Controlling Individual Atoms

Current team:
Alicia V. Carpentier, Yin H. Fung, and
Pimonpan Sompet

Previous team:
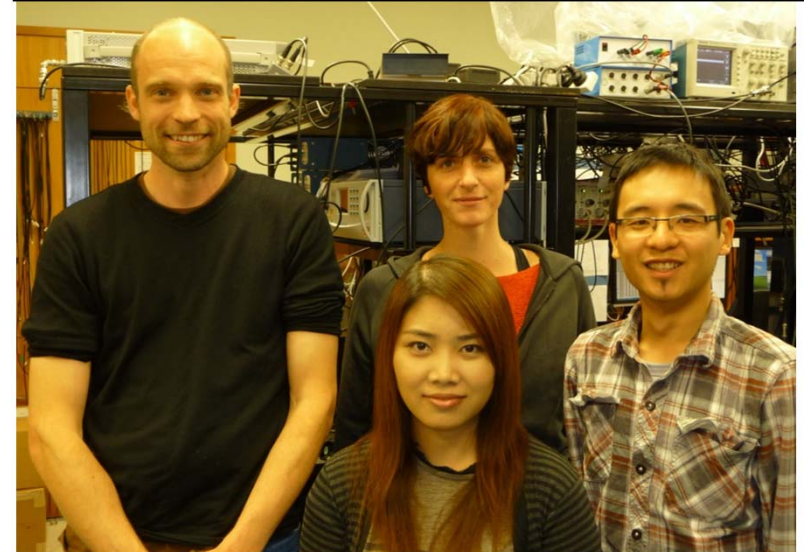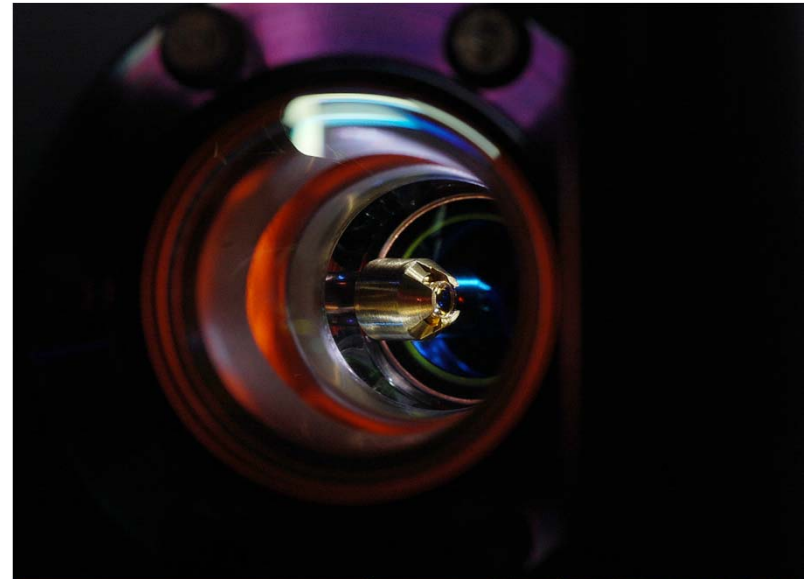Tzahi Grünzweig, Andrew Hilliard,
and Matt McGovern

Collaborator:
Professor Thad Walker

Outline

- Motivation

- Experimental Apparatus

- Counting atoms in a microscopic volume

- Isolating individual atoms

- Holographic "atom sorting"

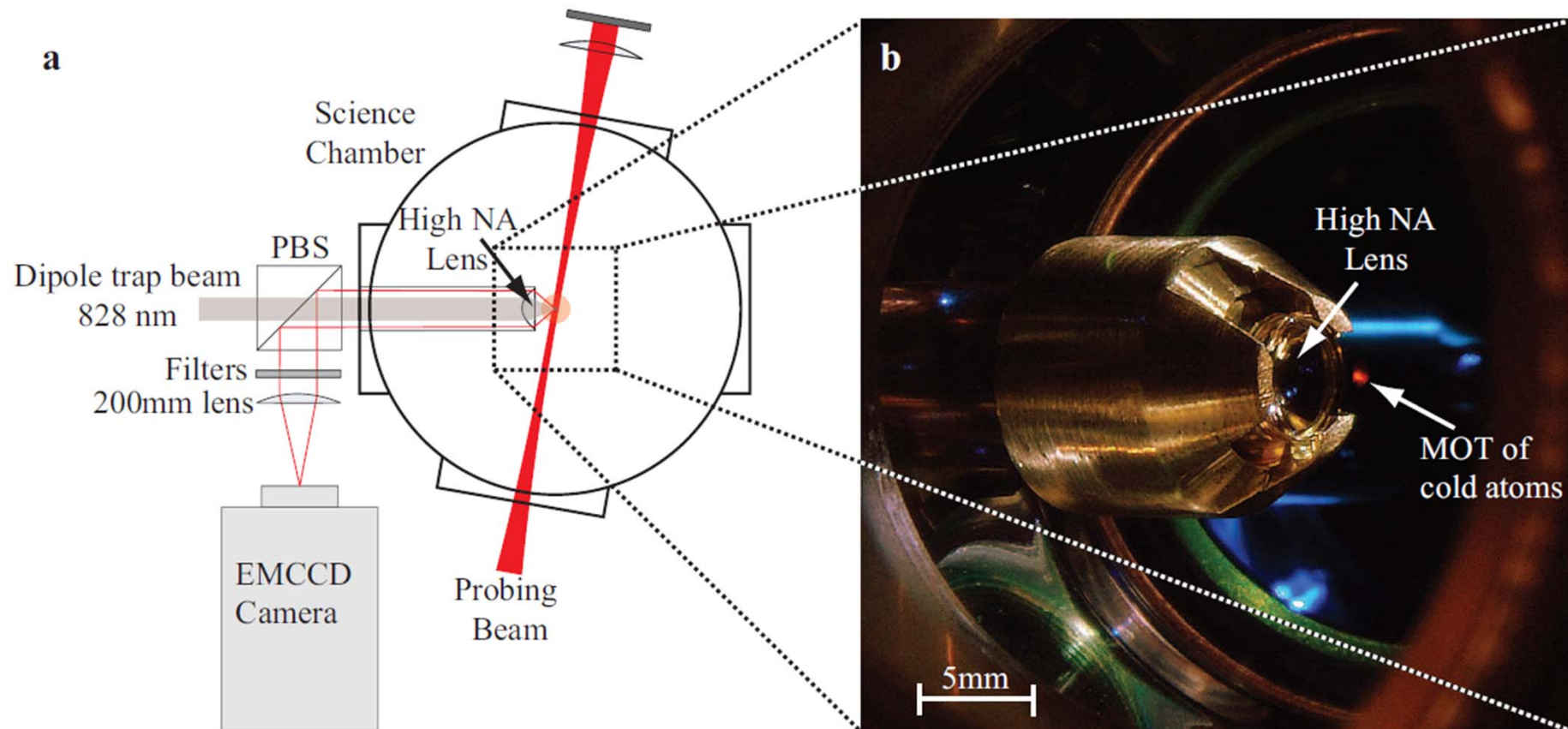- Conclusions

Motivation

- Direct investigations of the quantum world

- Quantum information processing

- Atomic scale engineering

Why Neutral Atoms?

- We can see them
- They are Quantum
- They provide the most versatile platform

What is their problem?

