بسم الله الرحمن الرحيم

LASER COOLING

Contents

- ✓ *Introduction.*
- ✓ *Laser Cooling.*
- ✓ *Type and wavelength of laser.*
- ✓ *Why the laser is used her rather than the ordinary light?*
- ✓ *Doppler Effect.*
- ✓ *The absorption-emission mechanism.*
- ✓ *Laser beams arrangement.*
- ✓ *Can we cool atoms to temperature that is lower than the Doppler temperature?*
- ✓ *Conclusion.*

Introduction

Lasers were invented about 50 years ago.
They are able to . .

heating

vaporizing

cutting

Introduction

Two Nobel prizes (in 1997 & 2001) in physics were related to the use of laser for

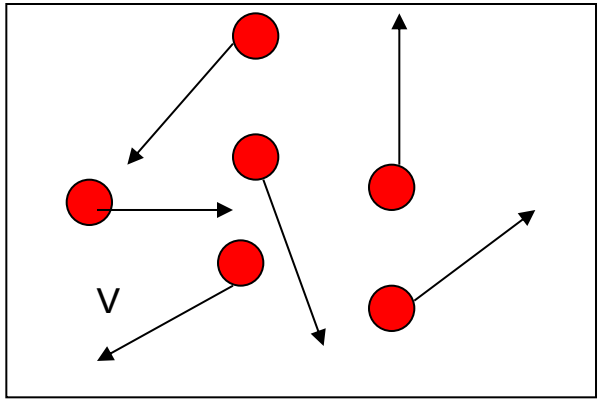
Introduction

Atoms are always moving in random directions with velocity around 1400 km/hr at room temperature

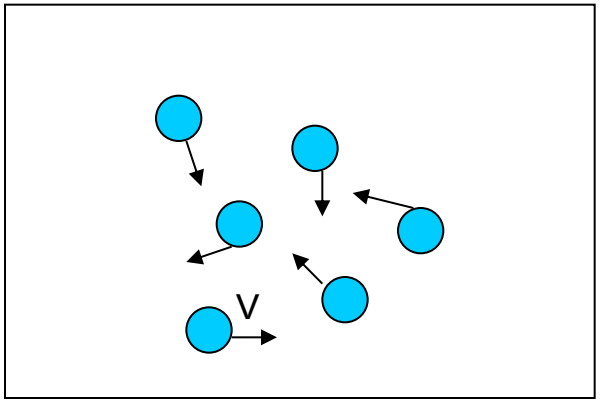
Introduction

$$v_{rms} = (3RT/M)^{1/2}$$

R *is the gas constant*
M *is the molar mass*
T *is the temperature*



High T *Large* v



Low T *Small* v

Introduction

Studying fast atom → *difficult*

So.. *we need to*

minimize the atoms' temperature

To.. *reduce the velocity*

Introduction

At low temperature

gas → liquid → soled

Bonds more complicated

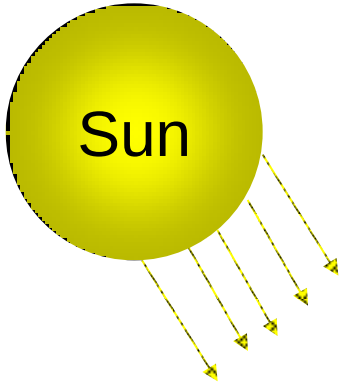
→ *Study is still difficult*

Introduction

We need a mechanism that gives temperature near the zero Kelvin & keep the density low.

Laser cooling

Introduction



cold body → Hot body

Absorption → Transformation to heat

Laser Cooling

Involves a series of absorptions and emissions

⇒ *a decrease in the atoms' velocity*

Laser cooling is a technique that uses light to cool atoms to a very low temperature.

The simplest form of laser cooling is the so called Optical Molasses

Type and Wavelength of Laser

The type and wavelength are chosen such that they suit the atoms which will be cooled

Na *vapor* ⇒ $\lambda = 589.0\ nm$

Rb *vapor* ⇒ $\lambda = 780.0\ nm$

Cs *vapor* ⇒ $\lambda = 852\ .0\ nm$

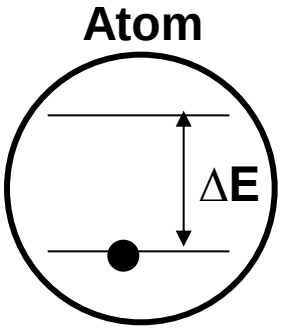
Why the laser is used her rather than the ordinary light?

