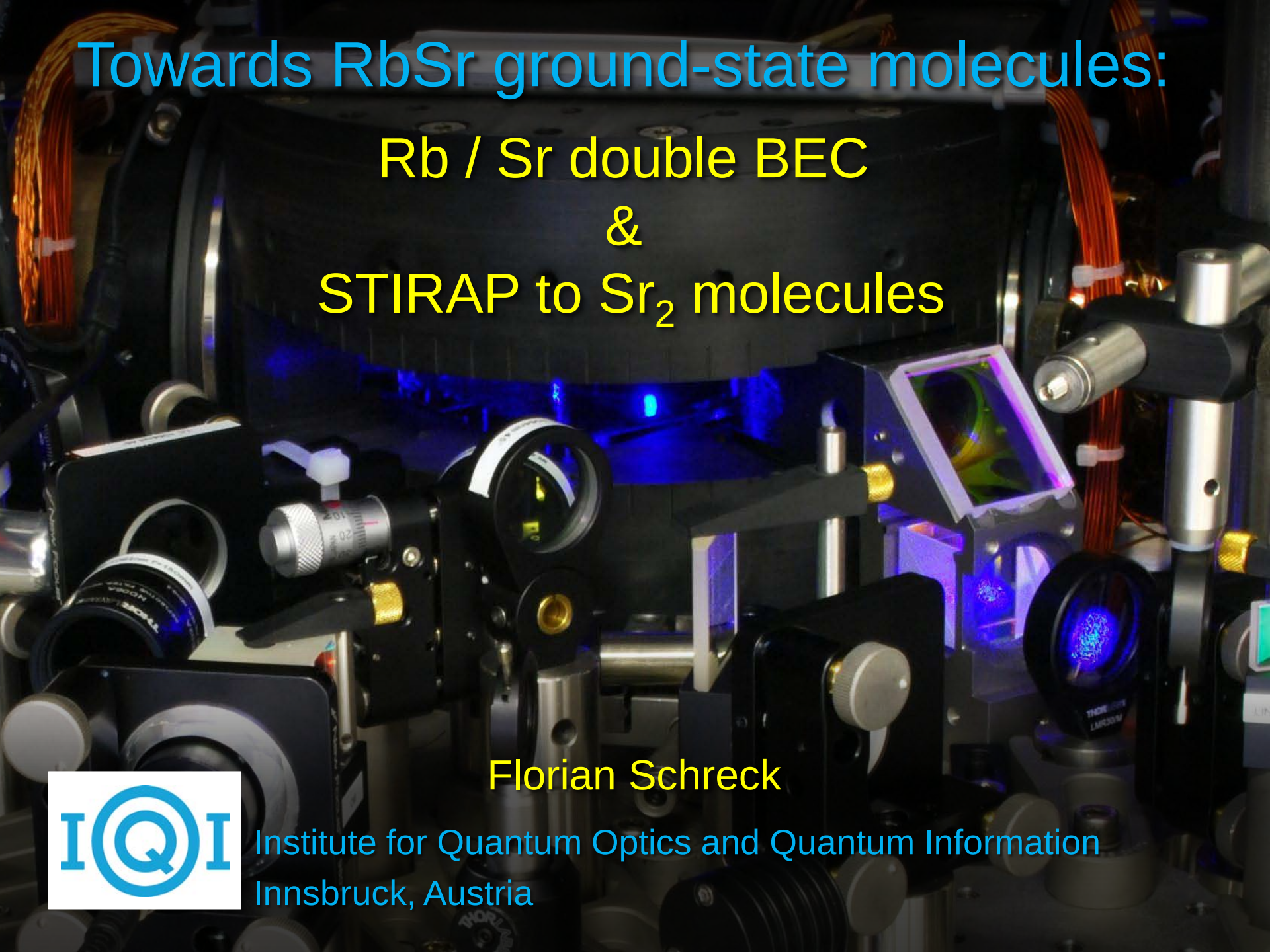


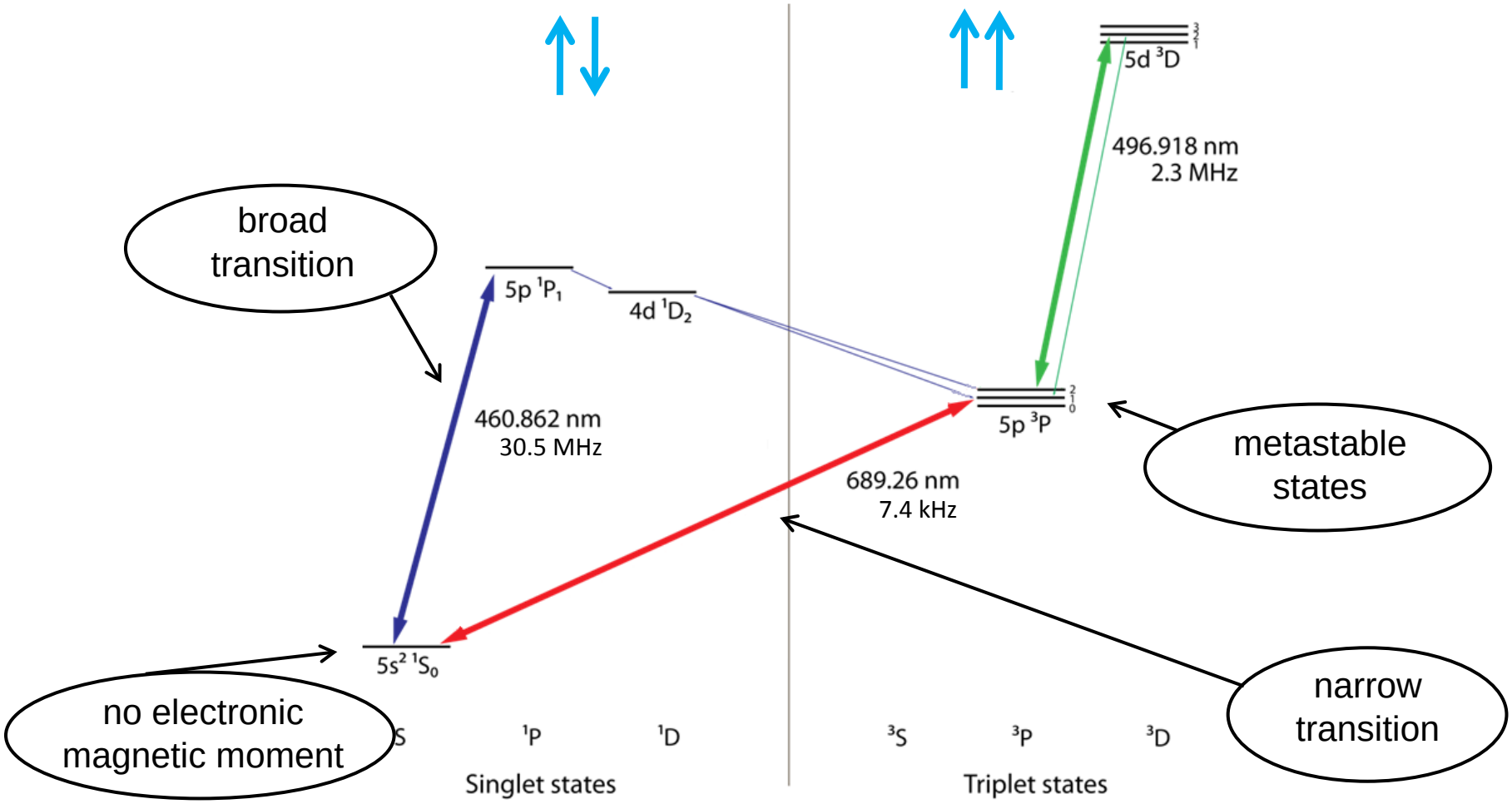
Towards RbSr ground-state molecules:

Rb / Sr double BEC
&
STIRAP to Sr_2 molecules

Florian Schreck

Institute for Quantum Optics and Quantum Information
Innsbruck, Austria

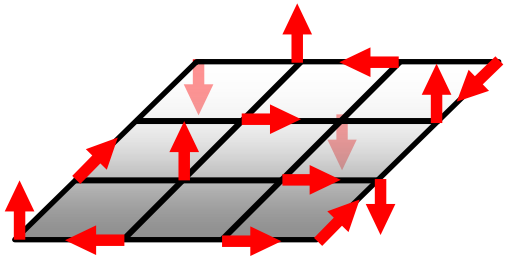
Strontium level scheme



Opportunities

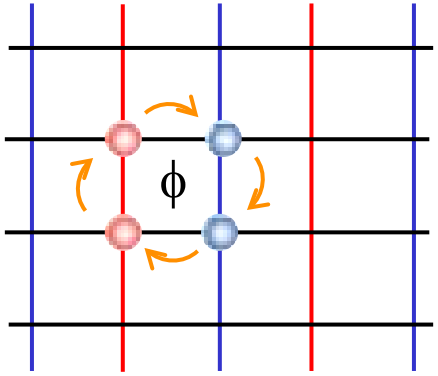
SU(*N*) magnetism

Hermele, Gurarie, and Rey, PRL 2009
Cazalilla, Ho, and Ueda, NJP 2009



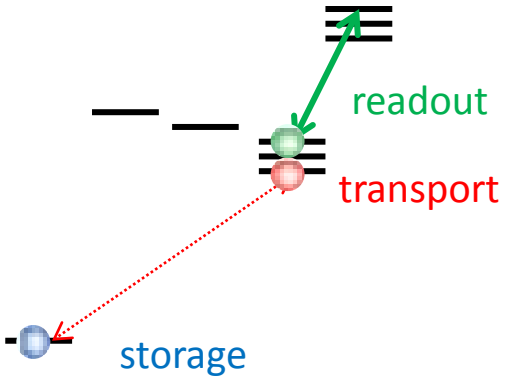
Artificial gauge fields

Gerbier and Dalibard, NJP 2010
Cooper, PRL 2011



Quantum computation schemes

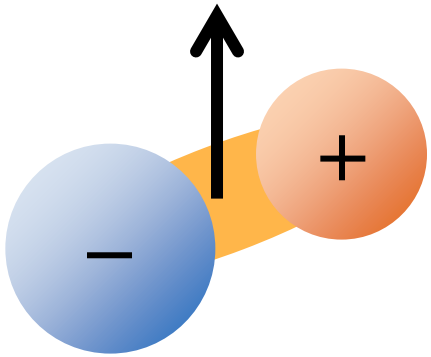
Daley, Boyd, Ye, and Zoller 2008



Many other possibilities:

