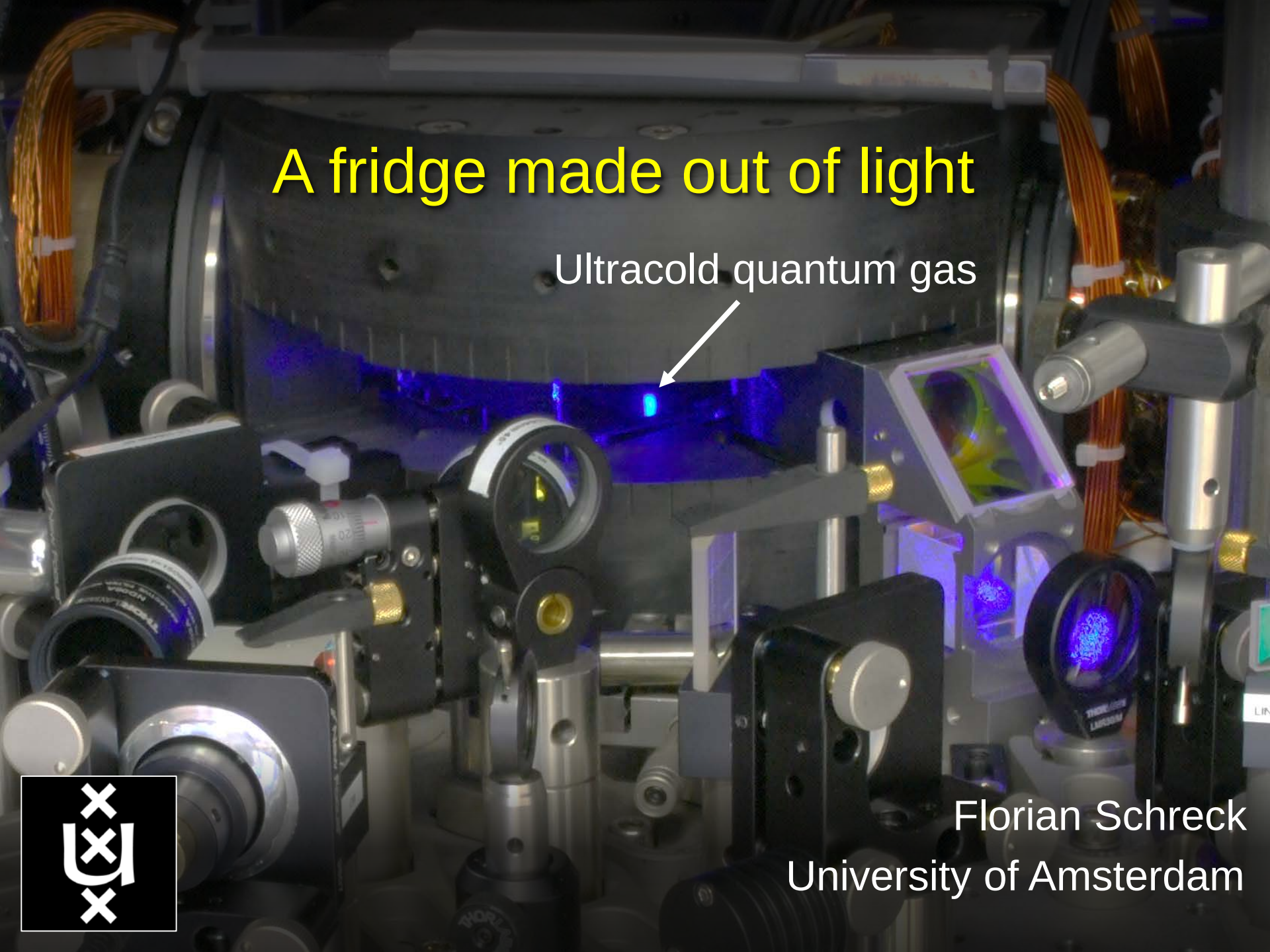
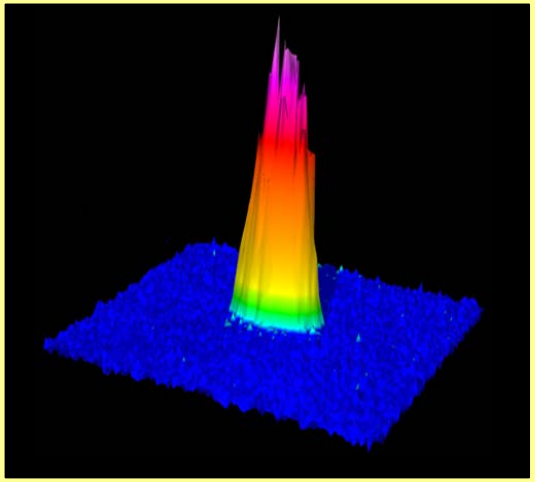


Florian Schreck
University of Amsterdam

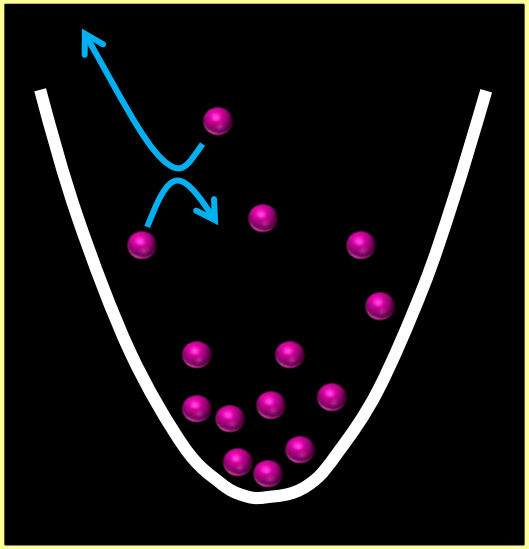
Ultracold quantum gases

What?



Why?

How?