Experiment

a

Science Chamber

Dipole trap beam
828 nm

PBS

High NA Lens

Filters
200mm lens

EMCCD Camera

Probing Beam

b

High NA Lens

MOT of cold atoms

5mm

Problems with counting atoms using flourecense imaging

- Many photons need to be scattered

- Radiation pressure blows atoms away

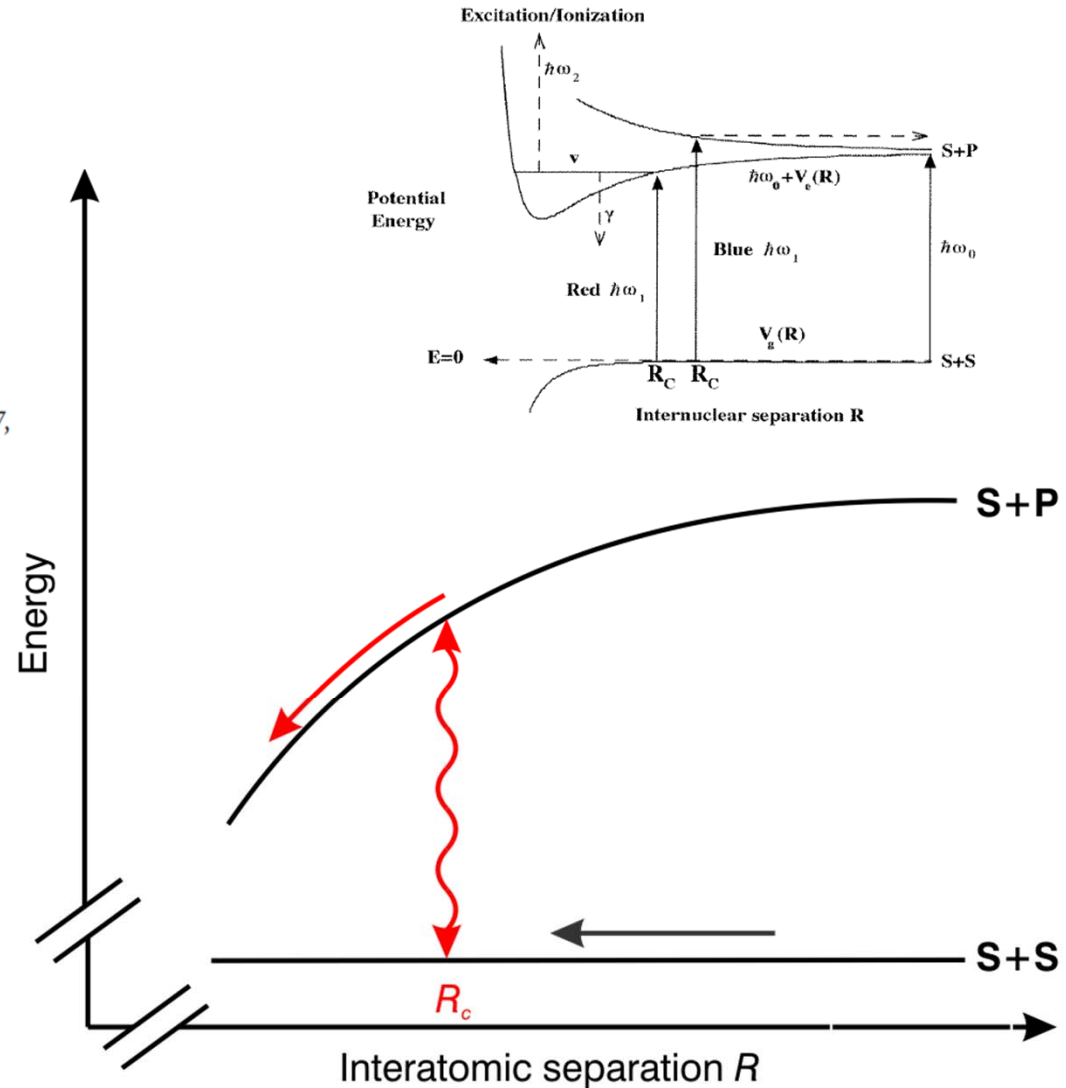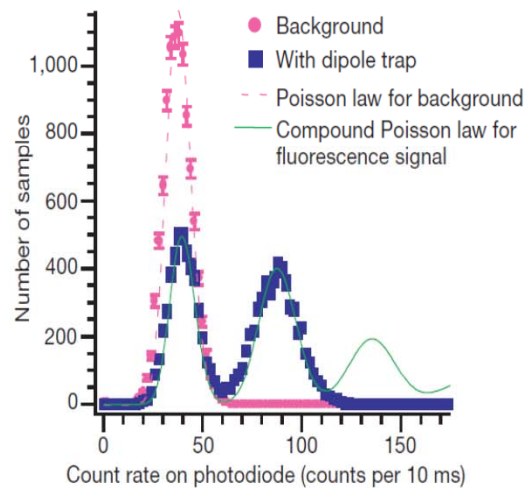- Light assisted collisions cause rapid loss at high densities
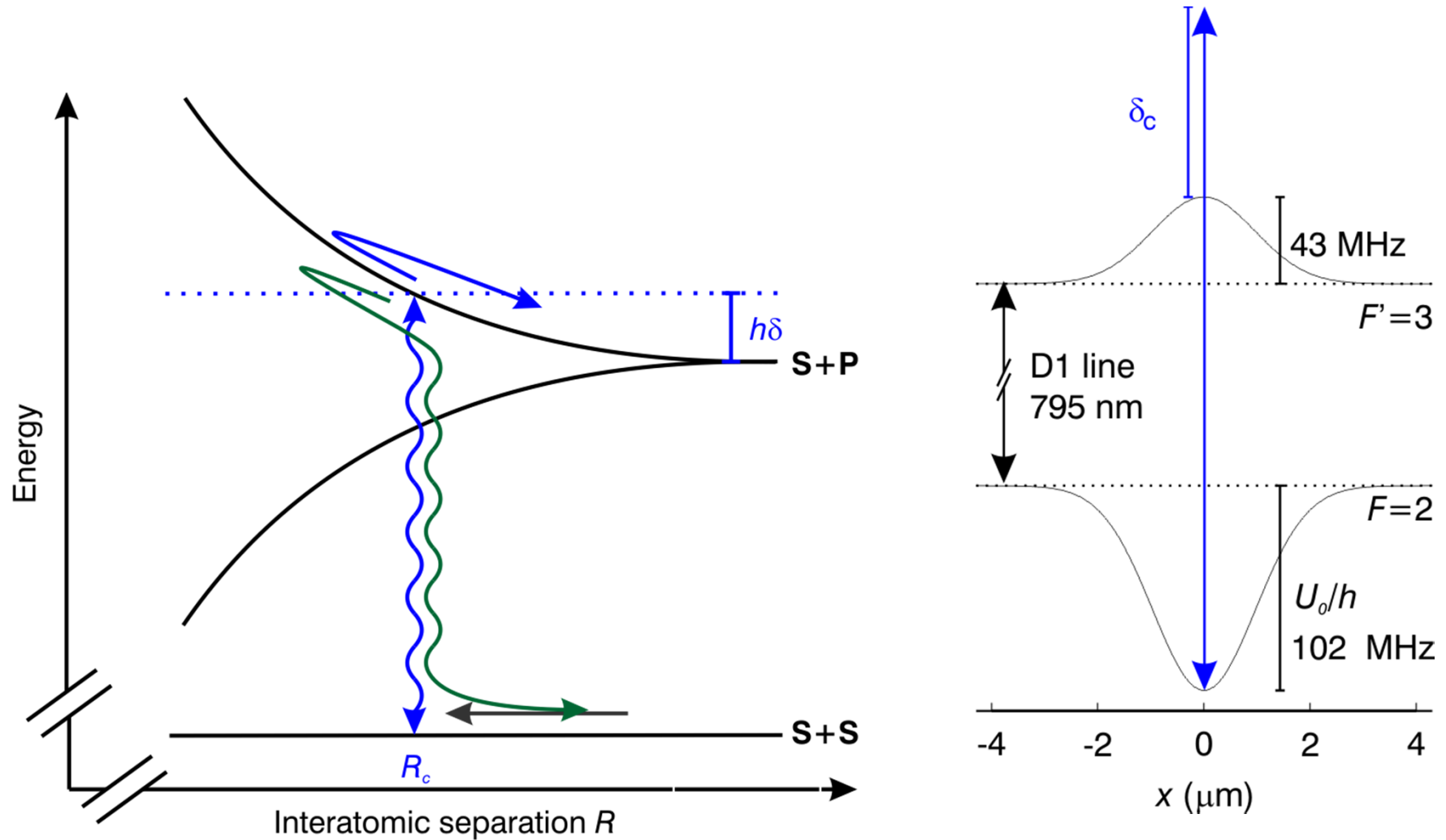
Light assisted collisions