- Precision measurement
- Continuous BEC
- Rydberg atoms
- Engineered dissipation
- …

RbSr ground-state molecules



Polar, open-shell molecules:

Have electric dipole moment (1.5 Debye)
and unpaired electron

Guérout *et al.*, PR A **82**, 042508 (2010)

Enhanced control parameter space:

Confinement:

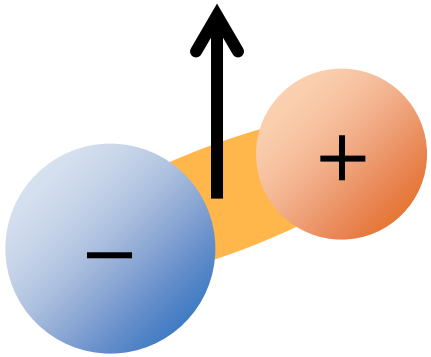
- Magnetic potentials
- Electron spin-state dependent potentials

Interactions:

- supress inelastic collisions by polarizing electron spin?
- electron spin-state dependent long-range interactions

Micheli *et al.*, nature physics **2**, 341 (2006)

RbSr ground-state molecules

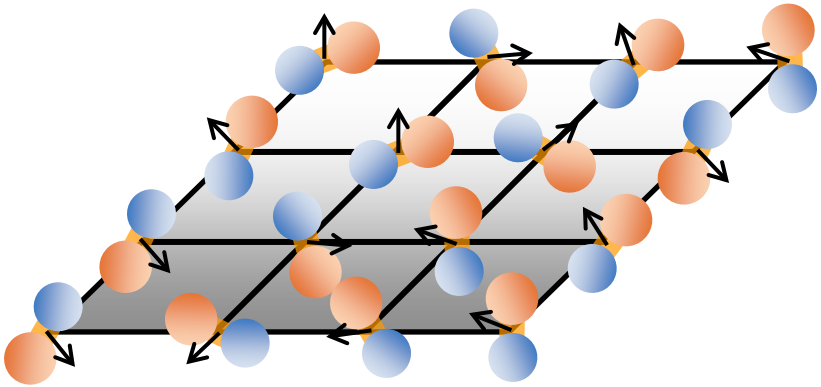


Polar, open-shell molecules:

Have electric dipole moment (1.5 Debye)
and unpaired electron

Guérout *et al.*, PR A **82**, 042508 (2010)

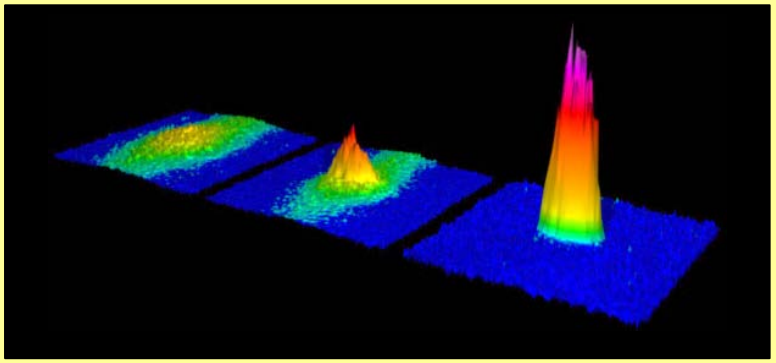
A way to simulate lattice-spin models



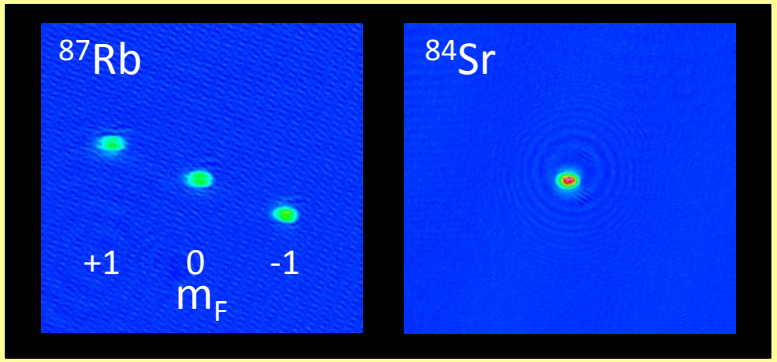
Micheli *et al.*, nature physics **2**, 341 (2006)

Overview

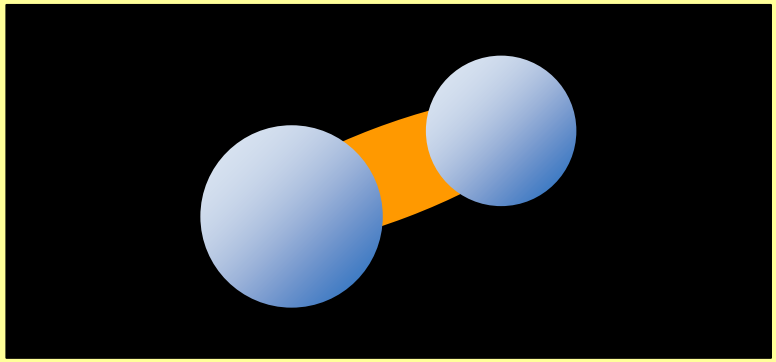
BEC of strontium



Rb / Sr double BEC



Sr_2 molecules



Towards high phase-space density

2000: ^{88}Sr at phase-space density of 0.1

PHYSICAL REVIEW A, VOLUME 61, 061403(R)

Optical-dipole trapping of Sr atoms at a high phase-space density

Tetsuya Ido,[1] Yoshitomo Isoya,[1] and Hidetoshi Katori[1,2]

2006: cooling of ^{88}Sr/ ^{86}Sr mixture to phase-space density of 0.06

PHYSICAL REVIEW A **73**, 023408 (2006)

Cooling of Sr to high phase-space density by laser and sympathetic cooling in isotopic mixtures

G. Ferrari, R. E. Drullinger, N. Poli, F. Sorrentino, and G. M. Tino*

New approach

Bosonic strontium isotopes:

Isotope	Natural abundance	Scattering length
~~^{88}Sr~~	82.58 %	-2 a_0
~~^{86}Sr~~	9.86 %	+800 a_0
^{84}Sr	0.56 %	?

no collisions

inelastic collisions

New approach

Bosonic strontium isotopes:

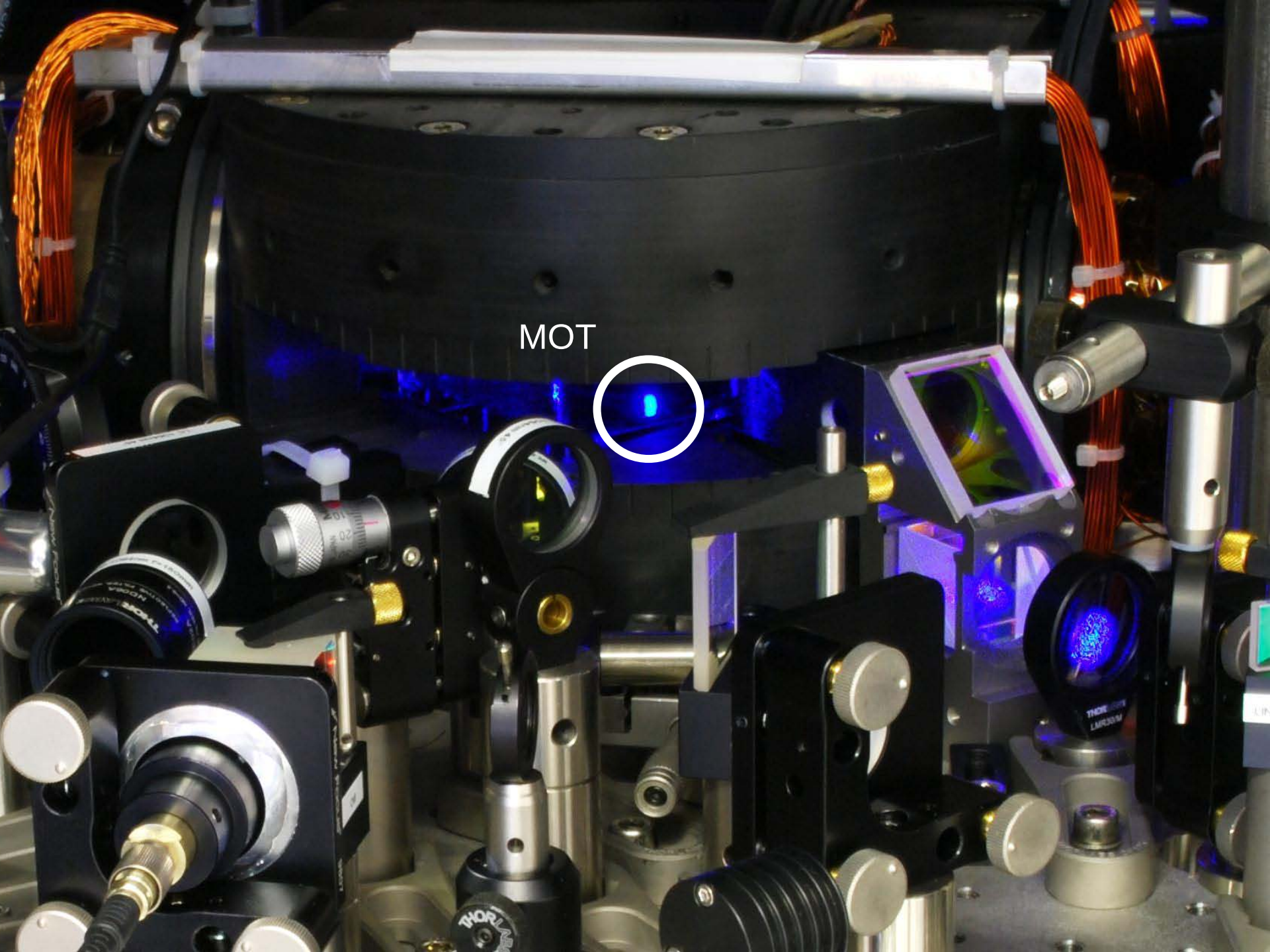
Isotope	Natural abundance	Scattering length
~~^{88}Sr~~	82.58 %	-2 a_0
~~^{86}Sr~~	9.86 %	+800 a_0
^{84}Sr	0.56 %	+124 a_0

