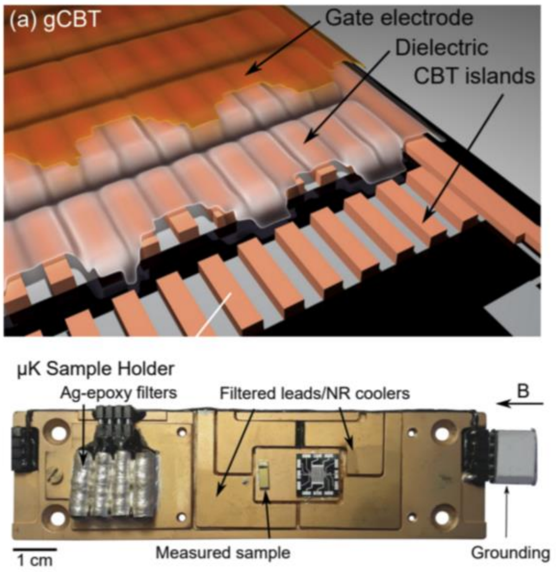
Quantum Transport at Microkelvin Temperatures

Open position

in the Quantum Coherence Laboratory, Zumbühl Group, University of Basel

We are looking for a highly motivated and talented physicist with strong laboratory and/or clean room nanofabrication skills, to join our MicroKelvin team, to work on pushing the boundaries of how far we can cool the electrons in nano-fabricated circuits and quantum devices. The position is for a PhD student or a postdoc, working in our microK team with a senior scientist and a PhD student, to start in (early) 2022.



a) Schematic of the gate Coulomb blockade thermometer (gCBT) produced at VTT. A gate electrode covers the islands, which act as on-chip nuclear refrigerators (NR). Lower panel: Custom-made µK sample holder. The holder is enclosed with a Cu lid, and all Cu acts a NR, forming a microkelvin environment for the samples.

Quantum transport experiments in semiconductor nanostructures typically are done at dilution refrigerator temperatures around or above 10 mK. In this project, we would like to lower the temperature well below 1 mK, where much improved quantum interference/coherence as well as new quantum states of matter were predicted.

We are adapting adiabatic demagnetization cooling to electronic transport measurements [1] by including a separate demagnetization cooler into each measurement wire [2]. Further, we integrate demagnetization coolers also on-chip [3], to deliver cooling locally where the transport experiment is taking place. The electronic temperature can be measured using a tunnel junction [4] or a Coulomb blockade thermometer (CBT) [5], which we have recently further improved to extend its temperature range, and we have demonstrated temperatures as low as 220 µK [6] on a pulsed tube dilution refrigerator platform.

The goal of this project is to integrate and deliver demagnetization cooling also to semiconductors such as 2D electron gases and/or quantum wires and quantum dots formed in such structures, to make accessible an entirely new range of ultralow temperatures for new science and quantum technology applications [7]. The frontier of the lowest attainable temperatures might further be pushed below 100 µK by further optimizations. The project involves electrical transport measurements, clean-room fabrication of semiconductor nanostructures, and some mechanical work on dilution refrigerator setups with custom-made nuclear stages. This project involves:

- Working with dilution refrigerators adapted for demagnetization transport experiments
- Working on nanofabrication (clean room) of semicond. nanostructures for µK experiments
- Automating measurements using Python (QCodes), IgorPro, and other coding environments
- Physics of tunnel junctions, normal metal-insulator-superconductor (NIS) junctions [5], nuclear spins (magnetic cooling), Coulomb blockade, thermal material properties at interfaces and in the bulk. See reference [5] for a review.
- Collaborating with researchers from other European and international laboratories to provide them access to microkelvin transport measurement apparatus
- Analyzing experimental data, developing thermal models of the devices and Monte-Carlo simulations to understand transport phenomena in tunnel junctions
- Presentation of the results at international conferences and publication in high-quality journals

References

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[3] *On-and-off chip cooling of a Coulomb blockade thermometer down to 2.8 mK* (Editor's pick), M. Palma*, C. P. Scheller*, D. Maradan, A. V. Feshchenko, M. Meschke, and D. M. Zumbühl, Appl. Phys. Lett. **111**, 253101 (2017).

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