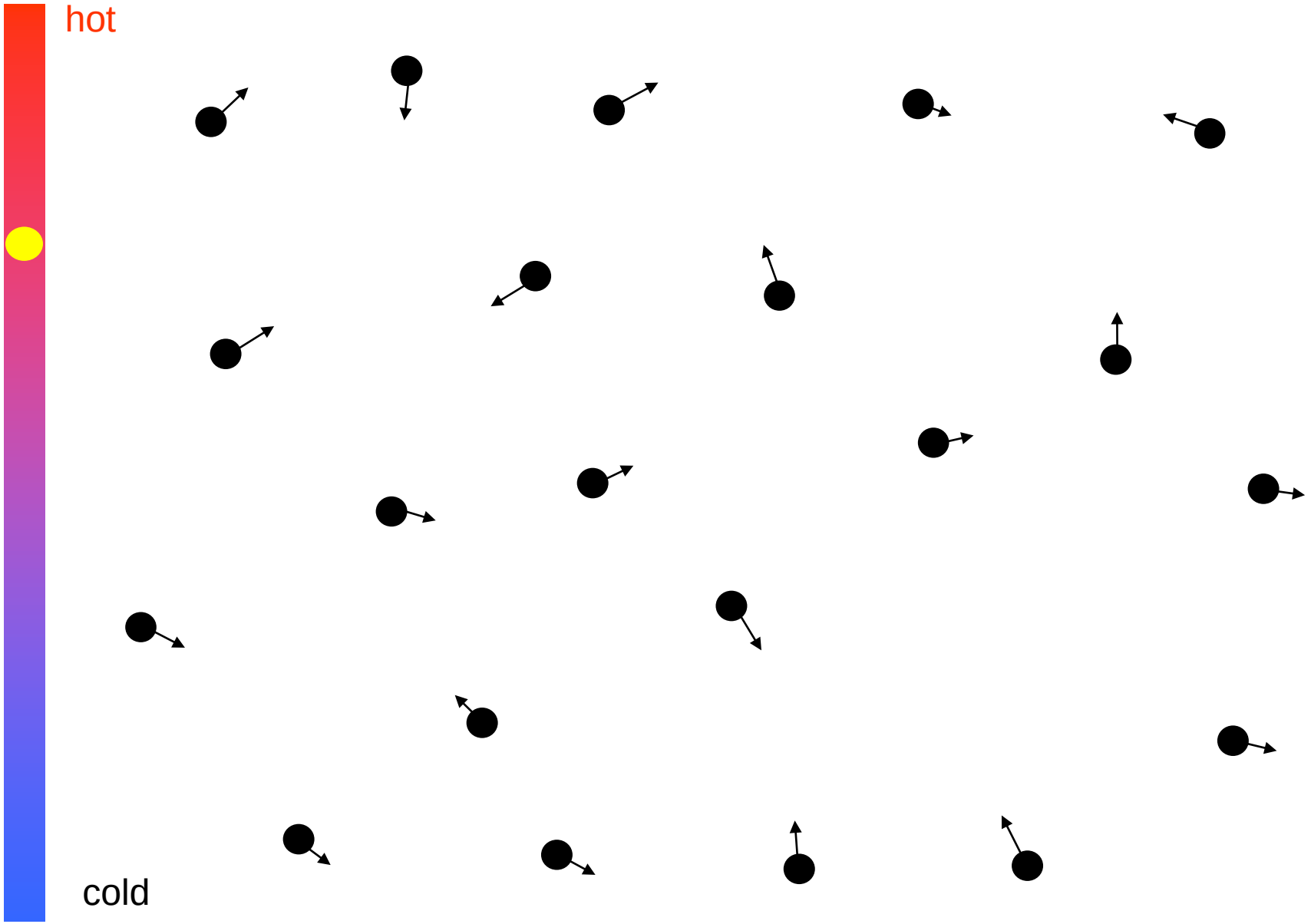


Cooling a gas of atoms

hot

cold

Cooling a gas of atoms



Entering the quantum world

hot

Louis de Broglie,
Nobel Prize 1929

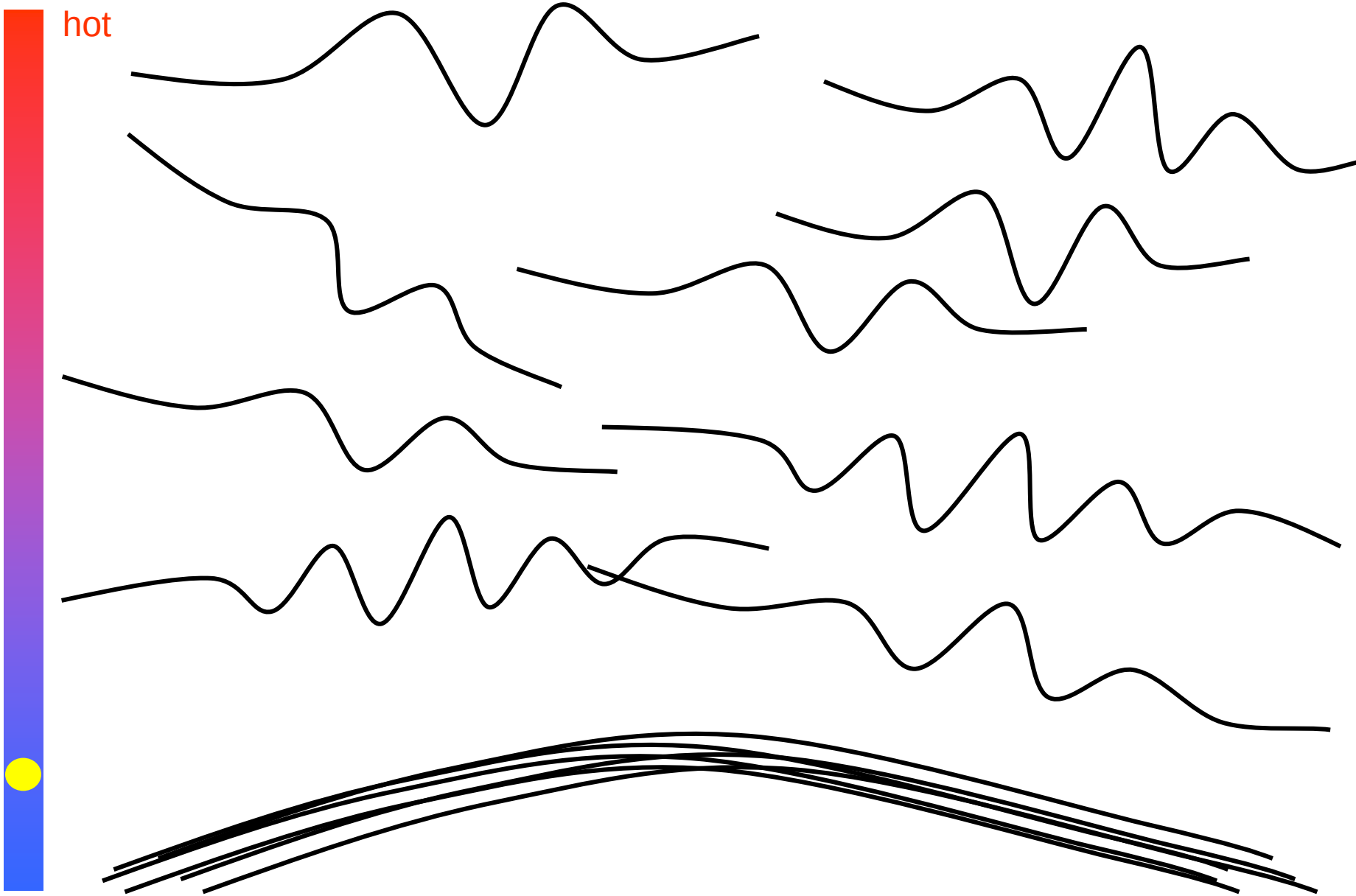
cold

Entering the quantum world

hot

cold

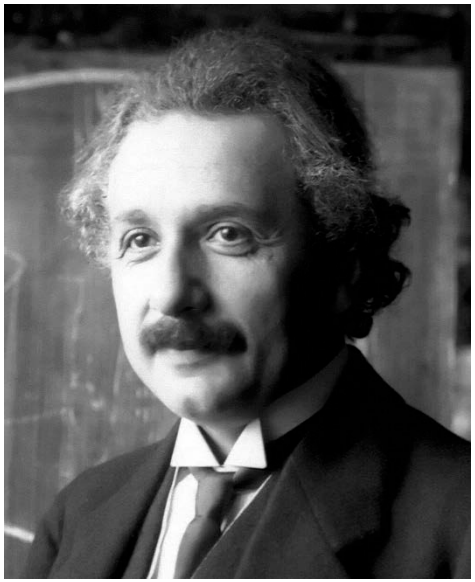
Entering the quantum world



Bose-Einstein condensation

hot

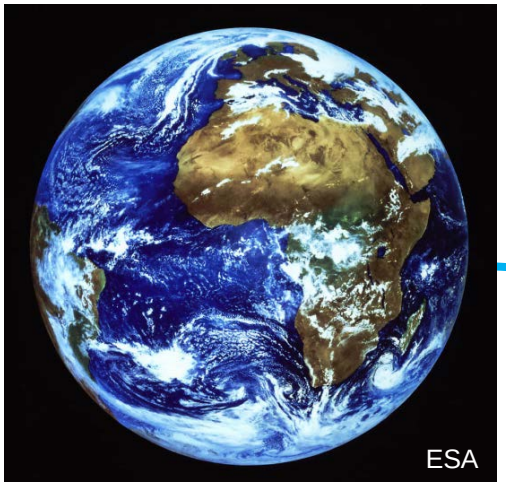
Satyendranath Bose



Albert Einstein

All atoms described by the same quantum wave

How cold is ultracold?



Earth

Outer space

Temperature

10^6 Kelvin

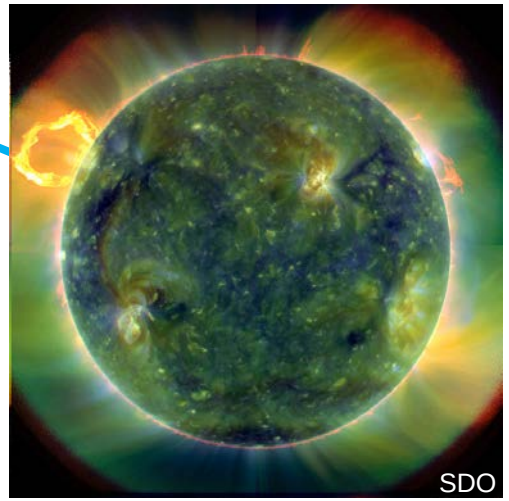
10^3 K

1 K

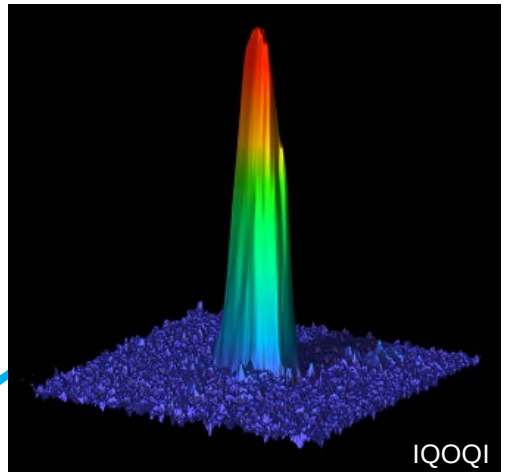
1 mK

1 µK

1 nK



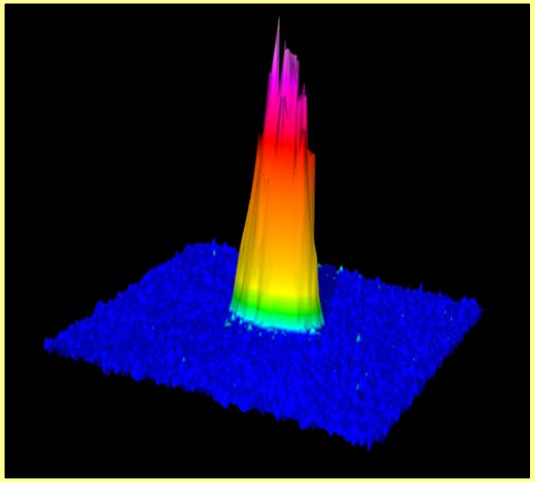
Center of sun



Ultracold atoms

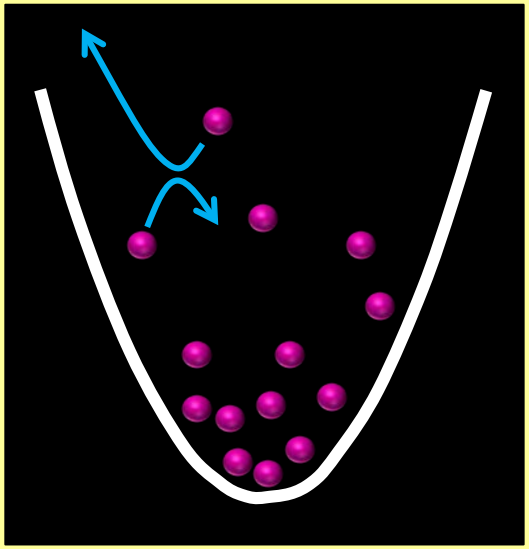
Ultracold quantum gases

What?



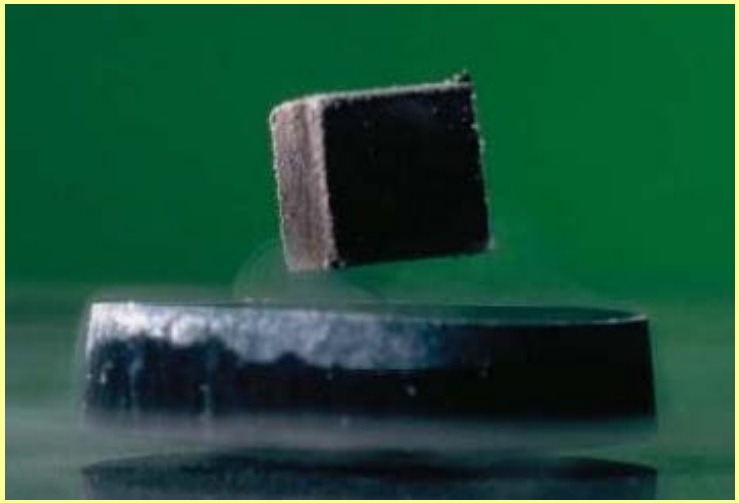
Why?

How?



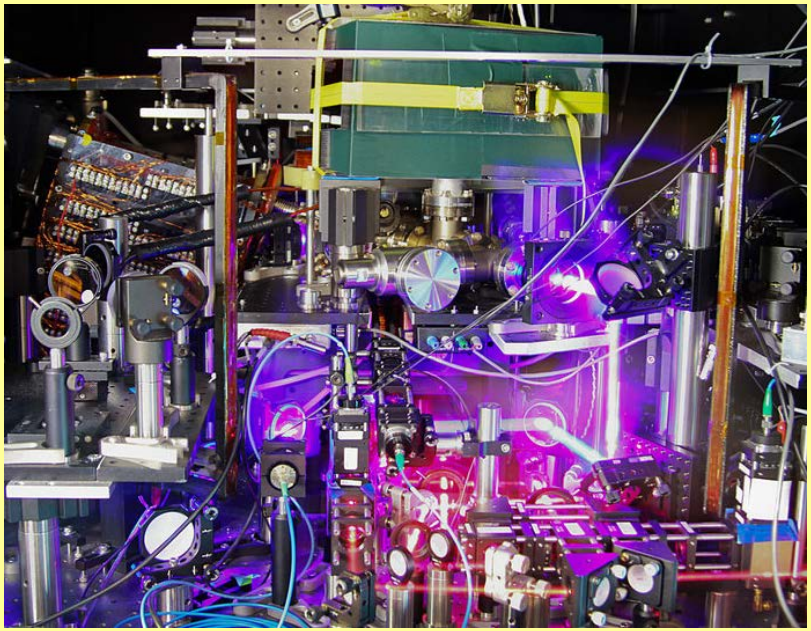
Goals

Fundamental insights



Understand quantum materials

Quantum devices



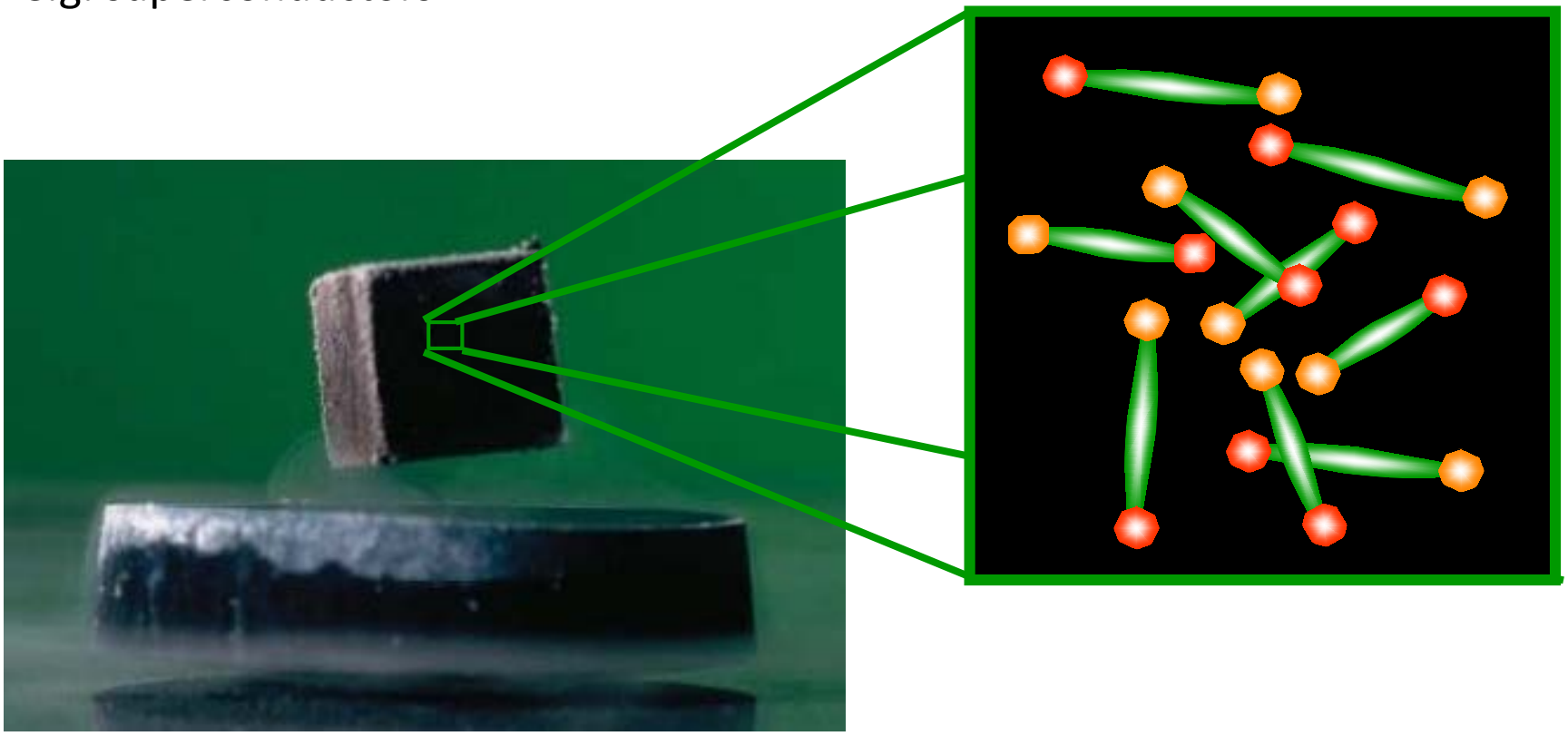
Atomic clocks

Many-body systems

e.g. swarming birds

Quantum many-body physics

e.g. superconductors



Intricate quantum motion of electrons gives rize to amazing macroscopic behavior

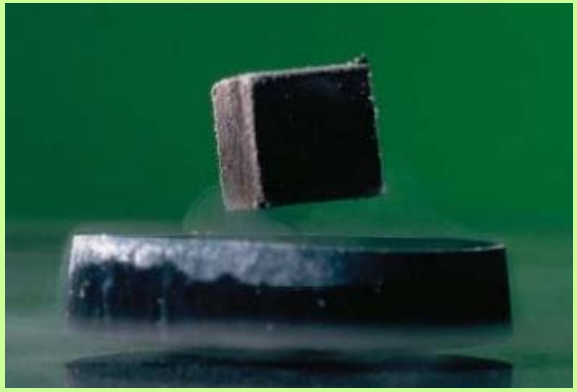
Understanding quantum systems

Problem: These quantum systems are extremely hard to understand, even using the best supercomputers.