no collisions

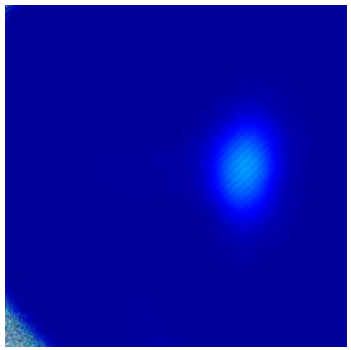
inelastic collisions

by Roman Ciurylo
using PRL **95**, 223002

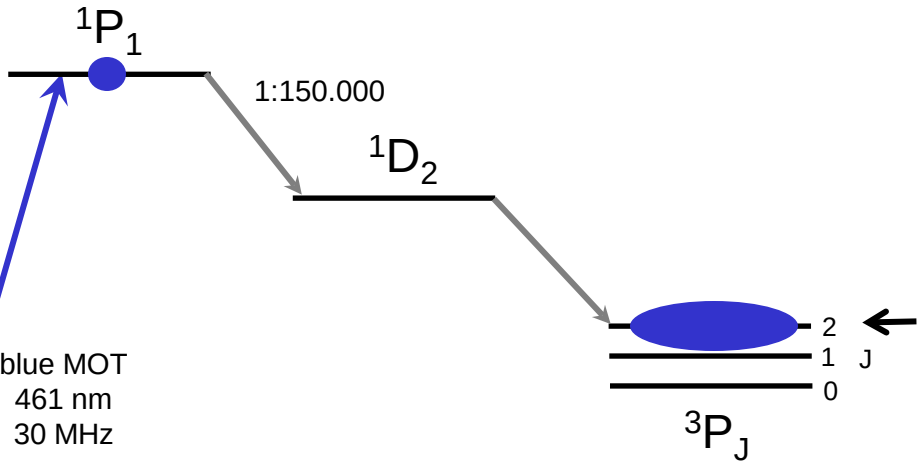
⟹ Our strategy: use ^{84}Sr

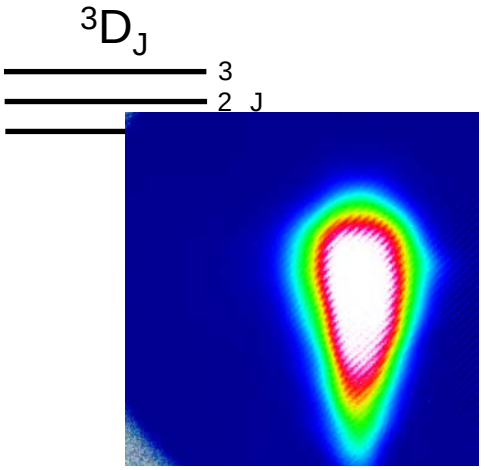

MOT

Accumulation in metastable state



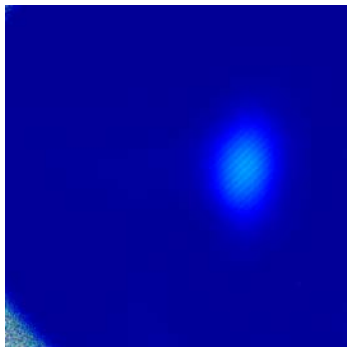
$3x10^5$ atoms





>10^8 atoms !
in magnetic trap

Narrow linewidth MOT



3x10^5 atoms

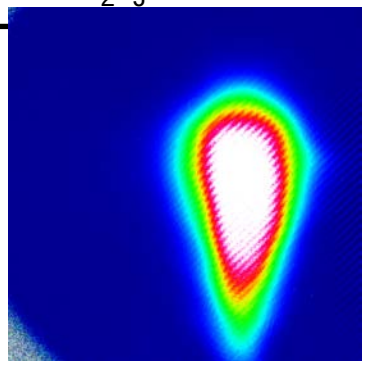
$^1P_1$

$^1D_2$

^3D_J

3
2 J

repump
497 nm
2.3 MHz



2
1 J
0

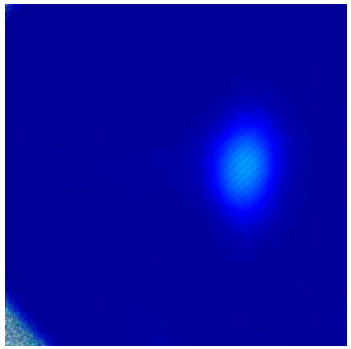
^3P_J

>10^8 atoms !
in magnetic trap

red MOT
689 nm
7.4 kHz

$^1S_0$

Narrow linewidth MOT



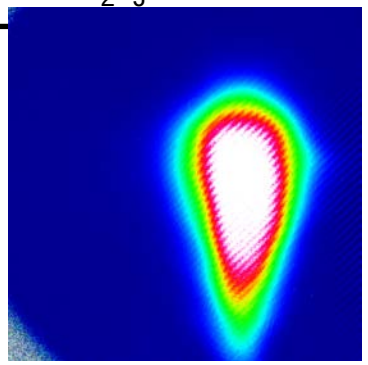
3x10^5 atoms

$^1P_1$

$^1D_2$

^3D_J

3
2 J



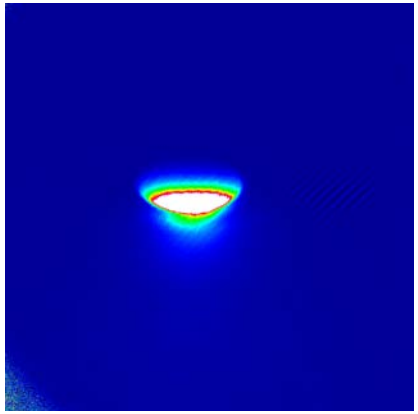
>10^8 atoms !
in magnetic trap

2
1 J
0

^3P_J

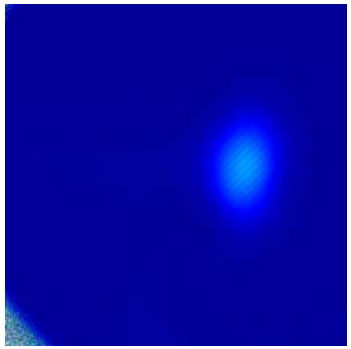
red MOT
689 nm
7.4 kHz

$^1S_0$



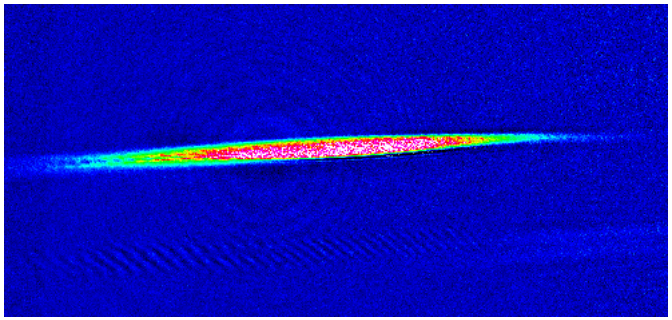
10^8 atoms
T ~ 1 µK

Narrow linewidth MOT



$3x10^5$ atoms

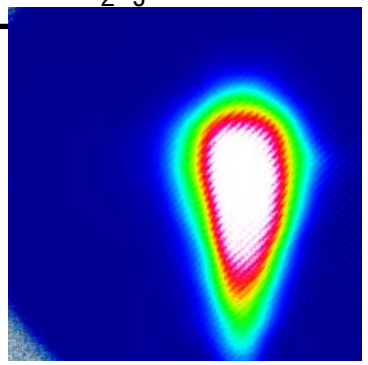
Atoms in dipole trap



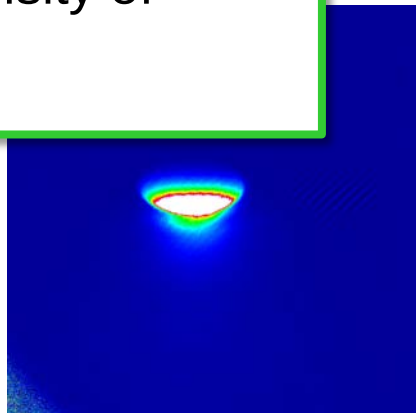
$5x10^7$ atoms with
phase-space density of
0.1 !

