Real Space Observation of a Quantum Hall Transition by STM

STM による量子ホール遷移の実空間観察

Two-dimensional electron systems such as the integer quantum Hall system are considered as paradigms for the study of quantum phase transitions. Although macroscopic aspects of the percolative behavior of the systems have been verified, the perhaps most fundamental aspect, i.e. how electron wave functions change across the transition, has not been tackled experimentally. We demonstrate the first real space observation of a quantum Hall transition by performing scanning tunneling spectroscopy on "surface" two dimensional electron system at low temperature (0.3 K). We find localized electronic states at energies of the Landau level tail and extended drift states at energies corresponding to the Landau level center. The observed microscopic behavior reveals that quantum tunneling plays a key role in this quantum phase transition.

We also clarify a robust nodal structure of Landau Level wave functions by using fourier transform scanning tunneling spectroscopy. Our findings demonstrate that Landau quantization implies disorder independent universal features on the microscopic scale. This complements the well-known universal quantum Hall plateaus.

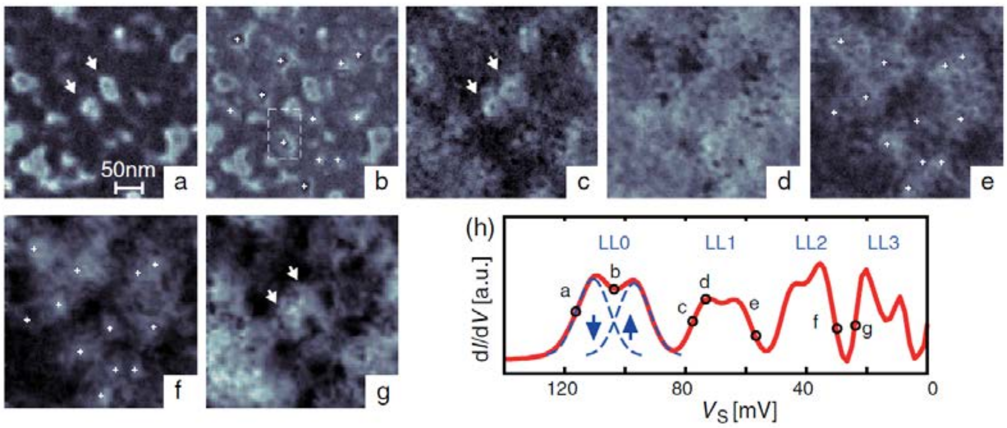

Fig.1 (a–g) Real-space LDOS (Local Density of States) taken at B=6 T for the sample voltages Vs marked as circles in (h); all dI=dV images are recorded in the same area and are displayed using the same color scale. White arrows at the same positions in (a), (c), (g) mark localized states, which exhibit additional nodal structure in (c), (g). Crosses in (b), (e), and (f) mark states localized at potential hills; the dashed rectangle in (b) marks an area around a drift trajectory. (h) Spatially averaged dI=dV curve.

Representative publications:

1. K. Hashimoto, C. Sohmann, J. Wiebe, T. Inaoka, F. Meier, Y. Hirayama, R. A. Romer, R. Wiesendanger, M. Morgenstem, Phys. Rev. Lett.101 256802 (2008).

2. K. Hashimoto, T. Champel, S. Florens, C. Sohrmann, J. Wiebe, Y. Hirayama, R. A. Römer, R. Wiesendanger, and M. Morgenstern, Phys. Rev. Lett. 109, 116805 (2012).