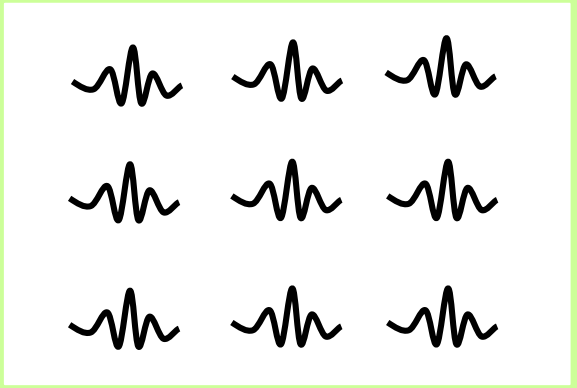
Solution: **Quantum simulation!**

Use well controlled quantum system
to simulate and study difficult to access quantum system of interest

Quantum LEGO

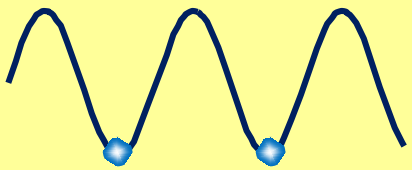


Difficult to control electrons in material

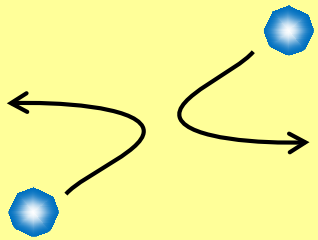


Well-controlled ultracold atoms

Design quantum simulation by controlling…



confinement



interactions

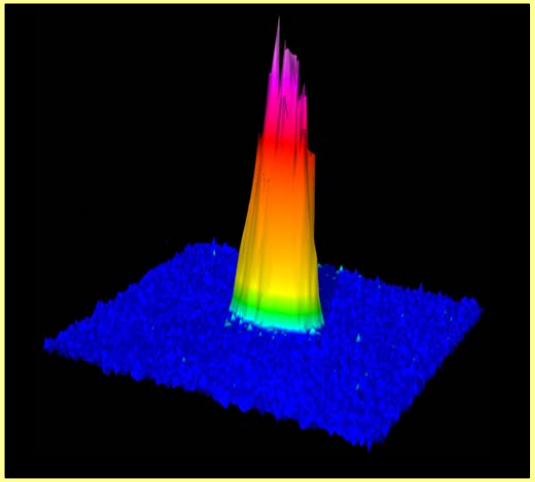
internal state

…

All of that requires first that we control **temperature**!

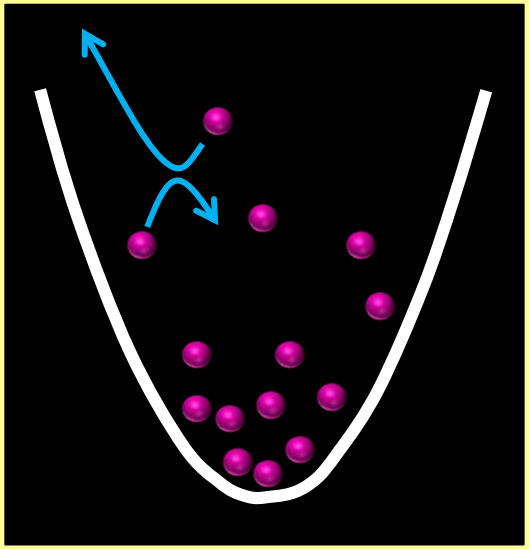
Ultracold quantum gases

What?

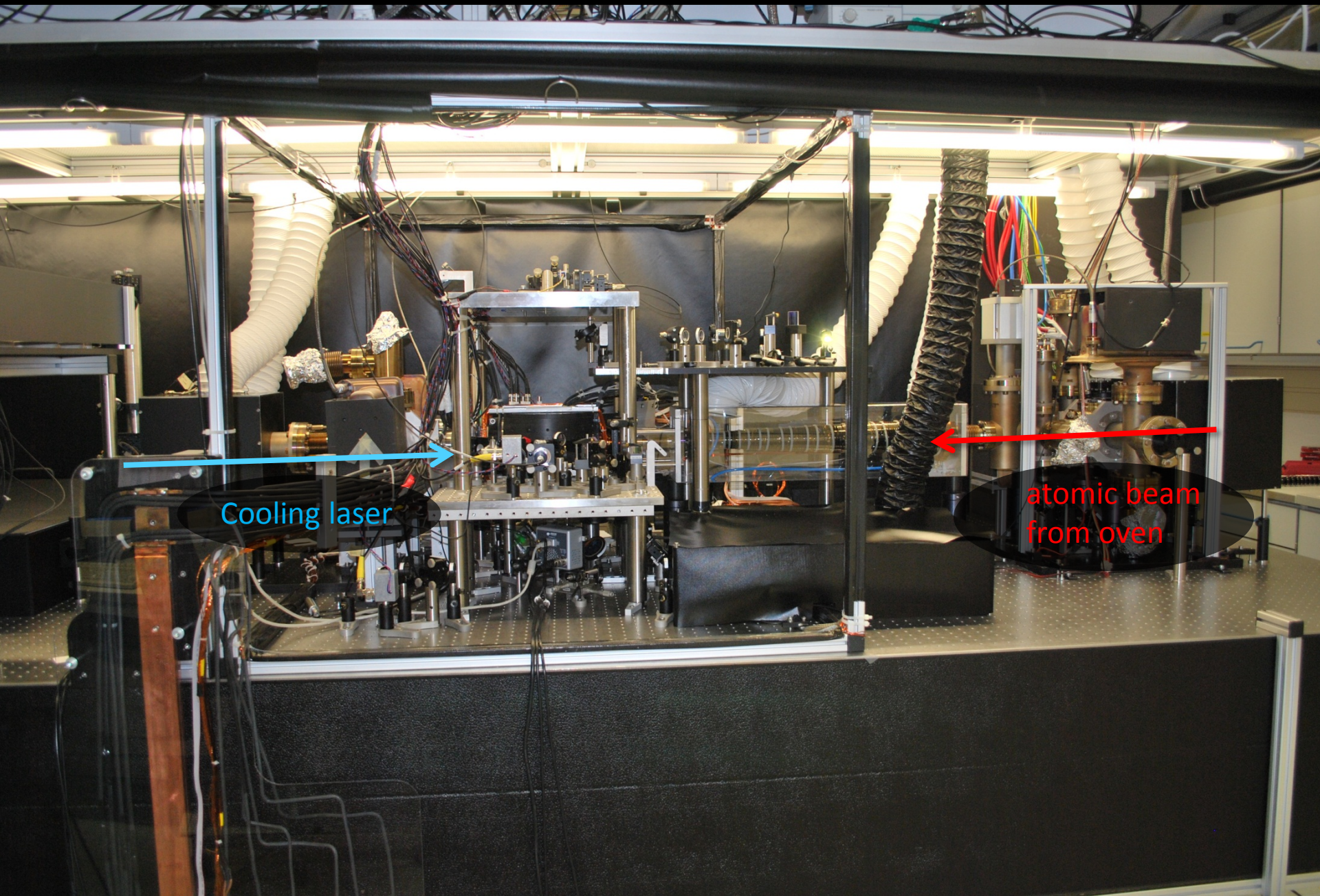


Why?

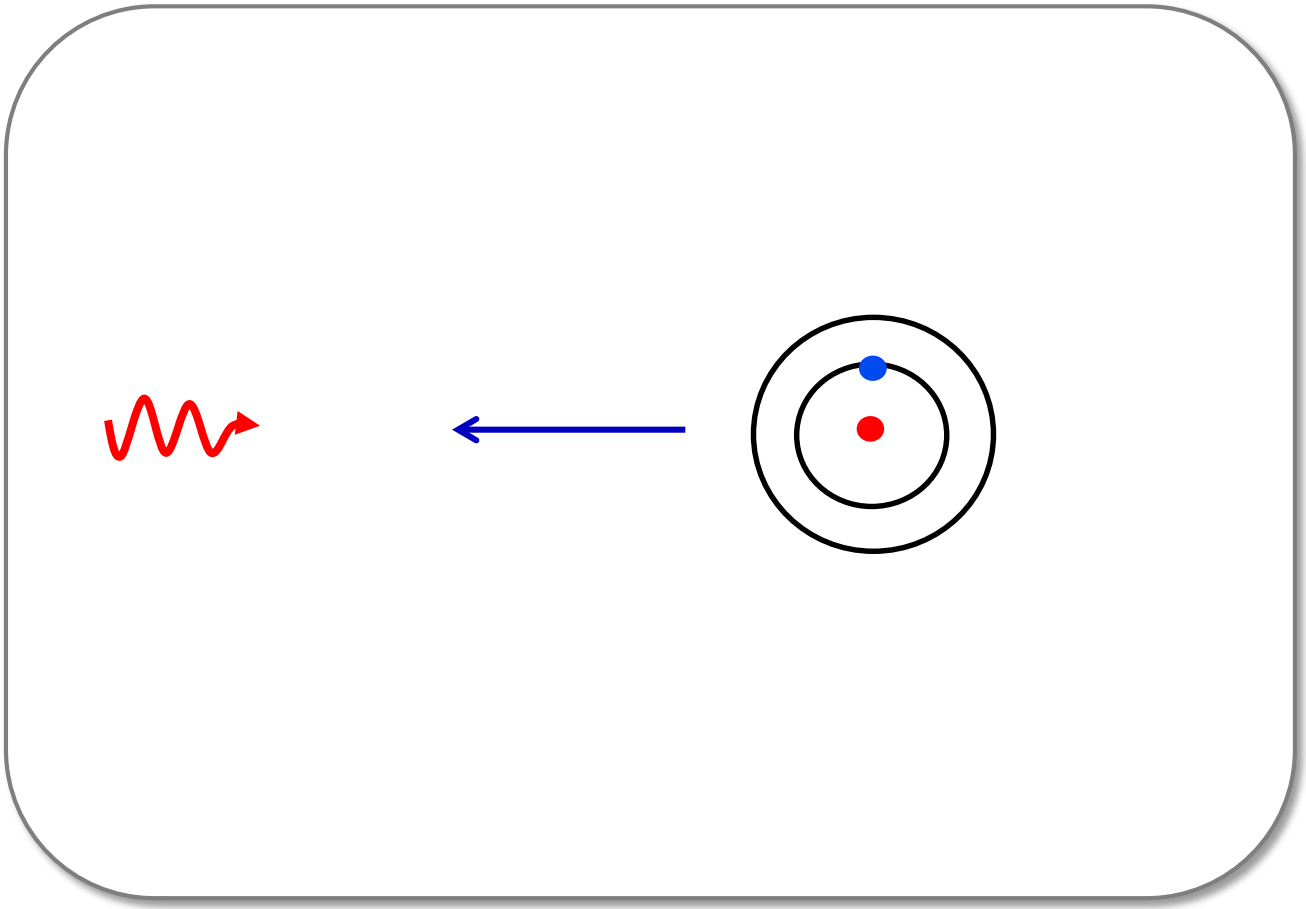
How?



