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Spatially resolved Rydberg Doppler broadening thermometry and prospects for Dy Rydberg spectroscopy

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Abstract: We present temperature measurements based on Doppler broadening of Rydberg transitions. Spatial resolution is achieved using a two-photon Rydberg transition with two orthogonal laser beams. Prospects of experimental developments for dysprosium Rydberg atoms are given.

Rydberg atoms are increasingly being used as quantum sensors for electromagnetic fields, ranging from static electric fields to THz [1]. Here we show that, thanks to their small intrinsic linewidth of only a few kHz, transitions to Rydberg states are also useful to infer the temperature of an atomic sample through the Doppler broadening induced by the thermal motion of the atoms. Moreover, by using a two-photon Rydberg transition it is possible to excite only the atoms in the overlap region of two laser beams, resulting in 3D spatial resolution.

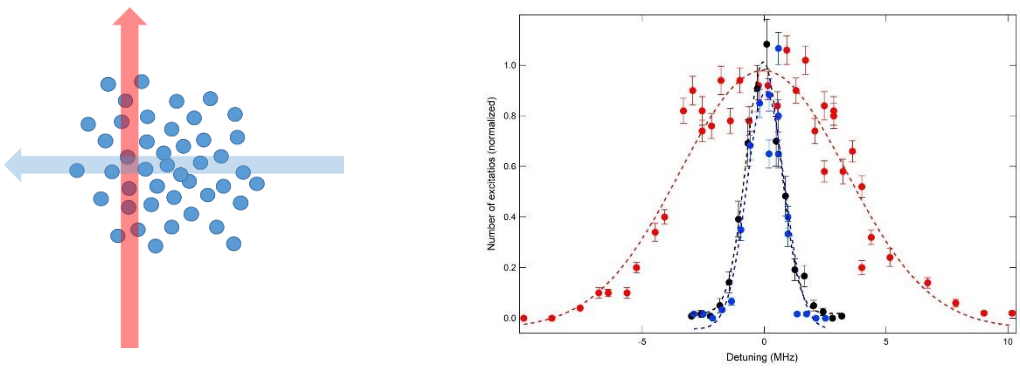

Fig. 1 Scheme for spatially resolved Doppler broadening thermometry (left), in which cold atoms are excited to Rydberg states via a two-photon transition using two intersecting laser beams. From the resulting excitation spectra (right) the local temperature can be calculated (blue data points: 40 μK, black: 200 μK, red: 15 mK)

Fig. 1 shows our scheme and some examples of temperature measurements for rubidium atoms in a magneto-optical trap at around 200 μK, after cooling to 40 μK in an optical molasses, and after resonant heating to 15 mK. We detect the excited Rydberg atoms by field ionization with a high efficiency (40%), which allows us to accurately measure temperatures also in very small samples containing only a few hundred atoms. Also, the spatial resolution makes it possible to investigate temperature gradients, such as those theoretically predicted to exist in magneto-optical traps [1]. This method will be employed in future experiments on rubidium Rydberg atoms in arrays of optical tweezers.

In parallel, another setup for Rydberg atoms of dysprosium of is currently being developed at INO Pisa. After a first spectroscopic investigation, we intend to exploit the large number of ground states and optical transitions available to realize a more versatile quantum toolbox.

References

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