Coherent control of pairs of atoms in a double-well optical lattice.

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I will describe a novel double-well optical lattice and several experiments where we control the vibrational and internal states of pairs of ^{87}Rb trapped in the lattice, including controlled pairwise interactions useful for quantum logic. The lattice is generated from a single, retro-reflected laser beam that is folded onto itself such that the beam passes through the origin four times[1]. The resulting four-beam, 2D optical lattice is phase stable, and by changing the input polarization the unit cell can be changed continuously from a single-site configuration to a double-well configuration. This lattice has several interesting properties: the lattice potential is two-dimensional, and is not separable in the x and y directions; and spatially varying polarization gradients (combined with the vector light shift of ^{87}Rb) give rise to site- and spin-dependent light shifts, resulting in two inter-penetrating sub-lattices of 'left' and 'right' sites with two different effective magnetic fields in the two sub-lattices.

Using this lattice, we have loaded and measured number-squeezed and Poisson states of atoms in the individual sites of the lattice[2] and demonstrated dynamic control of the motional state of atoms, adiabatically transferring atom population between adjacent sites of the lattice as well as between different energy bands[3]. The local effective field gradient allows us to spectroscopically resolve atoms in the two sub-lattices (separated by 400 nm), and we have demonstrated independent control of the atom spins in the separate sub-lattices[4]. Finally, combining these techniques, we demonstrate controlled spin-dependent exchange interactions of atoms that have been merged into the same well[5]. The observed exchange oscillations represent the essential component of an entangling $\sqrt{\mathrm{SWAP}}$ gate.

I will briefly discuss these experiments and our current work using coherent control of atoms in hyperfine clock states with long coherence times.

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