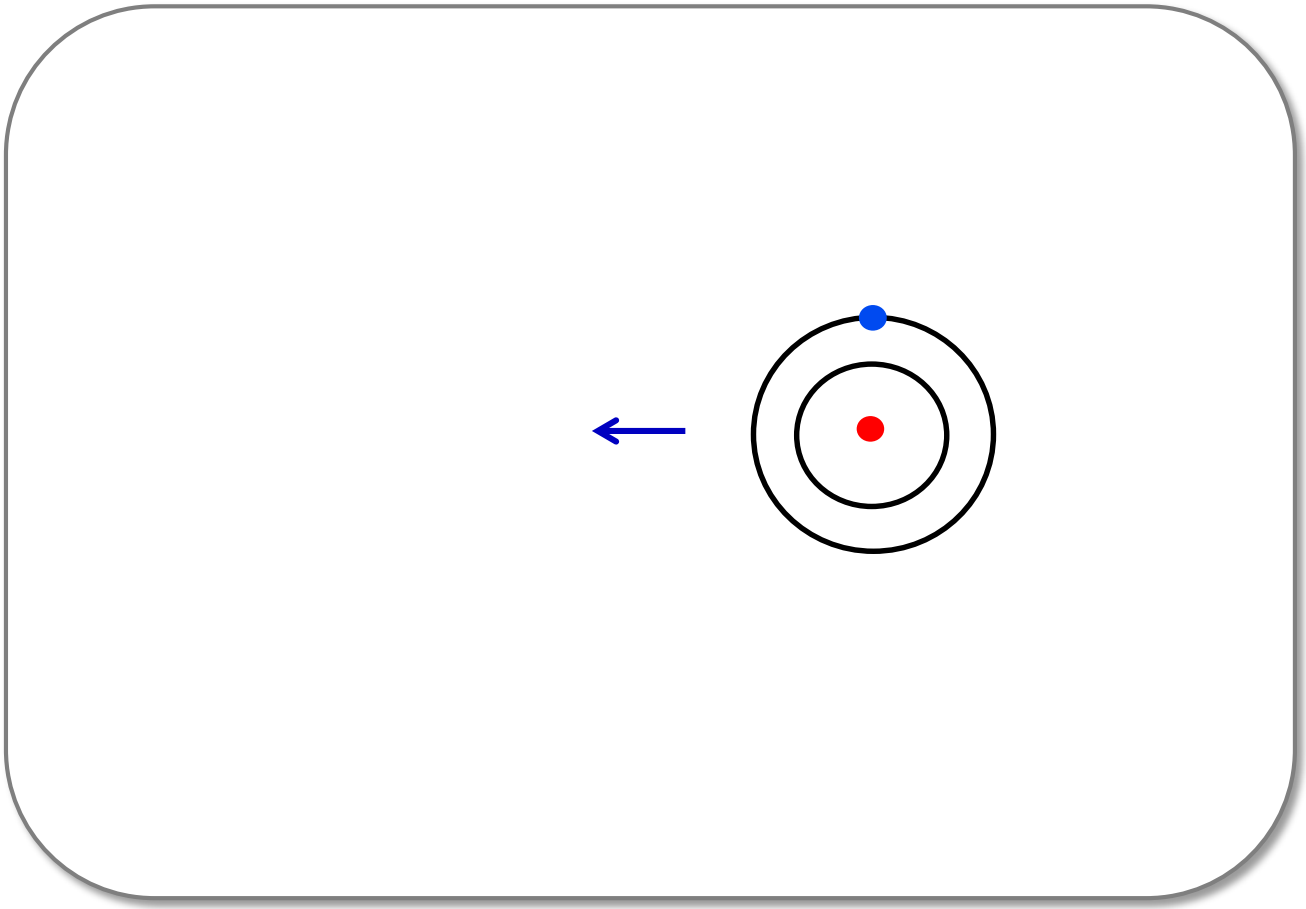
Our fridge



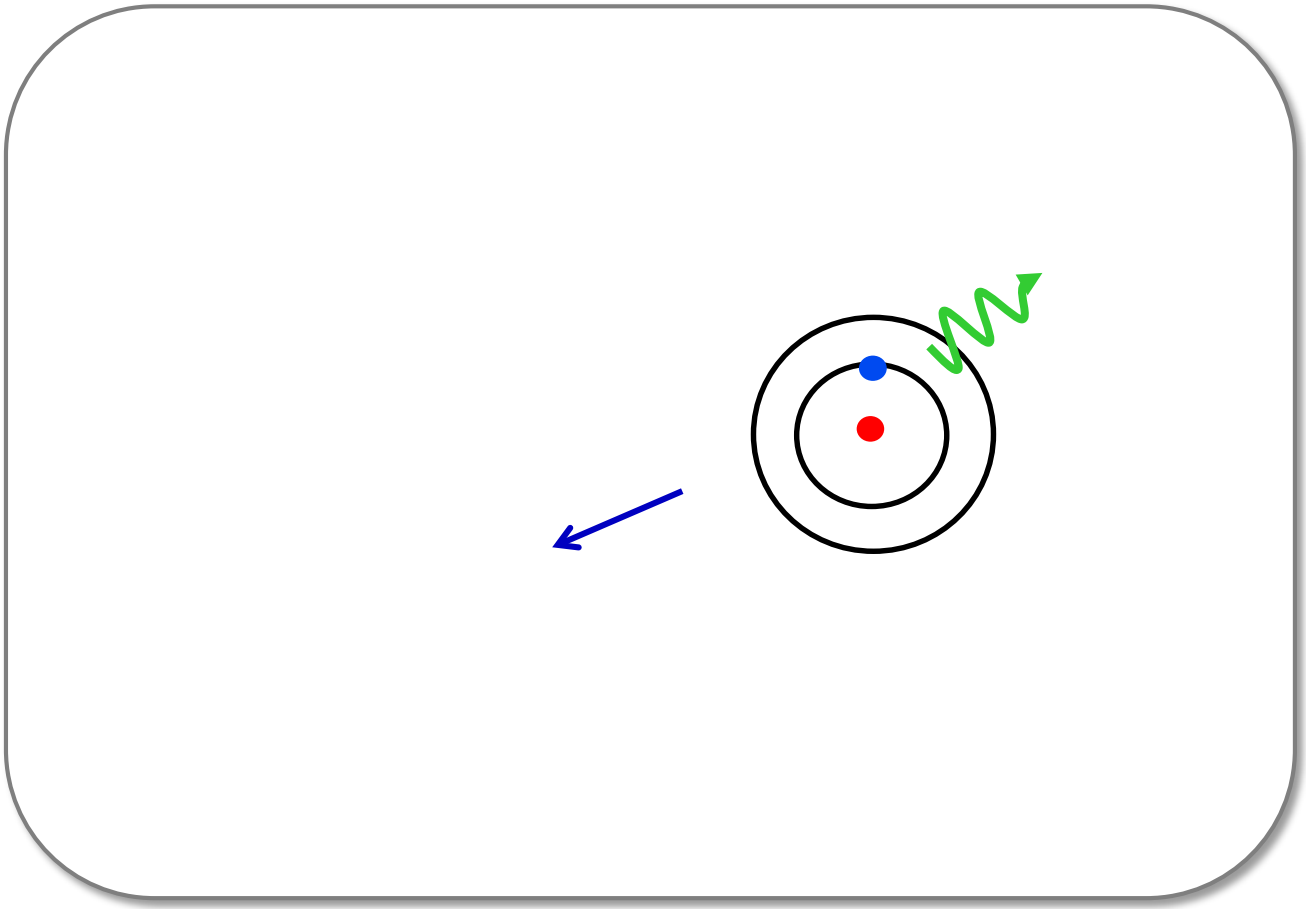
Laser cooling



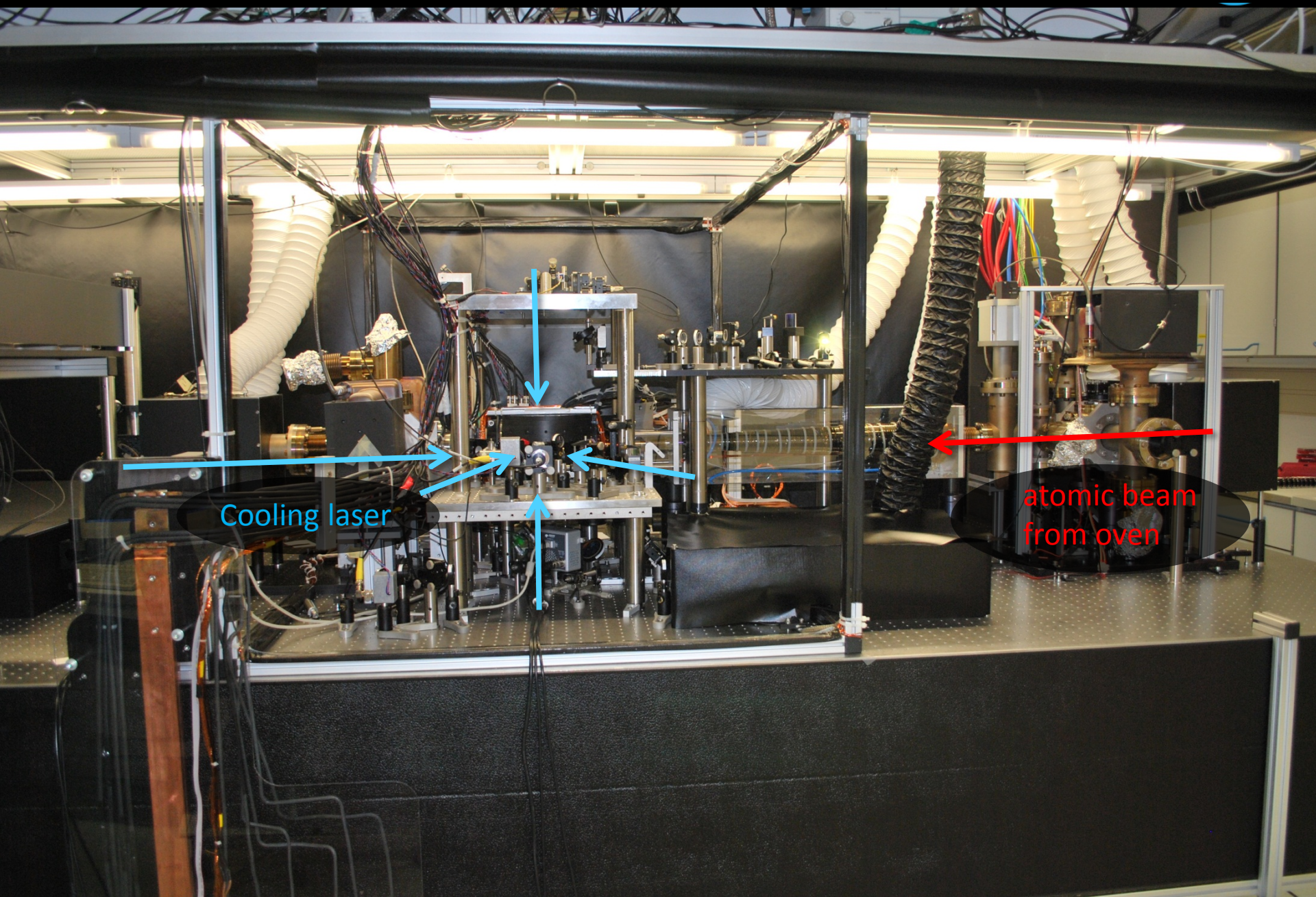
Laser cooling



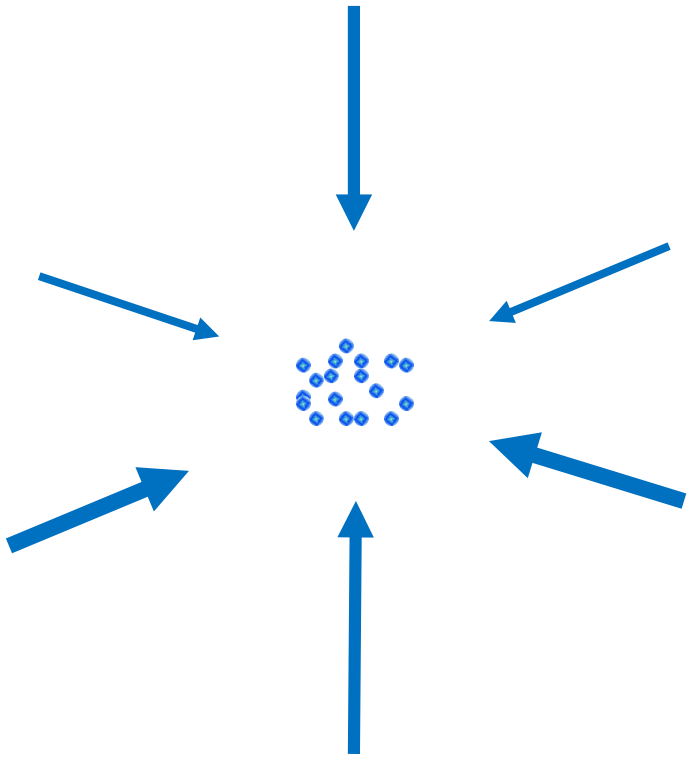
Laser cooling



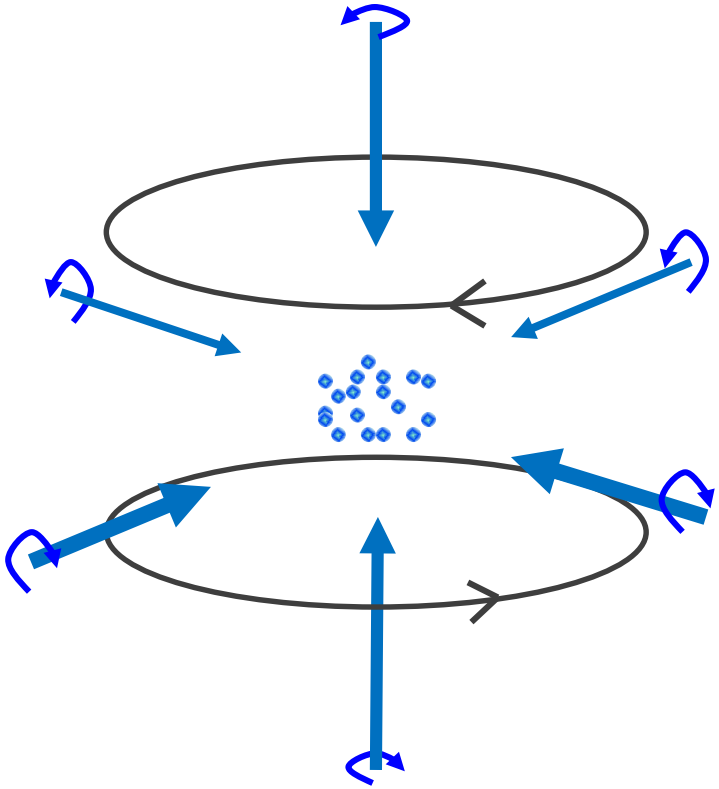
Our fridge



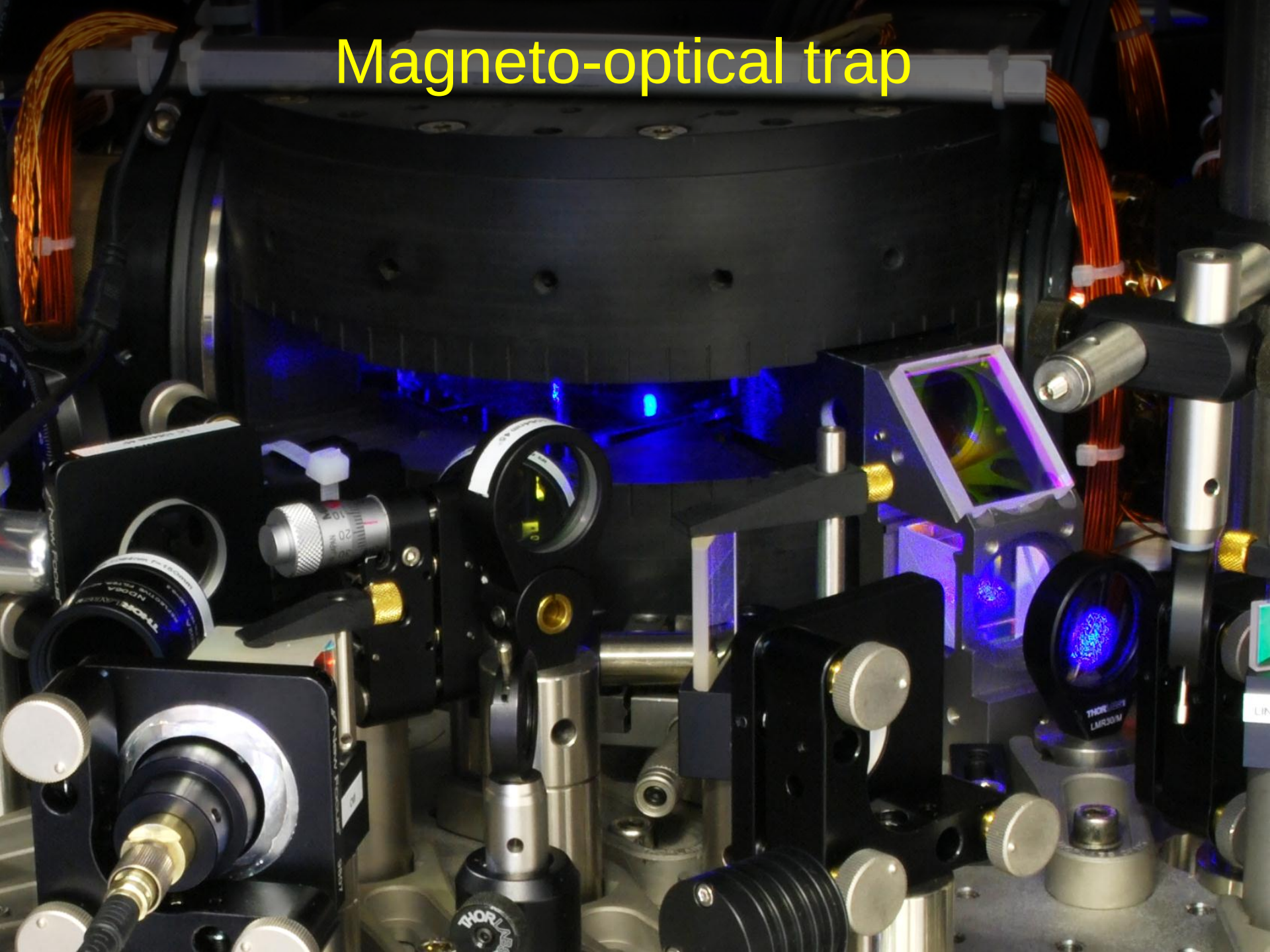