^3D_J

3
2 J



$>10^8$ atoms !
in magnetic trap



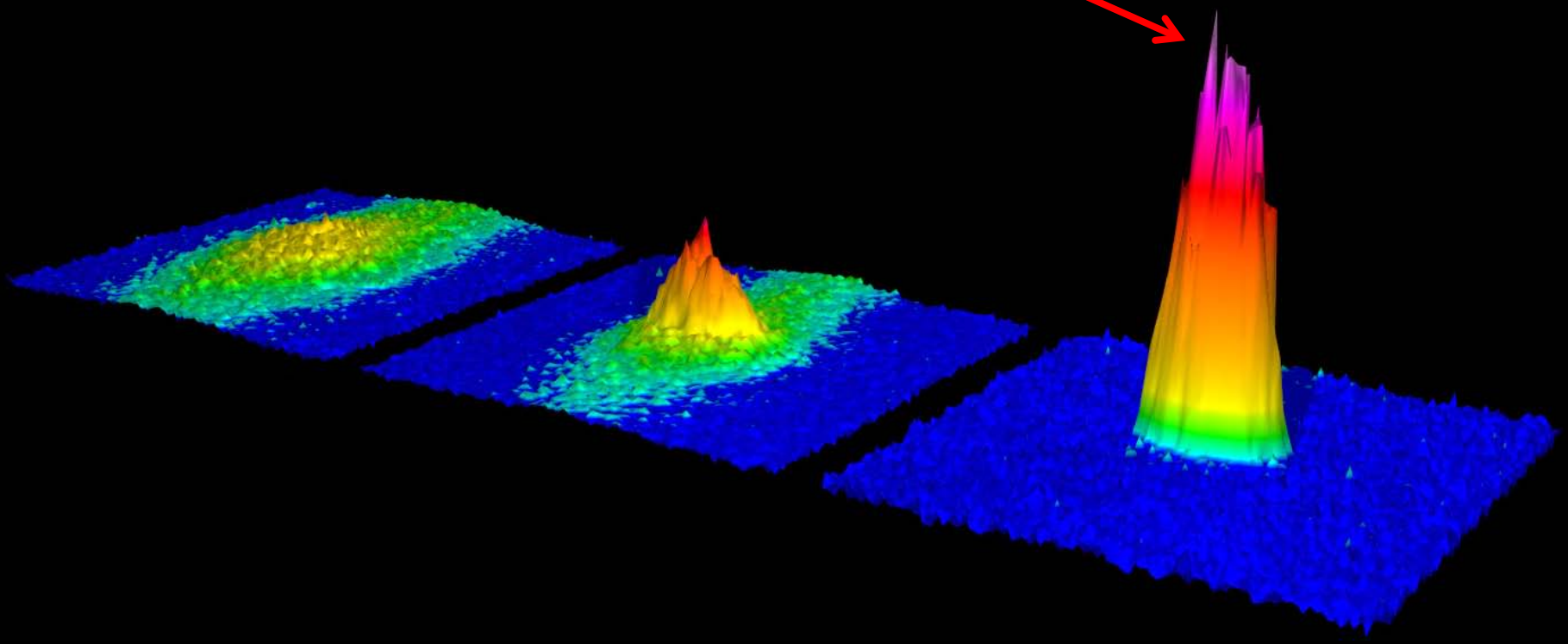
10^8 atoms
T ~ 1 µK

$^1S_0$

Sr BEC!

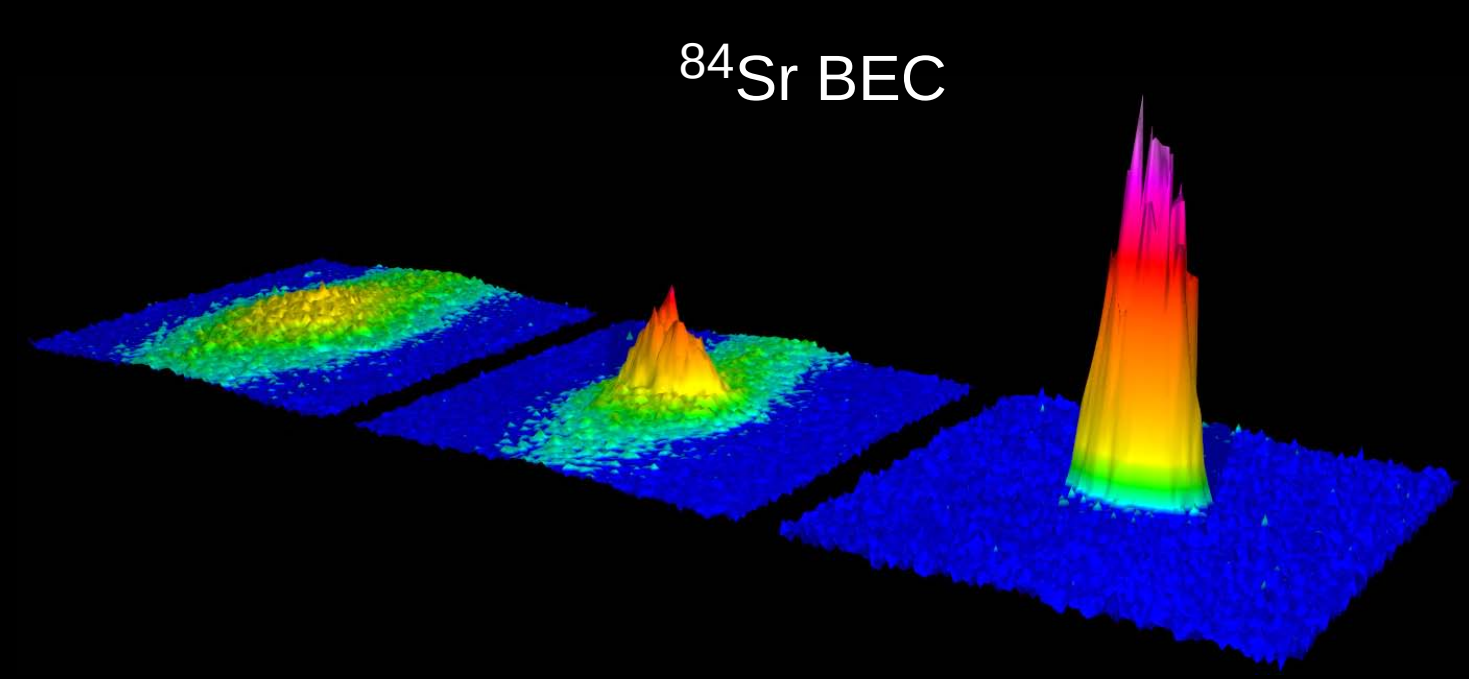
9/26/2009

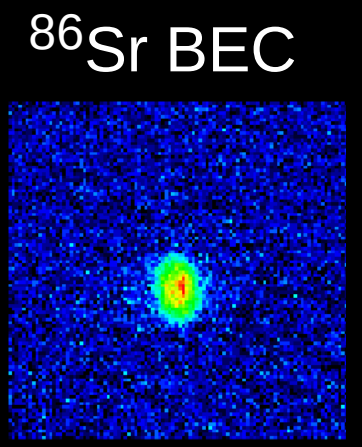
10 million atoms in pure BEC!

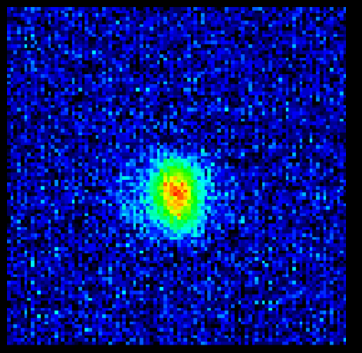


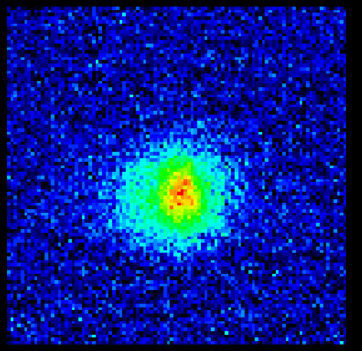
See also work by Tom Killian's group: PRL **103**, 200402 (2009)

