Breakdown of the Quantum Hall Effect

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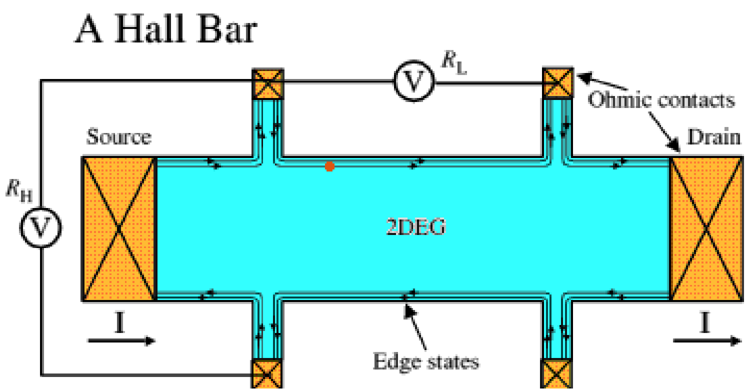
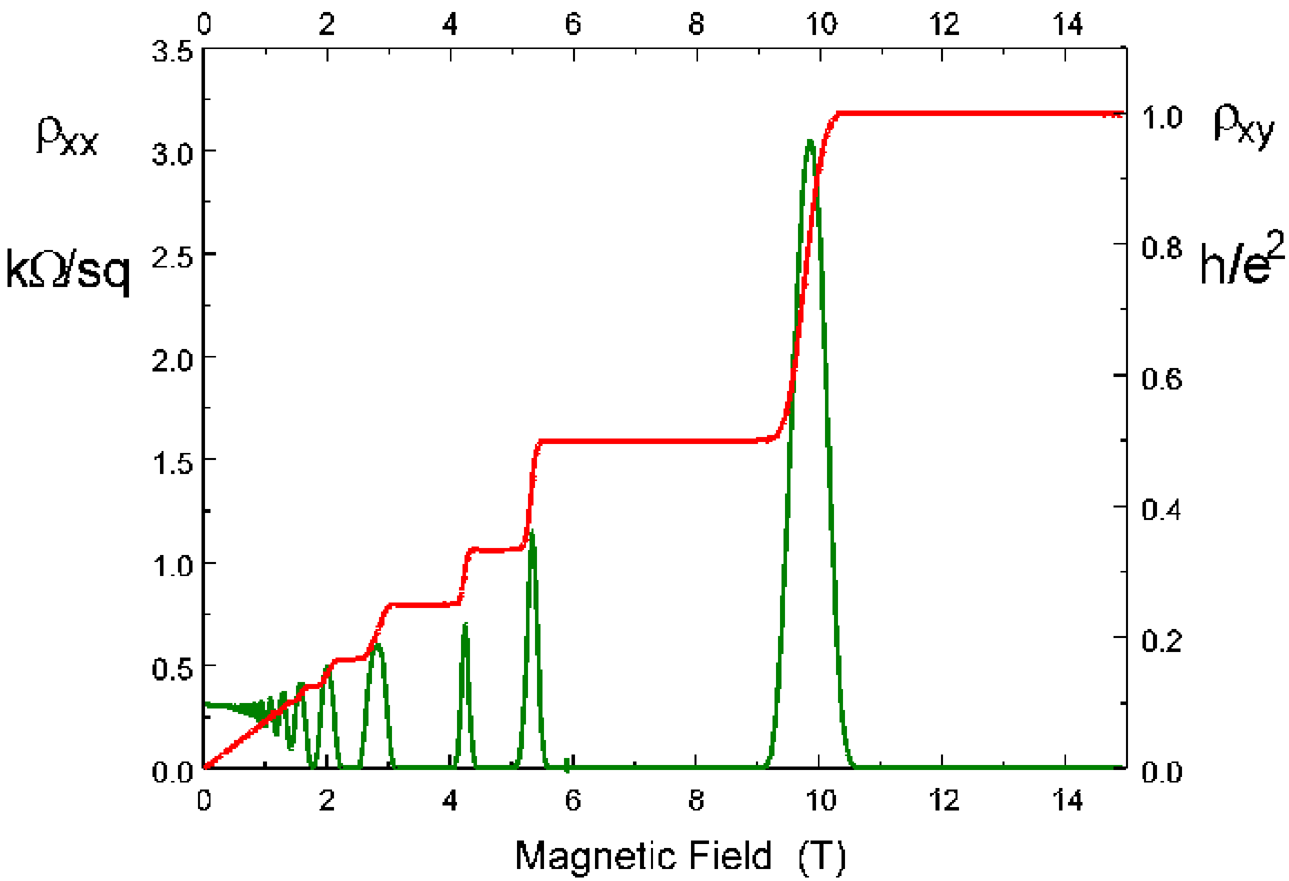
Review Paper: G. Natchtwei, Physica E **4** 79 (1999)
Experimental Paper: P.M. Mensz, D.C. Tsui PRB **40** 3919 (1989)
Theory Paper: D.J. Thouless et. al. PRB **55** R10201 (1997)

