

Energetics of transport in quantum dot devices

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QT60, Helsinki, 19 September 2018

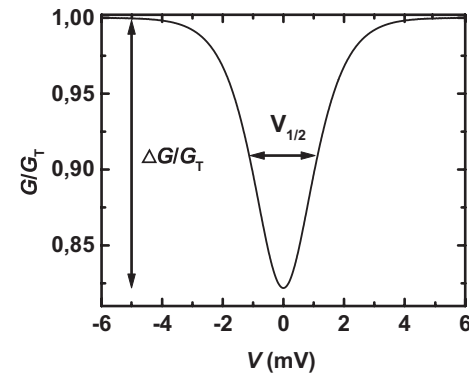


Thermometers, calorimeters and helium-3...

Journal of Low Temperature Physics, Vol. 134, Nos. 5/6, March 2004 (© 2004)

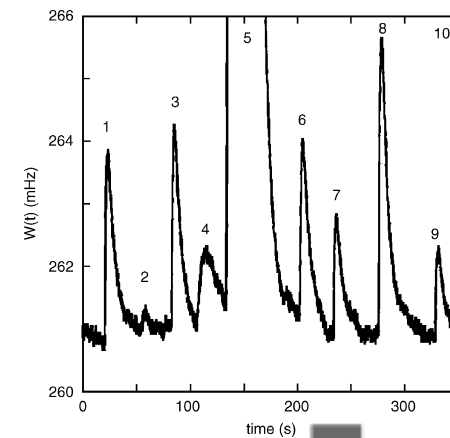
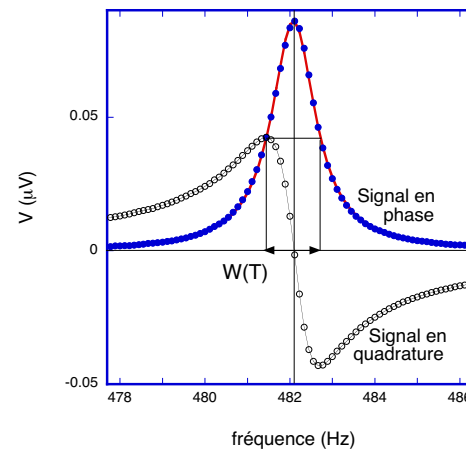
Electron Thermalization in Metallic Islands Probed by Coulomb Blockade Thermometry

M. Meschke,¹ J. P. Pekola,² F. Gay,¹ R. E. Rapp,³ and H. Godfrin¹



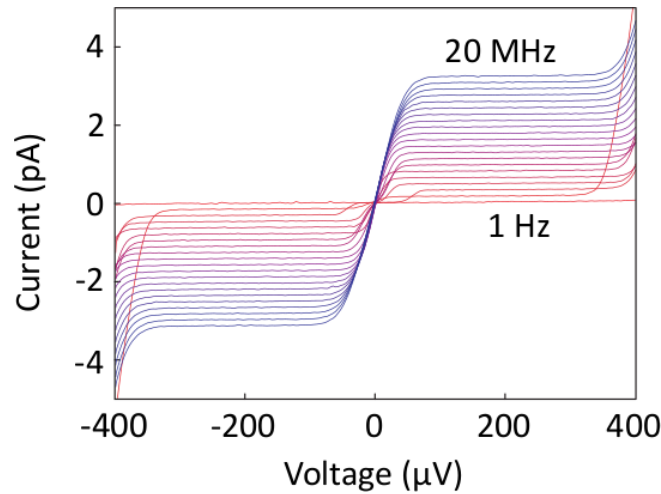
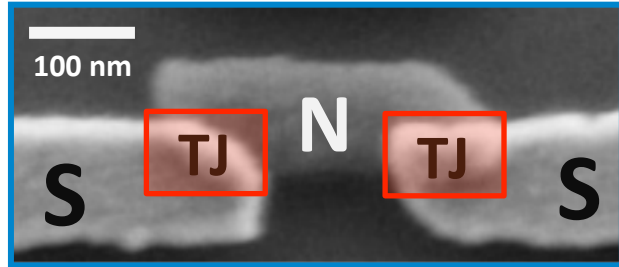
Thermometry:
With tunnel junctions...

... and with resonators

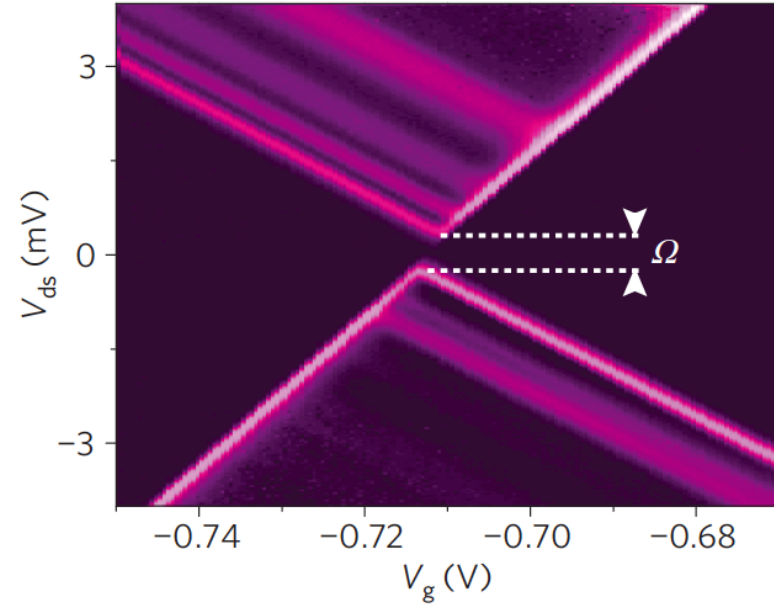


*Winkelmann et al., JLTP (2004),
NIMA (2006), PRL (2006)*

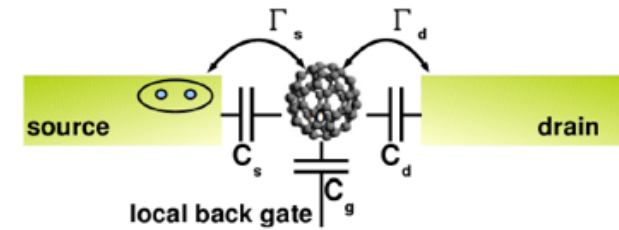
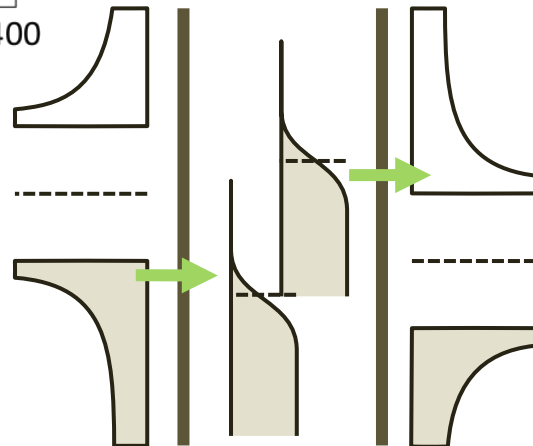
Superconducting electron turnstiles



