Quantum gas magnifier for sub-lattice-resolved imaging of three-dimensional quantum systems

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Imaging is central for gaining microscopic insight into physical systems, but direct imaging of ultracold atoms in optical lattices as modern quantum simulation platform suffers from the diffraction limit as well as high optical density and small depth of focus. We introduce a novel approach to imaging of quantum many-body systems using matter wave optics to magnify the density distribution prior to optical imaging, allowing sub-lattice spacing resolution in three-dimensional systems [1]. Combining the site-resolved imaging with magnetic resonance techniques for local addressing of individual lattice sites of a two-dimensional lattice of tubes, we demonstrate full accessibility to local information and local manipulation in a three-dimensional system. The method opens the path for spatially resolved studies of new quantum many-body regimes including exotic lattice geometries. In contrast to scanning techniques, the method also allows observing spontaneous symmetry breaking, as we demonstrate for a density-wave in a strongly tilted lattice [2].

[1] L. Asteria, H. P. Zahn, M. N. Kosch, K. Sengstock, C. Weitenberg, arXiv:2104.10089 (2021).
[2] H. P. Zahn, V. P. Singh, M. N. Kosch, L. Asteria, L. Freystatzky, K. Sengstock, L. Mathey, C. Weitenberg, arXiv:2108.11917 (2021).