QO Groupmeeting: Near-deterministic preparation of a single atom in an optical microtrap

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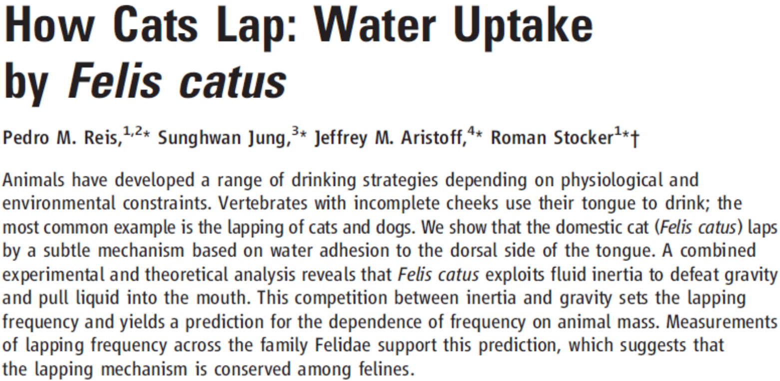

How Cats Lap: Water Uptake by *Felis catus*

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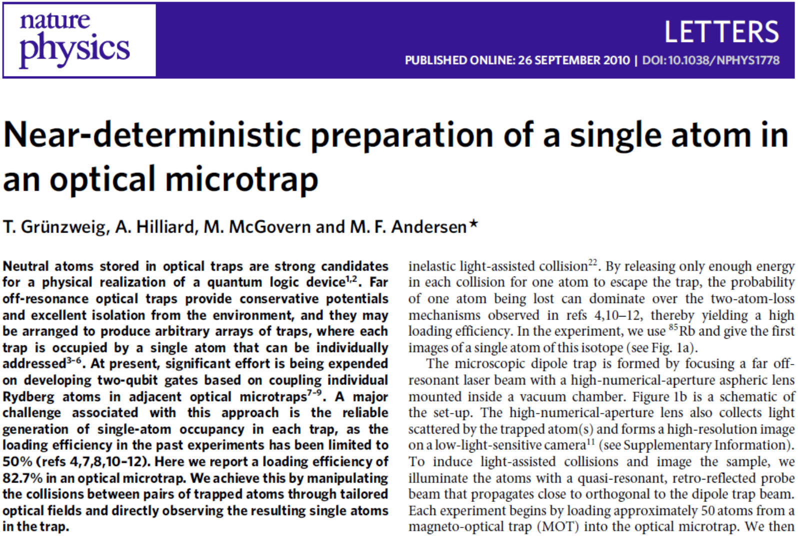
Animals have developed a range of drinking strategies depending on physiological and environmental constraints. Vertebrates with incomplete cheeks use their tongue to drink; the most common example is the lapping of cats and dogs. We show that the domestic cat (*Felis catus*) laps by a subtle mechanism based on water adhesion to the dorsal side of the tongue. A combined experimental and theoretical analysis reveals that *Felis catus* exploits fluid inertia to defeat gravity and pull liquid into the mouth. This competition between inertia and gravity sets the lapping frequency and yields a prediction for the dependence of frequency on animal mass. Measurements of lapping frequency across the family Felidae support this prediction, which suggests that the lapping mechanism is conserved among felines.



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Near-deterministic preparation of a single atom in an optical microtrap

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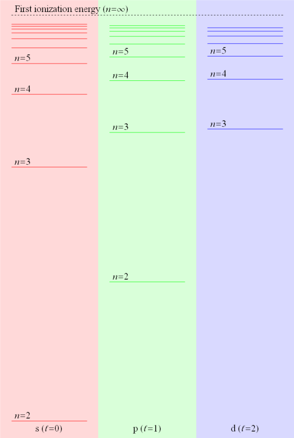
Neutral atoms stored in optical traps are strong candidates for a physical realization of a quantum logic device[1,2]. Far off-resonance optical traps provide conservative potentials and excellent isolation from the environment, and they may be arranged to produce arbitrary arrays of traps, where each trap is occupied by a single atom that can be individually addressed[3–6]. At present, significant effort is being expended on developing two-qubit gates based on coupling individual Rydberg atoms in adjacent optical microtraps[7–9]. A major challenge associated with this approach is the reliable generation of single-atom occupancy in each trap, as the loading efficiency in the past experiments has been limited to 50% (refs 4,7,8,10–12). Here we report a loading efficiency of 82.7% in an optical microtrap. We achieve this by manipulating the collisions between pairs of trapped atoms through tailored optical fields and directly observing the resulting single atoms in the trap.