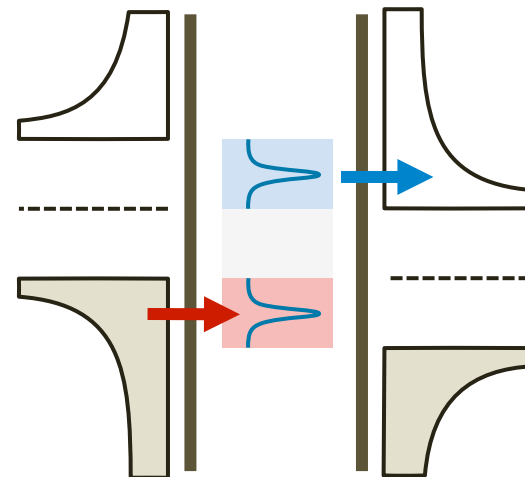
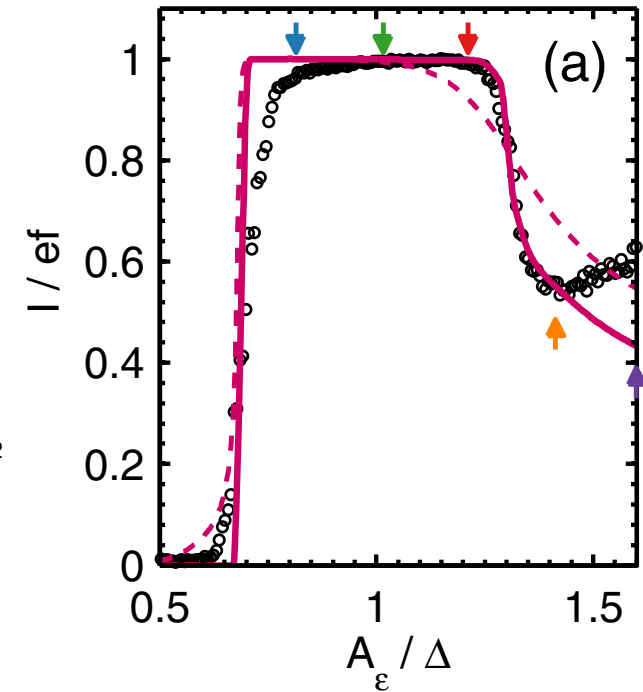
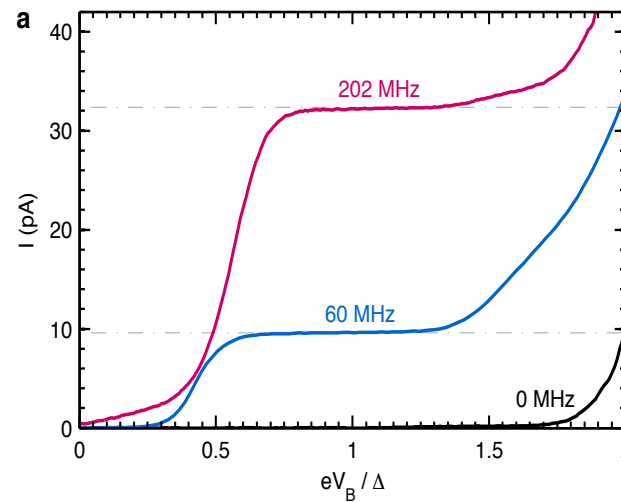
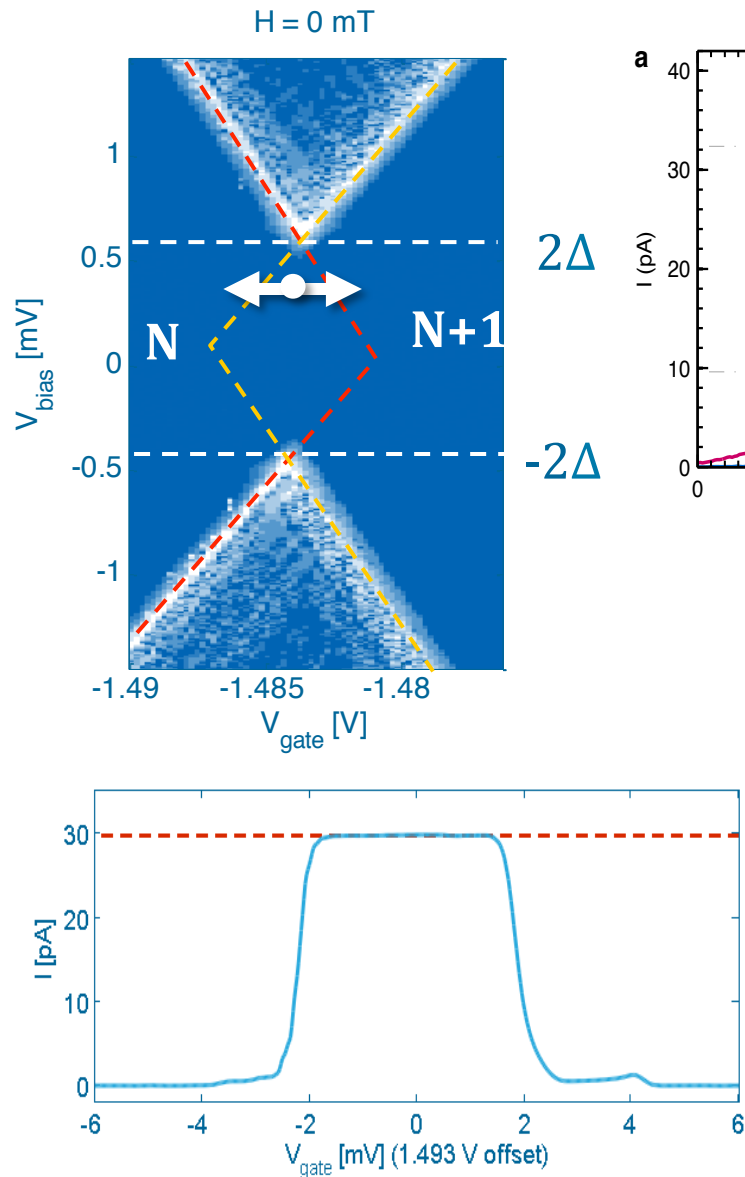
Pekola et al., Nature Phys. (2008)
Pekola et al., Rev. Mod. Phys. (2013)