Cooling in all directions



Collecting atoms at one location



Magneto-optical trap



Magneto-optical trap

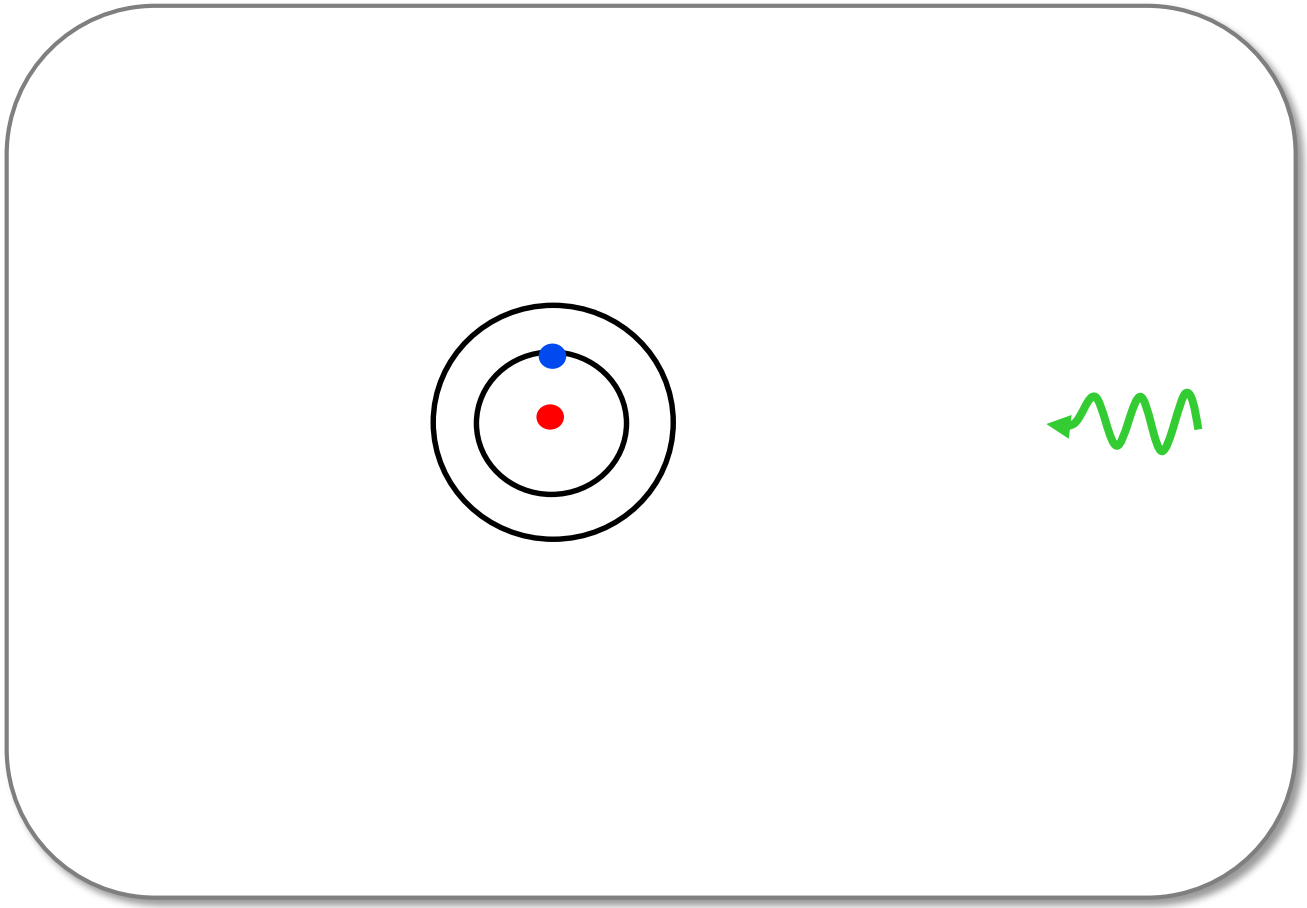
Nobel Prize 1997

Steven Chu
Stanford University, Stanford, California, USA

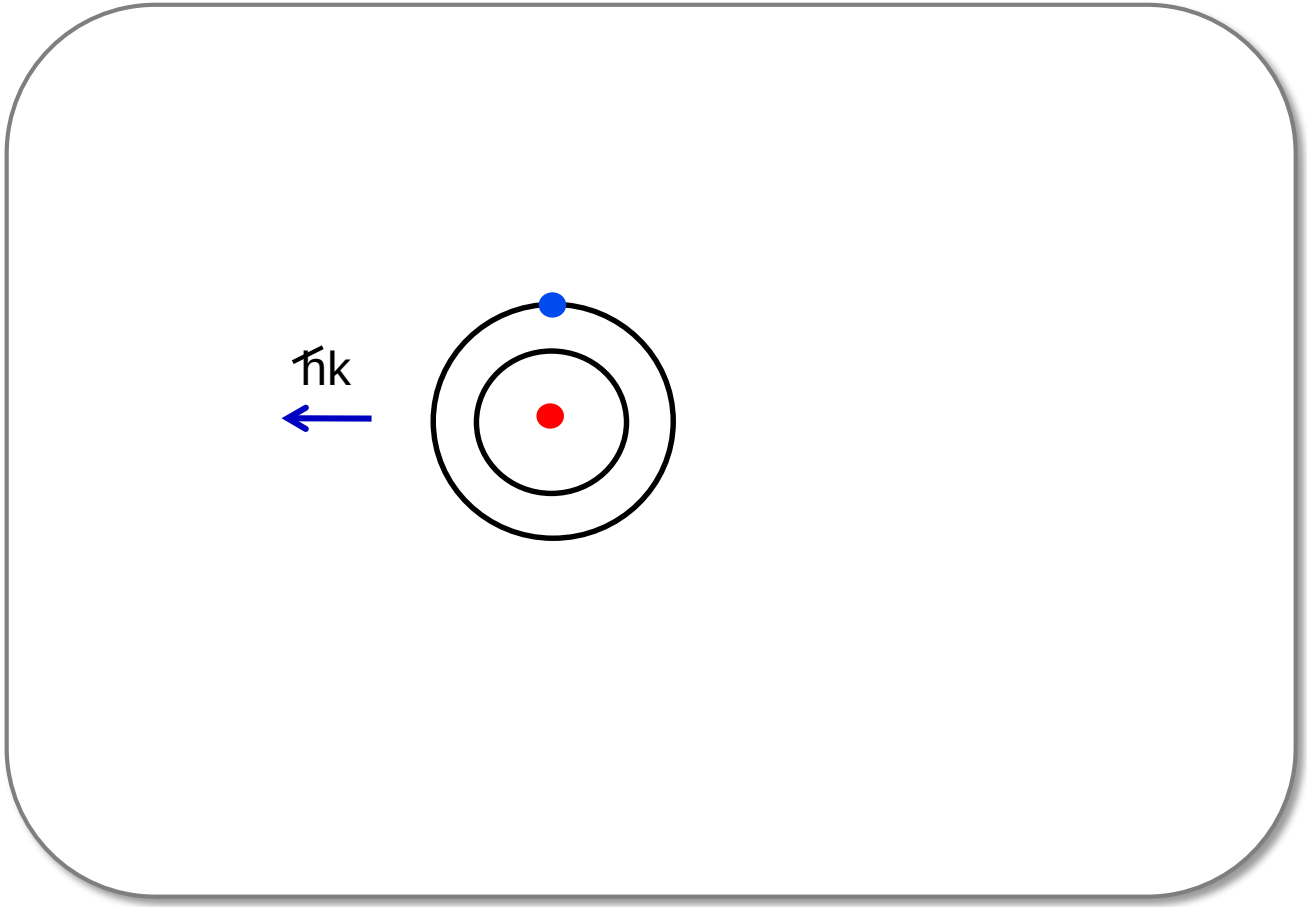
Claude Cohen-Tannoudji
