IUPAP Commission 5

Low Temperature Physics

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Commission Conferences

LT (International Conference on Low Temperature Physics)

- LT2, Oxford, UK 1951
- LT22, Helsinki, Finland 1999
- LT23, Hiroshima, Japan 2002
- LT24, Orlando, Florida 2005
- LT25, Amsterdam, Holland 2008

QFS (Conference on Quantum Fluids and Solids)

- Konstanz, Germany 2001
- Albuquerque, New Mexico 2003
- Trento, Italy 2004
- Kyoto, Japan 2006

Titles at LT2, Oxford, England 1951

A. Total number of talks 106

B. 5 talks about physics of thin He films
(t < 1 micron)

C. 5 talks about thin superconducting metallic films
(t < 1 micron)

9% of the program was related to nanophysics

Talks and papers at LT16, Los Angeles 1981

A. 68 invited talks, 13 related to nanophysics
   - 4 talks about thin liquid films and surfaces
   - 2 talks about thin superconducting films
   - 1 talk about microrefrigeration
   - 6 talks about electron localization and tunneling
      A. David Thouless
      B. Phil Anderson

B. 90 sorting categories of contributed papers
   13 related to nanophysics
   - Electron localization I, II and III
   - Point contact tunneling
   - Microbridges
   - Quasi-one-dimensional conductors
   - Low dimensional magnetism
   - Adsorbed films
   - Superfluid films
   - Vortex unbinding in two dimensions
   - Two dimensional phase transitons I, II
   - 2D-electrons on He surface

17% of the program related to nanophysics

Talks and papers at LT24, Orlando 2005

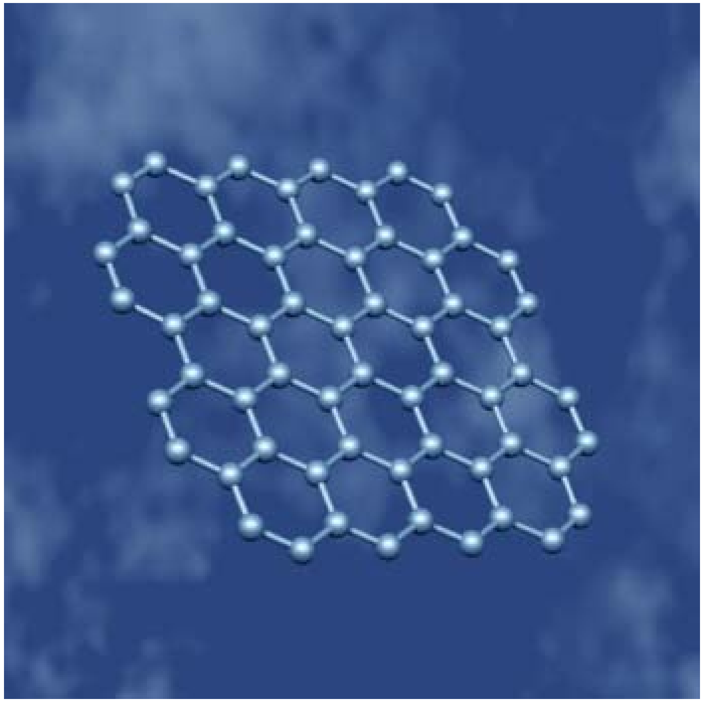
A. 31 invited talks, 9 of them related to nanophysics
   - 4 talks about quantum computing in nanoelectronics
   - 3 talks about single spin detection and manipulation
   - 2 talks about low dimensional magnetism

B. 40 parallel oral sessions,
   14 of them related to nanophysics
   - Low dimensional magnetism I, II
   - Nanomagnets
   - Spintronics
   - Spin detection and manipulation
   - Π- junctions and arrays/proximity effect
   - Kondo effects in quantum dots
   - QHE and 2DEG
   - Quantum wells and structures
   - Carbon nanotubes
   - Mesoscopic superconductivity
   - Nanostructures
   - He films
   - Low dimensional confined He