Winkelmann et al., Nature Phys. (2009)

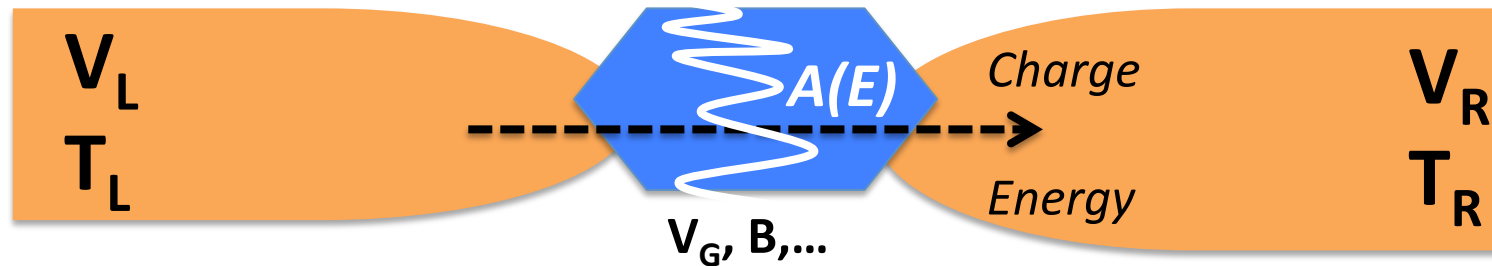


QDs as monochromatic single electron injectors



van Zanten, Basko, Khaymovich,
 Pekola, Courtois, Winkelmann,
 Phys. Rev. Lett. (2016)

Charge versus energy current



- Charge and heat flow

$$\begin{pmatrix} I \\ \dot{Q} \end{pmatrix} = \begin{pmatrix} G & -SG \\ -TSG & TS^2/G - \kappa \end{pmatrix} \begin{pmatrix} \Delta V \\ \Delta T \end{pmatrix}$$

- Heat engine

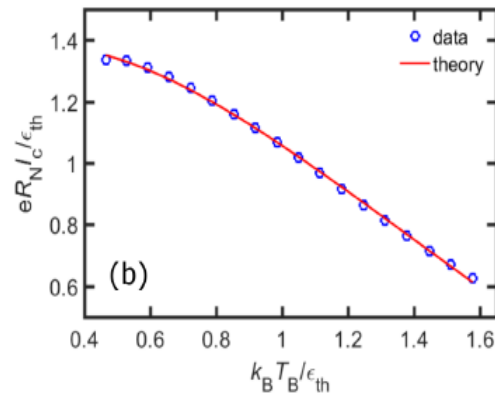
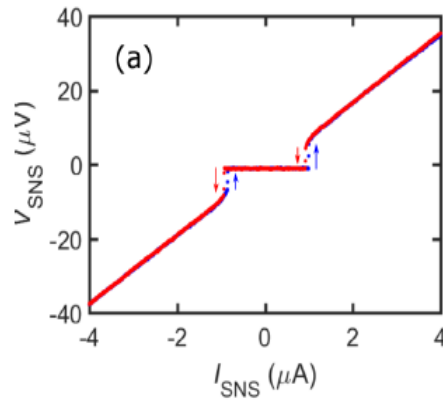
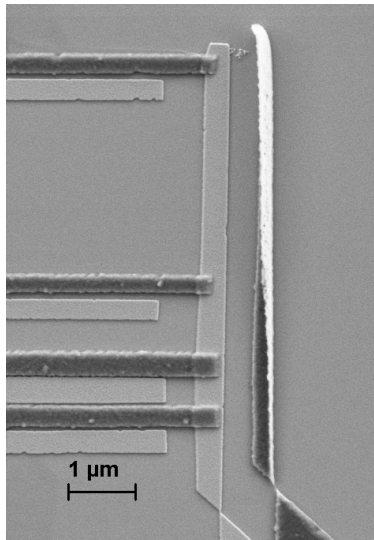
$$ZT = \frac{\dot{W}}{\dot{Q}} = \frac{GTS^2}{\kappa}$$

- Wiedemann-Franz law

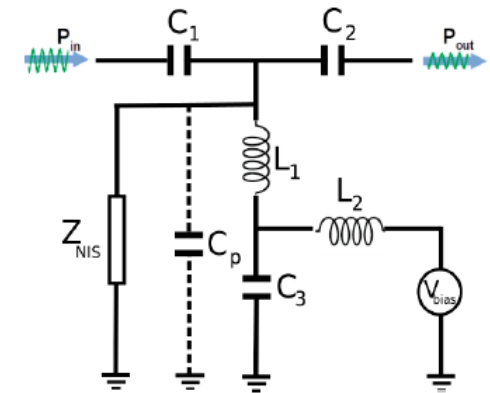
$$\frac{GT}{\kappa} = 3 \left(\frac{e}{\pi k_B} \right)^2 = \frac{1}{L_0}$$

