Spin thermometry of individual neutral impurities coupled to a Bose-Einstein condensate

J. Nettersheim[a], Q. Bouton[a], D. Adam[a], T. Lausch[a], D. Mayer[a], F. Schmidt[a], and A. Widera[a,b]

[a]Department of Physics and Research Center OPTIMAS Technische Universitat Kaiserslautern, Germany
[b]Graduate School Materials Science in Mainz Gottlieb-Daimler-Strasse 47, Kaiserslautern, Germany

The measurement of (local) thermodynamic properties of a quantum system is the key for a detailed understanding of thermalization and dynamic in nonequilibrium quantum systems. Temperature, i.e. the distribution of kinetic energy, was measured so far by investigating motional dynamics of the total system or impurities immersed.
Here, we present a novel way of local in-situ thermometry based on the spin dynamic of individual neutral Caesium (Cs) atoms with total spin F=3 in an ultracold gas of Rb atoms with total spin F=1. Elastic collisions thermalize the impurity, reflecting temperature in the kinetic energy distribution of the impurities. For the spin degree of freedom, the competition of endo- and exoergic spin-exchange processes map the temperature onto the quasi-spin population of the impurity. The sensitivity of the thermometer can be adjusted via the external magnetic field changing the Zeeman energy splitting. Moreover, our thermometer is not restricted to probing steady-state populations, but we also infer possible enhancement of sensitivity, if temperature information is obtained from nonequilibrium dynamic of the probe.
Our work thus provides a novel way of performing in-situ thermometry by measuring internal state populations rather than atomic motion.