Collège de France and École Normale Supérieure, Paris, France

William D. Phillips
National Institute of Standards and Technology, Gaithersburg, Maryland, USA

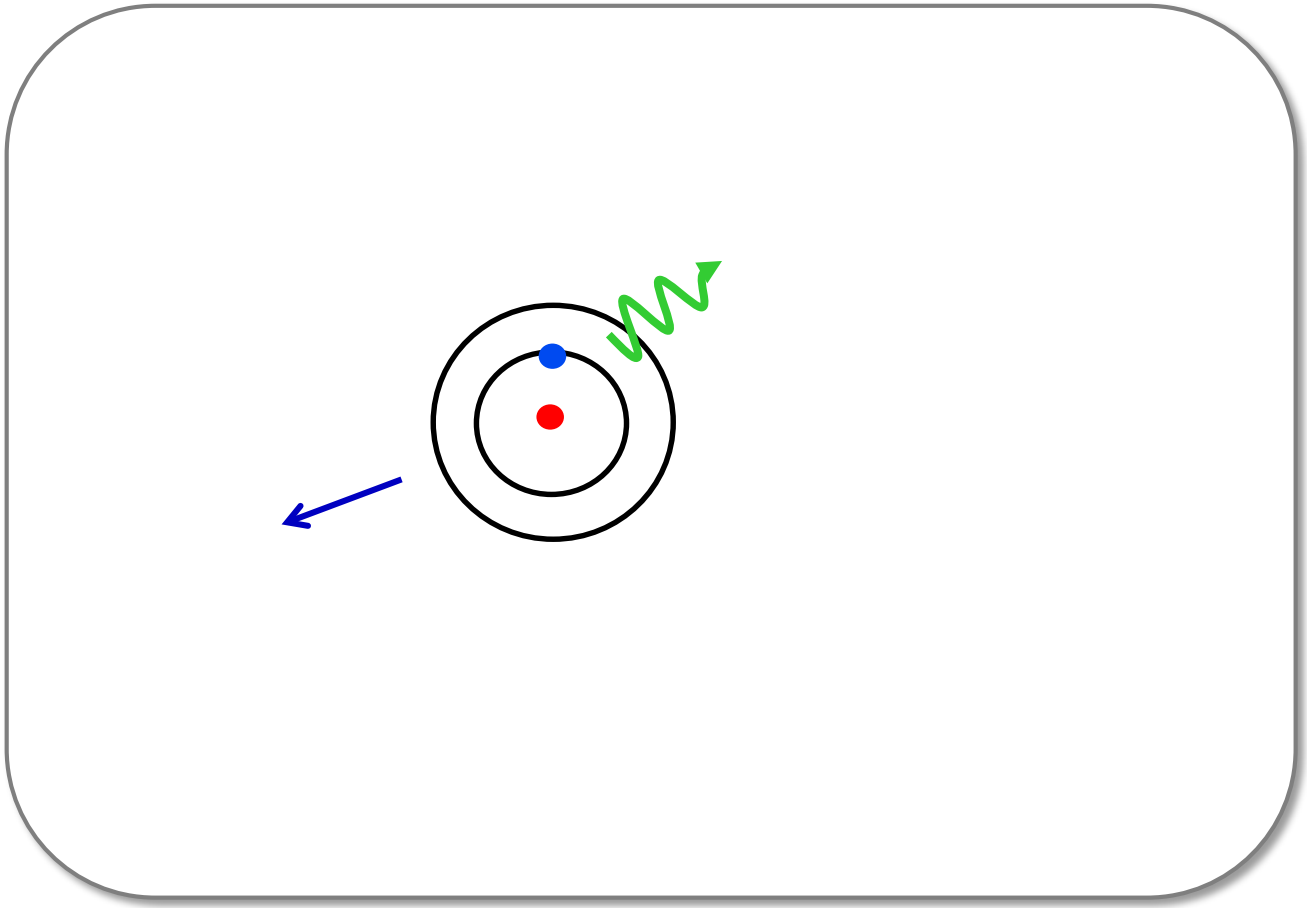
Why not cold enough?



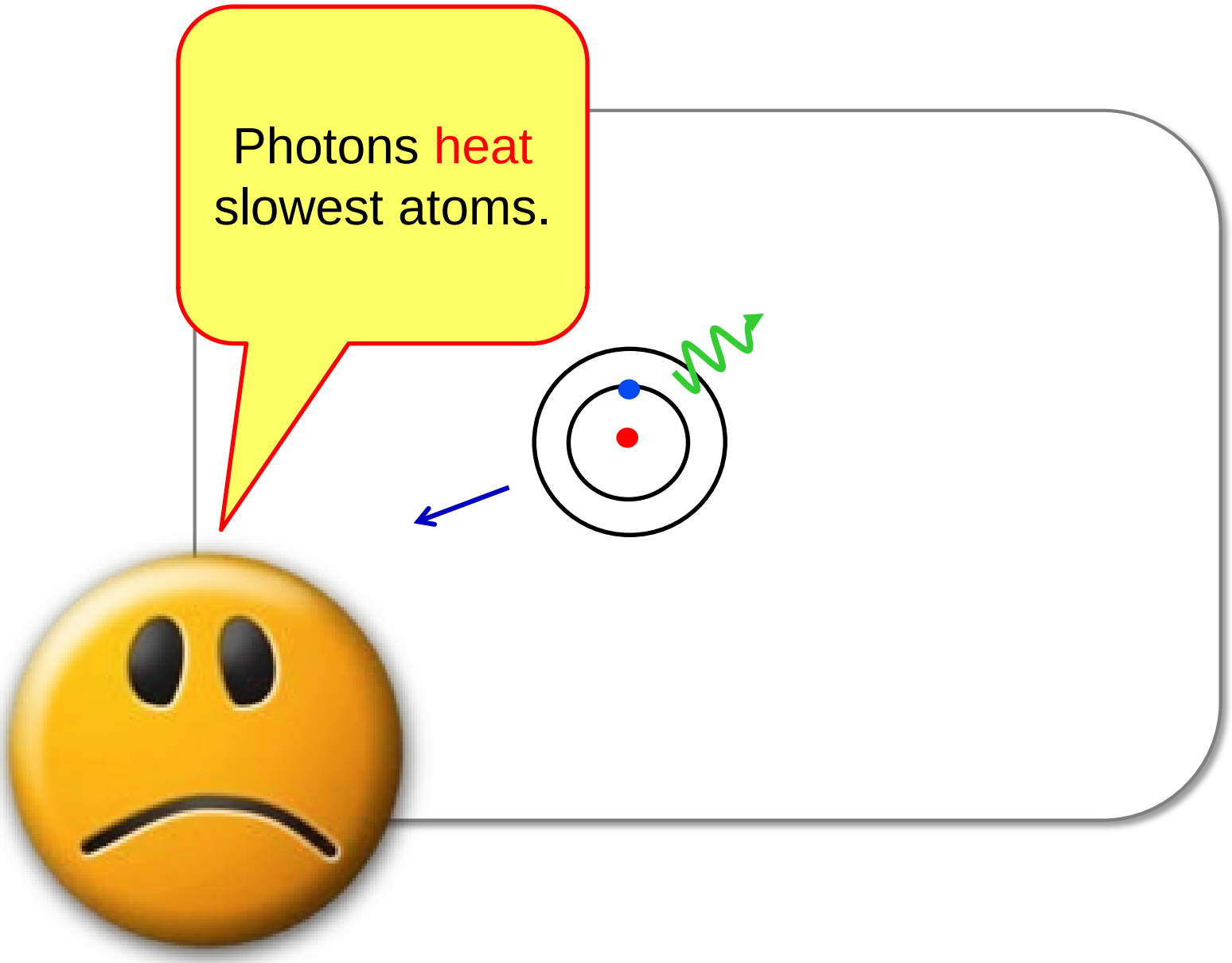
Why not cold enough?



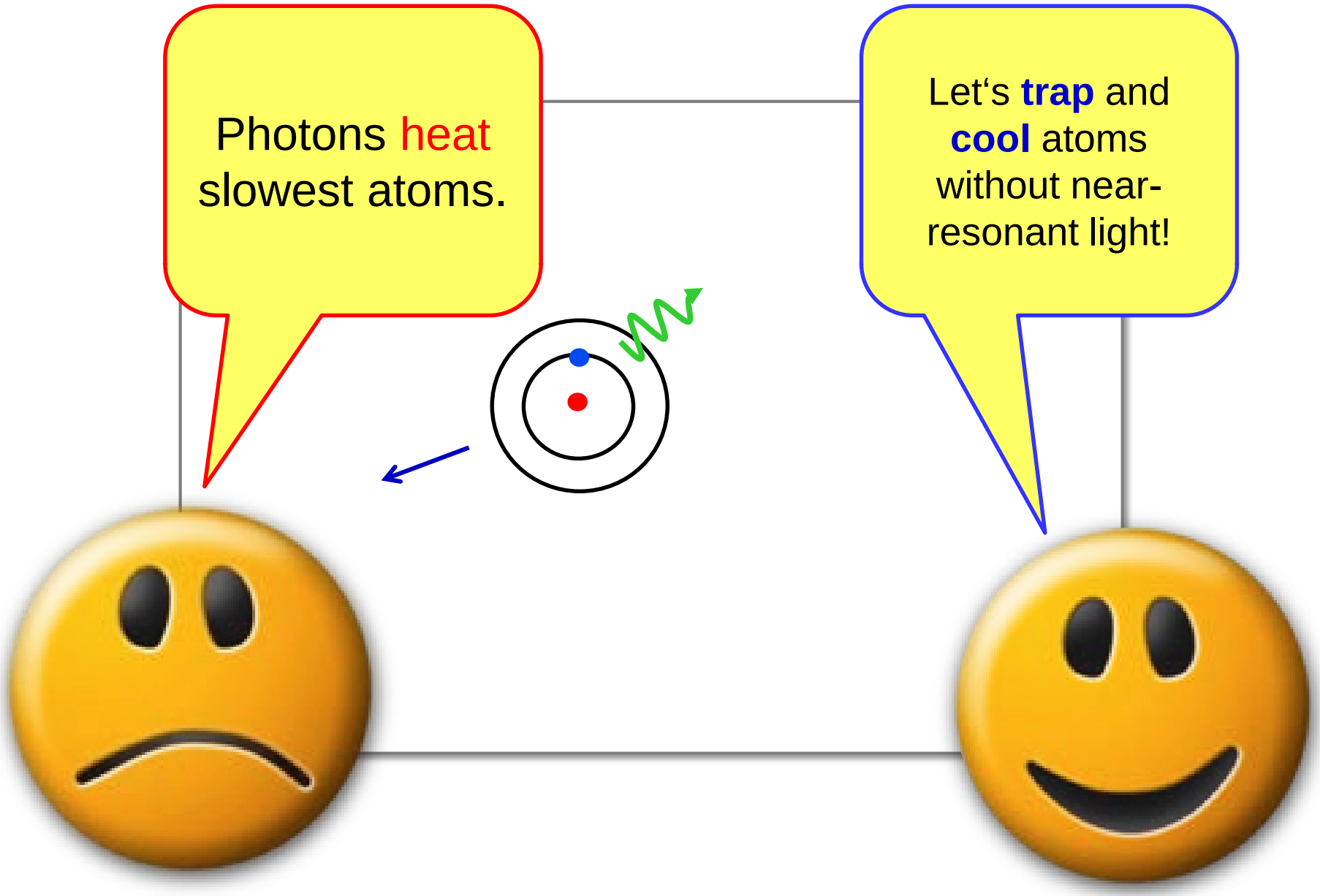
Why not cold enough?



