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Approaching Microkelvin Temperatures in Nanoscale Samples

The ability to reach low millikelvin or even microkelvin temperatures in nanoscale samples would open up the possibility to discover new physics in a variety of systems. For example, a nuclear spin ferromagnetic phase transition in a GaAs interacting 2D electron gas has been predicted to occur around ~1 mK at B=0 [1], constituting a novel type of correlated state which fully suppresses nuclear spin fluctuations, eliminating the main source of decoherence for GaAs spin qubits. Further, full thermodynamic nuclear spin polarization is possible at temperatures <1 mK in an external magnetic field of ~ 10 T.
Here, I present a new scheme aimed at cooling nanostructures to microkelvin temperatures [2], based on the well established technique of adiabatic nuclear demagnetization: we attach each device measurement lead to an individual nuclear refrigerator, allowing efficient thermal contact to a microkelvin bath. On a prototype consisting of a parallel network of nuclear refrigerators, temperatures of ~ 0.4 mK simultaneously on 20+ measurement leads have been reached upon demagnetization, thus completing the first steps toward ultracold nanostructures.

[1] P. Simon, B. Braunecker and D. Loss, Phys. Rev. B **77**, 045108 (2008)

[2] A. C. Clark, K. K. Schwarzwaelder, T. Bandi, D. Maradan, and D. M. Zumbuhl, Rev. Sci. Inst. **81**, 103904 (2010).

3. Juni 2011, 15:30 Uhr

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