Sub-poissonian loading of single atoms in a microscopic dipole trap

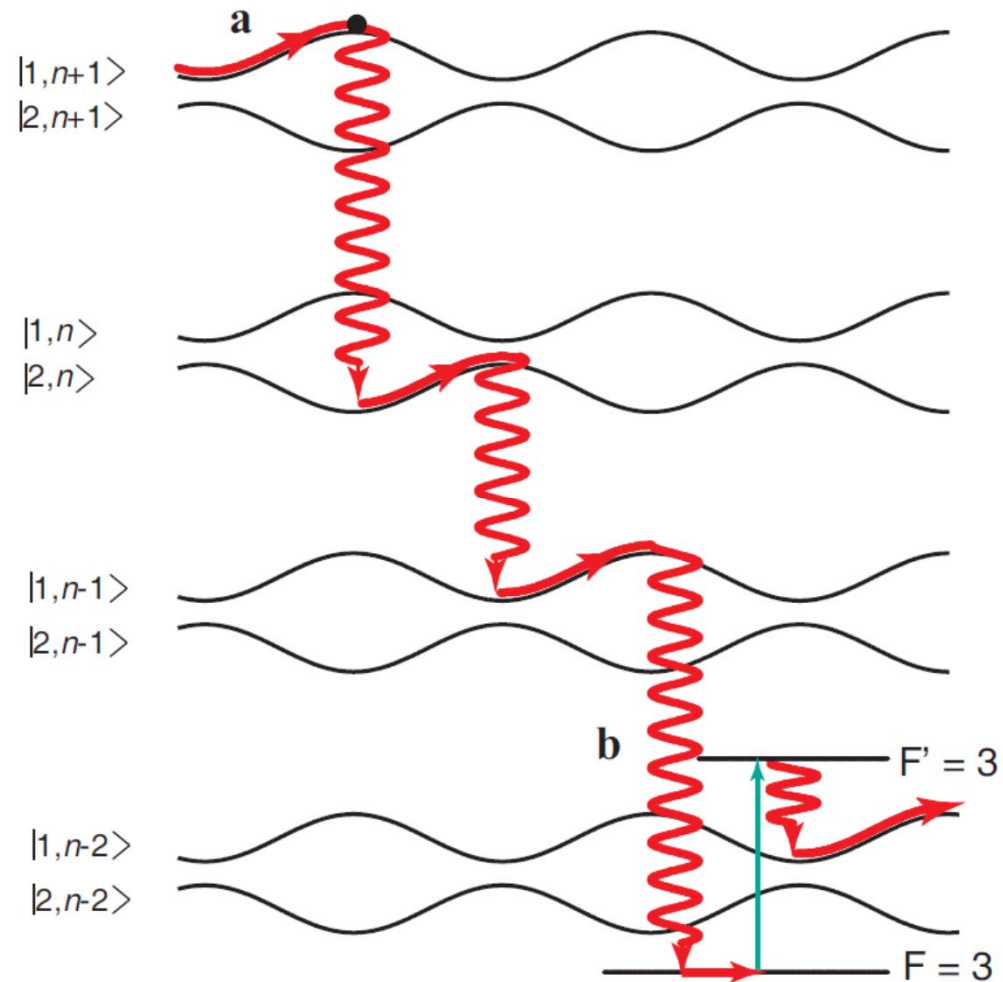Nicolas Schlosser, Georges Reymond, Igor Protsenko
& Philippe Grangier

Laboratoire Charles Fabry de l'Institut d'Optique, UMR 8501 du CNRS, BP 147, F91403 Orsay Cedex, France
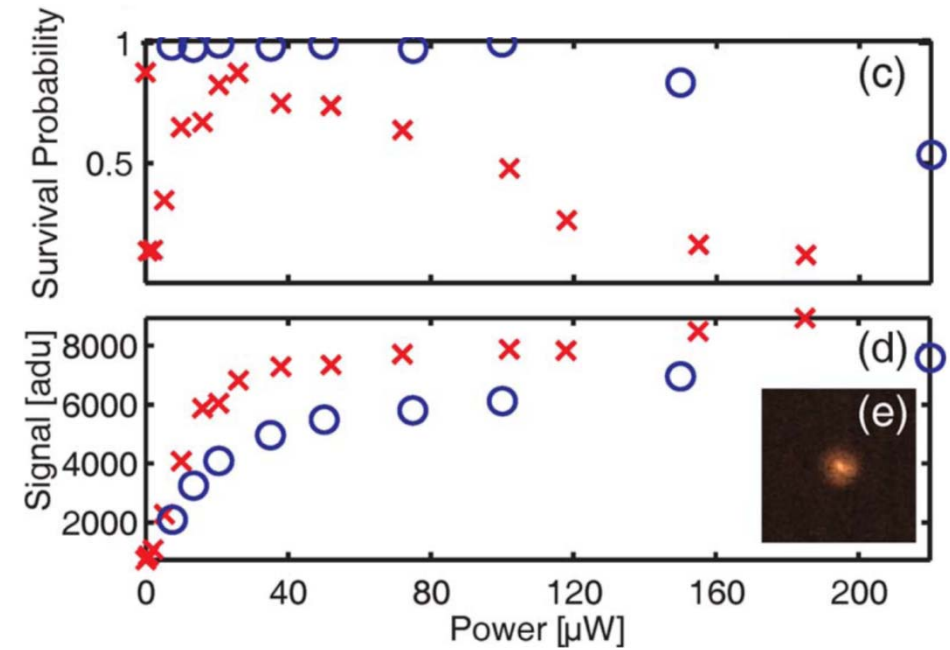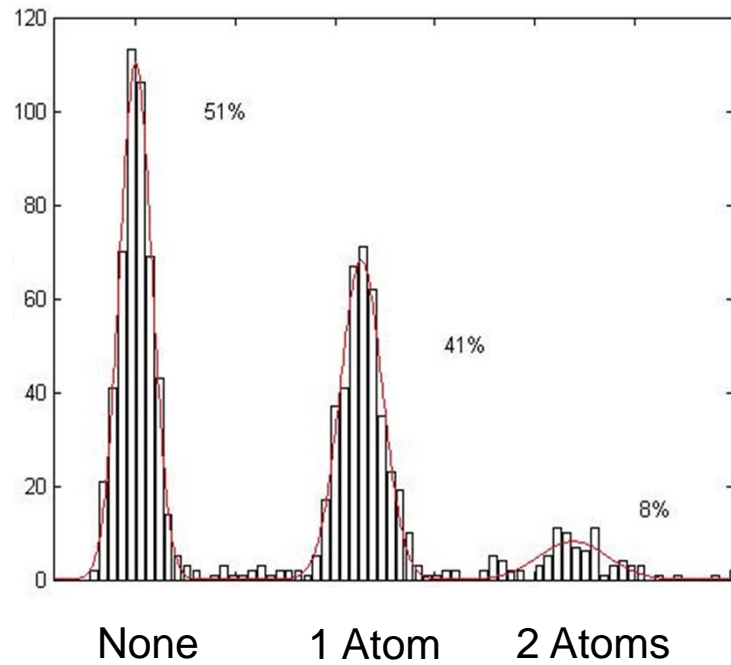
Blue detuned light