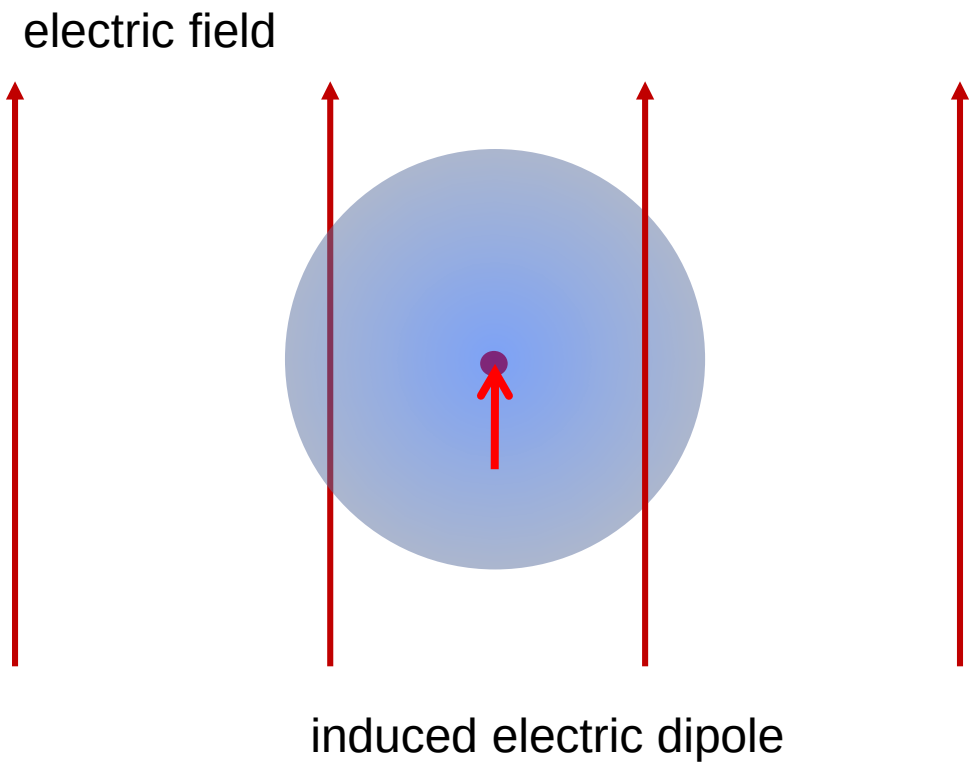
Why not cold enough?



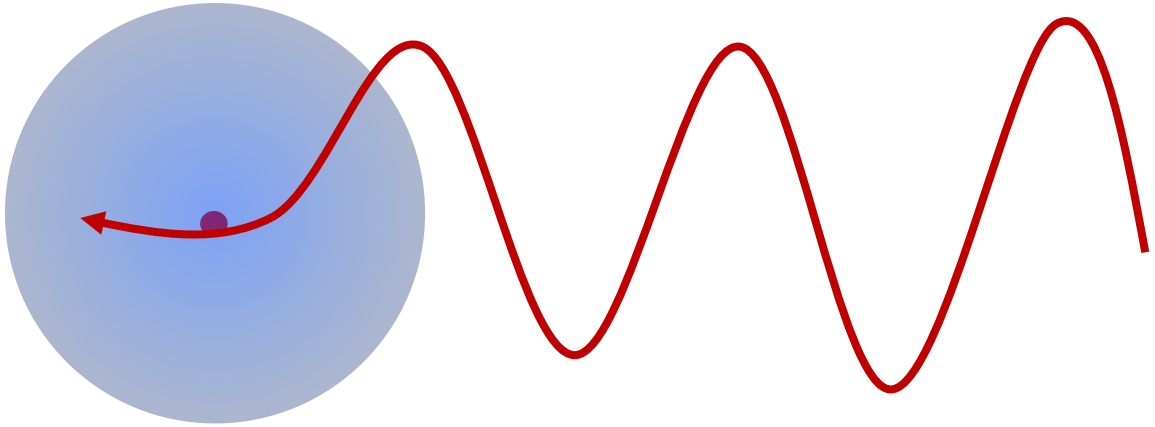
Why not cold enough?