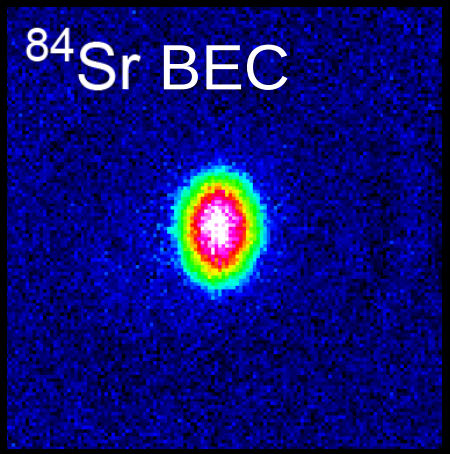
Quantum Degenerate Strontium

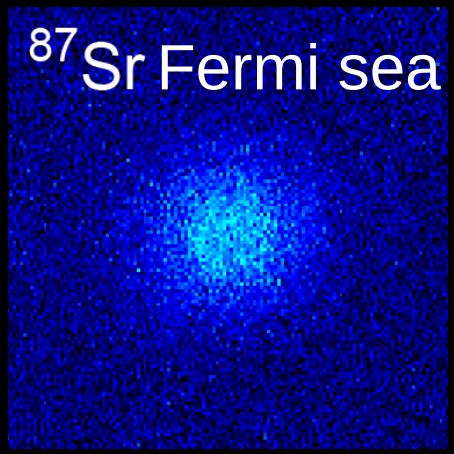


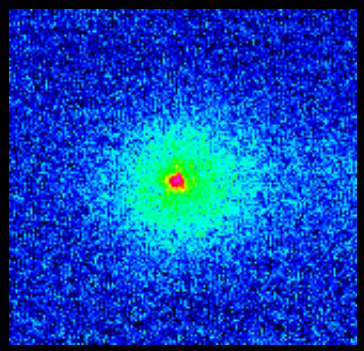






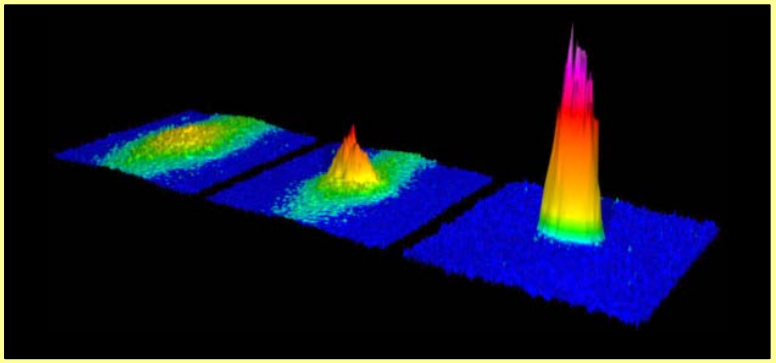




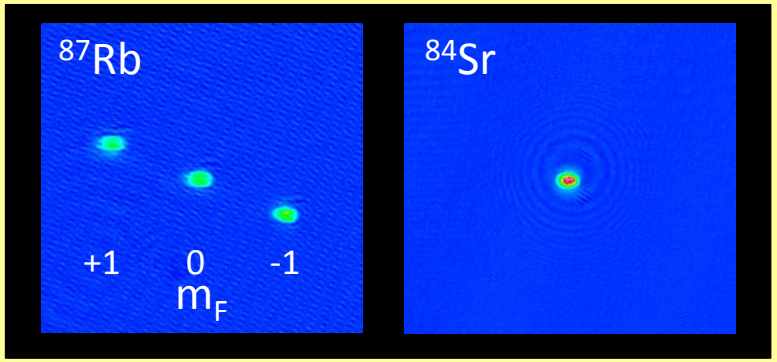


Overview

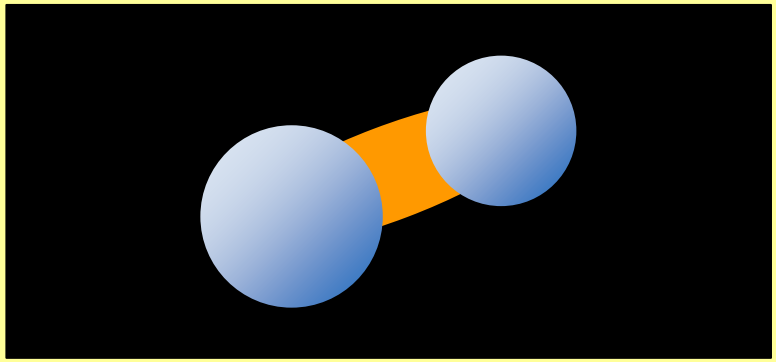
BEC of strontium



Rb / Sr double BEC

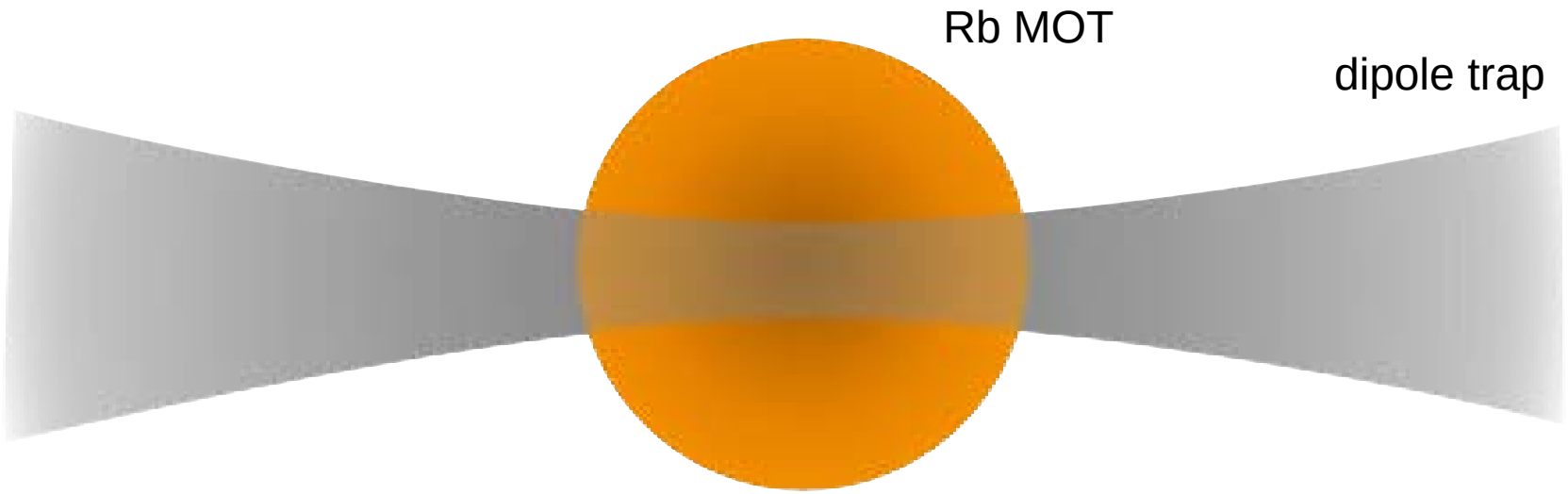


Sr_2 molecules



Sample preparation

Prepare ^{84}Sr, ^{87}Rb mixture in dipole trap:



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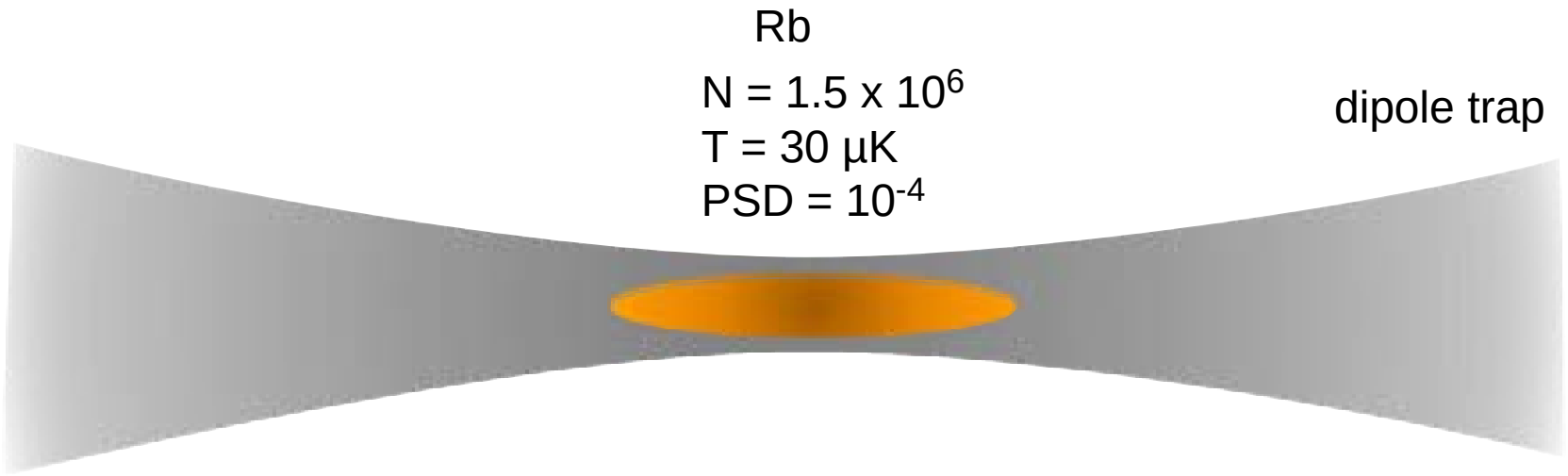
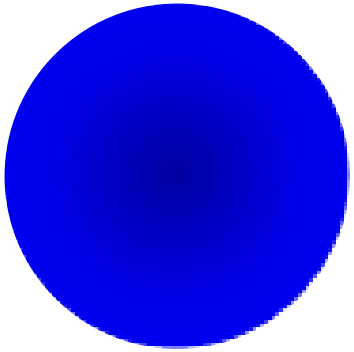