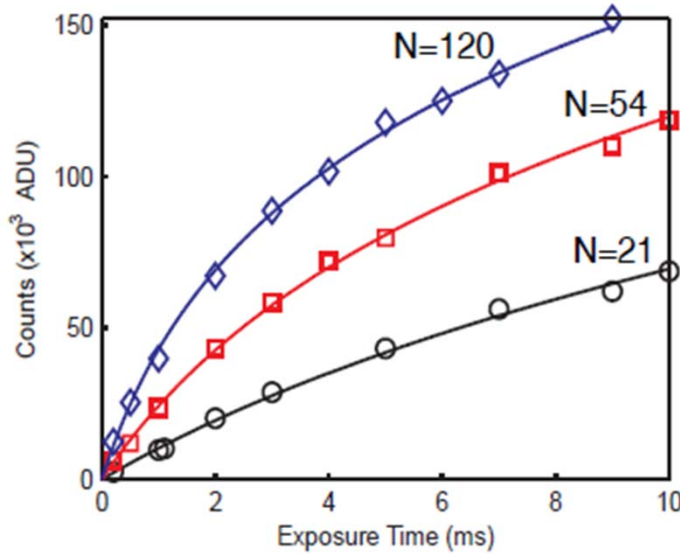# Cooling with blue detuned light

Counting Atoms

M. McGovern, Andrew Hilliard, T. Grünzweig, M. F. A., Opt. Lett., 36, 1041, 2011.
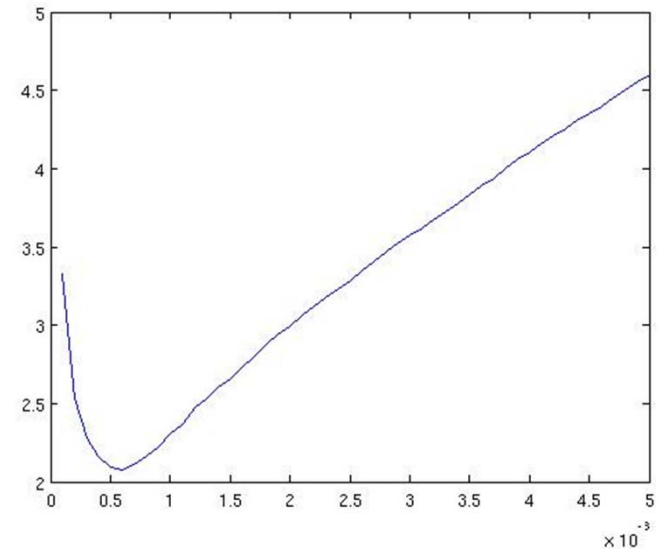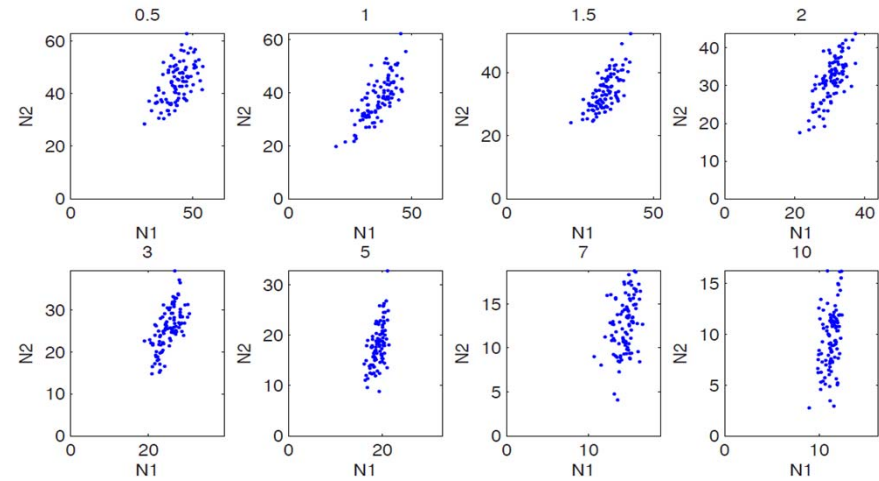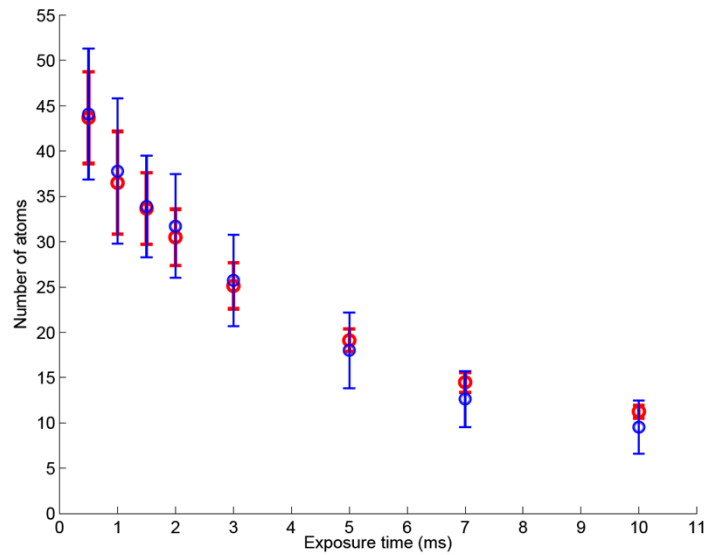
Image of single atom

Counting more atoms

$$dN/dt = -\beta N(N-1).$$

$$N(t) = \frac{1}{1 + \frac{1-N(0)}{N(0)}e^{-\beta t}}$$

$$F_{\text{tot}}(t) = F_1 \left[t + \frac{1}{\beta}\ln\left(N_0 + (1-N_0)e^{-\beta t}\right) \right]$$

Sub-shot-noise counting of high numbers

# Preparing individual atoms

Unity Occupation of Sites in a 3D Optical Lattice

Marshall T. DePue, Colin McCormick, S. Lukman Winoto, Steven Oliver, and David S. Weiss

Department of Physics, University of California at Berkeley, Berkeley, California 94720-7300

