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Matter-wave microscopy of ultracold atoms in tunable optical lattices

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Ultracold atoms in optical lattices form a versatile and well-controlled experimental platform for quantum simulation of solid-state physics. With typical lattice constants below one micrometer, optical resolution of individual lattice sites remains, however, technologically demanding. Here, I will present an imaging approach where matter-wave optics magnifies the density distribution before standard optical absorption imaging, allowing an effective resolution well below the lattice spacing as well as 2D imaging of extended 3D systems [1]. We use this real-space access for precision studies of the BEC phase transition as well as the observation of a density wave, which spontaneously breaks the discrete translational symmetry of the system after the sudden application of a tilt [2]. I will also discuss the new multifrequency scheme for our hexagonal optical lattice, which allows for fast and intrinsically stable control of the lattice geometry [3]. The methods open the path to exciting opportunities such as real-space studies of topological properties or of orbital physics.

References

[1] L. Asteria et al., Nature 599, 571-575 (2021).
[2] H. P. Zahn et al., Phys. Rev. X 12, 021014 (2022).
[3] M. Kosch et al., Phys. Rev. Research 4, 043083 (2022).

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