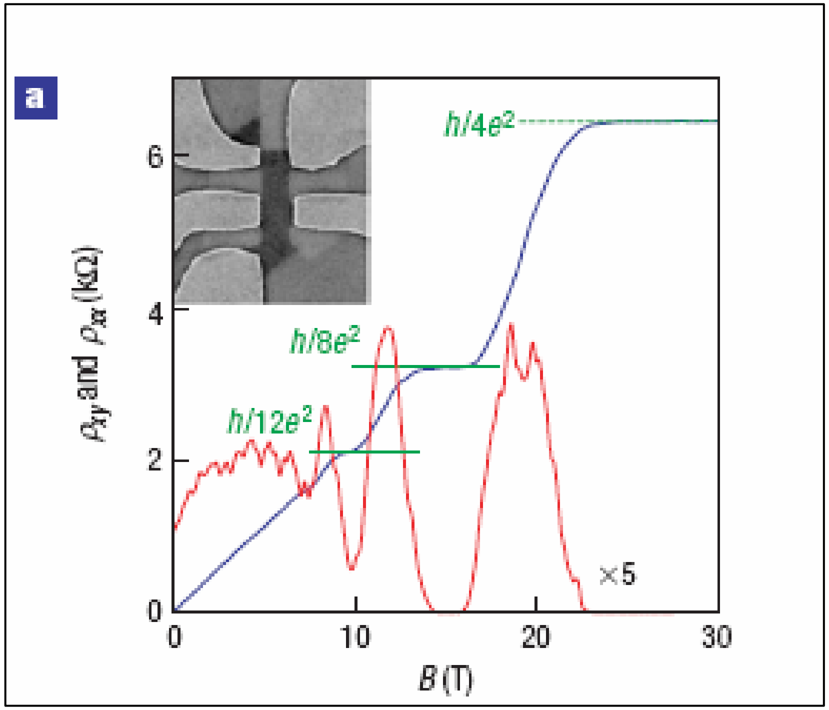
30% of the program related to nanophysics

ELECTRON TRANSPORT IN GRAPHENE SHEETS

SHEET OF GRAPHENE



QUANTUM HALL EFFECT



***K.S. Novoselov, E. McCann, S.V. Morozov, V.I. Fal'ko, M.I. Katsnelson, U. Zeitler, D. Jiang, F. Schedin & A.K. Geim*, Unconventional Quantum Hall Effect and Berry's Phase of 2π in Bilayer Graphene, *Nature Physics* 2, 177-180 (2006).**

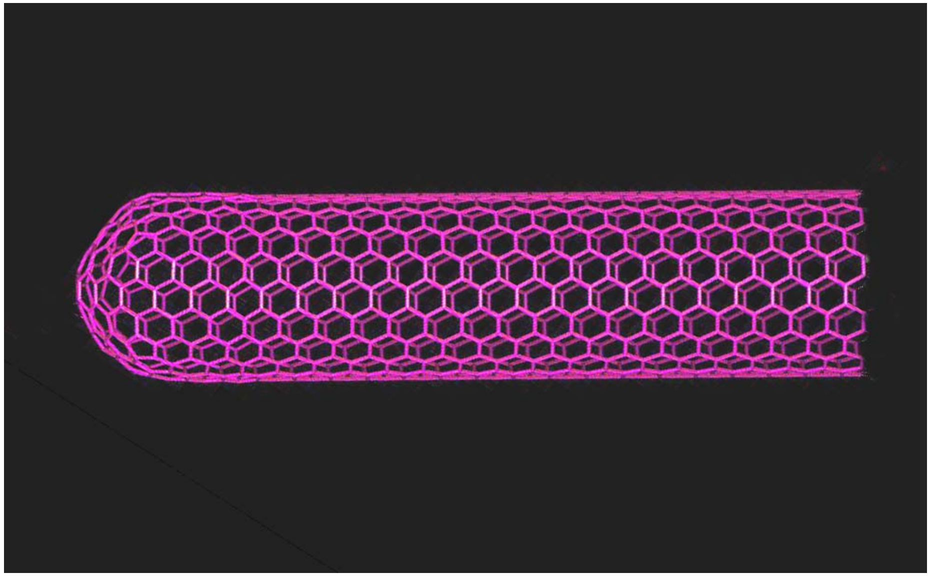
HEAT TRANSPORT IN 1D STRUCTURES IS QUANTIZED

Theoretical prediction:
Sir John B. Pendry, Quantum limits to flow of information and entropy, J. Phys. A16, 2161 (1983)

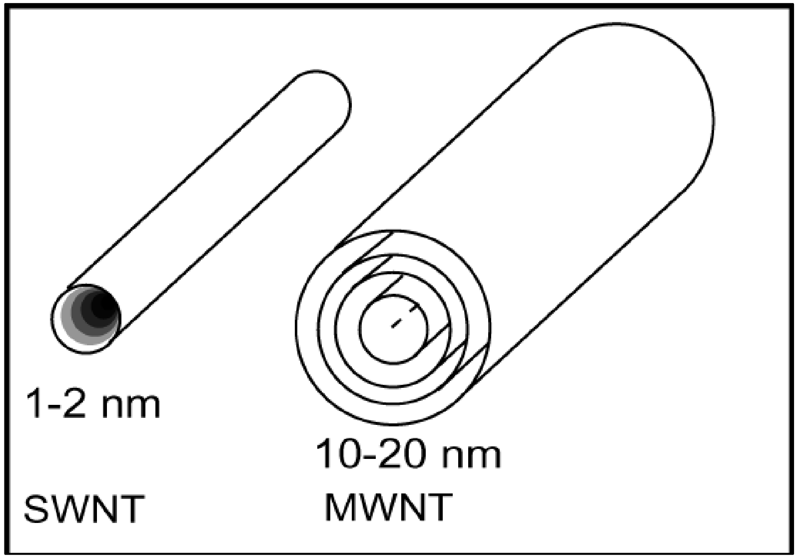
Experimental proofs:
1D phonons in 2000 by Michael Roukes et al, CalTech
1D electrons in 2006 by David Ritchie et al,Cambridge
1D photons in 2006 by Jukka Pekola et al, Helsinki