At each site, atoms undergo pairwise light-assisted collisions, which can either significantly increase their kinetic energy, or cause them to form a molecule. Either way, both atoms are lost more quickly than we can observe, so that sites that are initially occupied by an even number of atoms become empty and sites that are initially odd-occupied end up with a single atom
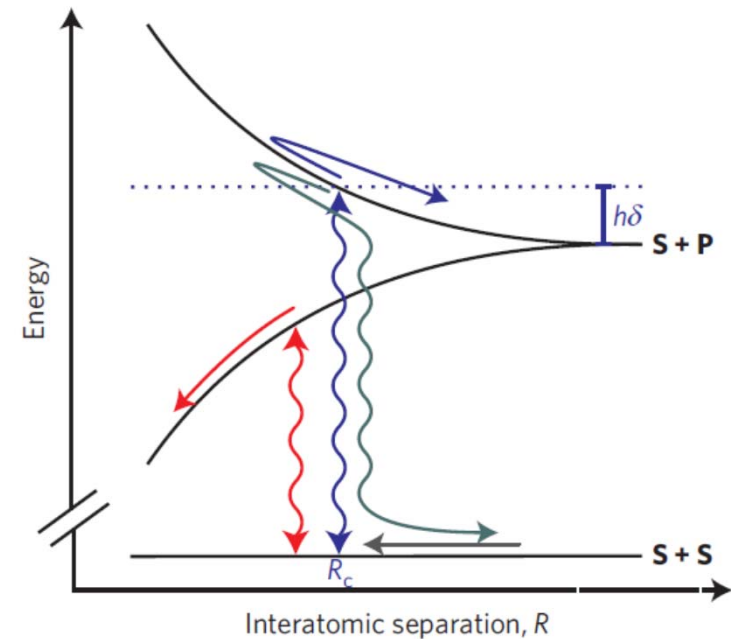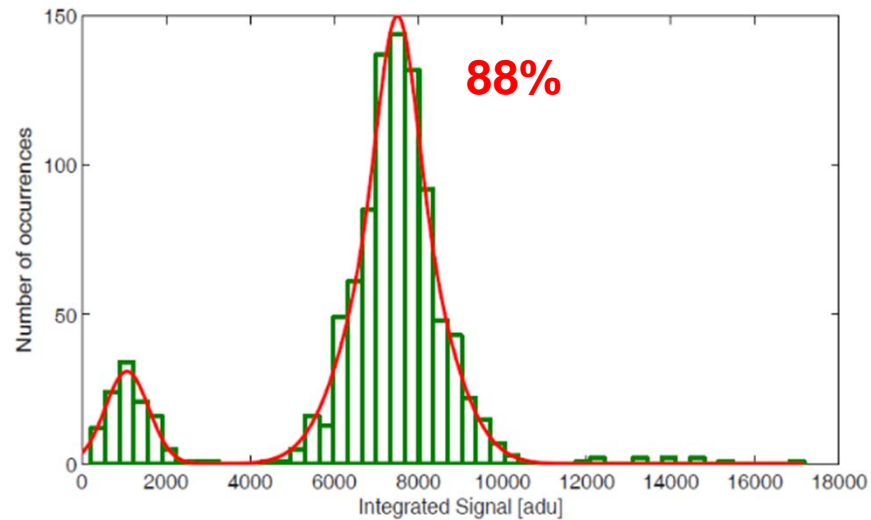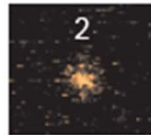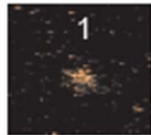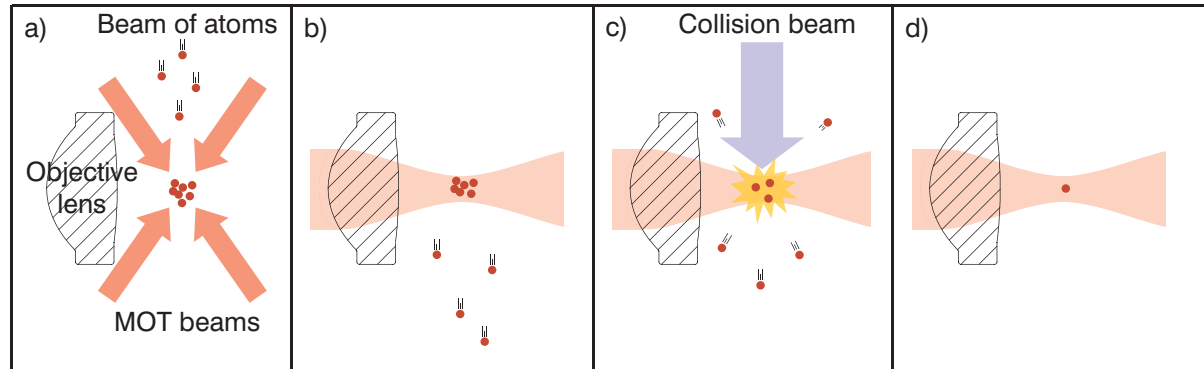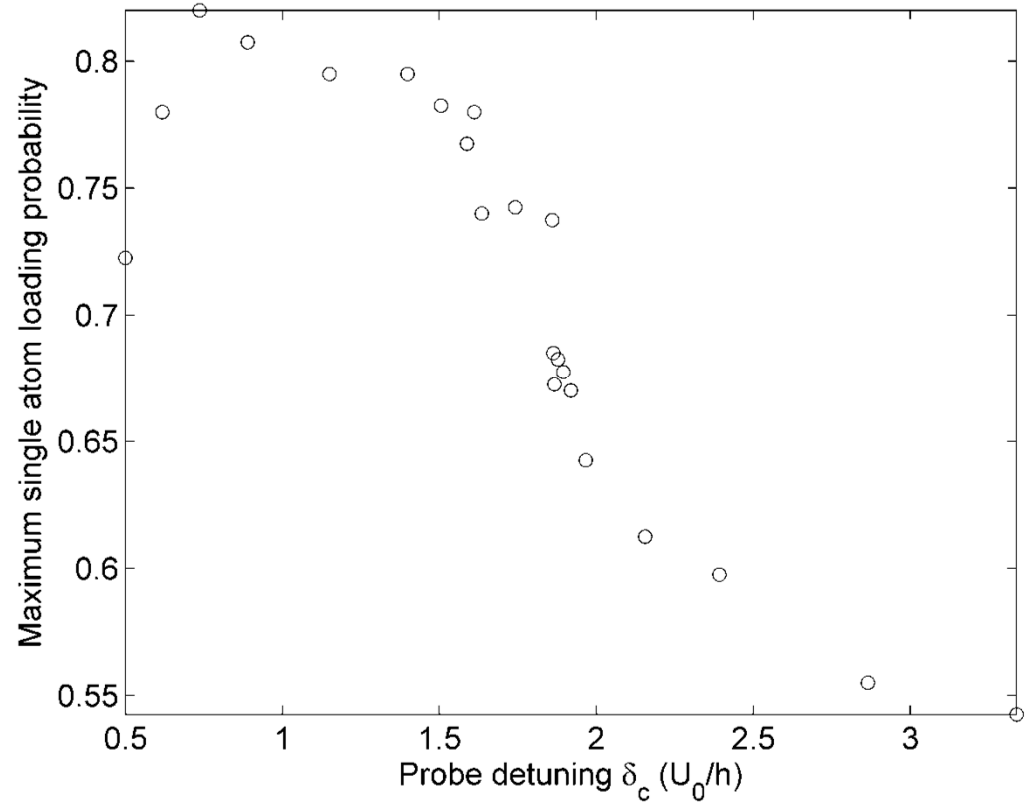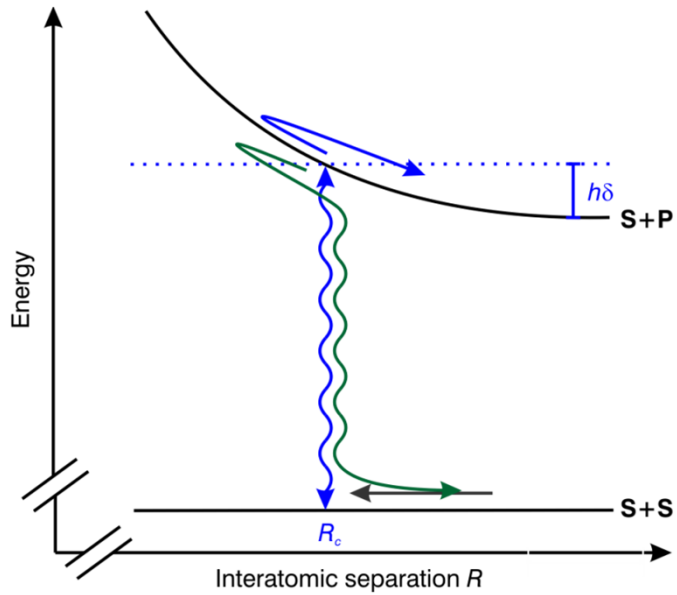
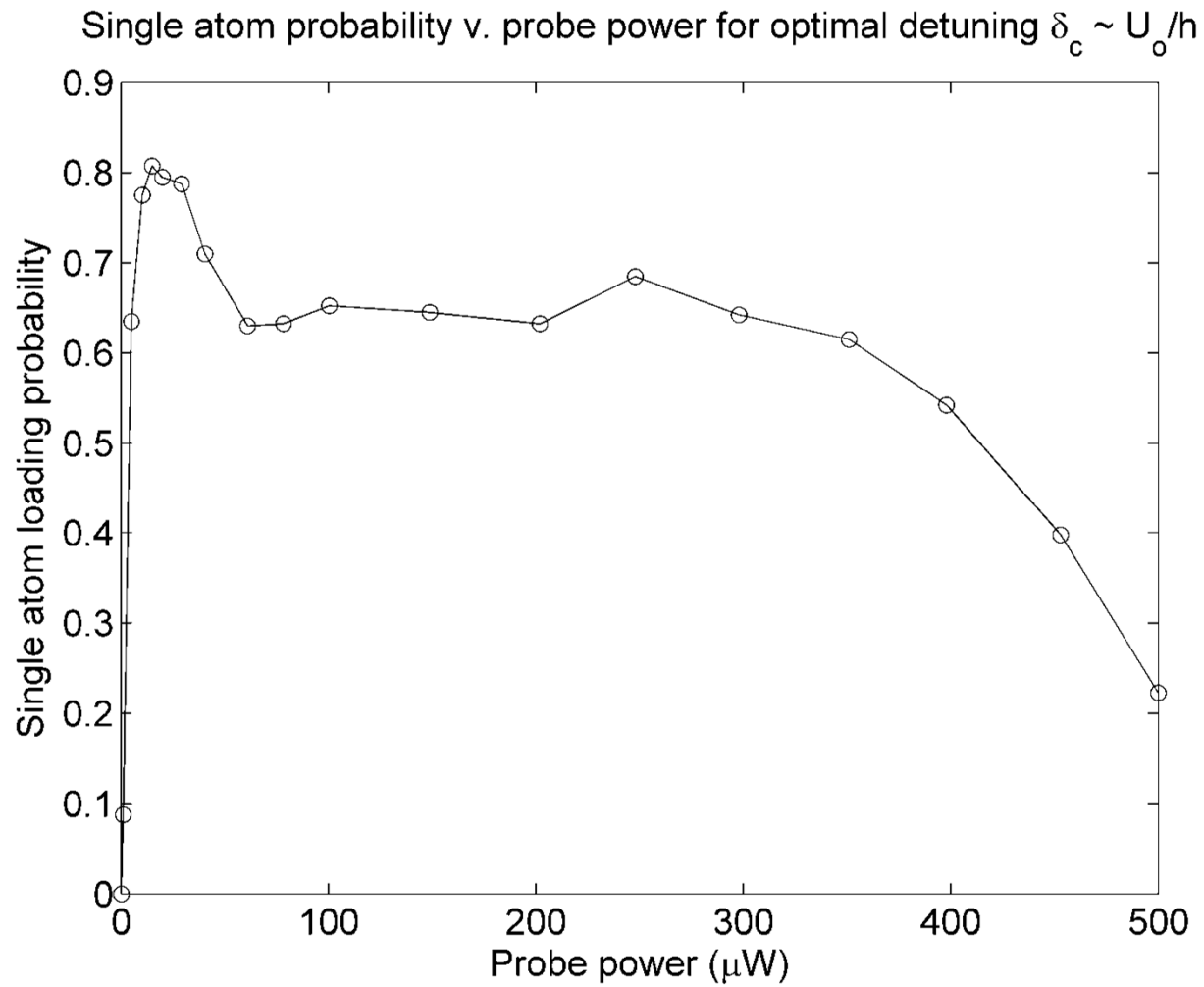# Individual Collisions
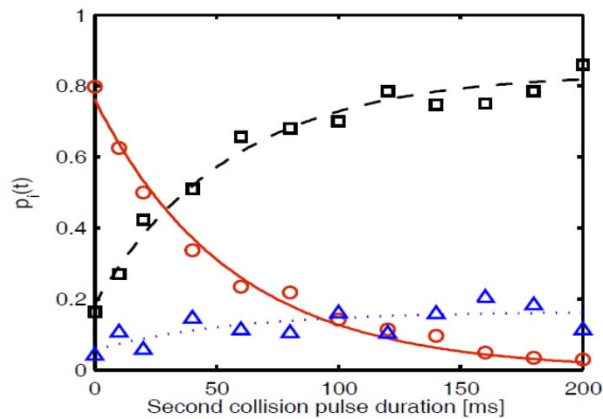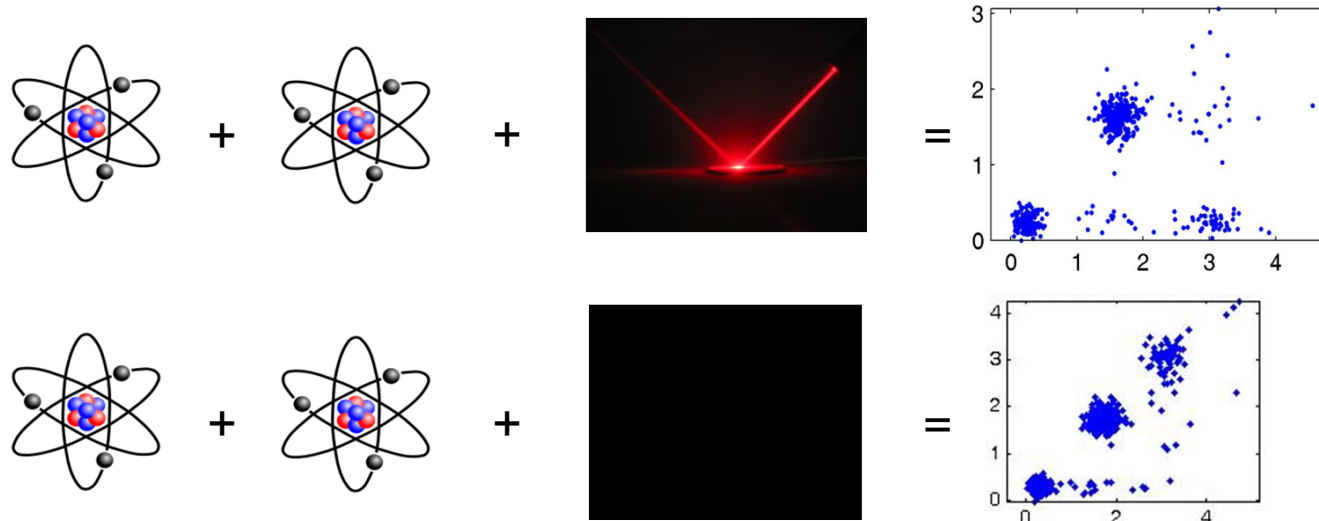
$$p(1|2) = 0.86$$

