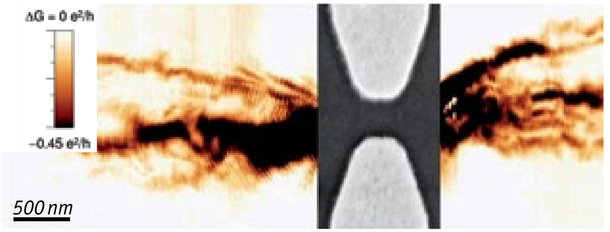
# Scanning Gate Microscopy

selected applications for cryogenic tuning fork based microscopy

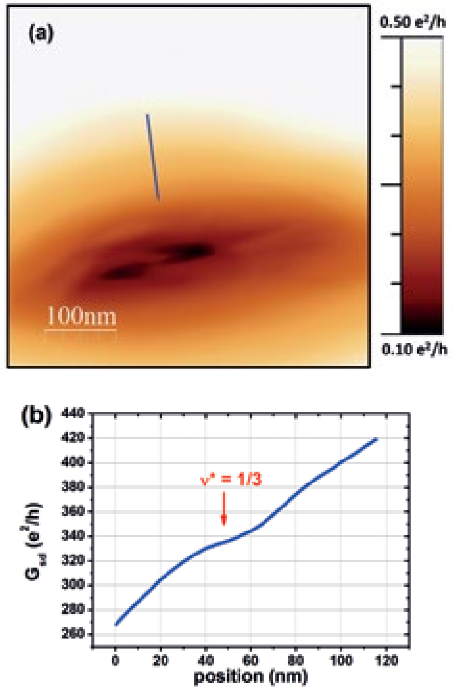
### Scanning Gate Microscopy at 300 mK




In this measurement, an attoAFM III was operated inside an attoLIQUID3000 cryostat at 300 mK in scanning gate microscopy mode (SGM) - investigating the trajectory and interaction of edge channels of a split-gate quantum point contact (QPC) device in the Quantum Hall (QH) regime. By scanning the SGM tip over the surface of the QPC at constant height and by simultaneously measuring and plotting the source-drain current, conductance maps were obtained. The image to the left is an example of such a conductance map depicting the characteristic branched-flow of electrons at zero magnetic field, which in turn shows electron interference fringes and the actual electron path. T = 400 mK, 2DEG density $n_{2D} = 3.37 \times 10^{11}\,cm^{-2}$.

*(Data and images were generously provided by S. Heun et al., NEST, CNR-INFM and Scuola Normale Superiore, Pisa, Italy.)*

### Imaging fractional incompressible stripes in integer quantum Hall systems




In newer measurements, the group performed SGM measurements at the temperature and magnetic field conditions required to observe the fractional quantum Hall effect. The goal is to image for the first time the presence of fractional incompressible stripes, i.e. the existence of an inner structure within the integer edge channel. WThe measurements were performed at bulk filling factor $\nu_b = 1$ (B = 8.23 T, T = 300 mK). The corresponding SGM map in the region close to the QPC center is depicted in the lower Figure (a). Analogously to the $\nu = 4$ case, one expects to find plateaus when the local electron phase is gapped, i.e. when the local filling factor $\nu^*$equals a robust fraction. The scan profile depicted in the Figure (b) reveals a clear shoulder for $G_{sd} = e^2/3h$ (corresponding to points where $\nu^* = 1/3$). A more careful analysis [1] allows to determine the occurrence of incompressible phases for $\nu^* = 1/3$, 2/5, 2/3, and 3/5, i.e. the two most robust fractions and their hole-particle conjugates, respectively. The SGM maps allow not only to reveal the fractional incompressible stripes, but also to measure their width and correlate it with the local electron density slope. The agreement between the data and a reconstruction model is remarkable, especially in light of the uncertainty on the fractional-gap value, which is known to be rather sensitive to the details of disorder potential.

*(Data and images were generously provided by N. Paradiso, S. Heun et al., NEST, CNR-INFM and Scuola Normale Superiore, Pisa, Italy.)*

*[1] N. Paradiso et al., Phys. Rev. Lett. 108, 246801 (2012). See also the Supplemental Material.*

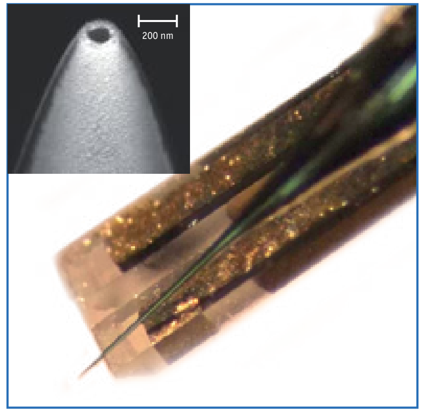


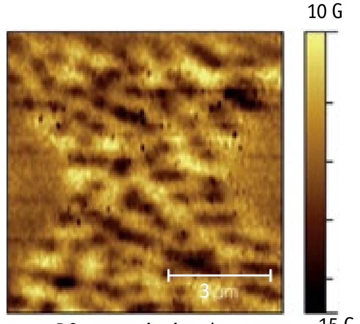


# Nano-sized SQUID-on-tip for scanning probe microscopy

selected cryogenic tuning fork applications based on attocube components

### Scanning SQUID microscopy

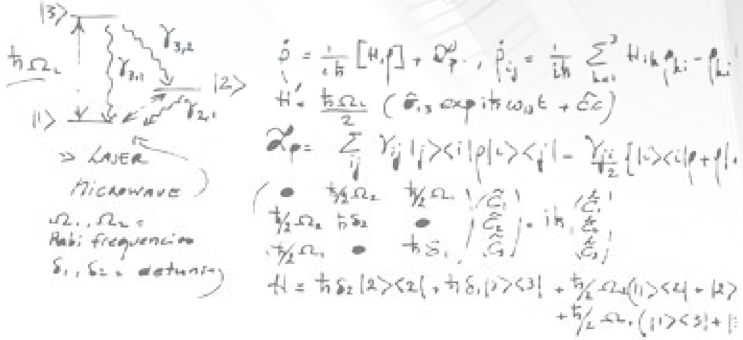



DC magnetic signal

A. Finkler and coworkers developed a novel design for a SQUID device and built a complete cryogenic scanning SQUID microscope [1]. They fabricated their SQUID loop on the tip of a fine quartz tube. Depending on the pulling parameters they can achieve tips between 20 and 2000 nm diameter. Thin (25 nm) aluminium is evaporated on two opposite sides of the tip, and and even thinner (17 nm) on the apex of the tip forming a weak link of a Dayem bridge nature. The inset shows an SEM image of such a tip. The nano sized SQUID is then glued on one prong of a quartz tuning fork (see large image). This arrangement allows simultaneous measurement of the topography on top of the magnetic field. This results in a much better control of the tip position relative to the sample reducing significantly the smallest safe distance, hence drastically increasing spatial resolution and sensitivity.
The setup is based on attocube systems' positioners and scanners, controlled through the ANC300 and the ultra-low noise amplifier ANC250. The microscope was controlled and data collected by the ASC500 Scanning Probe Microscopy Controller. The right image shows the magnetic signal with high spatial and field sensitivity measured a few nm above the surface of a patterned Nb film. The highly disordered vortex lattice is due to the strong pinning in the Nb film.

*[1] A. Finkler et al., Rev. Sci. Inst. 83, 073702 (2012)*



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