ELECTRON TRANSPORT IN CARBON NANOTUBES

CARBON NANOTUBEs



SINGLE AND MULTIWALLED TUBES



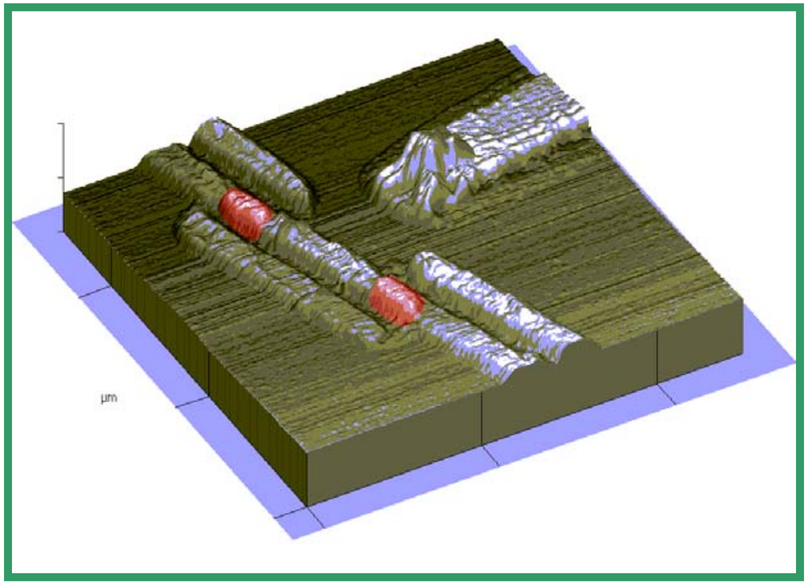
Induced superconductivity in MWNTs

Kowenhoven et al Delft 2005
Lindelof et al, Copenhagen 2005
Hakonen et al, Helsinki 2006

SINGLE ELECTRON TRANSISTOR - SET

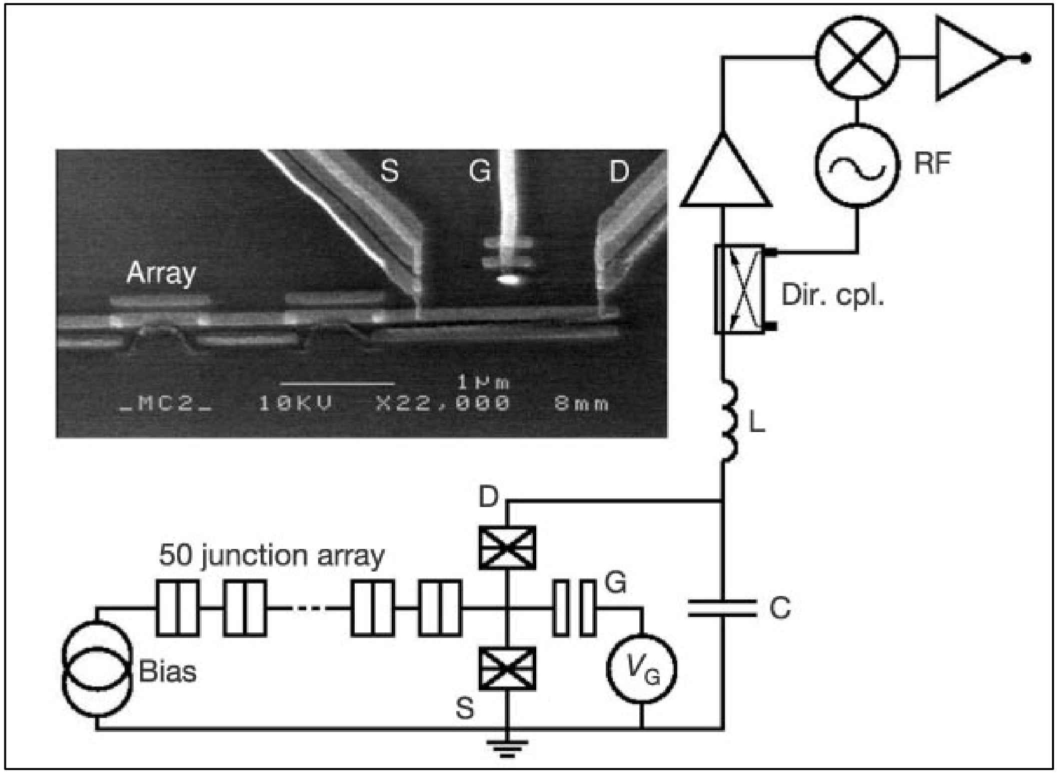
Invented in 1987
Works only at low temperatures $k_B T < E_C$..
Tunnel juntions smaller than 100 x 100 nm^2
Component for many applications:

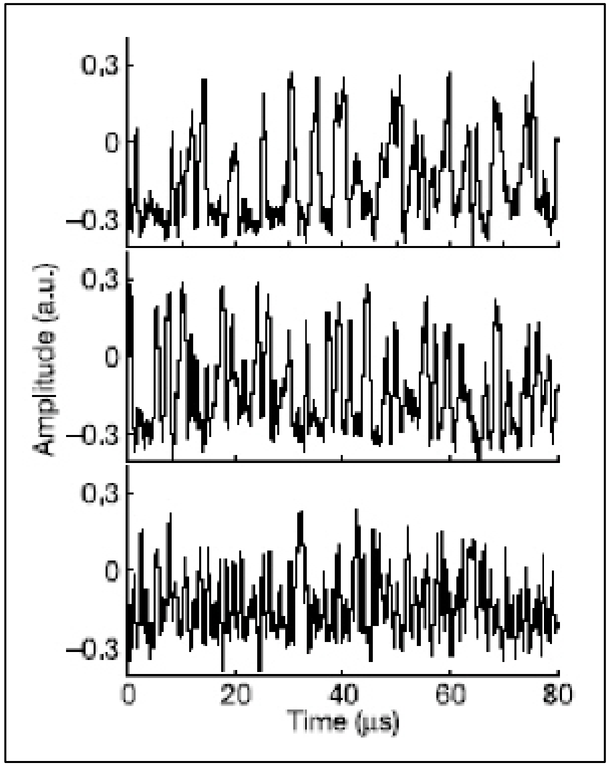
- ultra sensitive charge detection
- single electron counting and pumping
- quantum computing
- microrefrigeration
- nanothermometry



RF-SET
COUNTING SINGLE ELECTRONS IN REAL TIME

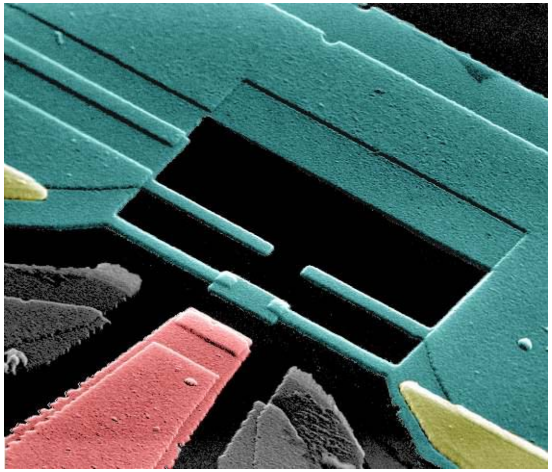
J. Bylander, T. Duty and Per Delsing, Chalmers Univ. of Tech. 2005 *Nature* **434** 361