inelastic light-assisted collision[22]. By releasing only enough energy in each collision for one atom to escape the trap, the probability of one atom being lost can dominate over the two-atom-loss mechanisms observed in refs 4,10–12, thereby yielding a high loading efficiency. In the experiment, we use ^{85}Rb and give the first images of a single atom of this isotope (see Fig. 1a).

The microscopic dipole trap is formed by focusing a far off-resonant laser beam with a high-numerical-aperture aspheric lens mounted inside a vacuum chamber. Figure 1b is a schematic of the set-up. The high-numerical-aperture lens also collects light scattered by the trapped atom(s) and forms a high-resolution image on a low-light-sensitive camera[11] (see Supplementary Information). To induce light-assisted collisions and image the sample, we illuminate the atoms with a quasi-resonant, retro-reflected probe beam that propagates close to orthogonal to the dipole trap beam. Each experiment begins by loading approximately 50 atoms from a magneto-optical trap (MOT) into the optical microtrap. We then

Rydberg Atoms



Properties:

- Radius $\propto n^2$
- Lifetime $\propto n^3 - n^{4.5}$
- Dipole Moment $\propto n^2$
- Polarizability $\propto n^7$

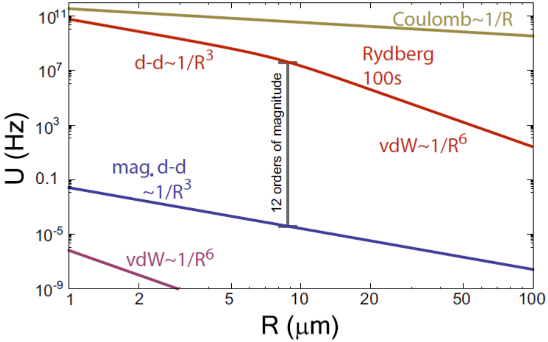


FIG. 1 (Color online) Two-body interaction strength for ground state Rb atoms, Rb atoms excited to the 100*s* level, and ions.

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Quantum Information

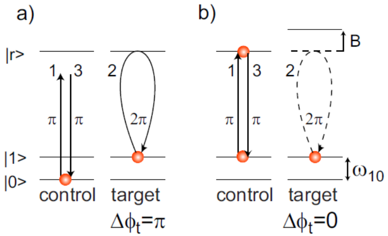

FIG. 2 (Color online) Rydberg blockade controlled phase gate operating on input states a) $|01\rangle$ and b) $|11\rangle$. Quantum information is stored in the basis states $|0\rangle, |1\rangle$ and state $|1\rangle$ is coupled to a Rydberg level $|r\rangle$ with excitation Rabi frequency Ω. The controlled phase gate is implemented with a three pulse sequence: 1) π pulse on control atom $|1\rangle \to |r\rangle$, 2) 2π pulse on target atom $|1\rangle \to |r\rangle \to |1\rangle$ and 3) π pulse on control atom $|r\rangle \to |1\rangle$. Panel a) shows the case where the control atom starts in $|0\rangle$ and is not Rydberg excited so there is no blockade, while panel b) shows the case where the control atom is in $|1\rangle$ which is Rydberg excited leading to blockade of the target atom excitation.

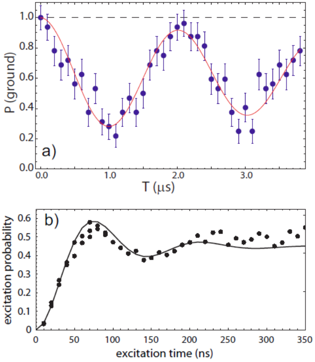

FIG. 21 (Color online) Rabi oscillations between ground and Rydberg levels: a) using single atoms from (Johnson *et al.*, 2008) and b) in a sample with ∼ 100 atoms from (Reetz-Lamour *et al.*, 2008a).