Experimental tools

Local electronic thermometry

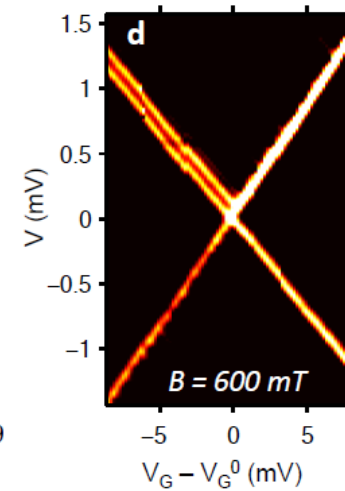
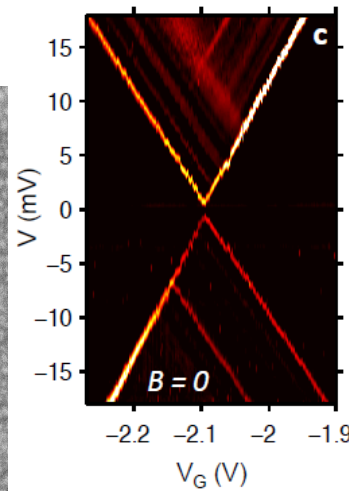
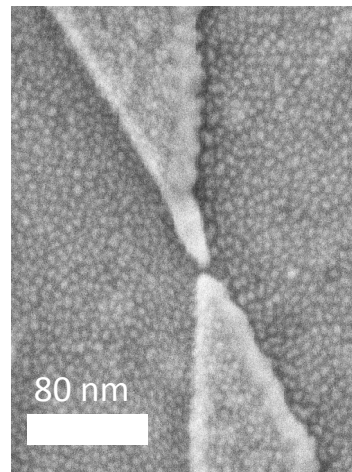
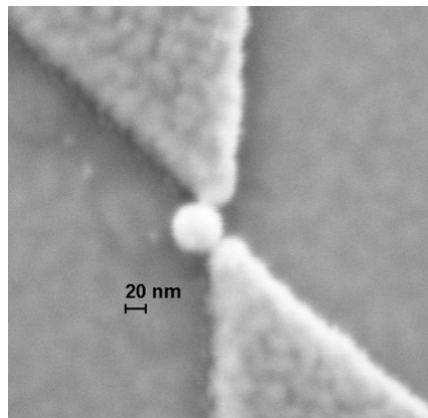


RF read-out



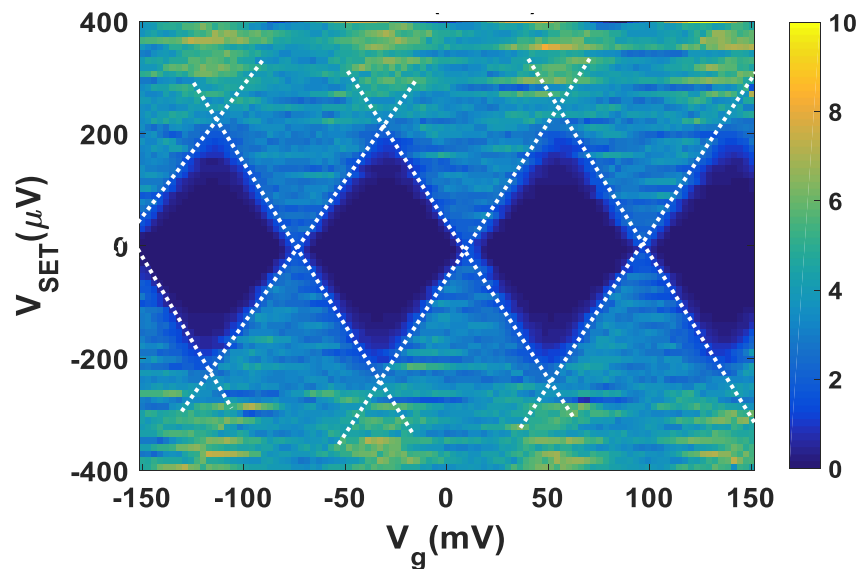
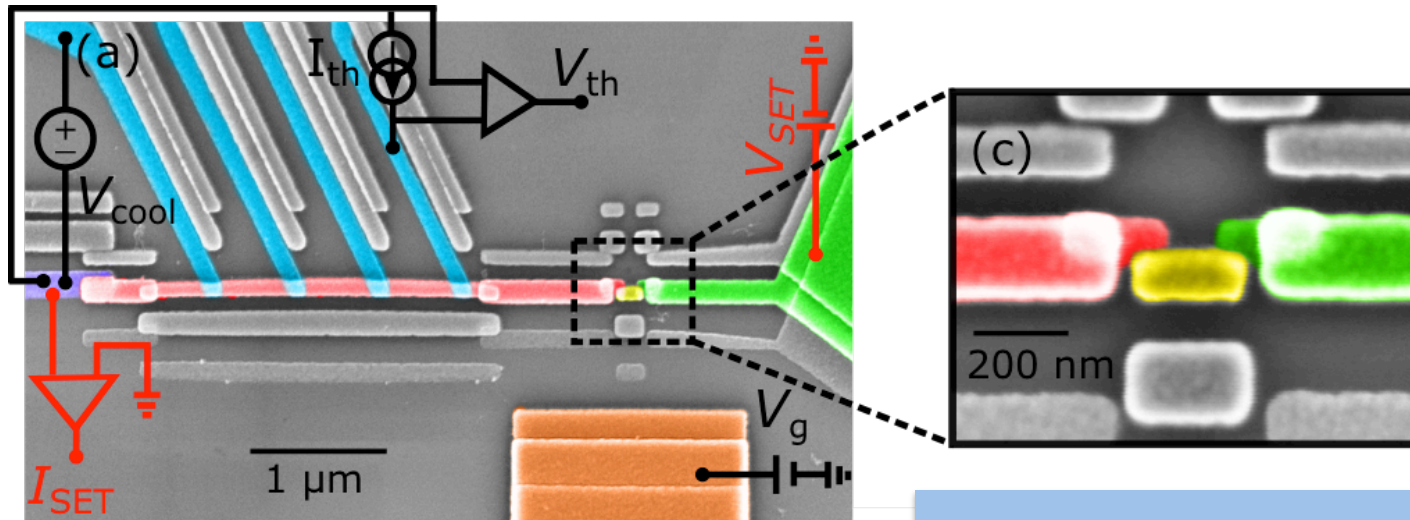
Gasparinetti et al.,
Phys. Rev. Appl. (2015)

Electromigration



van Zanten et al.,
Phys. Rev. B (2015)