The Quantum Hall Effect

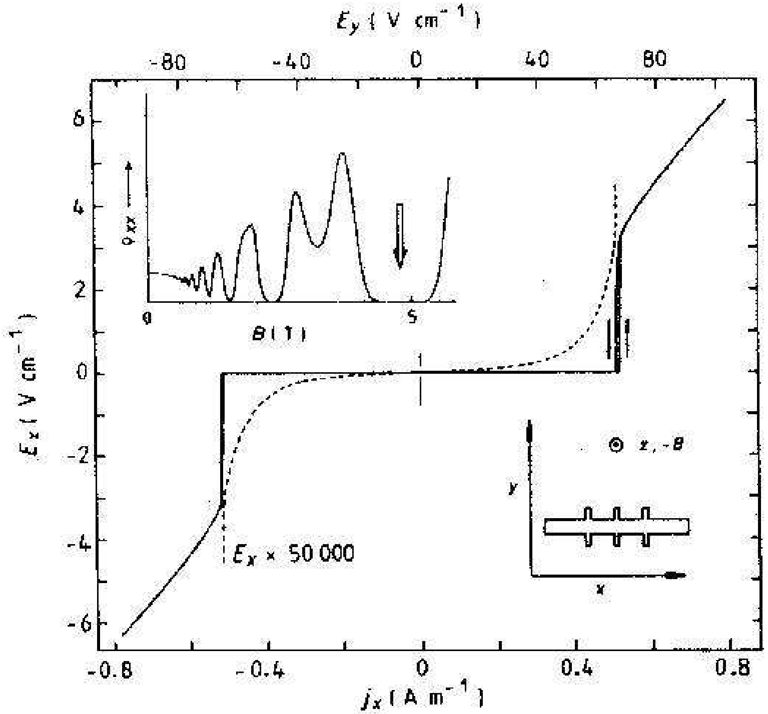


Dissipationless current due to suppression of backscattering



Quantized Hall voltage understood as the quantization of conductance through ballistic one dimensional edge channels

Breakdown of the Quantum Hall Effect at Large Currents



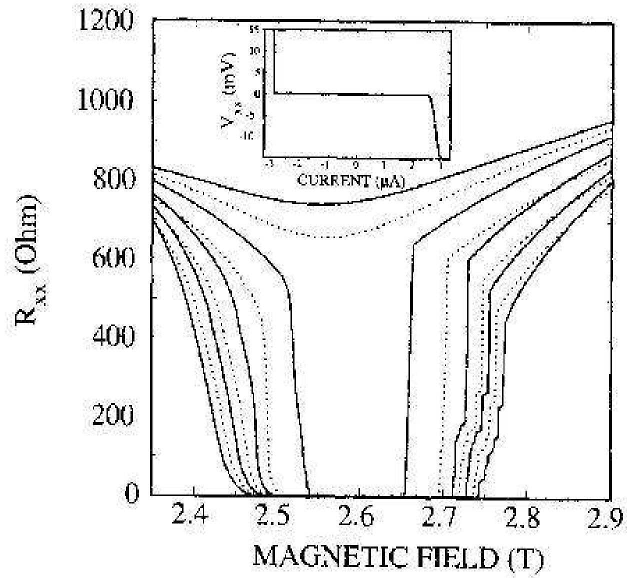


FIG. 2. Determination of I_c by measuring ρ_{xx} vs magnetic field, around $\nu=2$, for a sample of $W=20$ μm, at increasing currents. The current increment between consecutive curves is 0.136 μA; the bottom curve starts at 2.318 μA. I_c is the current at which the $\rho_{xx}=0$ plateau is fully eliminated. Inset: voltage vs current for the same sample at $B=2.6$ T.

