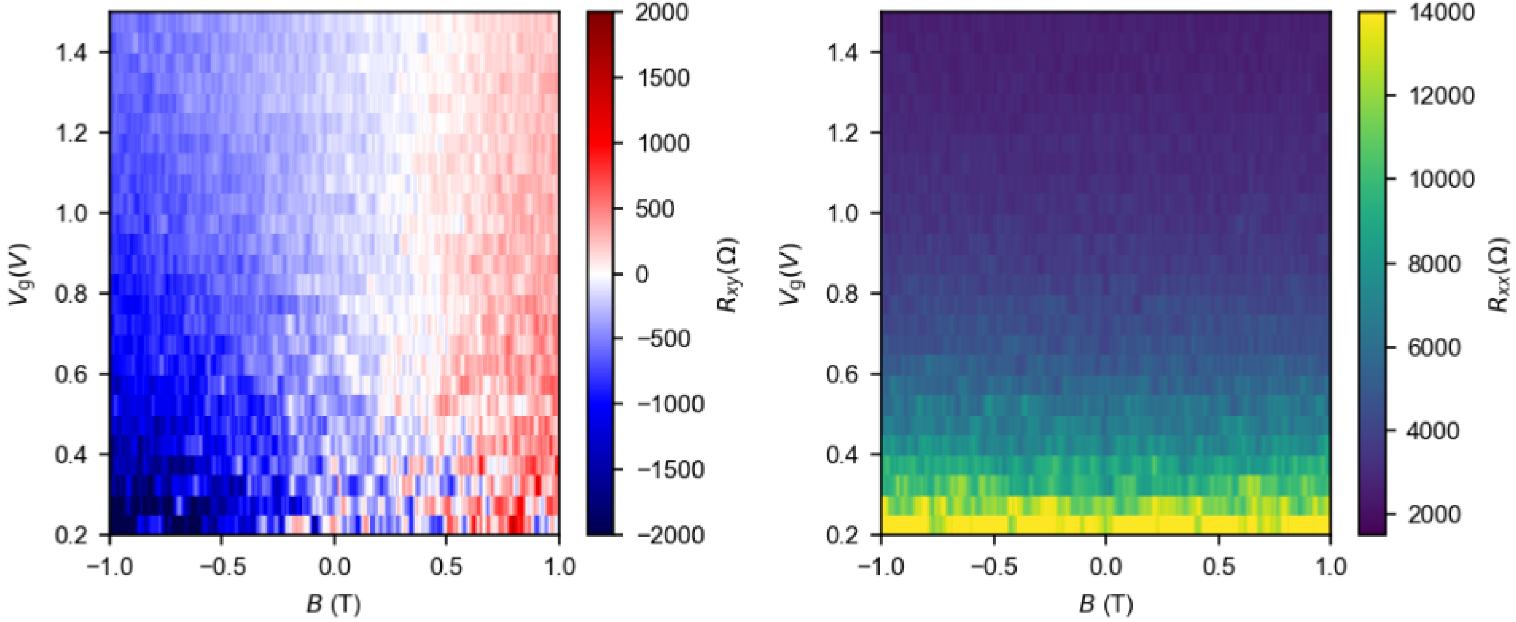


Figure S11 Examples of the raw Hall effect data taken on Hall bar device C used for $n(V_g)$, $\mu_H(V_g)$ calculation and interface charge simulations. An AC-excitation current of $I_{\mathrm{bias}} =$ 10nA was applied and the measured voltages V_{xy}, V_{xx} plotted in the two panels for the B and V_g values sampled. The slope obtained by a linear fitting of $V_{xy}(V_g)/I_{\mathrm{bias}}$ against B yields the carrier density and the averaged $V_{xx}(V_g)/I_{\mathrm{bias}}$ over B at each V_g is used to calculate the conductivity.