SELF-ORGANISED CRITICALITY IN THE QUANTUM HALL EFFECT

KL Phillips, *M Elliott, Y Lu, WG Herrenden-Harker[1], AJ Matthews, JD Gething, A Usher[2], M Henini[3] and DA Ritchie[4]

[1]Cardif University, [2]Exeter University, [3]Nottingham University, [4]Cambridge University

*Presenting author: elliottm@cf.ac.uk

Abstract

Breakdown of the integer quantum Hall effect (QHE) in a two-dimensional electron system (2DES) has been an intensely-researched area for a number of years, and has produced a variety of experimental results for which there is still no generally accepted microscopic model. Breakdown is known to occur in Hall bars at integer filling factor ν when the current density exceeds a certain critical value (depending on the details of sample geometry and quality) and is characterised by a sharp increase in the longitudinal resistance ρ_{xx} away from its virtually dissipation-free value $\rho_{xx} \to 0$ observed at low temperature. Nearly all experiments on the QHE are performed on Hall bars, although there are some measurements on Corbino geometries. The Corbino geometry is interesting because (i) the (radial) current distribution is less sensitive to details of the contacts (ii) the current distribution will have a simpler (macroscopically, at least) symmetry, and (iii) the presence of edge channels is avoided. Here, we use a geometry which has the simple circular symmetry of the Corbino geometry, but is topologically equivalent to the Hall bar geometry. Furthermore, we make no electrical contact to the sample. In our method, a ring, disc, or (more often) square-shaped 2DES has circulating eddy currents induced upon sweeping the perpendicular field. Edge states may exist at the periphery of the samples, and at the inner edge of the ring-shaped samples. The circulating currents are accompanied by strong radial Hall electric field.

Induced currents are detected via their magnetic moment m using a sensitive magnetometer and give information on the resistivity of the 2DEG. Eddy current peaks can be observed around both integer and fractional filling factors, where the longitudinal resistivity ρ_{xx} takes sufficiently small values. The magnitude of the induced currents thus depends on the sample mobility, filling factor and temperature, as well as the sample size and sweep rate dB/dt. We have measured breakdown of the quantum Hall effect in various two-dimensional electron gases formed in MBE-grown GaAs-(Al,Ga)As modulation-doped heterostructures around filling factor $\nu = 2$, using this contact-free method. At sufficiently high sweep rates, and temperatures below about 1K, the induced eddy current peak size saturates, and often a 'noisy' breakdown of the current is observed superimposed on the main eddy current peak. We describe a simple interpretation of this breakdown in terms of a self-organised criticality model of breakdown of the quantum Hall effect, due to the strong Hall field perpendicular to the eddy current direction.