Sudden break down of dissipationless state upon increasing current

Also see an associated loss in quantization of hall voltage

Experiments

- Scaling with Hall Bar Width

- Voltage Steps in the breakdown

- Transient Fluctuations in Rxx near transistion
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Scaling With Sample Width

TABLE I. Summary of the properties of the materials used in different experiments to determine the dependence of I_c vs W: n (10^{11} cm^{-2}); μ (10^5 cm^2/V s), and s (nm). Sublinear dependence is observed in samples having large spacers and high mobility.

	Ref. 11	Ref. 10	Ref. 15	Ref. 17	This work	
					Before illumination	After illumination
n	2.6	2.1	4.7	2.5	1.3	2.2
μ	9.0	7.0	2.1	0.5	1.2	2.1
s	54	36	6		40	40
I_c vs W	sublinear	sublinear	linear	linear	linear	sublinear

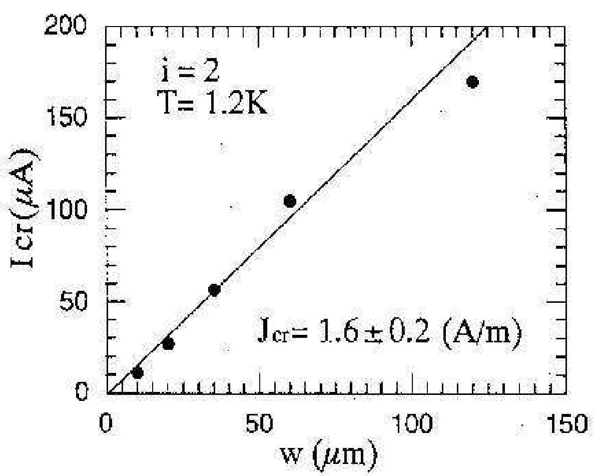


Fig. 6. Critical current I_{cr} versus device width w for a wafer with a mobility of $\mu_H = 2.1 \times 10^5$ cm^2/V s. The slope of the full line corresponds to a critical current density of 1.6 A/m. Data from Kawaji et al. [13].

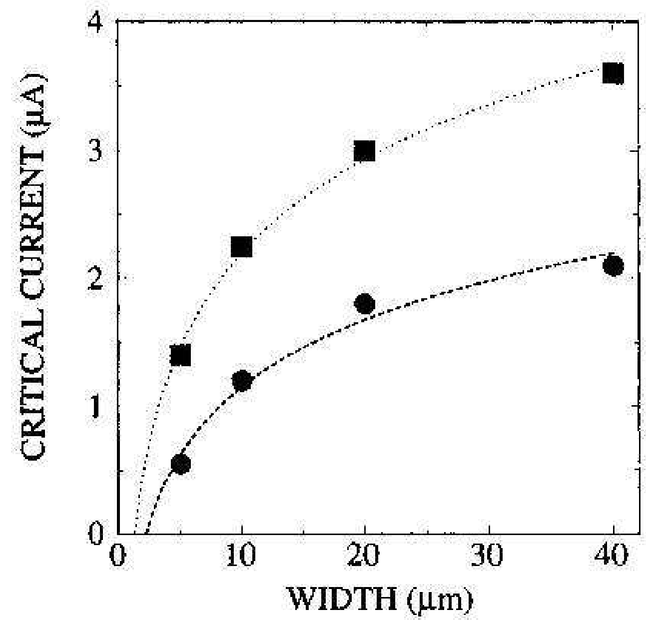


FIG. 1. Critical current vs the channel width measured in the samples of Ref. 11 for filling factors $\nu = 1$ (●) and 2 (■). The dashed lines are logarithmic fits.