Thermal transport in the presence of Coulomb blockade

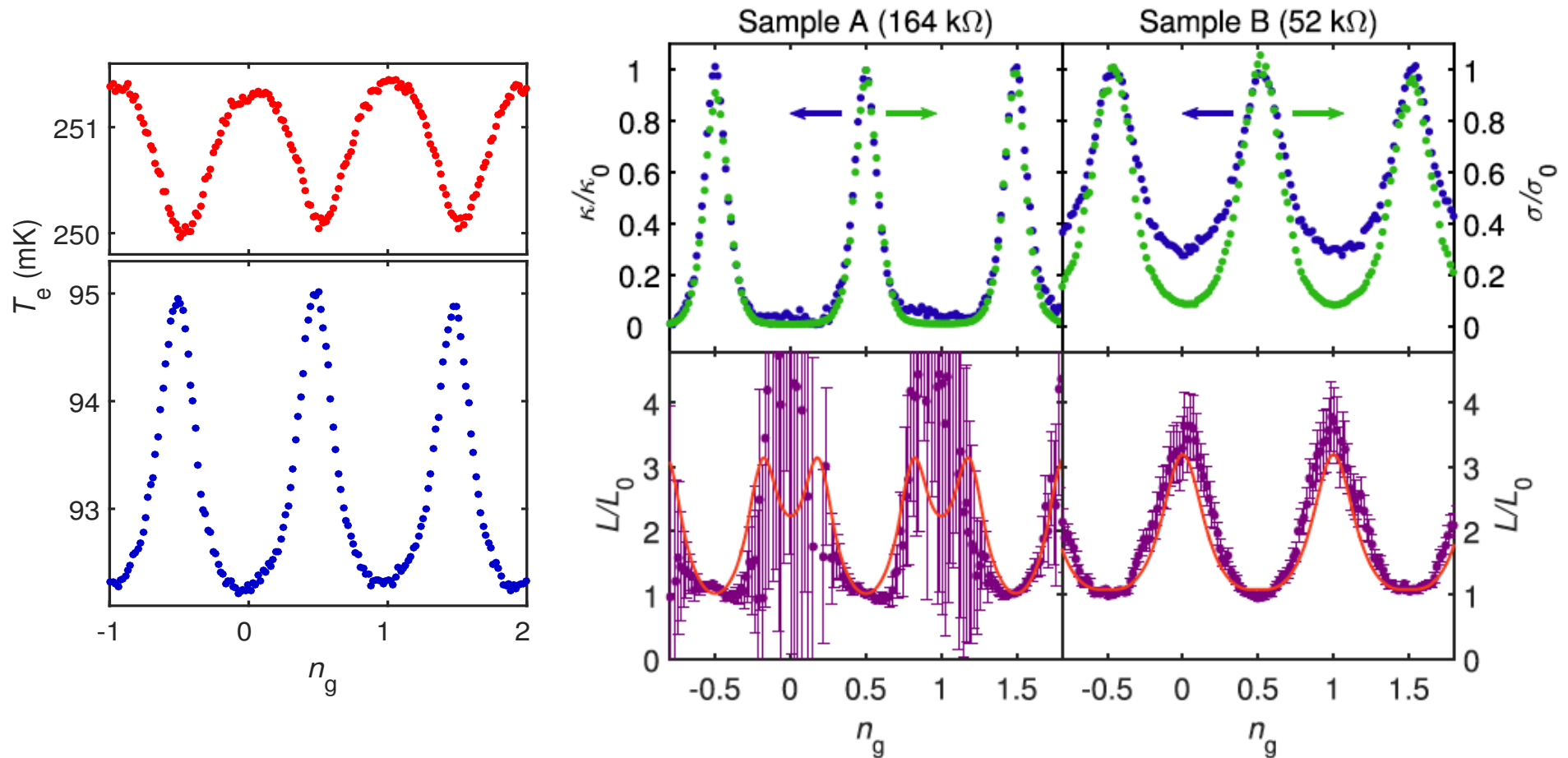


UGA Nanoscience Foundation
Chair of Excellence J.P. Pekola
2015-2018



Bivas Dutta

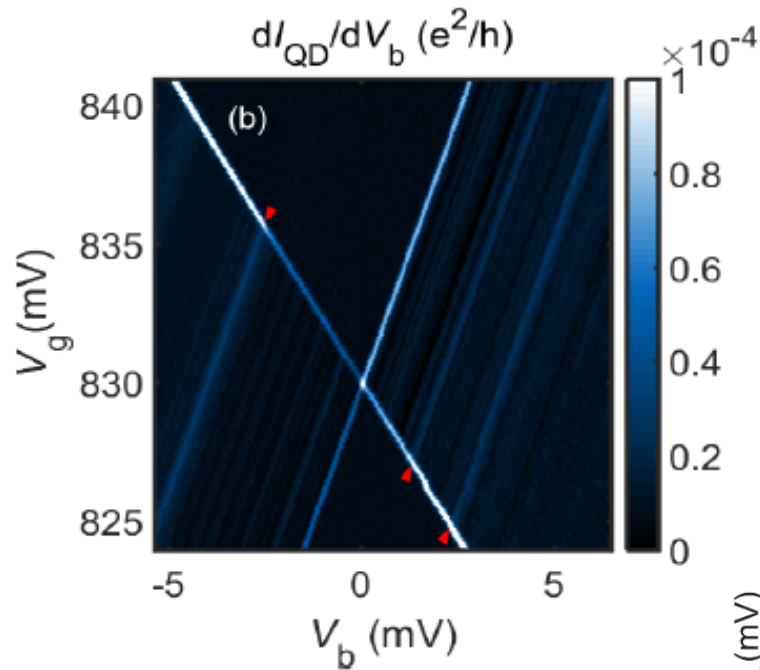
Thermal transport in the presence of Coulomb blockade



B. Dutta, J.T. Peltonen, D.S. Antonenko, M. Meschke, M.A. Skvortsov, B. Kubala, J. König, C.B. Winkelmann, H. Courtois, and J.P. Pekola, *Phys. Rev. Lett.* 2017