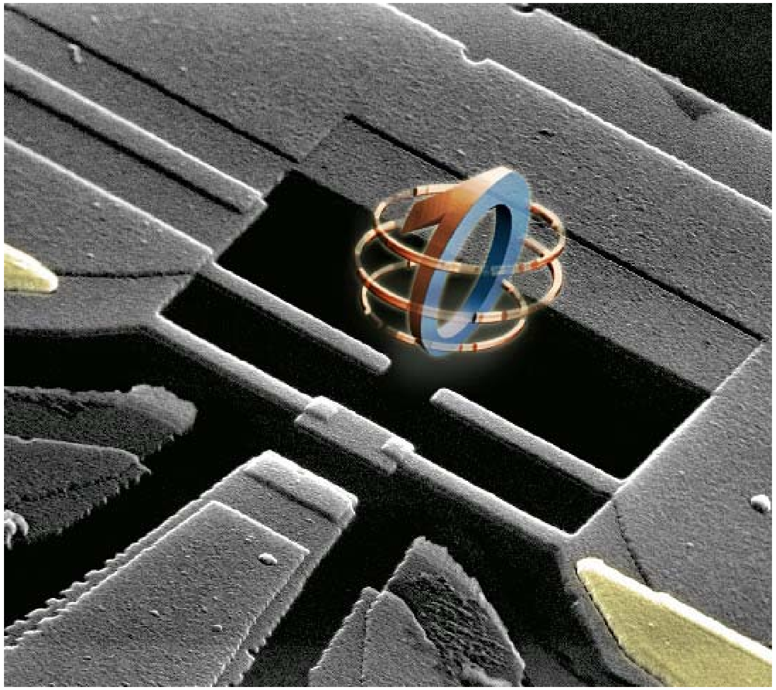




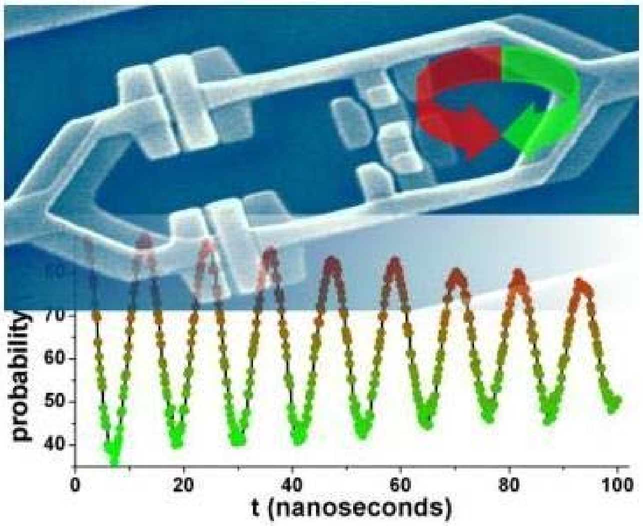
QUANTUM COMPUTING WITH JOSEPHSON JUNCTIONS

Quantronium (Saclay)