Steps in Voltage Breakdown

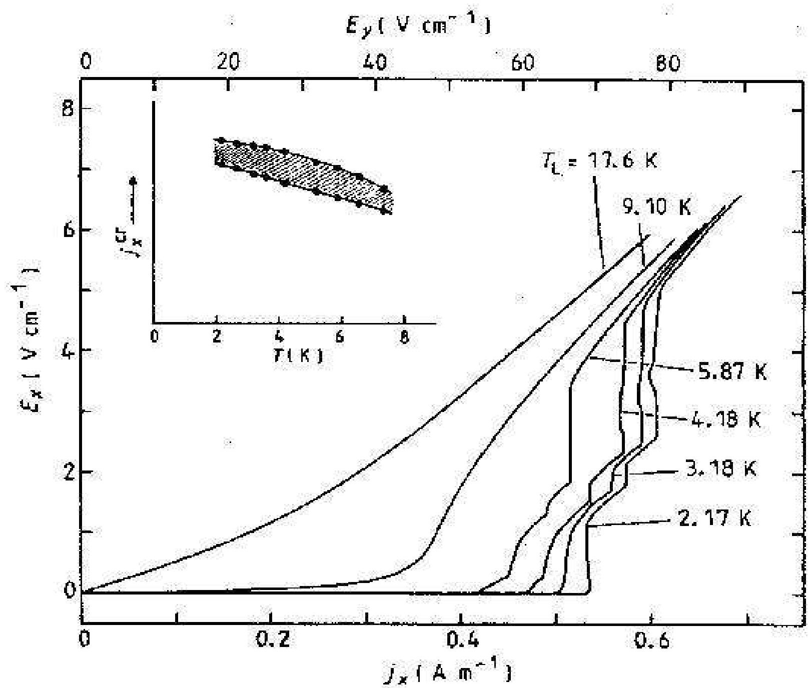


Fig. 13. Current–voltage characteristics (2nd QH plateau, $B = 6$ T) of a Hall bar ($w = 380\,\mu$m, $\mu_H = 3.8 \times 10^4$ cm^2/V s) at different lattice temperatures T_L (inset: critical current density versus T_L). Several jump-like transitions are visible for $T_L \leqslant 5.87$ K. Data from Ebert et al. [3].

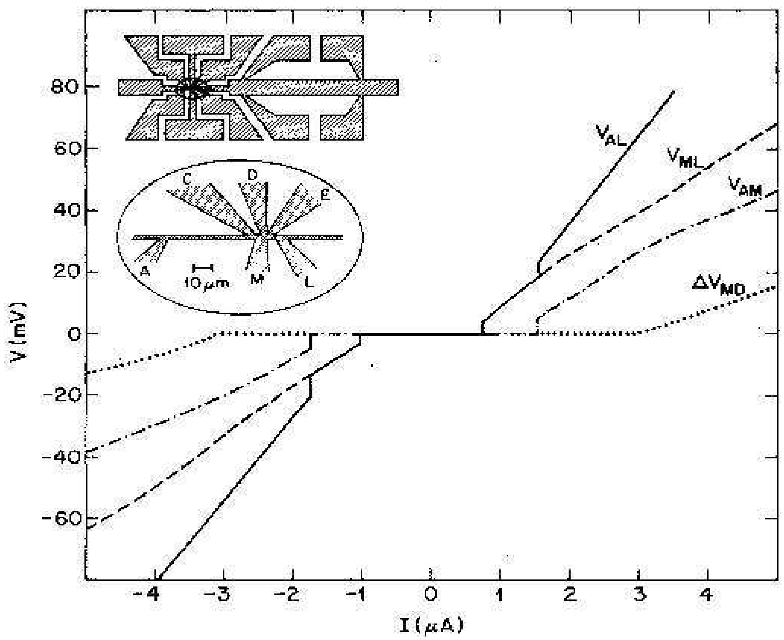
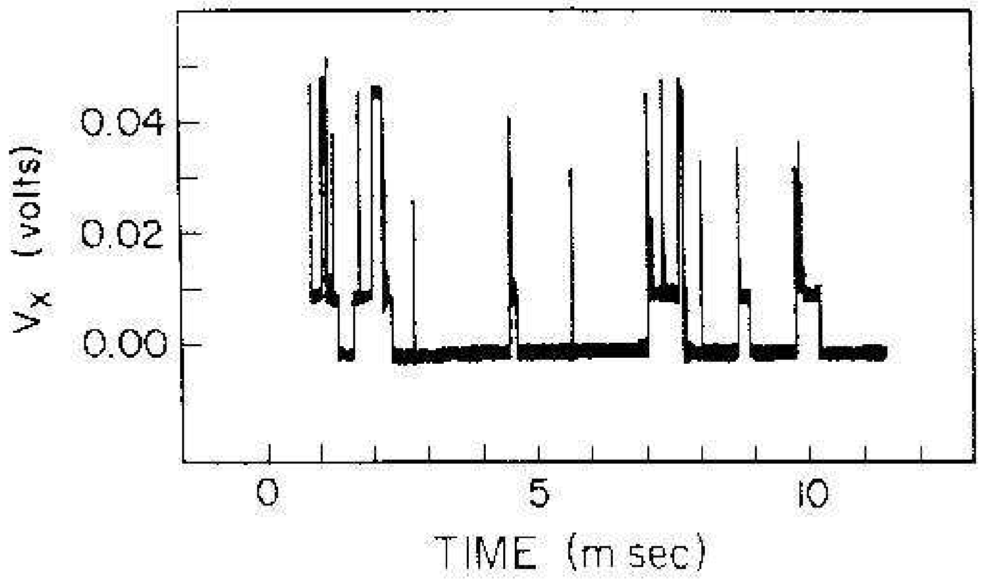