In this application we need light of certain wavelength (frequency).

Doppler Effect

Photon 

$E = h\nu = \Delta E$

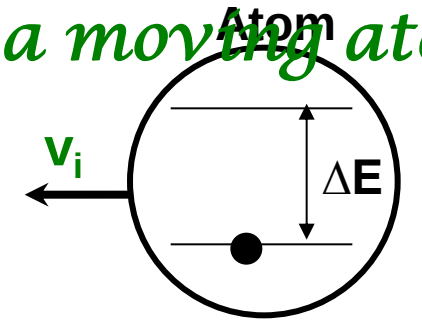


Stationary atom

What about a moving atom???

Photon 

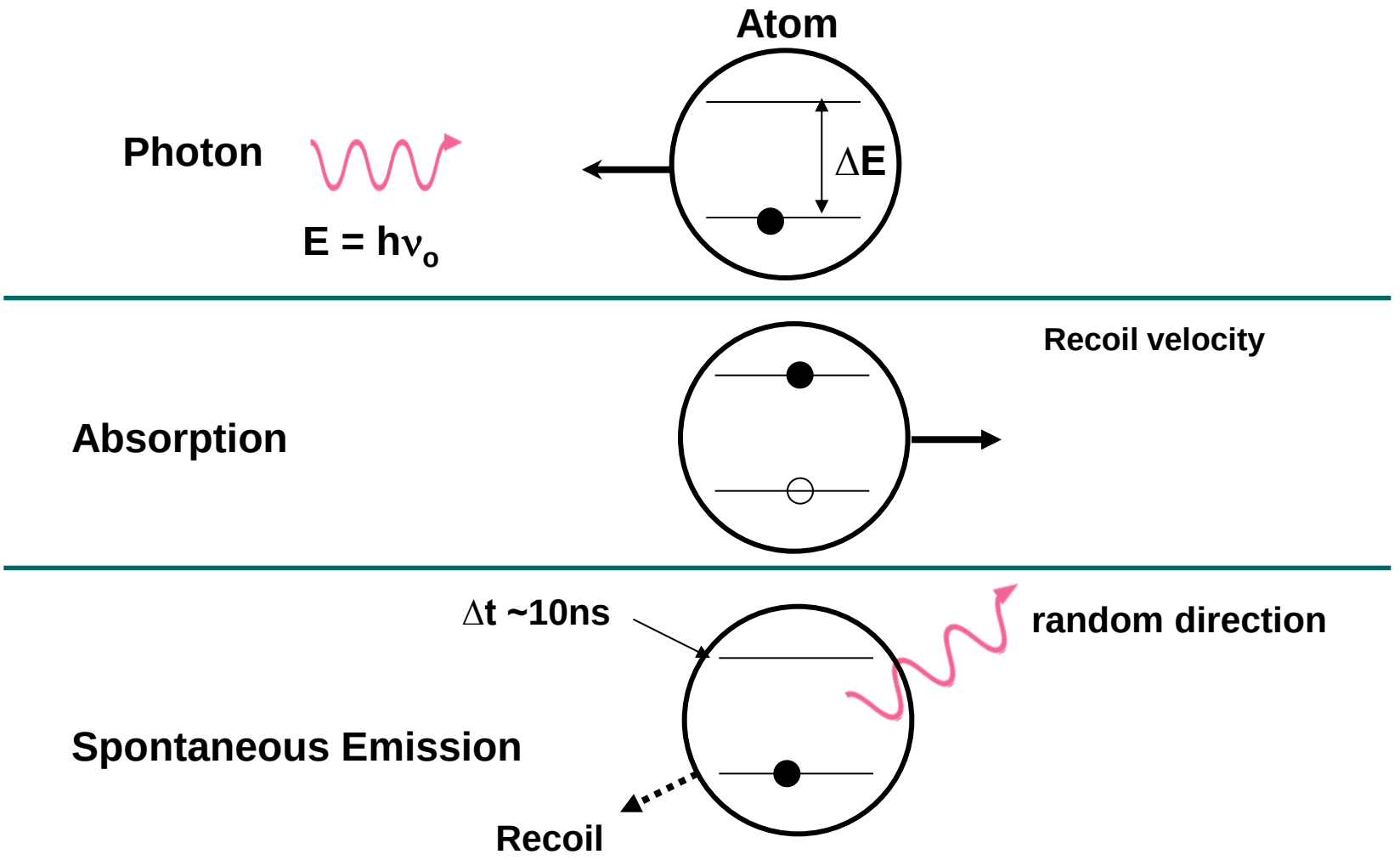
$E = h\nu_o$



Moving atom

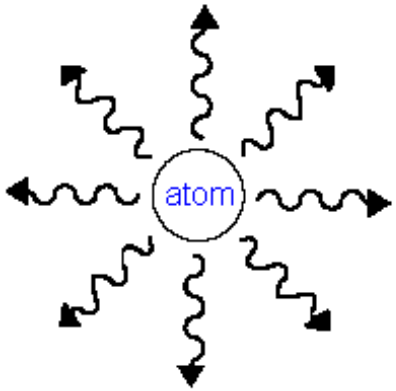
$v = v_o (1+v_i/c)^{1/2} / (1-v_i/c)^{1/2}$

The absorption-emission mechanism



The absorption-emission mechanism

What is the effect of the recoil velocities due to the emissions?



