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In Situ Observation of Quantum Phase Transition and Quantum Dynamics in Optical Lattices

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Ultracold atoms in optical lattices constitute one of the cleanest systems for the realizations of quantum phase transition, a phase transition that occurs even at zero temperature. By tuning the optical lattice depth or the interaction between cold atoms, a weakly-interacting superfluid of atoms can be converted into a strongly correlated Mott insulator. Near the phase boundary, quantum criticality, resembling that of Ising-type magnetic systems in higher dimensions, is expected to emerge with a full universal behavior. Our in situ imaging technique for atoms in 2D optical lattices provides a powerful tool to capture the full quantum state of the many-body system, from the microscopic statistics of site occupancy to the macroscopic thermodynamics. I will describe our efforts to identify the superfluid-Mott insulator phase boundary, to extract thermodynamic evolution time scales, and also future prospects to study quantum criticality based on density profiles of atoms in optical lattices.