FIG. 1. Voltage measured at $B = 5.7$ T and $T = 1.2$ K across the different probes A and L, M and L, A and M, and the Hall probes M and D plotted as a function of current I. $\Delta V_{MD} = V_{MD} - (h/2e^2)I$. The value of the magnetic field B was chosen to set a condition for the IQHE with Landau filling factor $i = 2$ at $n_s = 2.8 \times 10^{11}$/cm^2. Inset: the probe arrangement along the narrow section of sample 1. The bar indicates 10 μm distance.

Fluctuations and Hysteresis



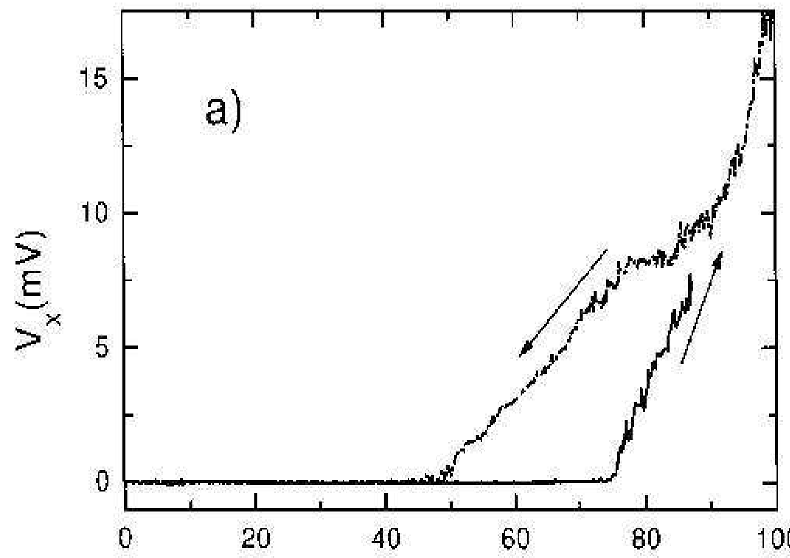


Fig. 14. Time-dependent fluctuations of the longitudinal voltage V measured on a Hall bar ($w = 380\,\mu$m, $\mu_H > 1 \times 10^5$ cm^2/V s) ne the breakdown of the 4th QH plateau ($B = 5.65$ T, $T_L = 1.1$ K), a source-drain current of $I = 325\,\mu$A. Data from Cage et al. [4

Possible Mechanisms for Breakdown