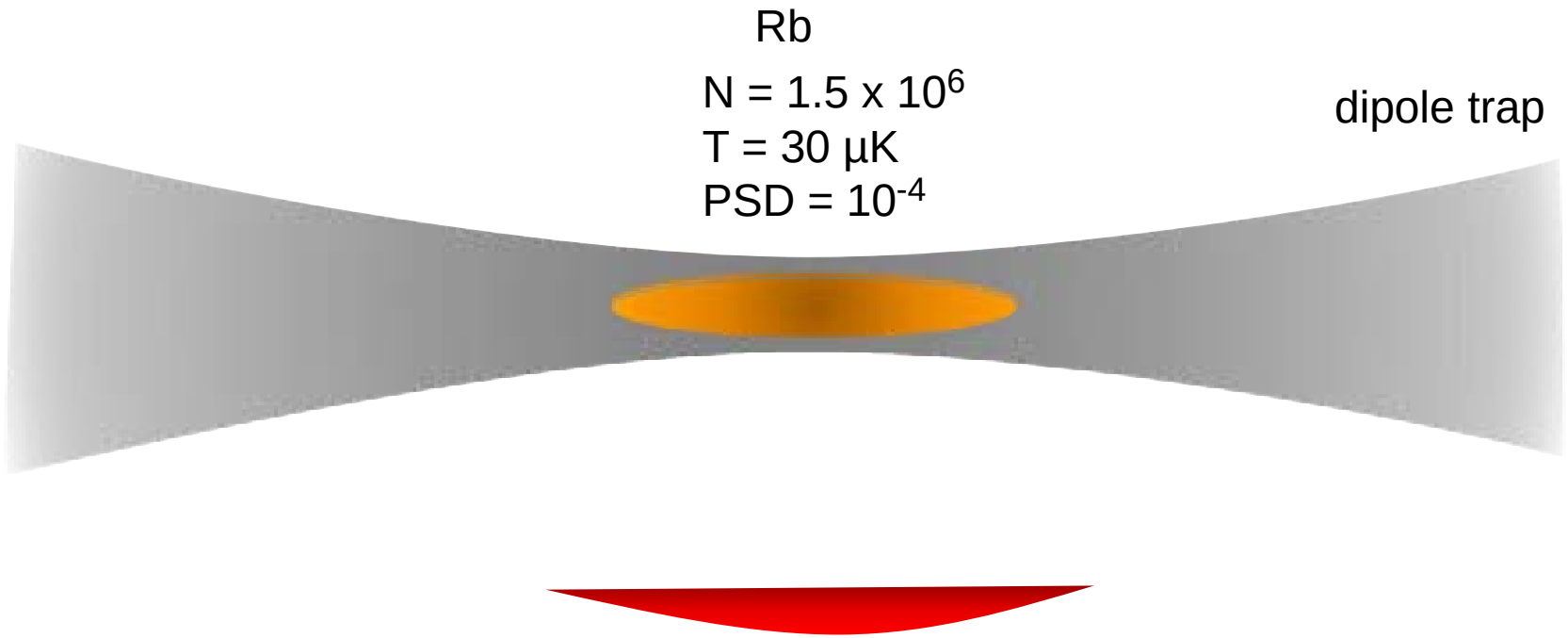


Sr reservoir loading:

10 s ^{84}Sr MOT

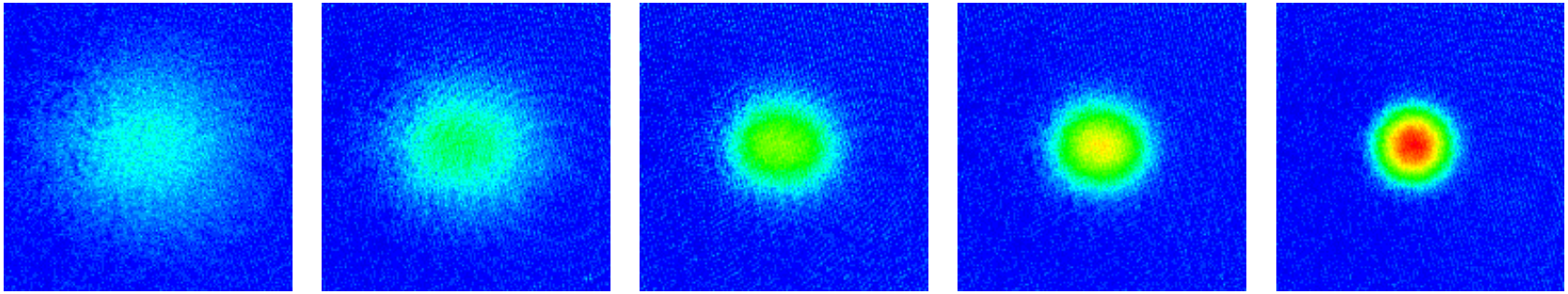
Sample preparation

Prepare ^{84}Sr, ^{87}Rb mixture in dipole trap:



Sympathetic laser cooling

Rb momentum distribution



0 ms

time

400 ms

T = 30 µK

N = 1.6 x 10^6

PSD = 10^{-4}

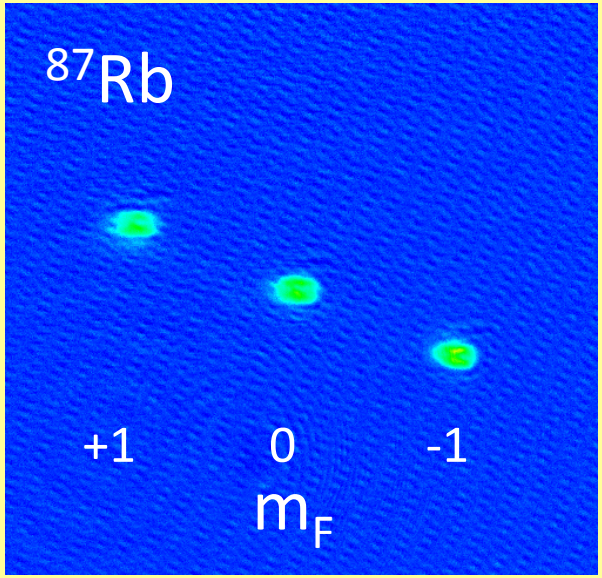
x 200
in phase-space
density!

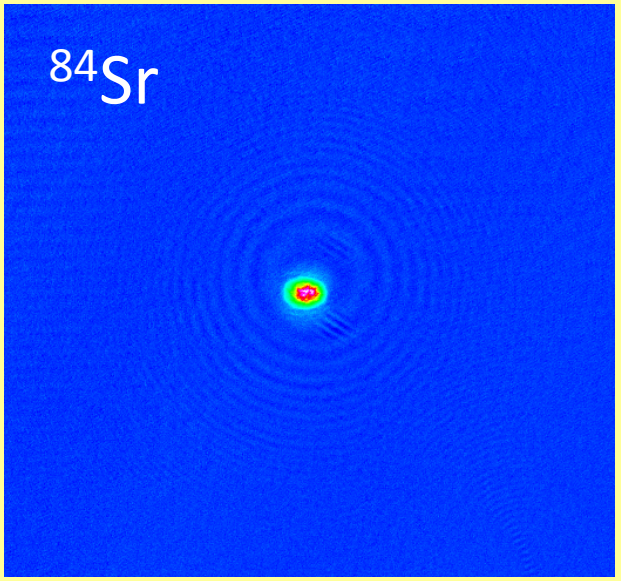
T = 5 µK

N = 1.3 x 10^6

PSD = 0.05

^{87}Rb / ^{84}Sr double BEC



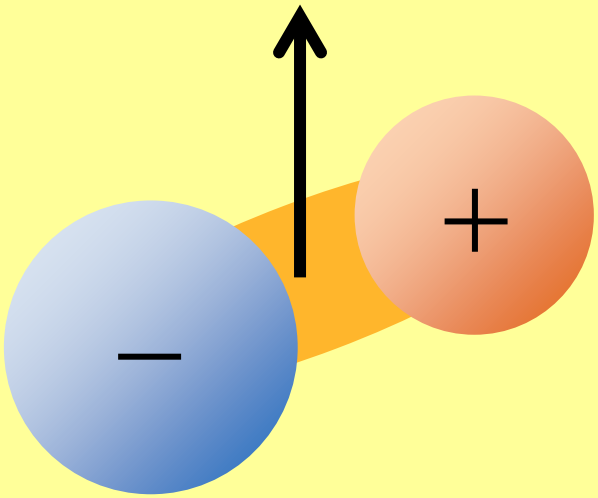


$N=1.3 \times 10^5$

$N=2.5 \times 10^5$

Next goal

RbSr molecules



Molecule association

Magneto-association

PRL **105,** 153201 (2010) PHYSICAL REVIEW LETTERS week ending 8 OCTOBER 2010

Ultracold RbSr Molecules Can Be Formed by Magnetoassociation

Piotr S. Żuchowski,[1] J. Aldegunde,[2] and Jeremy M. Hutson[1]

[1]*Department of Chemistry, Durham University, South Road, Durham, DH1 3LE, United Kingdom*

[2]*Departamento de Química Física, Facultad de Ciencias Químicas, Universidad de Salamanca, 37008, Salamanca, Spain*

(Received 15 June 2010; published 6 October 2010)

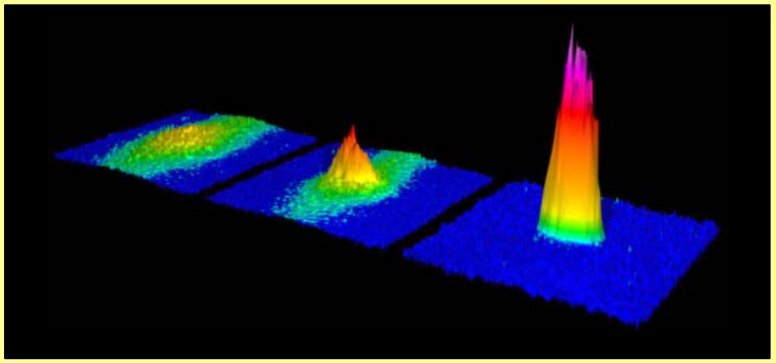
Resonances probably quite narrow ⟶ alternative technique might be handy