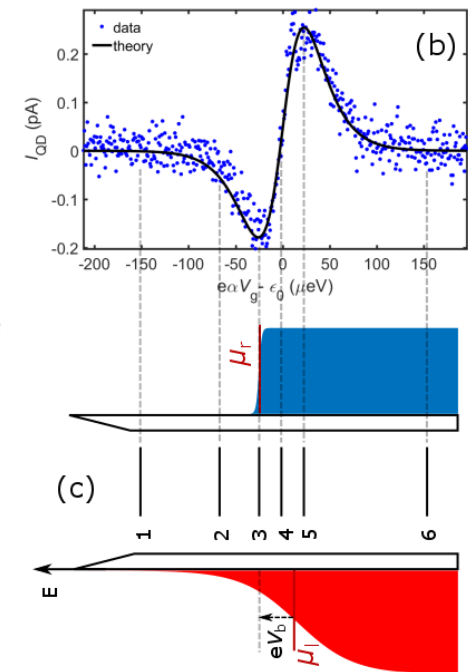
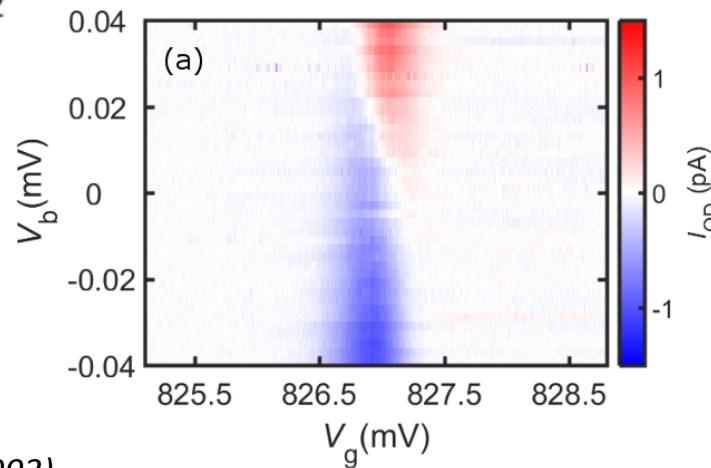
Theory: Kubala, König, Pekola, *Phys. Rev. Lett.* 2008

Thermopower of a weakly coupled quantum dot



Independent access to device parameters and T_L, T_R

Applications as a heat engine



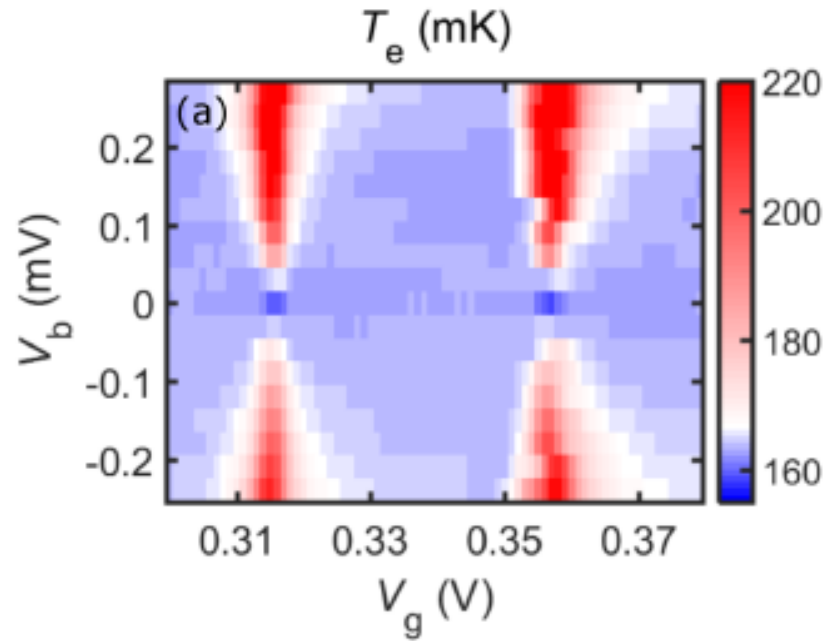
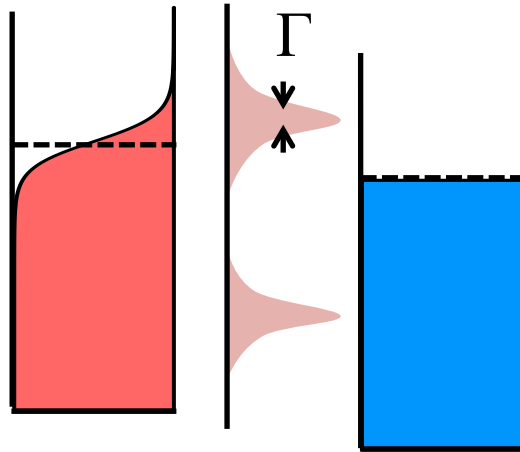
Beenakker and Staring, *Phys. Rev. B* (1993)

Matveev and Turek, *Phys. Rev. B* (2002)

Erdman et al., *Phys. Rev. B* (2017)

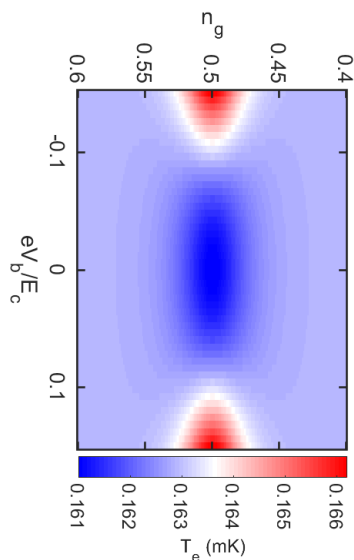
See also: Joseffson et al., *Nature Nanotechnol.* (2018)