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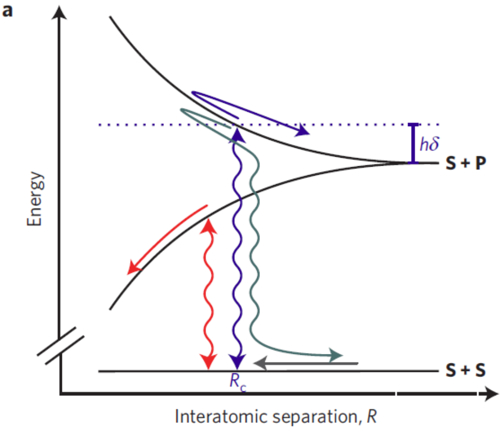
Light-assisted Collisions



Apparatus

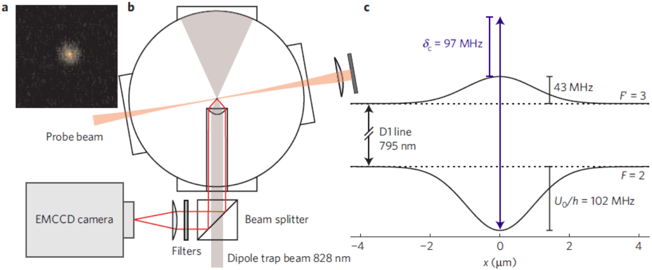
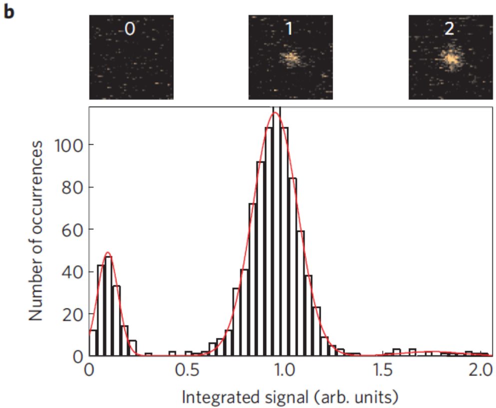


Figure 1 | Experimental schematics. a, An image of a single ^{85}Rb atom. **b**, A schematic of the experiment. The high-numerical-aperture lens focuses the dipole trap beam to form an optical microtrap at the centre of the vacuum chamber. This lens is the first element in an infinity-corrected microscope that images fluorescence from a trapped atom onto an electron-multiplying charge-coupled device (EMCCD). **c**, Calculated spatially dependent light shifts of the $F = 2$ to $F' = 3$ D1 transition along the tight dimension of the trap for 36 mW of light at 828 nm and a waist of $w_0 = 1.8\,\mu$m. The blue double-headed arrow indicates the frequency of the collision light. At the centre of the trap, the light is blue detuned by an amount δ_c.

Single Atom Efficiency



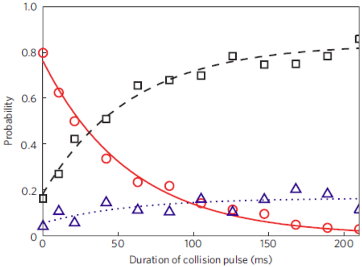


Figure 3 | Time evolution of pairs of atoms. The red circles show the probability of pair survival as a function of the collision pulse duration. The black squares and blue triangles show the probabilities of obtaining one or zero atoms respectively after the collision pulse. The curves are a fit of the measured probabilities of two (red solid line), one (black dashed line) and zero (blue dotted line) atoms (see Supplementary Information).

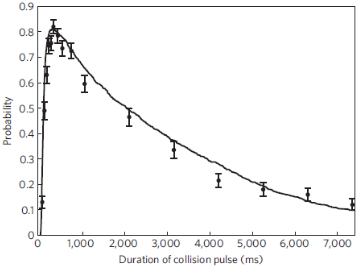


Figure 4 | Single-atom probability as a function of the duration of the collision pulse. Measurement with error bars that represent the 95% confidence estimate of the error resulting from binomial statistics of the 200 realizations used per data point. The line is a Monte Carlo simulation of the model described in the Supplementary Information, with model parameters deduced from Fig. 3.

That’s It!