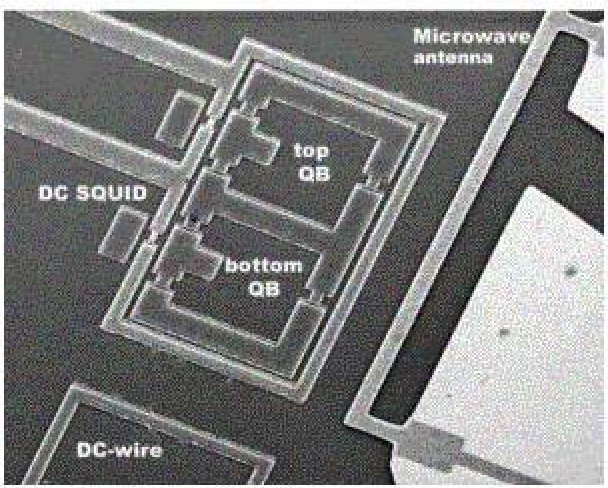




QUANTUM COMPUTING WITH JOSEPHSON JUNCTIONS

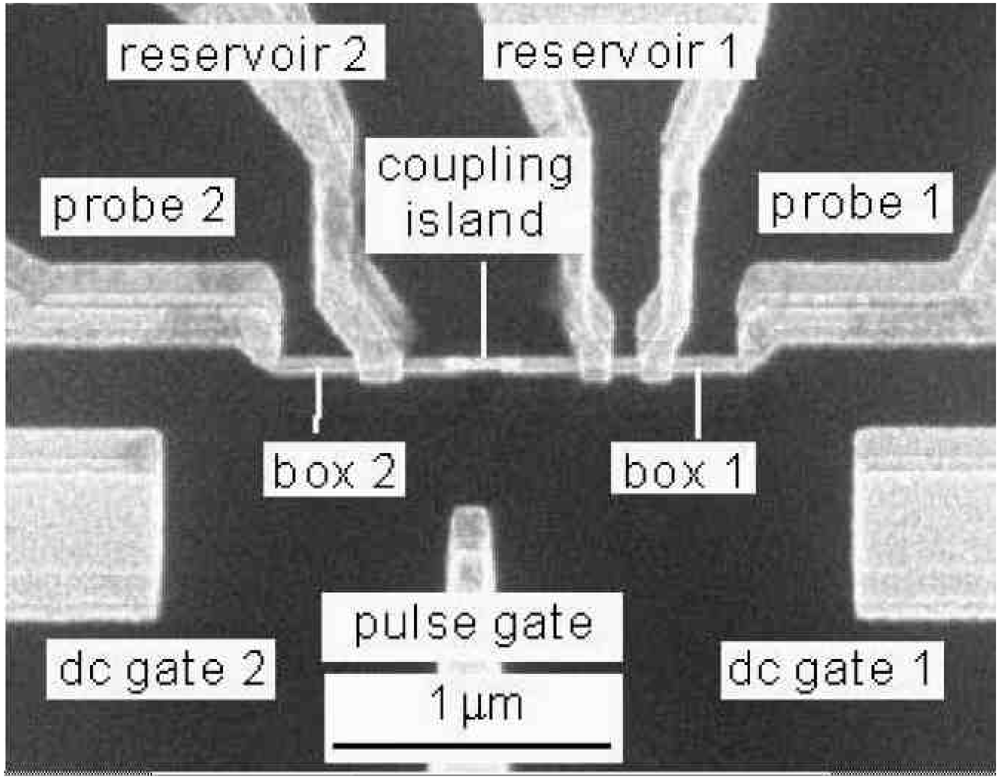


Delft: a flux qubit + Rabi oscillations

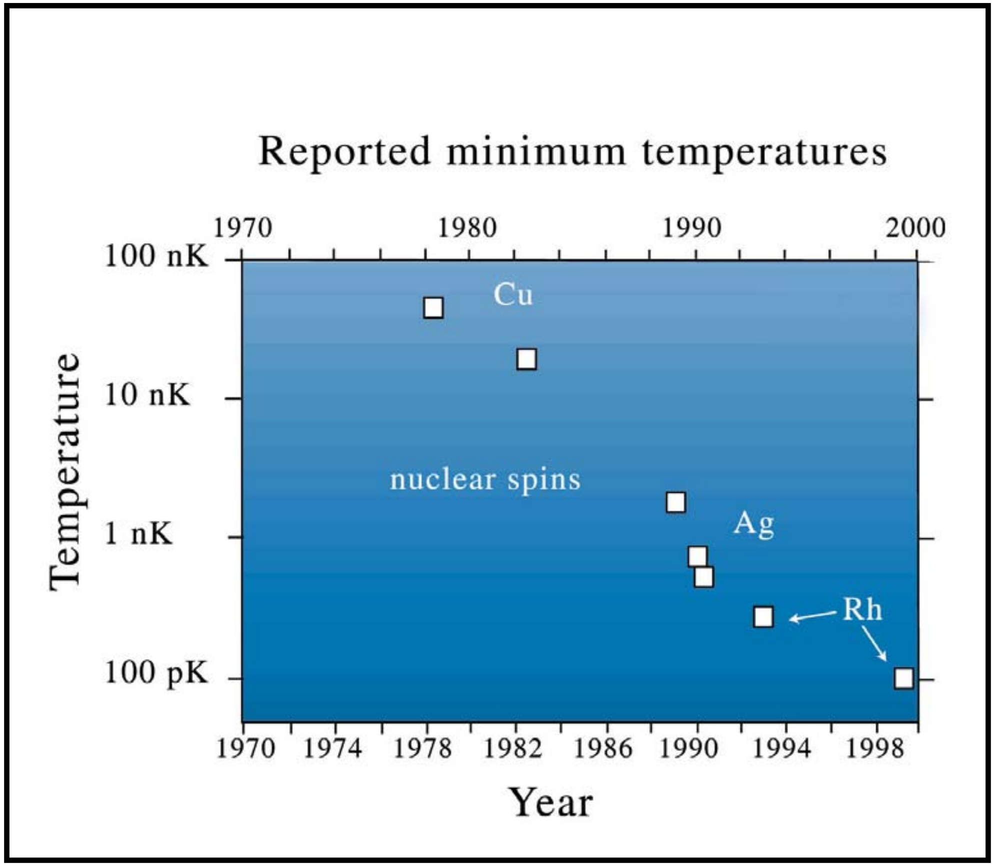


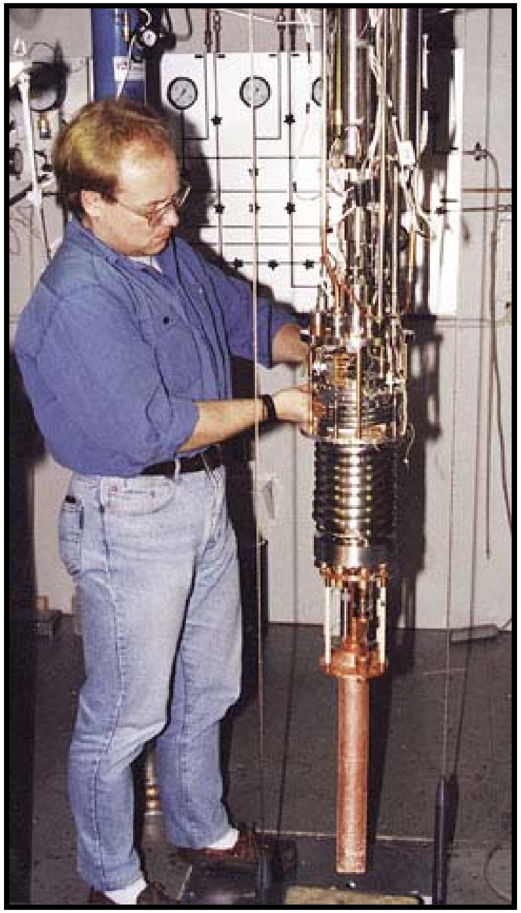
Delft: 2 coupled flux qubit

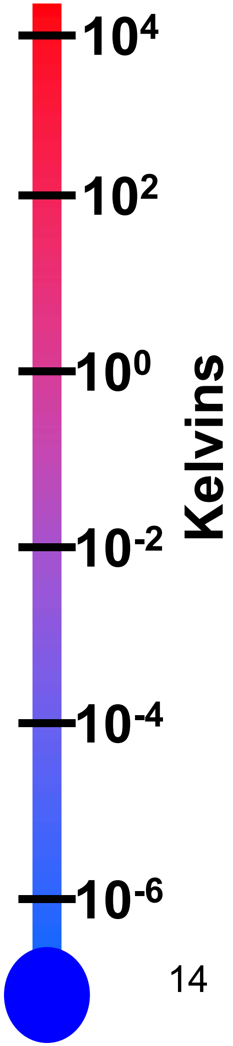
NEC (Tsukuba): entanglement in 2 coupled charge qubits



