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Quantum Microscopy of Ultracold Atoms in Optical Lattices

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We report a new scheme to realize an atom-based quantum Microscope. The scheme is based on probing the target atoms with a different species of atoms; each species is confined in an independently controlled optical lattice. Precise and dynamic translations of the lattices are realized by common optics and phase modulation of the lattice beams. For this purpose, we have fabricated two highly stable, hexagonal optical lattices, at two different wavelengths, but identical lattice constants using diffractive optical elements. The relative lattice site instability of < 2 nm permits controlled interactions and even entanglement operations with high fidelity. Translation of the lattices is realized through a monolithic electro-optic modulator array, capable of moving the lattice smoothly over one lattice site, or rapidly on the order of 100 ns.