STIRAP of atom pair to molecule

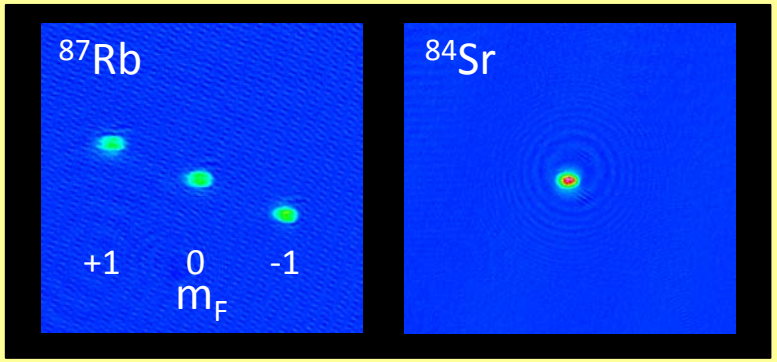
Demonstrate by creating Sr_2

Overview

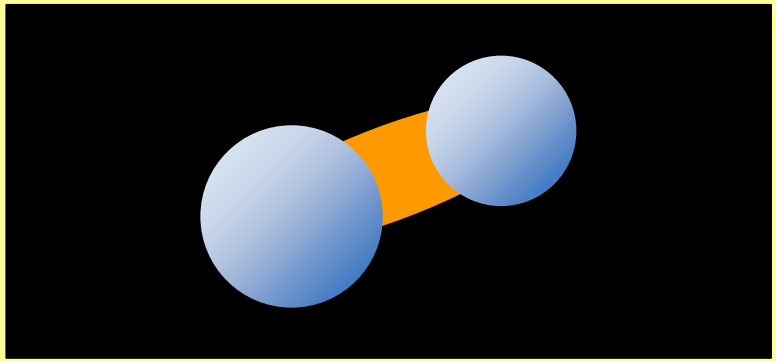
BEC of strontium



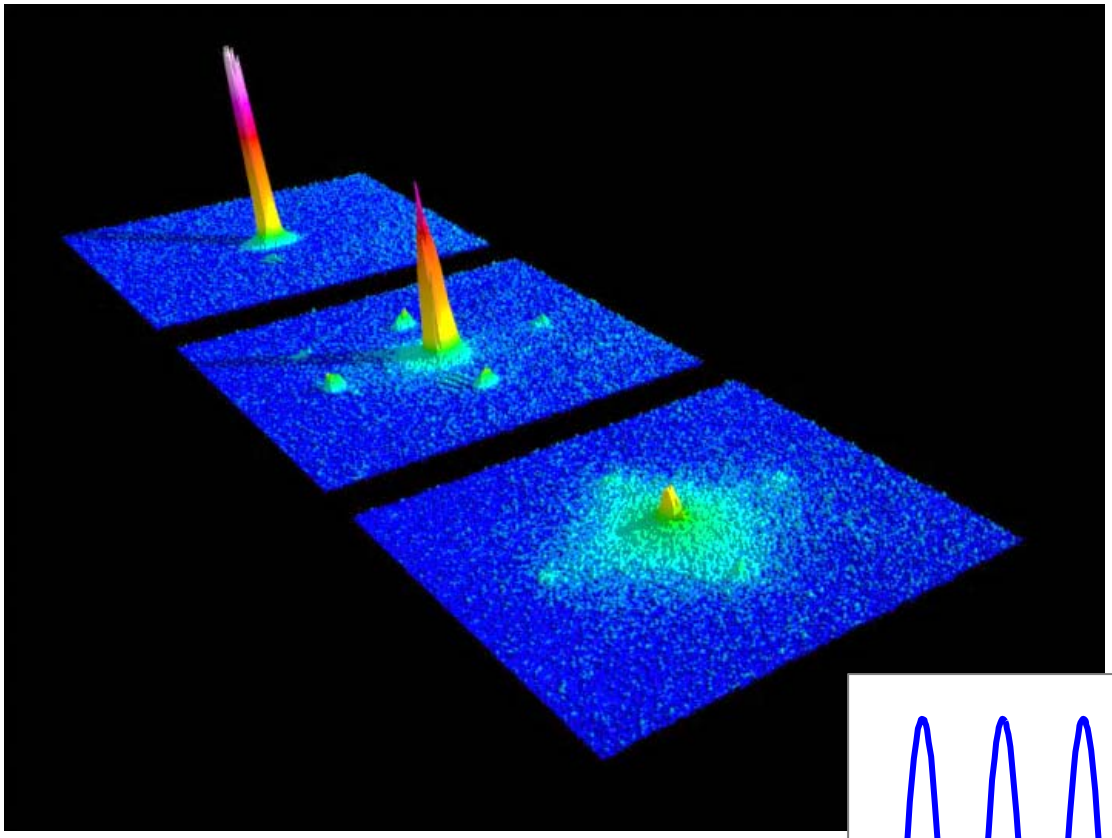
Rb / Sr double BEC

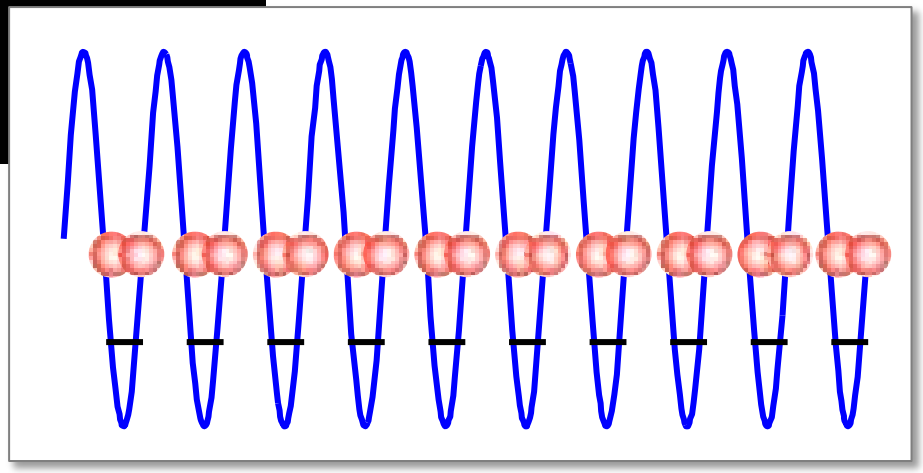


Sr_2 molecules

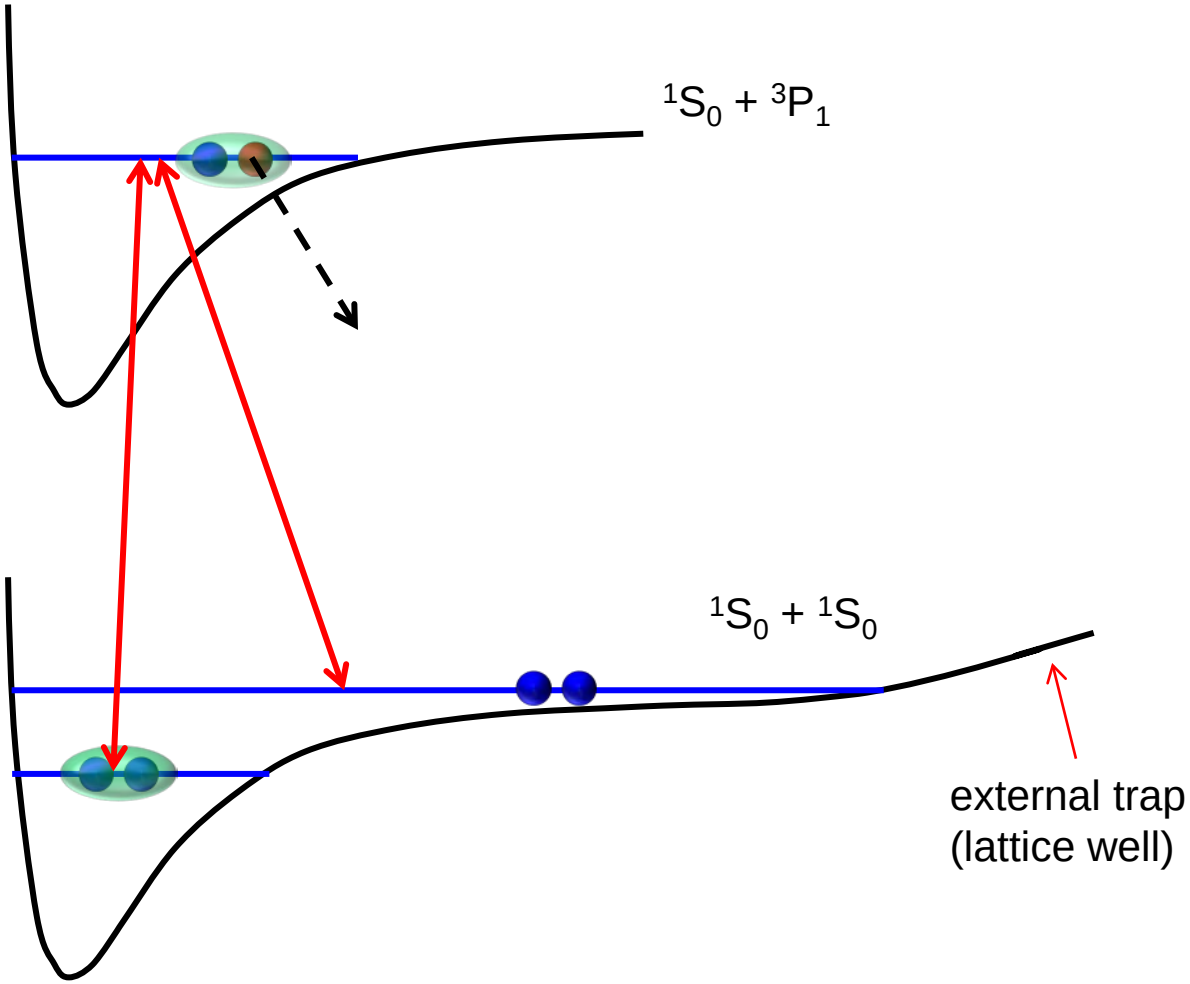


Step 1: Mott insulator of ^{84}Sr

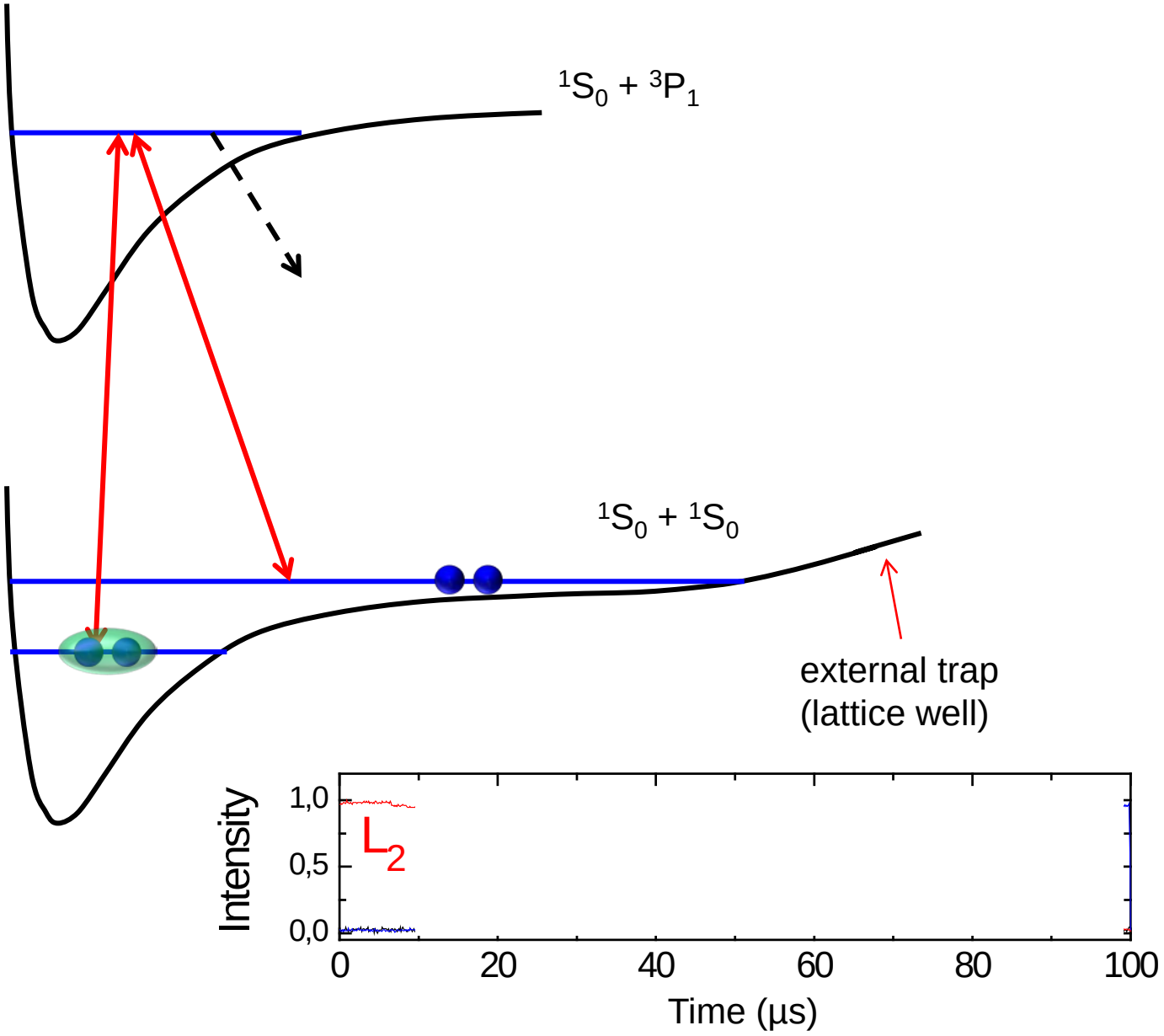




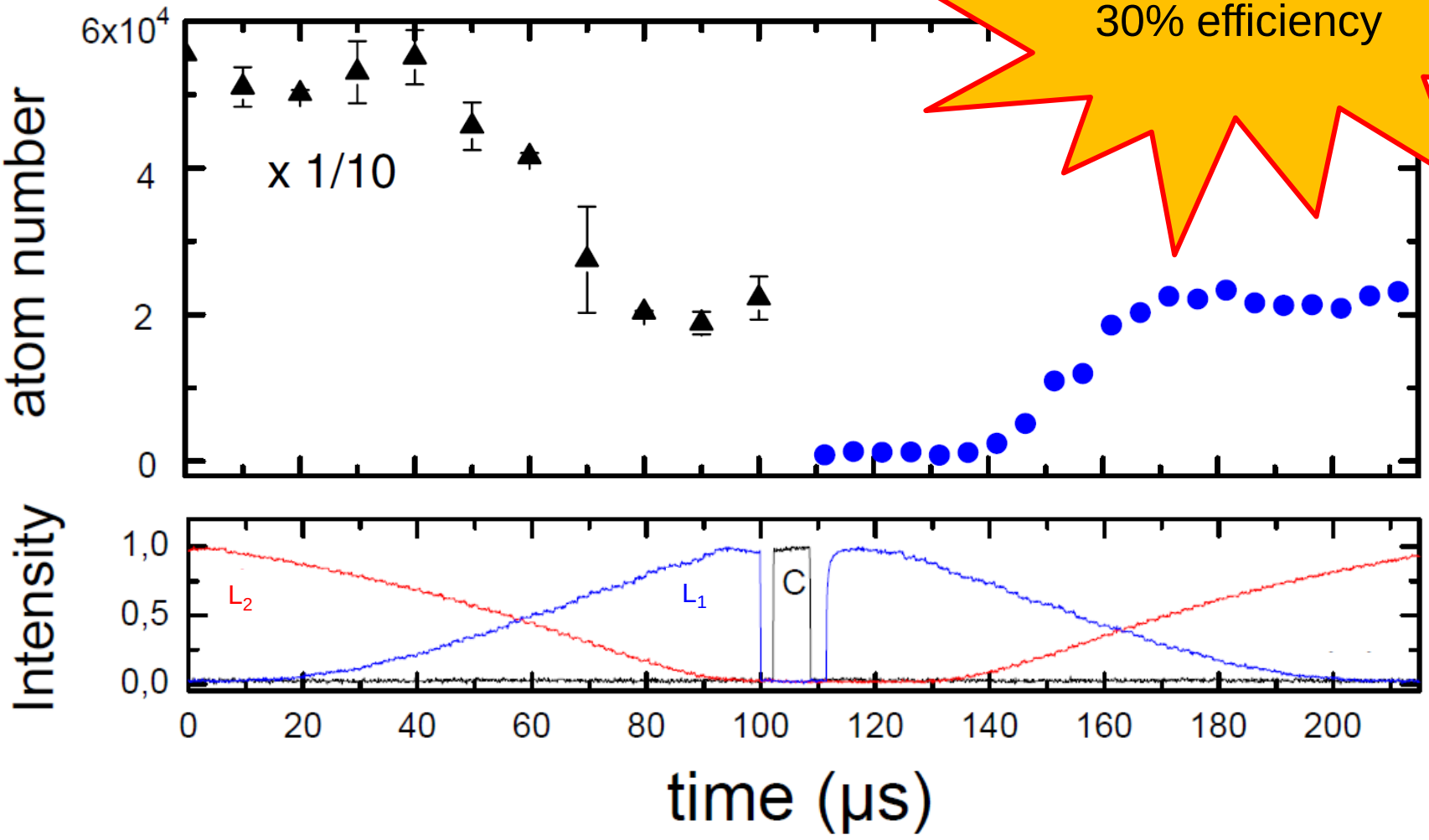
Step 2: association by STIRAP