Efficient Preparation

T. Grünzweig, A. Hilliard, M. McGovern, M. F. A., Nature Physics 6, 951-954, 2010.

How does it work?

Power

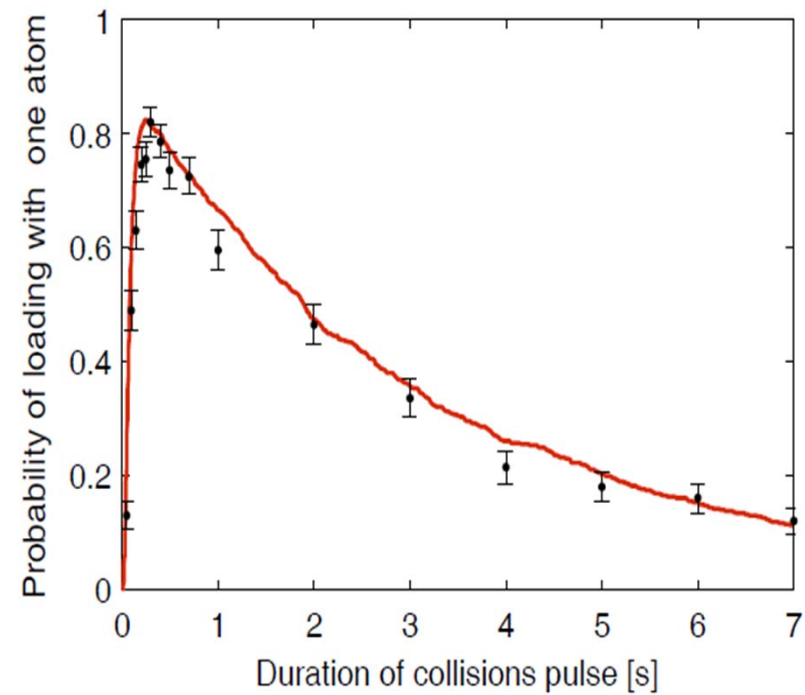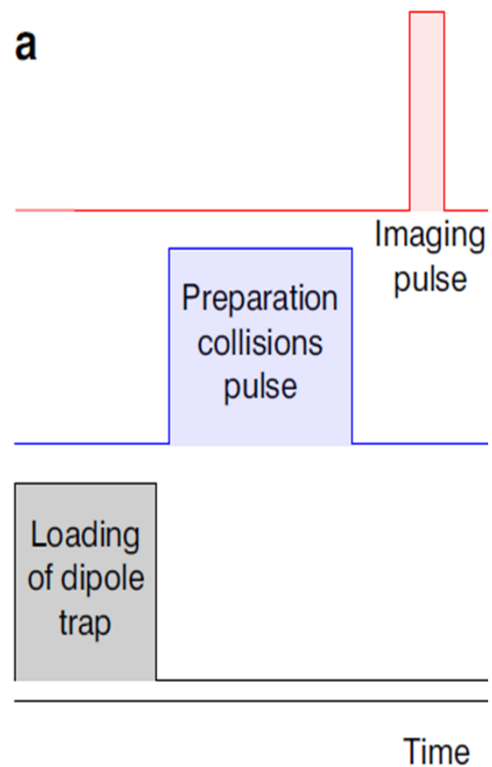Single atom probability v. probe power for optimal detuning $\delta_c \sim U_o/h$
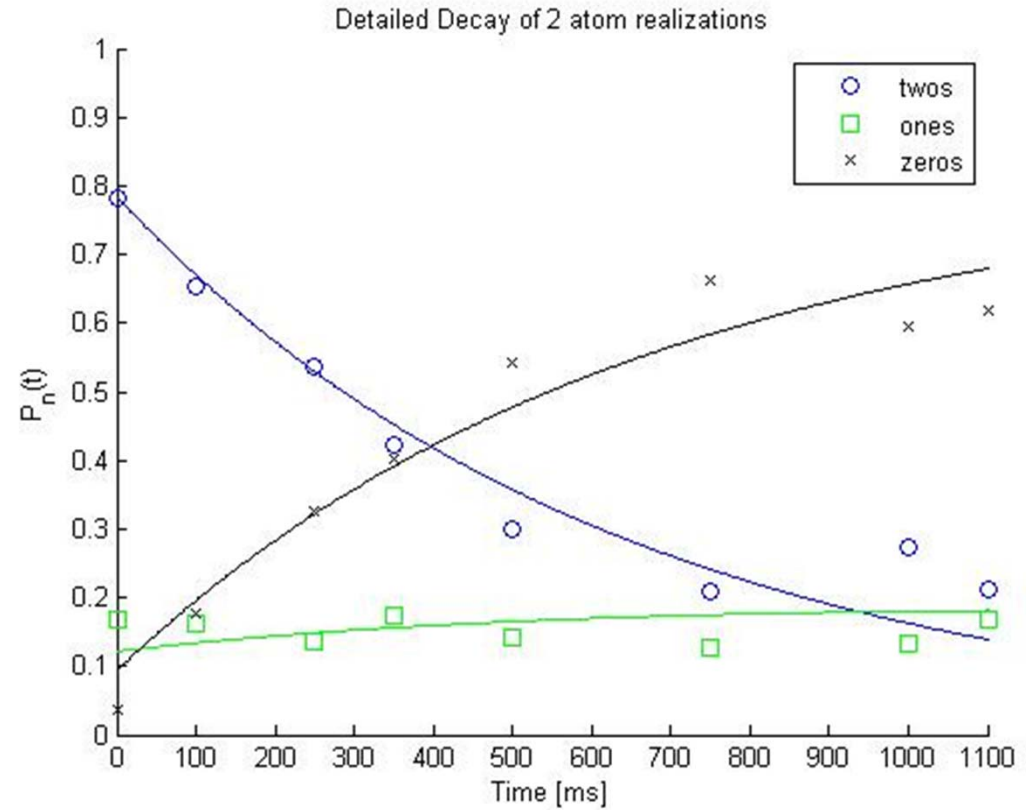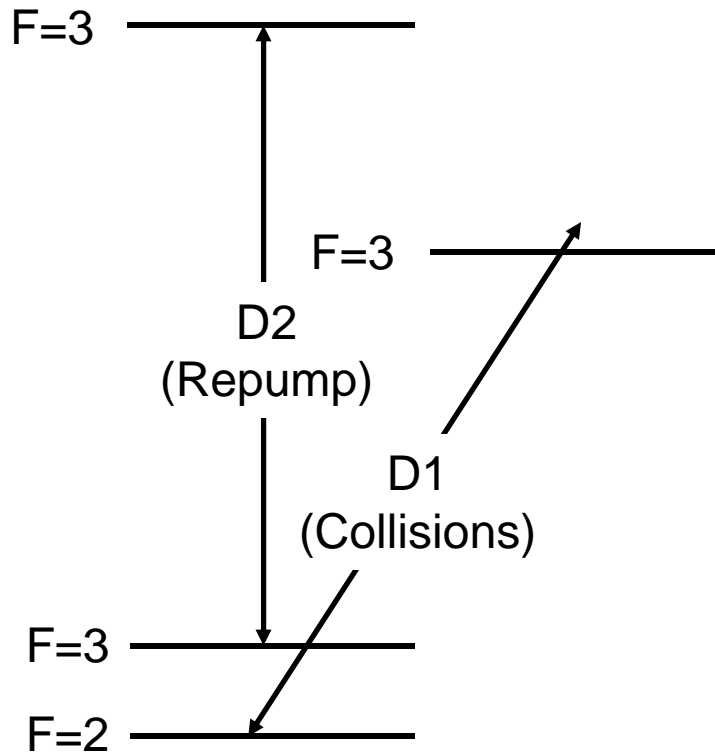
What is missing?

