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Rydberg Impurity Probes in Ultracold Gases MARK MITCHISON, Imperial College London, TOMI JOHNSON, National University of Singapore, University of Oxford, MARTIN PLENIO, Universitat Ulm, Imperial College London, DIETER JAKSCH, University of Oxford, National University of Singapore — Impurities immersed in ultracold gases can act as highly sensitive, tunable and potentially non-destructive probes of their environment. In this setting, we propose the use of an atomic impurity in a Rydberg state to measure density fluctuations via Ramsey interferometry. The rapid collisional dynamics of the light Rydberg electron interacting with the heavy gas particles, combined with the capability to quickly change the state of the impurity with optical pulses, make such a probe ideal for measuring local properties of ultracold gases. Our proposed device promises angle-resolved density measurements with sub-micron spatial resolution, and with no need to integrate over the line of sight. We outline how Rydberg impurity probes could be applied to study various interesting quantum states of current experimental relevance. We also discuss the possibility of using multiple Rydberg atoms to extract the spatial pair distribution function $g^{(2)}(\boldsymbol{r})$. Our work is placed in the context of other recently proposed impurity-based probes.

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