Thermal signature of transport in a QD junction

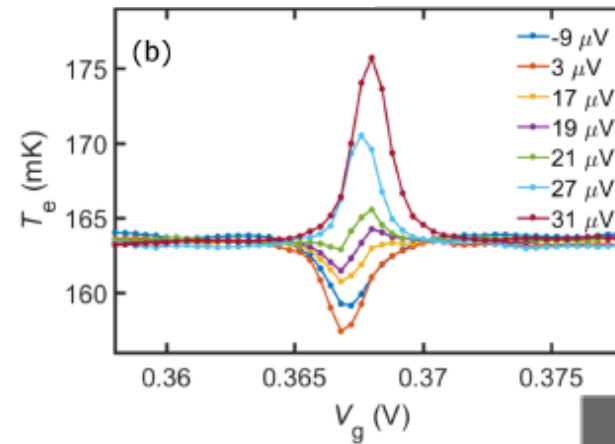
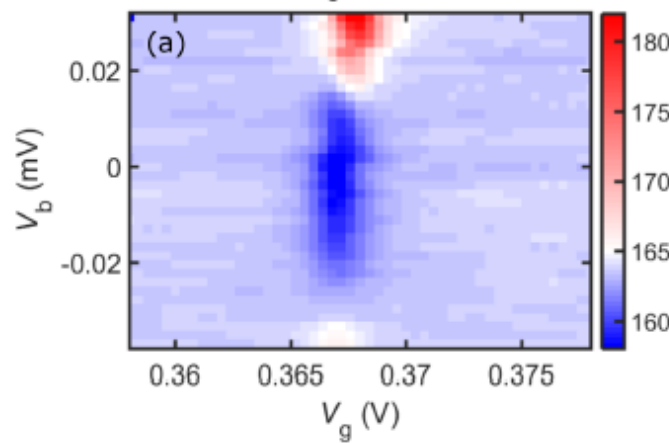


Temperature map of transport

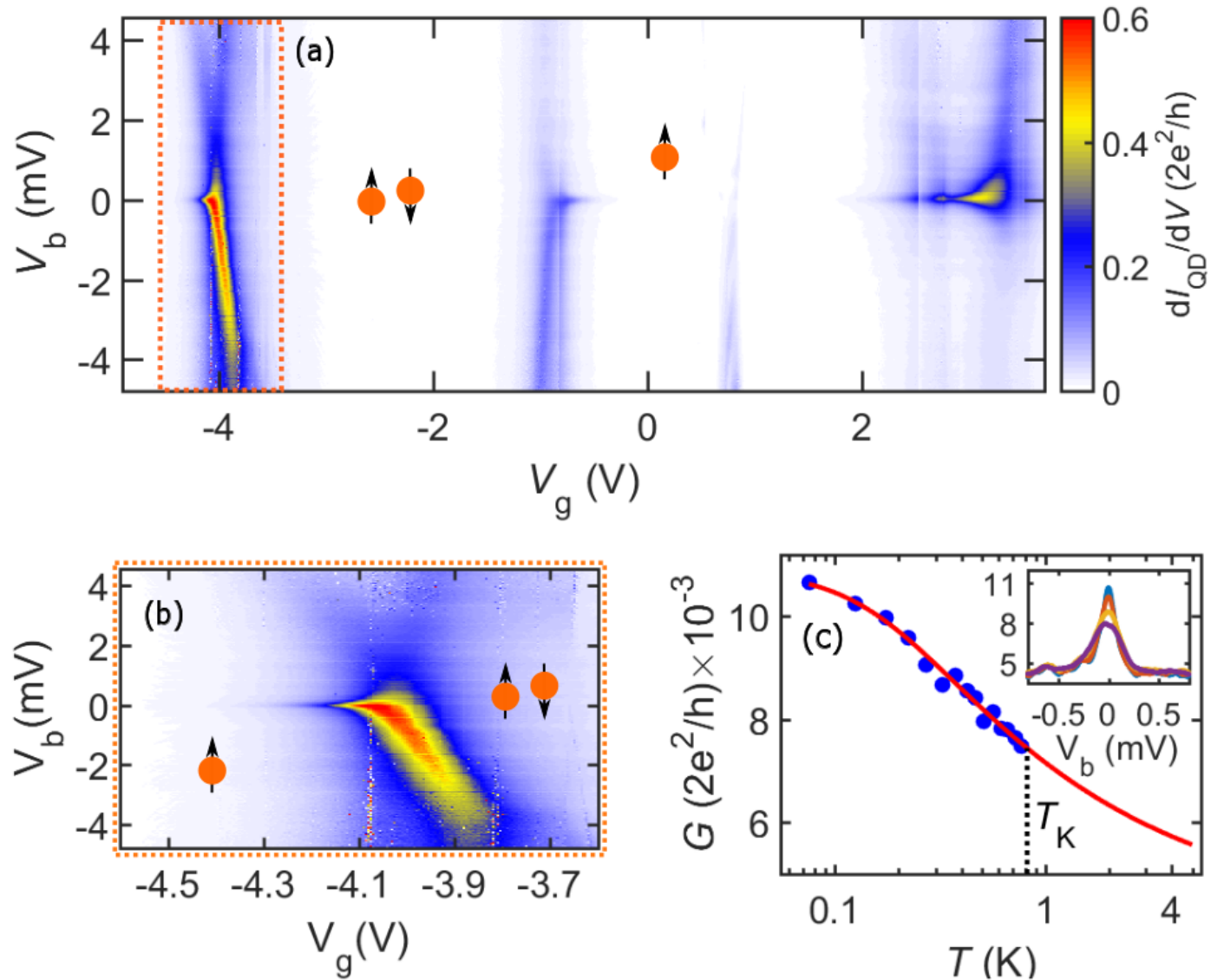
- Heat valve
- Dissipation
- Refrigeration



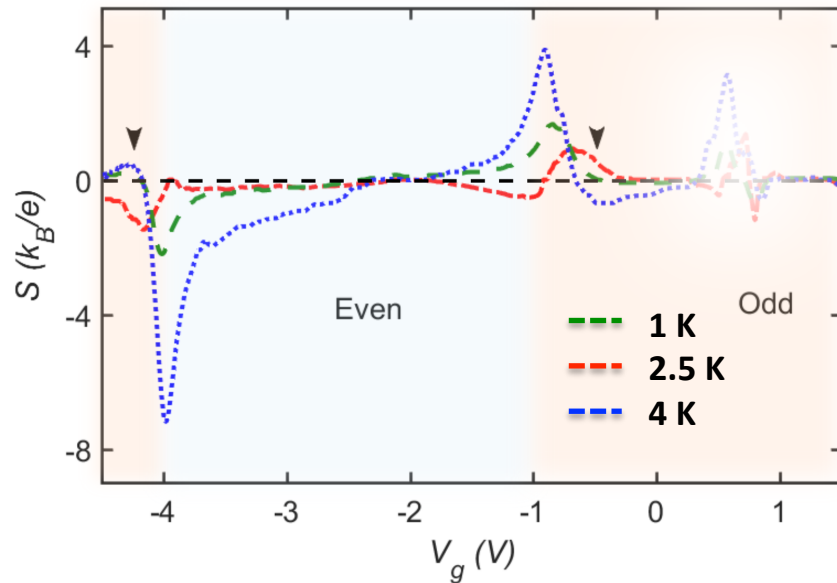
Theory (SET)



