In the so called bottom-up approach to controlled atomic quantum matter small quantum systems are synthesized involving single, few or many atom systems. We will discuss two examples:

I will show that controlled interaction of atoms with a high finesse optical resonator can lead to a strongly preferred emission of light into optical wave guides (Purcell effect) which is useful for future interconnects in hybrid quantum networks. Quantum networks will have to rely on so called quantum repeaters for large scale distribution of quantum states. Quantum repeaters present an enormous challenge for experimenters.

With quantum walks – i. e. driven discrete transport on a lattice conditioned on the spin state – we have a tool realizing controlled coherent transport of atoms over tens of lattice sites – up to the so called quantum speed limit available. I will present the experimental realization of “ideal negative measurements” showing strong violation of the Leggett-Garg inequality. The experiment distinguishes quantitatively the macro realist’s world from the quantum world.

Quantum indistinguishability is now opening up a new window to study interacting few body systems in unusual lattice settings including very strong pseudo magnetic fields, topologically interesting situations, and a scheme to create entanglement without interaction. The ultimate aim of these experiments is the creation of quantum cellular automata.