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Controlling and Imaging Quantum Gases at the Single Atom Level

IMMANUEL BLOCH, Max-Planck-Institute of Quantum Optics

Over the past years, ultracold quantum gases in optical lattices have offered remarkable opportunities to investigate static and dynamic properties of strongly correlated bosonic or fermionic quantum many-body systems. In this talk I will show how it has recently not only become possible to image such quantum gases with single atom sensitivity and single site resolution, but also how it is now possible to coherently control single atoms on individual lattice sites within a strongly correlated quantum gas. Using a tightly focused laser beam, atoms on selected lattice sites can be addressed and their spin state fully controlled. Magnetic resonance control techniques were employed to achieve sub-lattice period and sub-diffraction limited resolution in our addressing scheme. The ability to address single atoms on a lattice opens a whole range of novel research opportunities, ranging from quantum information processing over the investigation of quantum spin systems to local entropy control, some of which will be discussed in the talk.