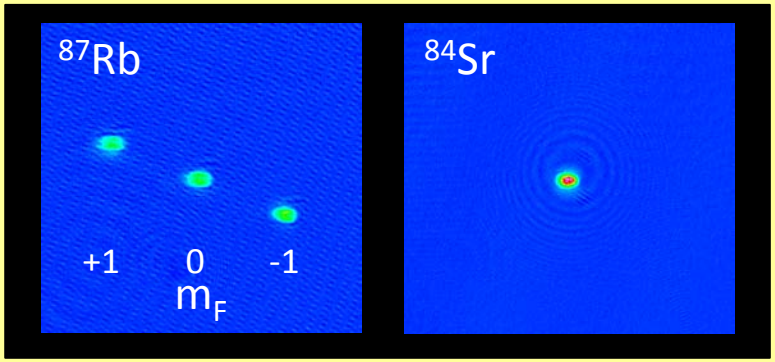
Step 2: association by STIRAP

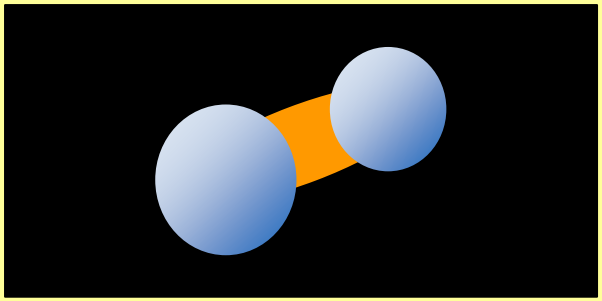


Result


30% efficiency
6x10^4
4
2
0
x 1/10
atom number
Intensity
1,0
0,5
0,0
L2
L1
C
0
20
40
60
80
100
120
140
160
180
200
time (µs)

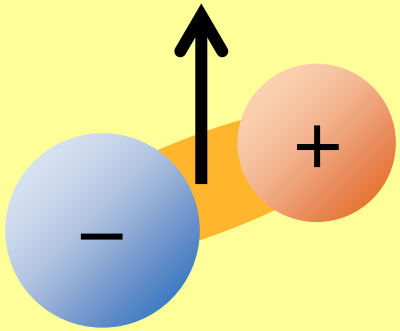
Next goal





Sr_2 molecules

RbSr molecules



Ground-state transfer by (second) STIRAP

The RbSr team

Former members:

Meng Khoon Tey (postdoc)

Bo Huang (master)

Jacek Szczepkowski (visiting scientist)

Mark Parigger (master)