Optical dipole trap

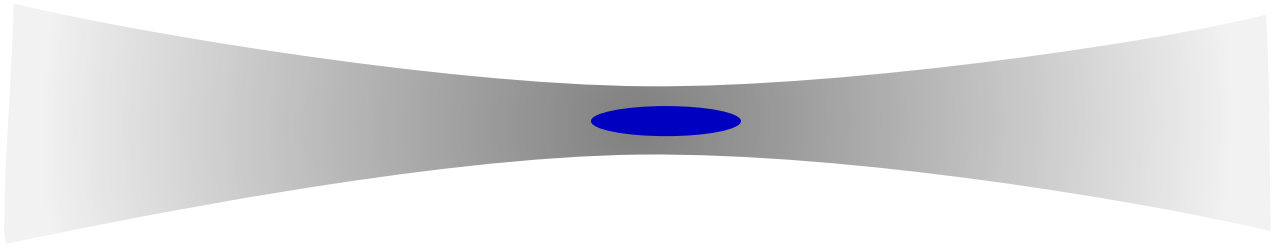


Optical dipole trap

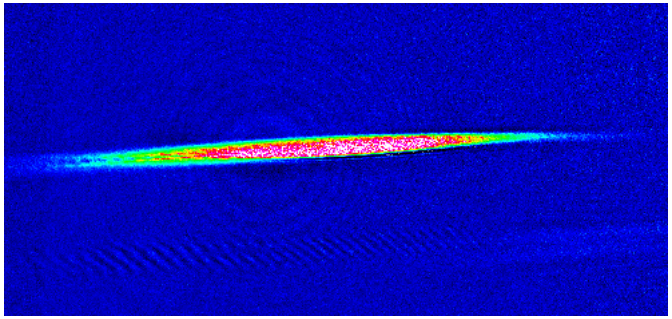


Optical dipole trap

Infrared laser beam

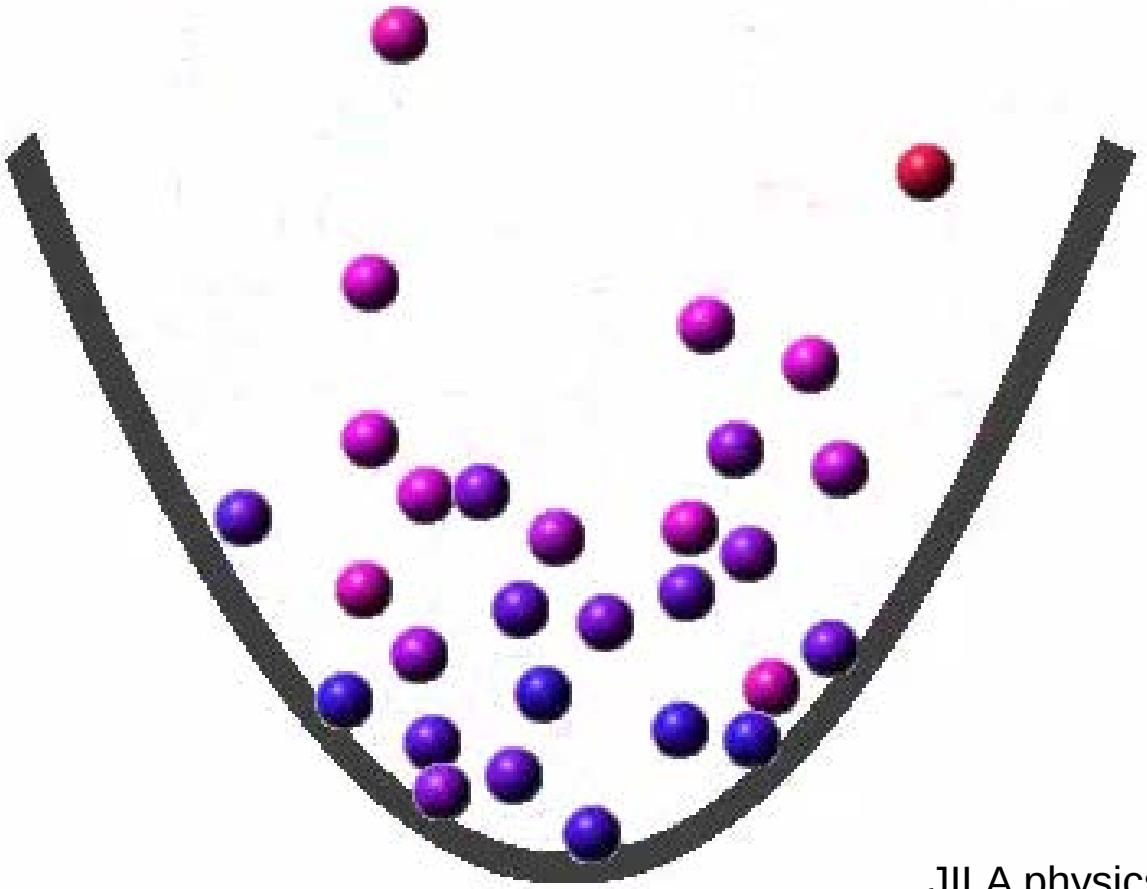


Trapped atomic cloud



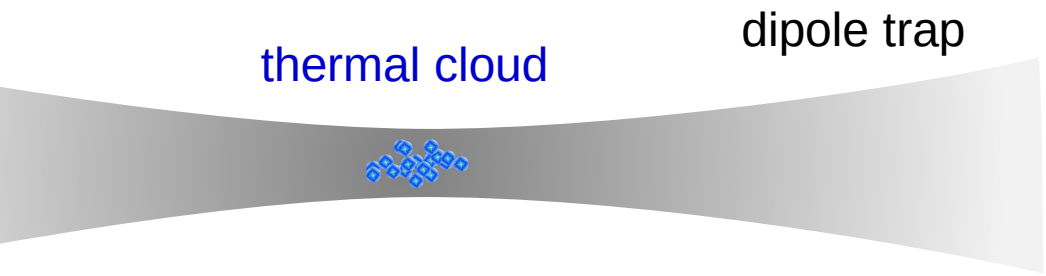
Evaporative cooling

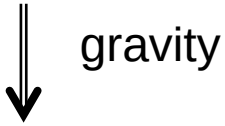
Evaporative cooling

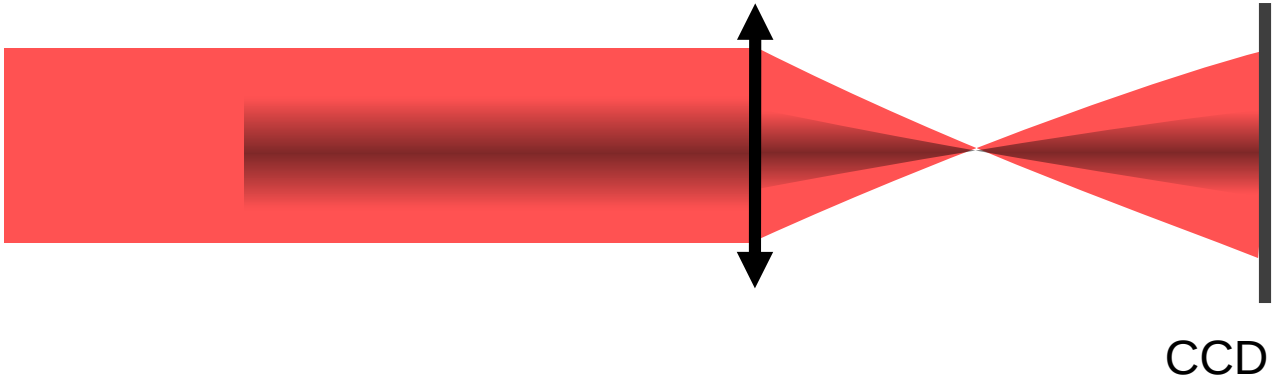


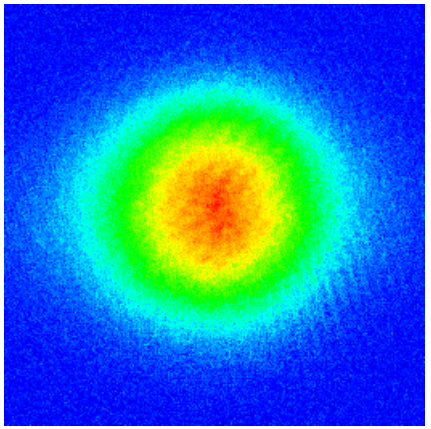
JILA physics 2000 webpage

Signatures of BEC

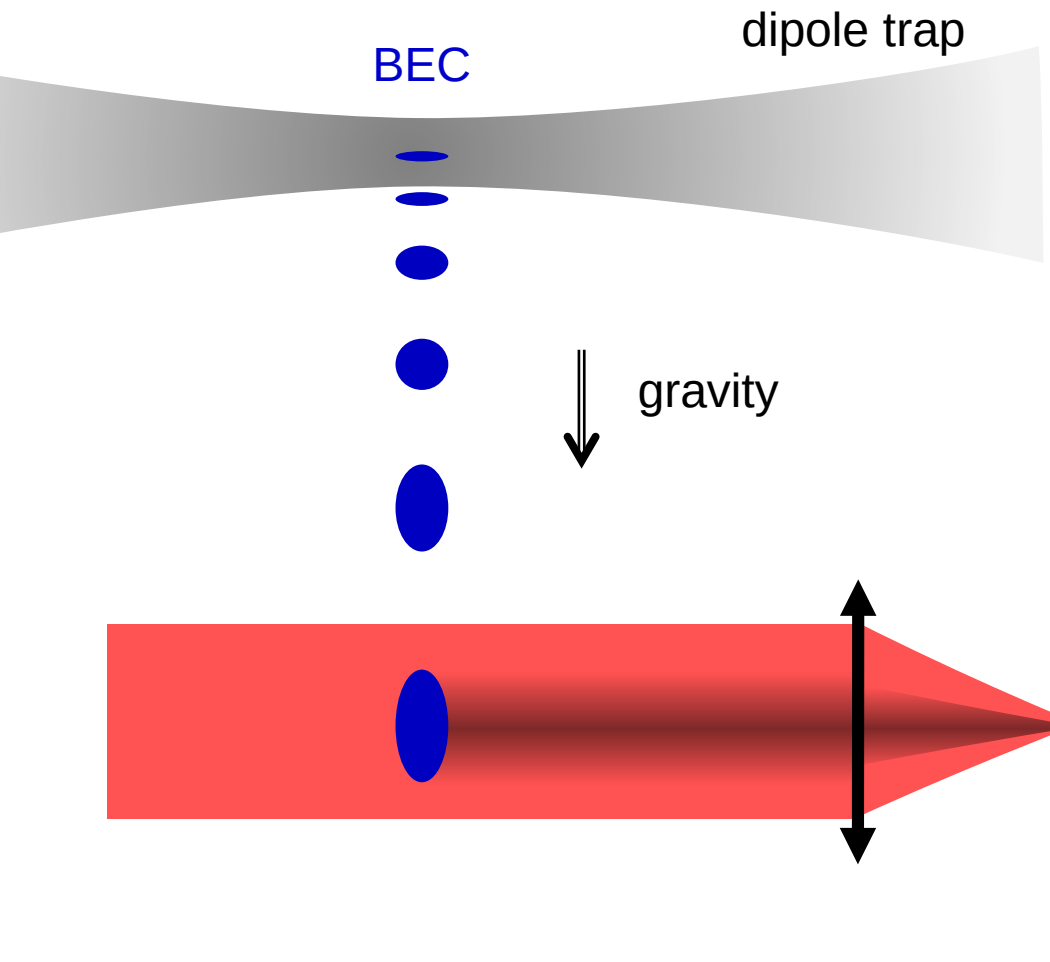


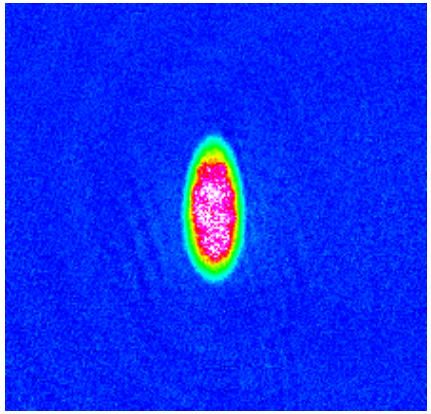




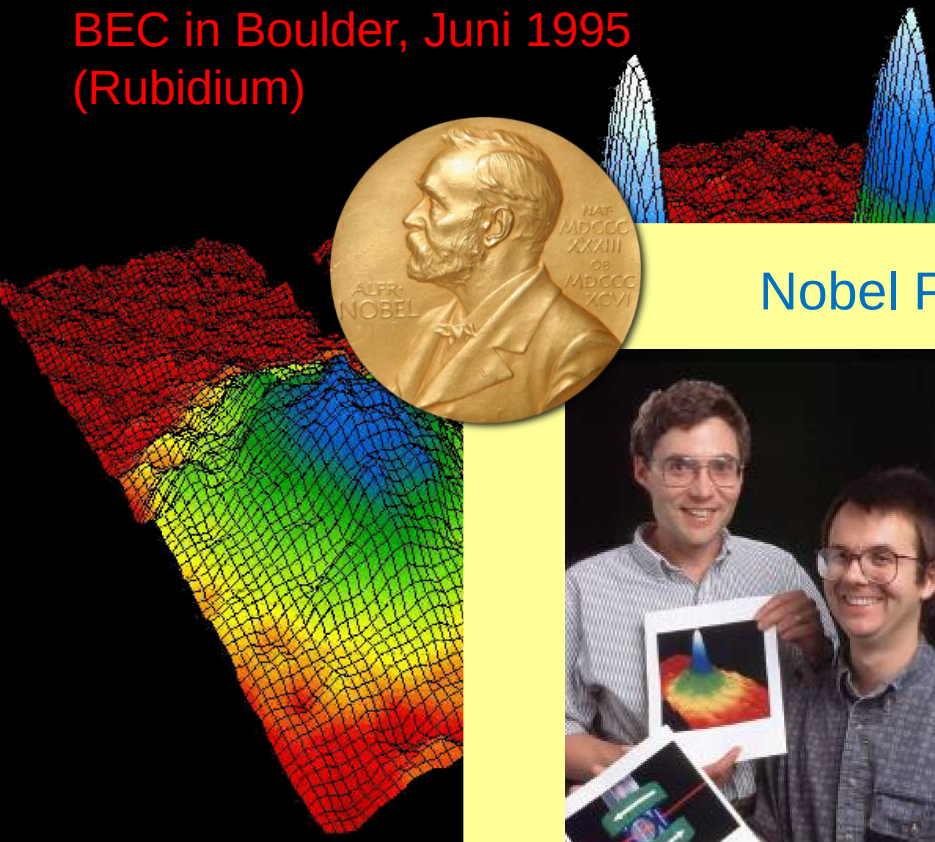


Signatures of BEC



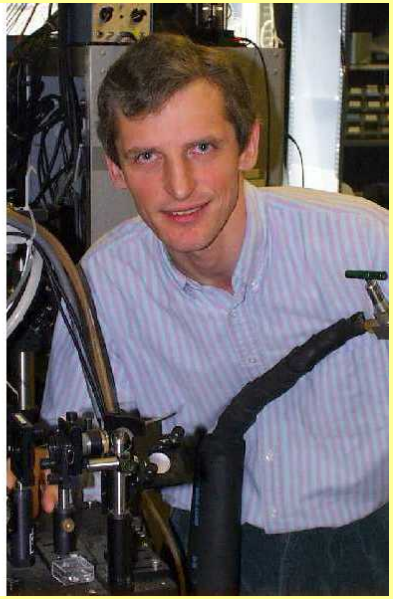


BEC in Boulder, Juni 1995
(Rubidium)

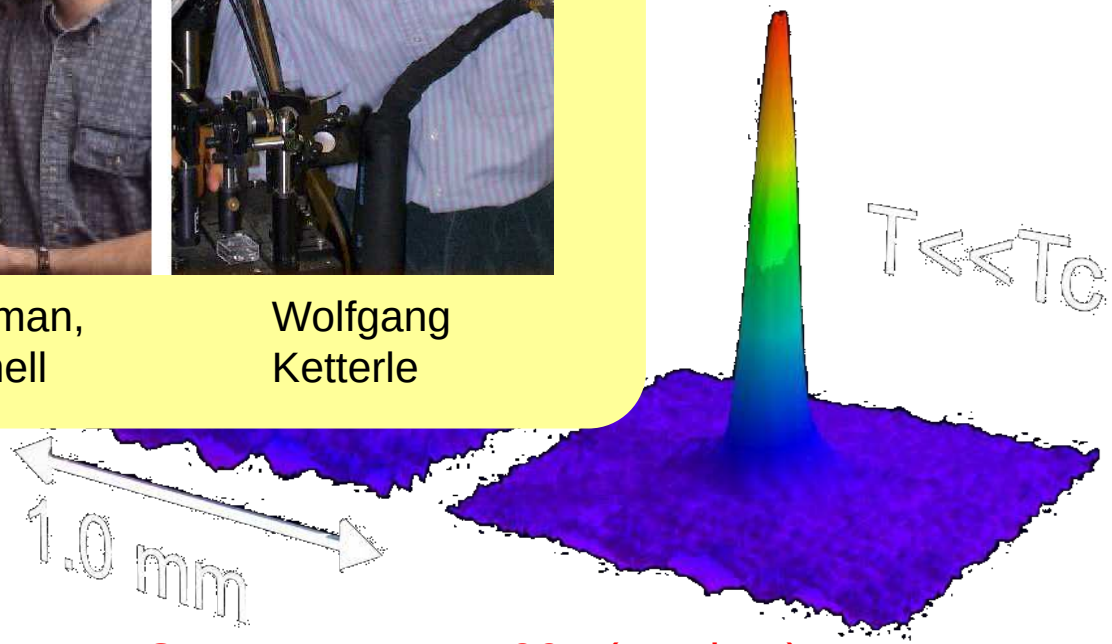


Nobel Prize 2001

Carl Wieman,
Eric Cornell



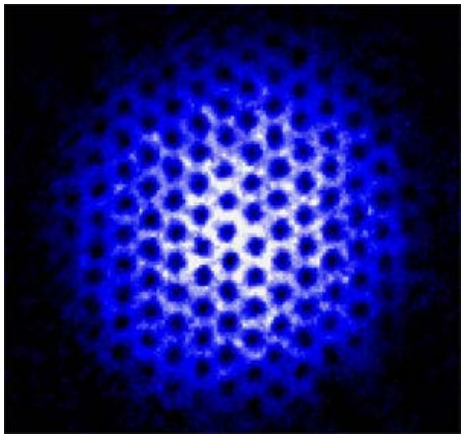
Wolfgang
Ketterle



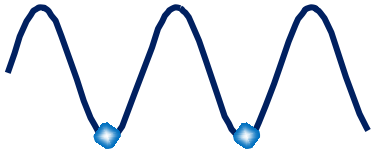
BEC am MIT, Nov. 1995 (Natrium)

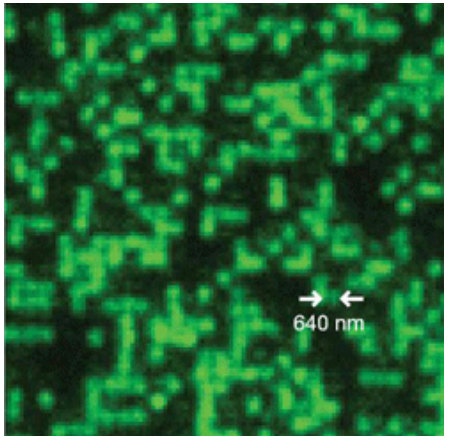
Outlook

Rotating quantum gas



Quantum gas in lattice





Quantum simulation

Precision measurement