$$P(1|\infty) = \frac{1}{2 - P(1|2)}$$
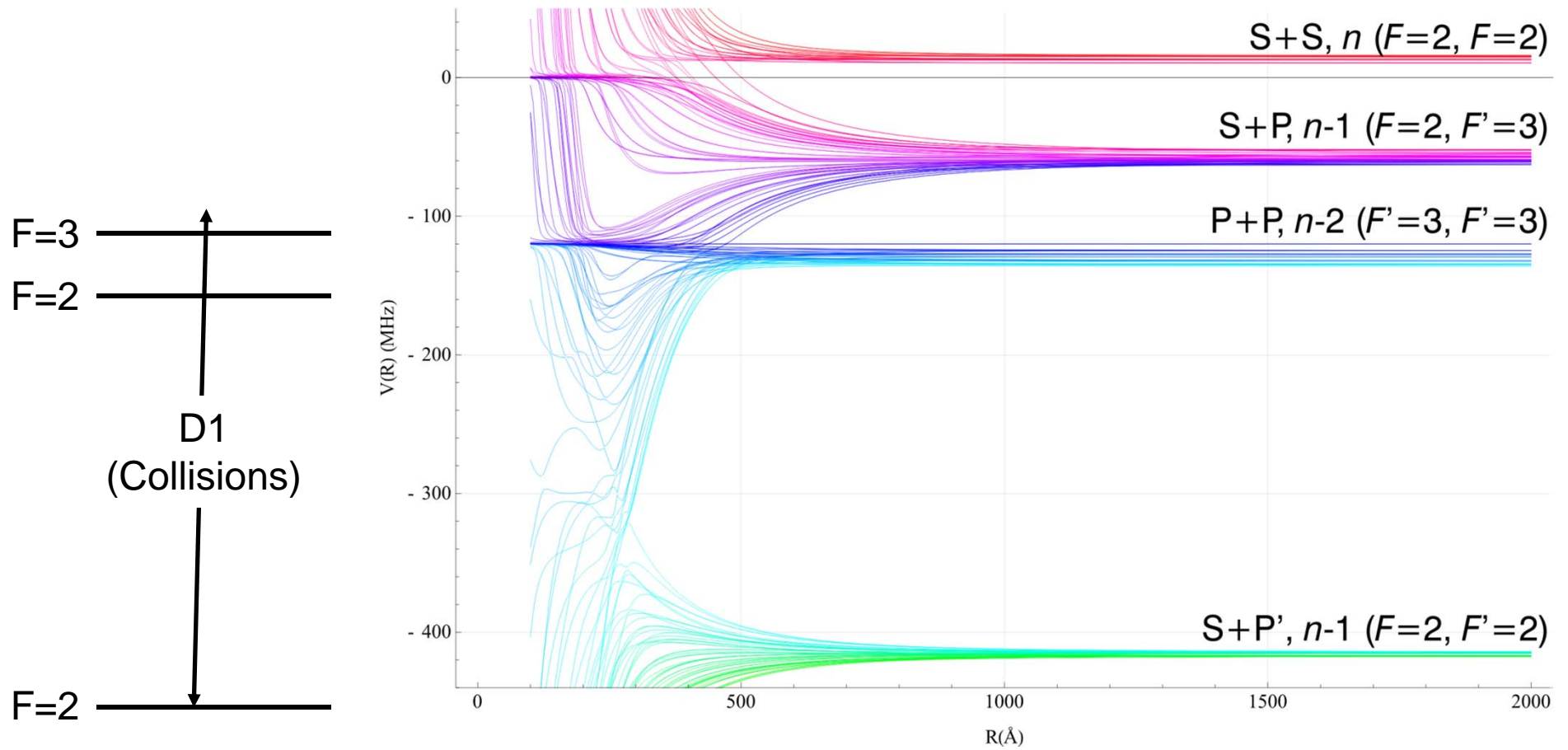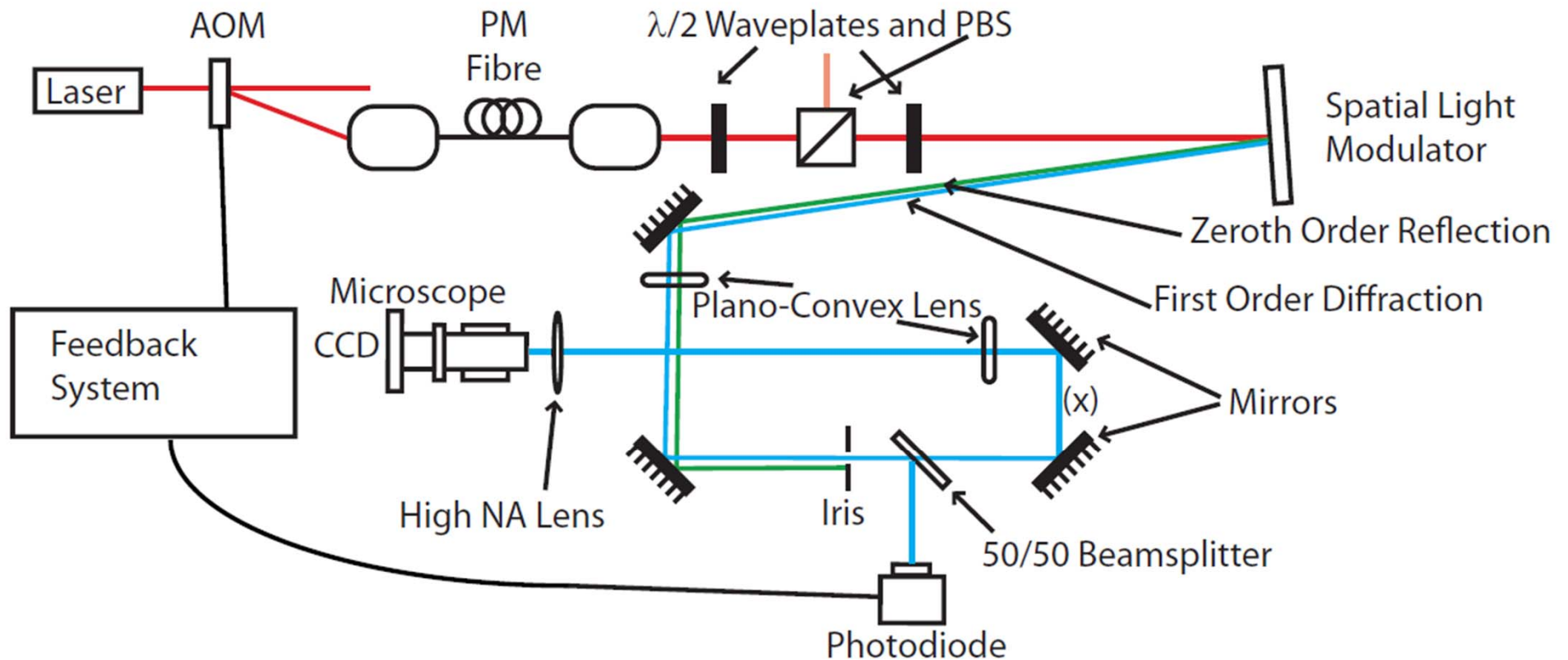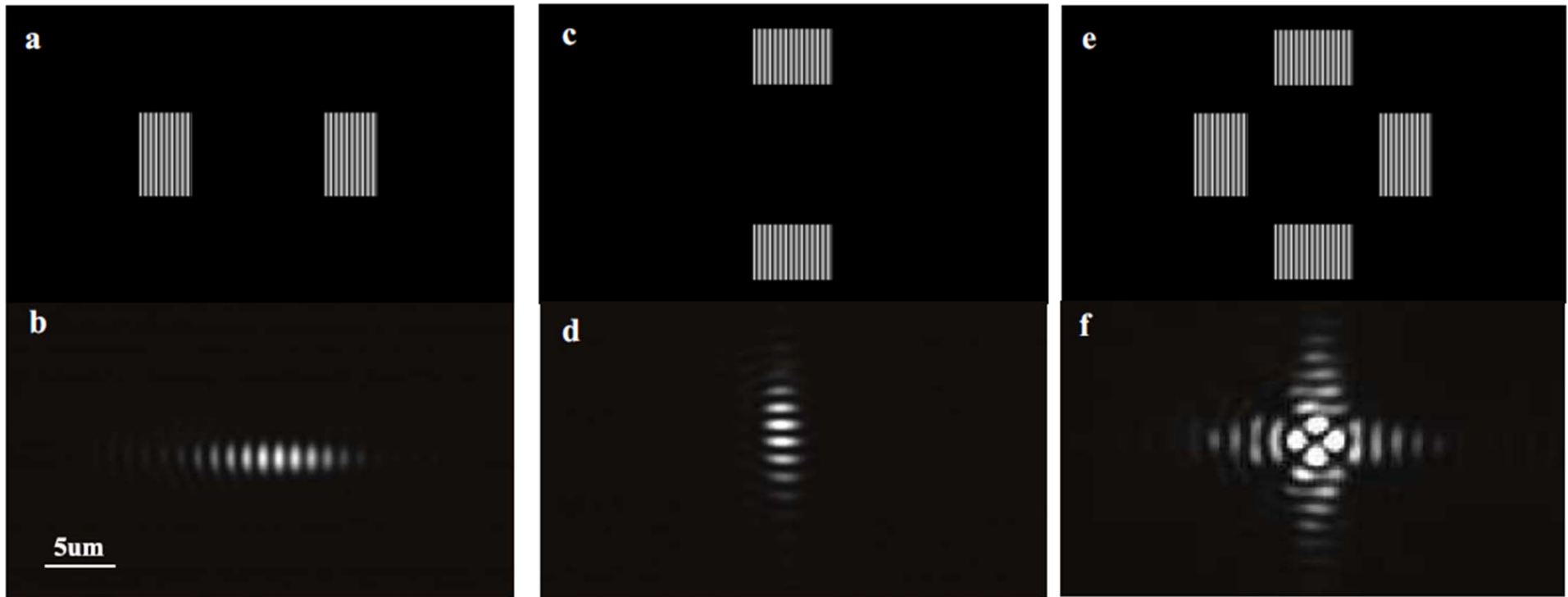
What more?

Multi-level structure

Figure: Thad Walker

Atom Sorting

M. McGovern, T. Grünzweig, A. J. Hilliard, M. F. A., Laser Phys. Lett., Early View, 2011.

Atom Sorting

Conclusions

- Blue detuned light can be used for flourescence imaging.

- We can count several atoms in a microscopic volume

- Light assisted collisions can lead to only one atom being lost

- Investigating individual events reveal information not available from ensemble average measurements

- We can (almost) deterministically prepare a single atom in an optical microtrap

- Atom sorting can be done on the 1 um scale

Acknowledgements

Power and Detuning

Single atom probability v. probe power for several probe detunings δ_c