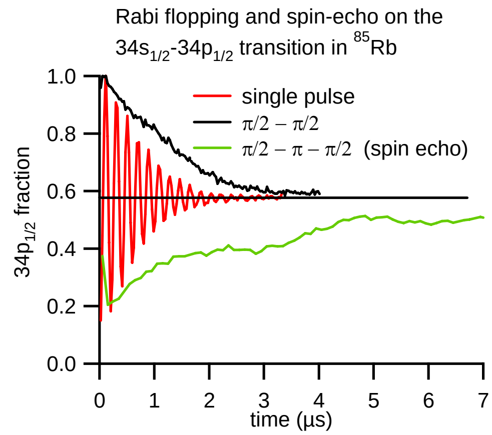
Research Activities of the Ultracold Rydberg Atom Group

Dipolar Interactions and the Preservation of Coherence

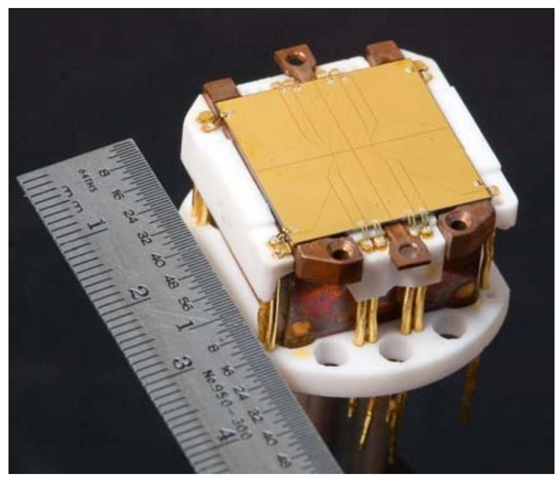
A Rydberg atom consists of a loosely bound electron orbiting an ion-core. The large average separation of the electron from the ion-core is responsible for many exaggerated properties in comparison with less excited atoms. For example, the interaction between two Rydberg atoms is much stronger than between two ground-state atoms. Thus, temporary excitation to Rydberg states may be used quantum gates between atoms storing qubits (which are otherwise not interacting). Cold Rydberg atoms, obtained from optical excitation of laser cooled and trapped atoms, are appealing as their separation can remain unchanged over timescales long enough to observe their interaction. The last few years have seen rapid progress in understanding these cold Rydberg atom interactions. For example, our group has been able to demonstrate that microwave transitions between Rydberg states are a sensitive probe of resonant electric dipole-dipole interactions between cold Rydberg atoms. We plan to continue to exploit this newly developed approach to better understand cold Rydberg atom interactions. For example, to the right is some of our preliminary studies of Rydberg atom coherence using microwave transitions between Rydberg states. Initially we would like to demonstrate that the dephasing due to a well-characterized inhomogeneity -- an externally created magnetic field gradient -- can be reversed using spin-echo. This would be significant for preservation of quantum information stored in Rydberg atoms. Our eventual goal is to understand the practical details of how the dipolar interaction may be used to implement gate operations in this system.



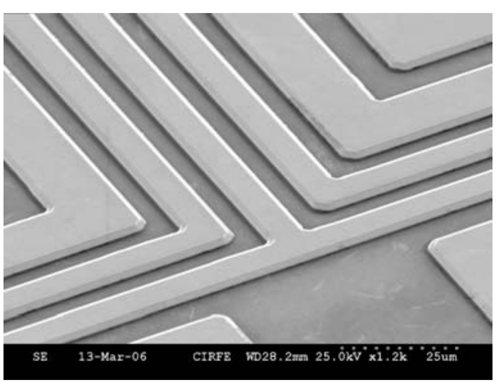
Bohlouli-Zanjani, Petrus and Martin (unpublished).

Rydberg Atom Chip Experiments

Atom chips are based on the principle that paramagnetic atoms experience mechanical forces in inhomogeneous magnetic fields. In particular, atoms in low-field seeking states are drawn to regions of low magnetic field magnitude. Micron-scale current-carrying wires lithographically patterned on a substrate can be used to produce local magnetic field minima. These "atom chips" can trap translationally cold atoms obtained from laser and evaporative cooling at variable distances from their surfaces. The distance from the surface may be varied by changing the currents in the wires generating the potentials. We are currently examining the optical excitation spectra of Rydberg atoms at specific, controllable distances over gold surfaces, using atom chips.



Complete UW atom chip. We are currently doing experiments with this chip (O. Cherry, Martin Group).



Scanning electron microscope image of UW atom chip wire quality (O. Cherry, Martin Group).

The first stage of this research is to determine the residual electric fields over gold surfaces. These are virtually the best electrostatic shields that exist -- but not perfect. Their residual fields limit precision experiments on charged particles – where shielding from external electric fields is necessary. The miniaturization of ion-traps and time-of-flight mass and electron spectrometers are subject to the limitations of stray electric fields. Patch fields have been observed to limit quantum non-demolition (QND) Rydberg atom measurements of radiation fields in cavities. There are exciting proposals for experiments exploiting coherent interactions between Rydberg atoms and superconducting transmission lines -- which will require a better understanding of patch fields near metal surfaces. The eventual goal of this research is the coherent coupling of mesoscopic systems (superconducting transmission line/qubit) to atomic systems in a way that utilizes the benefits of both systems (ie. quantum memory).

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For a list of recent publications please see: http://www.science.uwaterloo.ca/~jddmarti/research.html

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