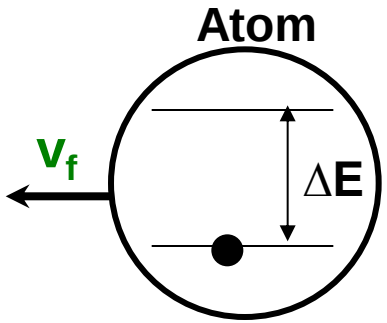
$$\langle \Delta \vec{p} \rangle = 0$$

The absorption-emission mechanism

After a few absorptions **v** *decreases So, atom "sees" the incoming photon with a frequency less than when the it was moving fast and it reaches the lowest temperature using Doppler effect.*

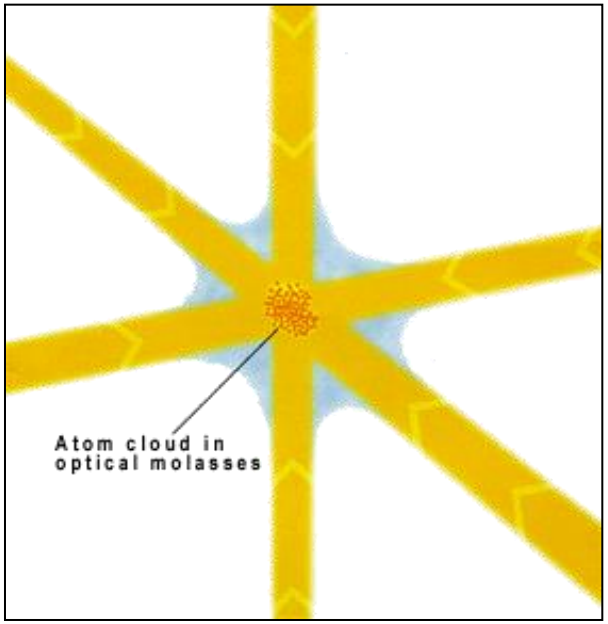
Photon

$E = h\nu_o$



$$v = v_o (1+v_f/c)^{1/2} / (1-v_f/c)^{1/2}$$

Laser beams arrangement



optical molasses

Can we cool atoms to temperature that is lower than the Doppler temperature?

