Detecting Trapped Atoms with Minimal Disturbance: Real-Time Readout through Spin Noise

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Detecting trapped atoms while preserving their dynamics is a central challenge in quantum science. Conventional fluorescence and absorption measurements obtain information through light scattering, which can disturb the atomic sample. This talk will explore an alternative route: using optically measured spin fluctuations to reveal local atomic density with minimal perturbation. Drawing particularly on our work published in Applied Physics Letters 127, 044004 (2025), I will present Raman-driven spin noise spectroscopy as a practical probe of trapped cold atoms. The method combines two coherent Raman fields that couple neighbouring Zeeman states with a tightly focused, far-detuned optical probe. Detecting fluctuations in the probe's Faraday rotation provides a spatially selective signal of the driven atomic spin coherence. I will discuss its experimental implementation in cold potassium ensembles, the dependence of the signal on trapping and loading conditions, and the reconstruction of local density profiles. Comparison with fluorescence-based profiles provides a benchmark, while direct local probing offers particular advantages for clouds without spherical symmetry. The talk will also examine the prospects enabled by MHz rate data acquisition for following atomic dynamics, alongside connections to spin correlation measurements and precision magnetometry. Finally, I will discuss how minimally perturbative optical detection could support neutral-atom quantum computing and quantum sensing, distinguishing demonstrated ensemble-density measurements from future qubit-readout applications.

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