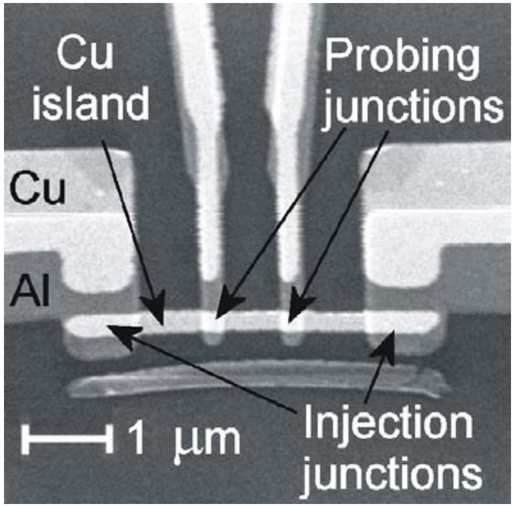
Brute force refrigeration methods

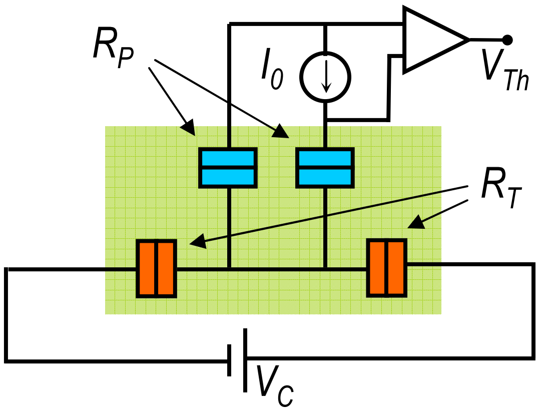




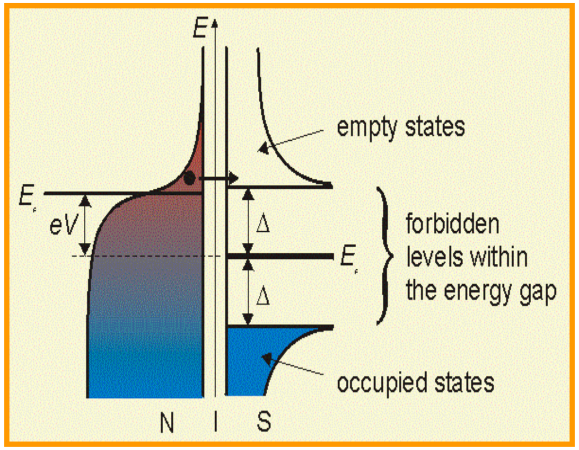


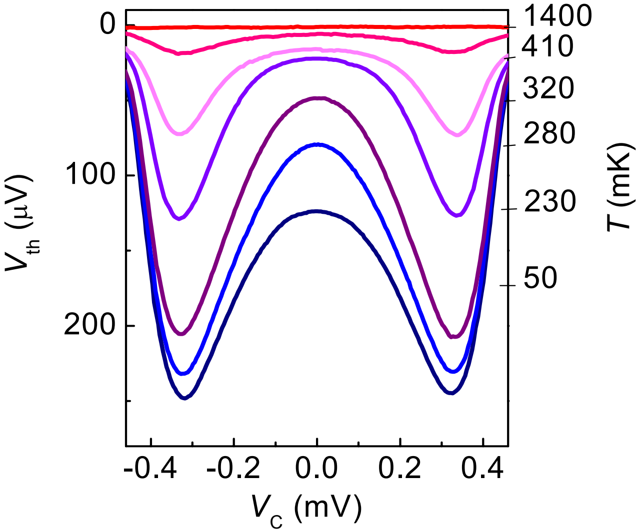
Microrefrigeration on a silicon chip

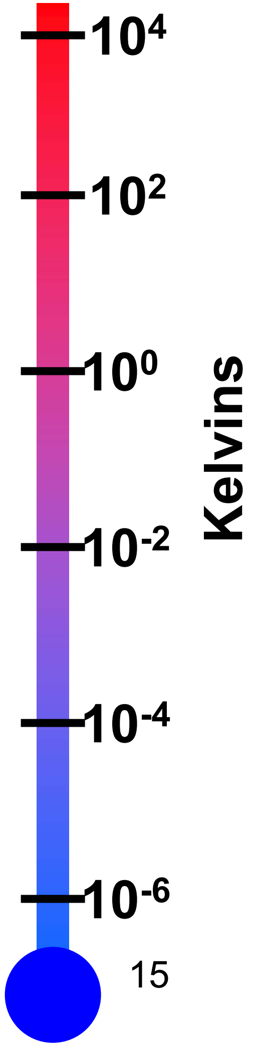




Pekola et al: Rev. Mod. Phys. 2006







NANOTHERMOMETER

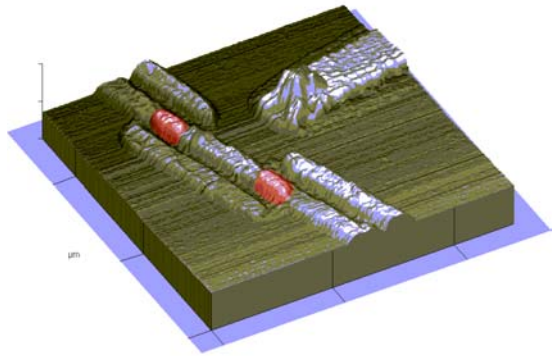
Coulomb Blockade Thermometry

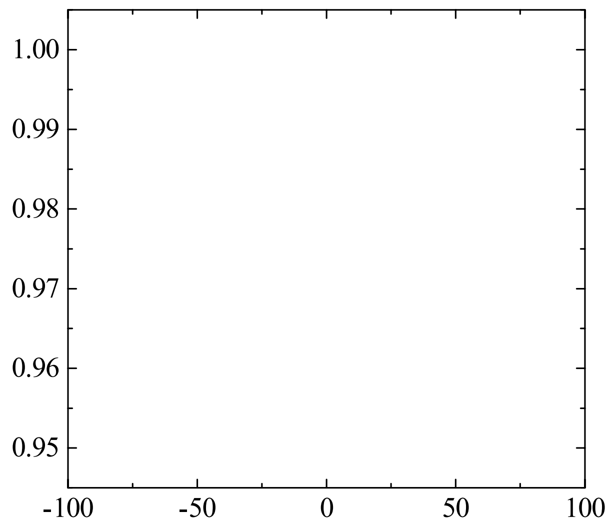
$V_{1/2} = 5.439 N k_B T / e$

primary thermometer

$\Delta G / G_T = \varepsilon_c / 6 k_B T$

secondary thermometer

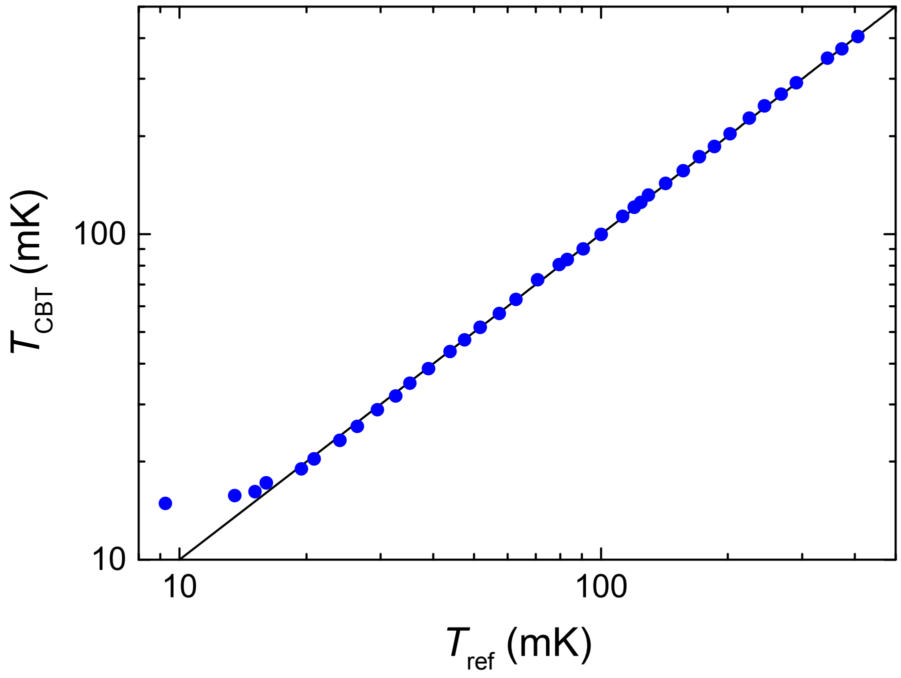




Normalised conductance, G/G_T, of a CBT sensor vs. voltage V. The theoretical curve is shown as a black line.

J. Pekola, K. Hirvi, J. Kauppinen, M. Paalanen, PRL**73**, 2903 (1994).

NANOTHERMOMETRY



Measurements by *M. Meschke, H. Godfrin, R. E. Rapp, J. P. Pekola* at CNRS, CRTBT, Grenoble (2002).

Conclusions

- Studies of nano-size samples have a long history in low temperature physics
    - Quantum electron transport in 2D, 1D and 0D (quantum dot) samples
    - Magnetism in nanoparticles

- Recent exciting developments in low temperature nanophysics:
    - QHE in sheets of graphene
    - Quantization of heat current in 1D wires (phonons, electrons, photons)
    - Induced superconductivity in carbon nanotubes (MWNT)
    - Counting and pumping of single electrons
    - Quantum computing
    - Imaging of single electron spins
    - Nanothermometry and microrefrigeration
- Quantum computing common to C5 with C15 and C17.
- Quantum electron transport common to C5 and C8
- Low temperature applications in metrology common to C5 and C2
- Nanomagnetism common to C5 and C7