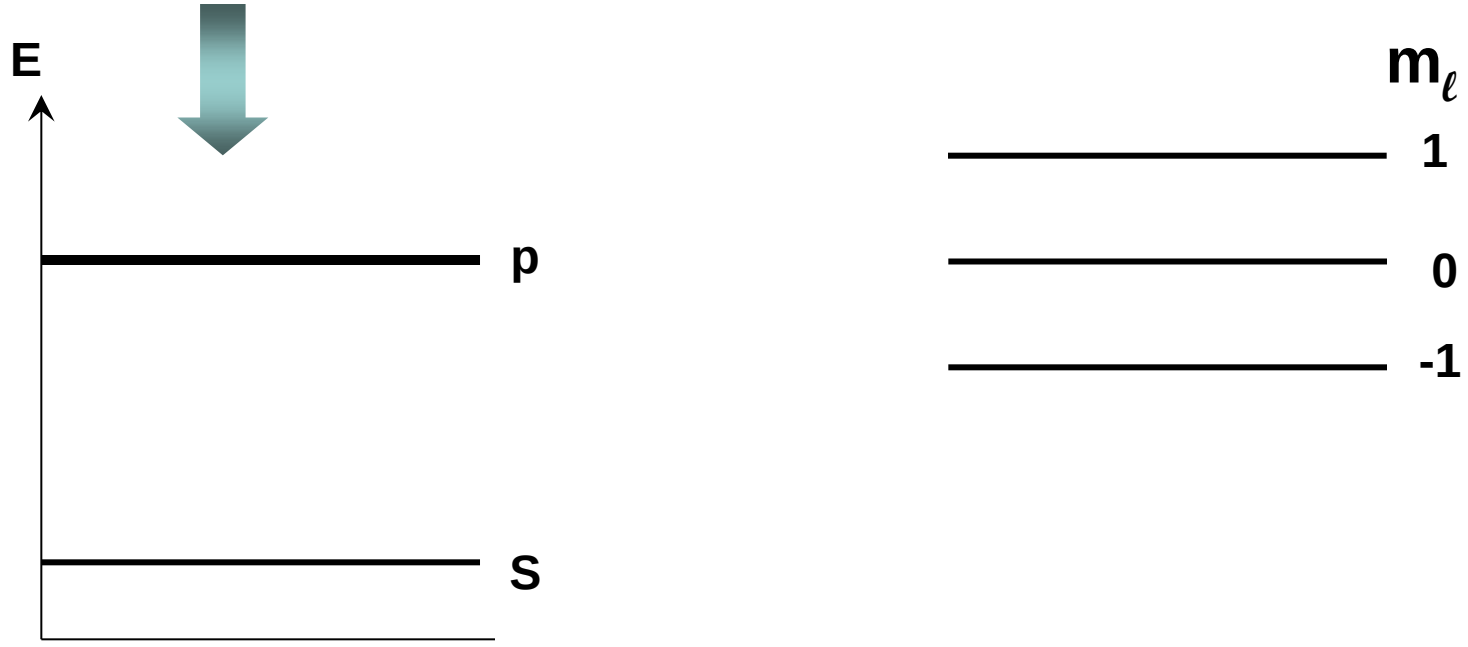
We can do that using either

Zeeman effect
(Zeeman tuned cooling)

