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Quantum Control and Transport of a Bose-Einstein Condensate

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I will discuss recent work in my group on many-body quantum control and transport. In our rubidium experiment, a single Bose-Einstein condensate is optically trapped in crossed TEM01 modes, and we achieve confinement in two dimensions that is comparable to an optical lattice, but with single-atom addressability and detection. These conditions should enable the experimental realization of a "quantum tweezer" for atoms, preparation of atomic number states, and controlled atomic entanglement. In our sodium experiment we focus on the study of many-body quantum transport. Our system consists of a BEC confined to a hybrid magnetic/optical trap. Transverse confinement is provided by a 2-D axially symmetric magnetic trap and the BEC is confined axially by two focused spots that are separated by a controlled distance, creating an optical box. The atoms are then released into an optical potential along the axial direction that is created by an array of far detuned laser spots. Each spot can be independently controlled both in position and power, with a spatial resolution of six microns. This potential can be combined with a standing wave that is aligned along the trap axis, enabling transport measurements in potentials that can range from periodic to disordered. Finally, I will discuss recent ideas on constructing an optical "one-way" barrier for atoms. I will show how this idea can be used for phase space compression and cooling, as an optical realization of Maxwell's demon.