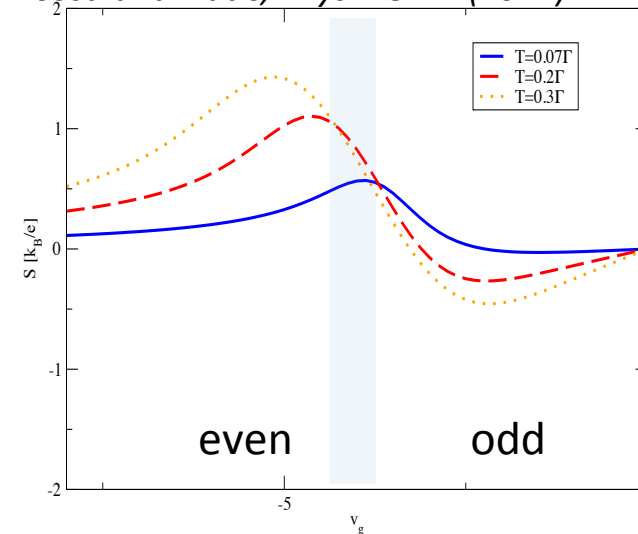
Thermopower in the Kondo regime



Thermopower in the Kondo regime

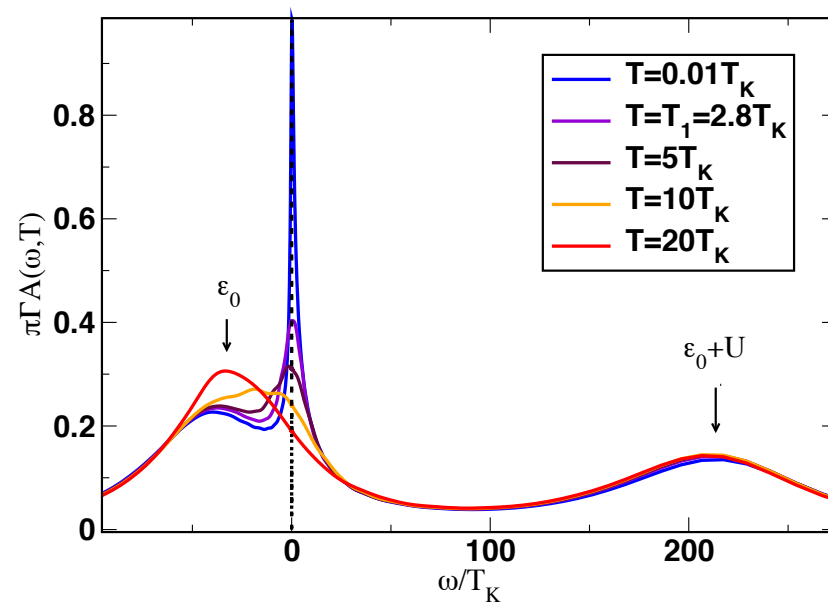


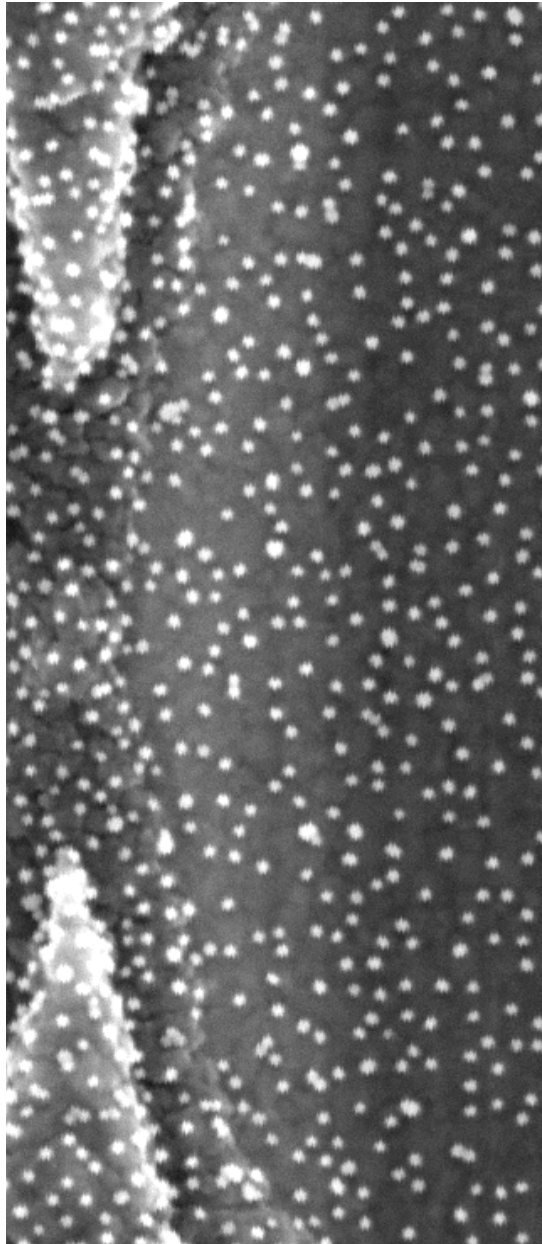
NRG calculations by T. Costi
Costi and Zlatic, Phys. Rev. B (2011)



- 2e-periodic thermopower signal
 - Sign change as temperature is increased
- (as opposed to mixed valence regime
Scheibner et al., Phys. Rev. Lett. 2005)

See also: *Svilans et al., arXiv:1807.07807*





People

Frank Balestro, Denis Basko, Theo Costi, Hervé Courtois, Bivas Dutta, Paolo Erdman, Alvaro Garcia Corral, Frank Hekking, Bayan Karimi, Ivan Khaymovich, Danial Majidi, Matthias Meschke, Joonas Peltonen, Jukka Pekola, Fabio Taddei, David van Zanten...