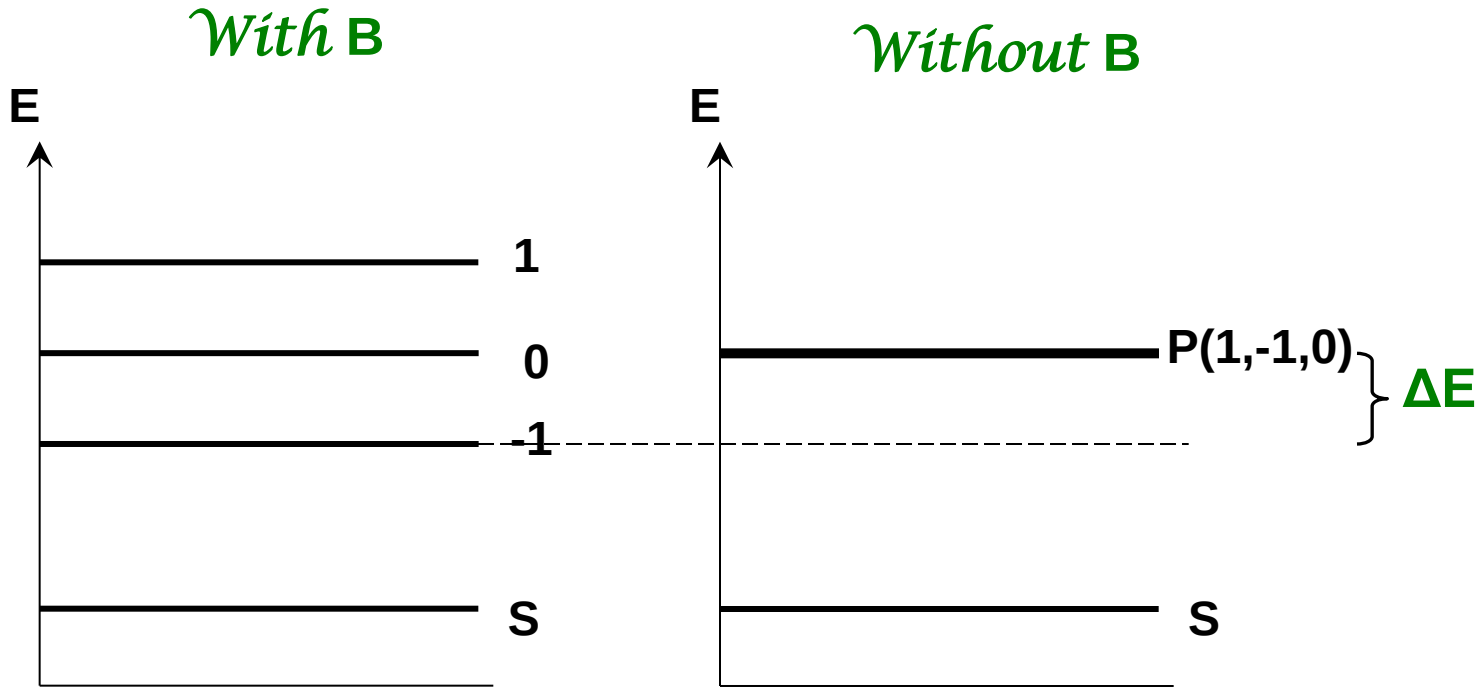
Dye laser beam
(chirped cooling)

Using Zeeman effect (Zeeman tuned cooling)

Level **p** *splits into 3 states with same energy in absence of* **B**

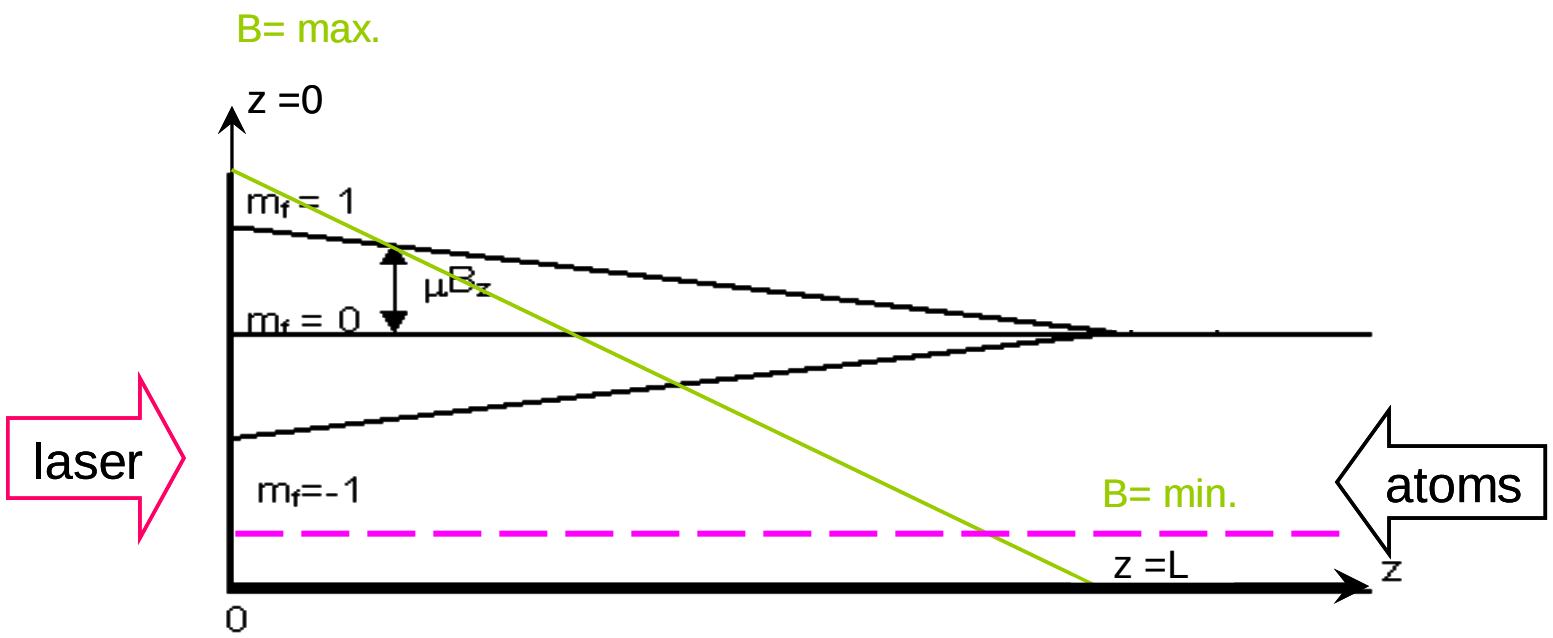


Zeeman effect



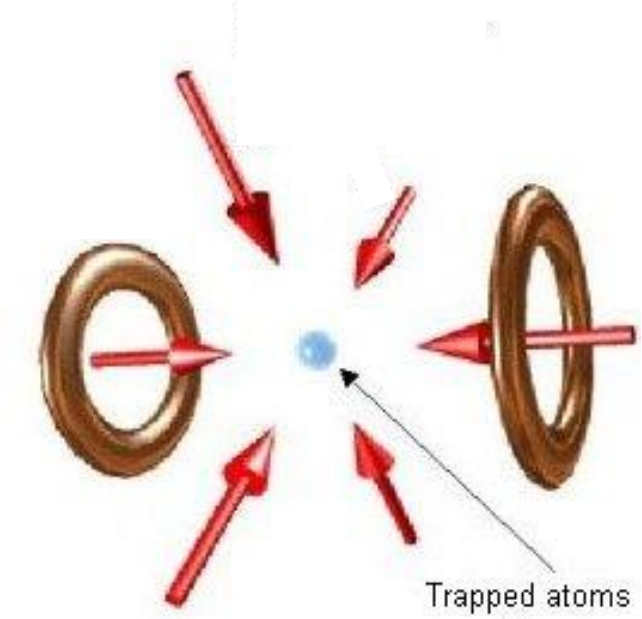
$$\Delta E = m_\ell \, (e \, h/4 \, \pi \, m) \, B$$

Magnetic trap



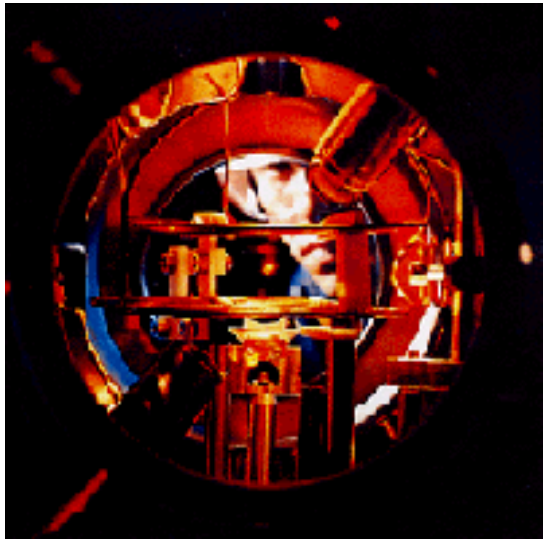
$$\Delta E = m_\ell \, (e\, h/4\, \pi\, m)\, B$$

Magneto-optical trapping (MOT)



Magnetic trap & optical molasses "magneto-optical trapping."

Magneto-optical trapping (MOT)



A collection of sodium atoms
(yellow dot in middle of picture) trapped in a MOT.

Using dye laser beam (chirped cooling).

The dye lasers give a wide rang of frequencies and are tunable. So, we can increase the frequency as the atom's velocity decreases. This will keep the atom in resonance with the laser

Conclusion

- lasers not only used for cutting, welding or heating.
- lasers can be used to cool atoms
- Doppler effect in collaboration with a magnetic trap or dye laser beam can cool the atoms to micro-kelvin.
- Further cooling may be achieved using the so-called evaporative cooling

والسلام عليكم ورحمة الله وبركاته