

Laser cooling

...

By group 8

**But why should we cool
down atoms?**

● Physics at ultra-low temp

Phase transition

- Superconductivity
 - Bose- Einstein condensation
 - Superfluidity
 - Quantum tunneling
 - Josephson effect
 - Quantum hall effect
 - And ...
-

- **ACCURATE
MEASUREMENT**

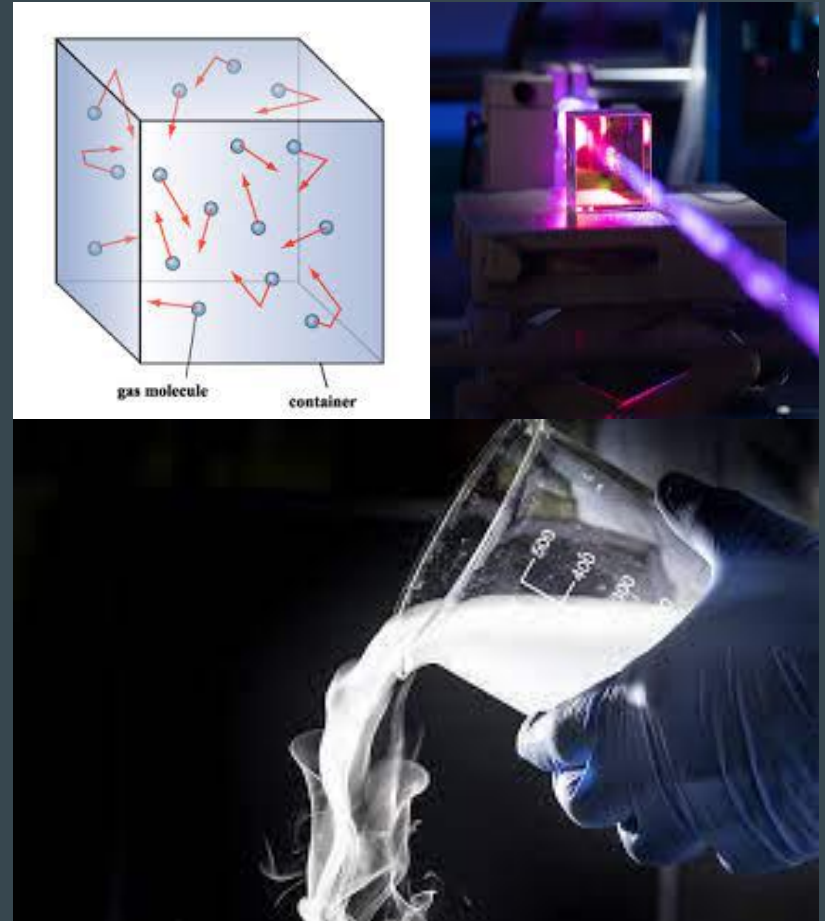
- Measuring energy or frequency levels is DIFFICULT at Finite Temperatures(room temperature)

- # Technological Applications

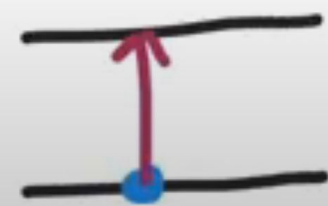
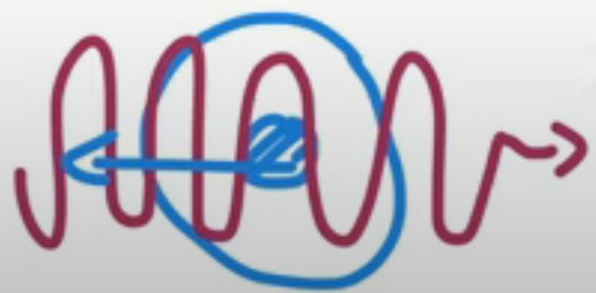
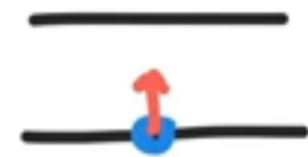
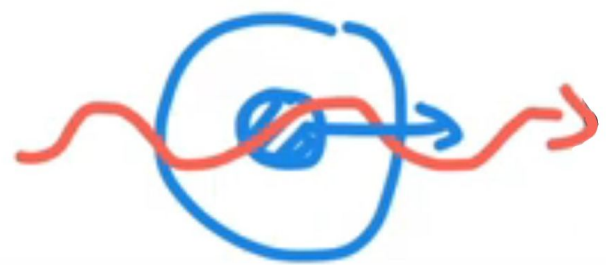
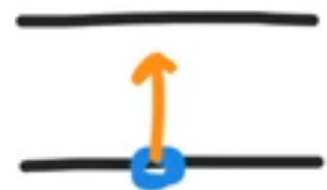
- Atomic clock. 1 second is DEFINED relative to the energy separation of these TWO STATES of CAESIUM_GPS
- Quantum Computers
- Quantum Simulators

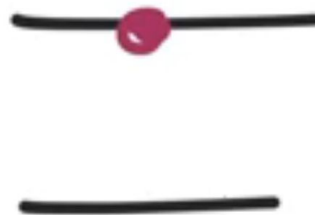
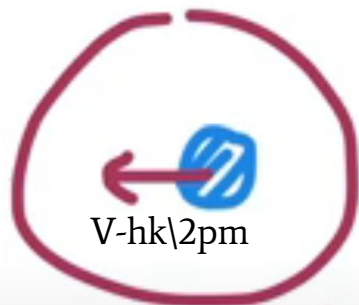
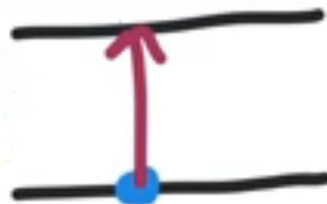
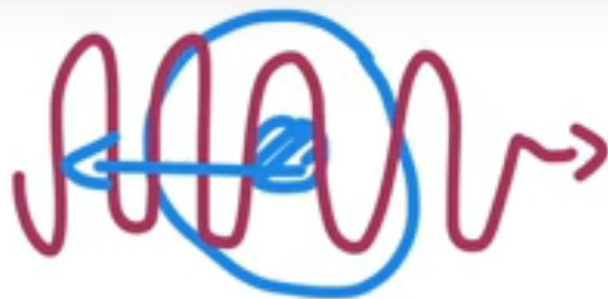
How cool we are?;) How cool we wanna be?

- 300 m/s to 1 m/s?
- Isn't N₂ cool enough? He should be cool enough...



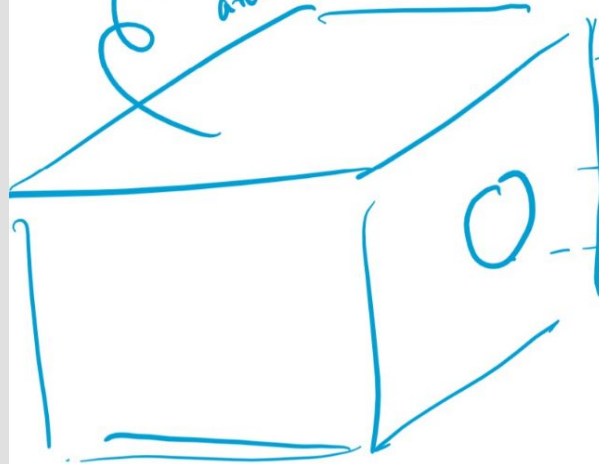
Doppler effect !





beam of atom

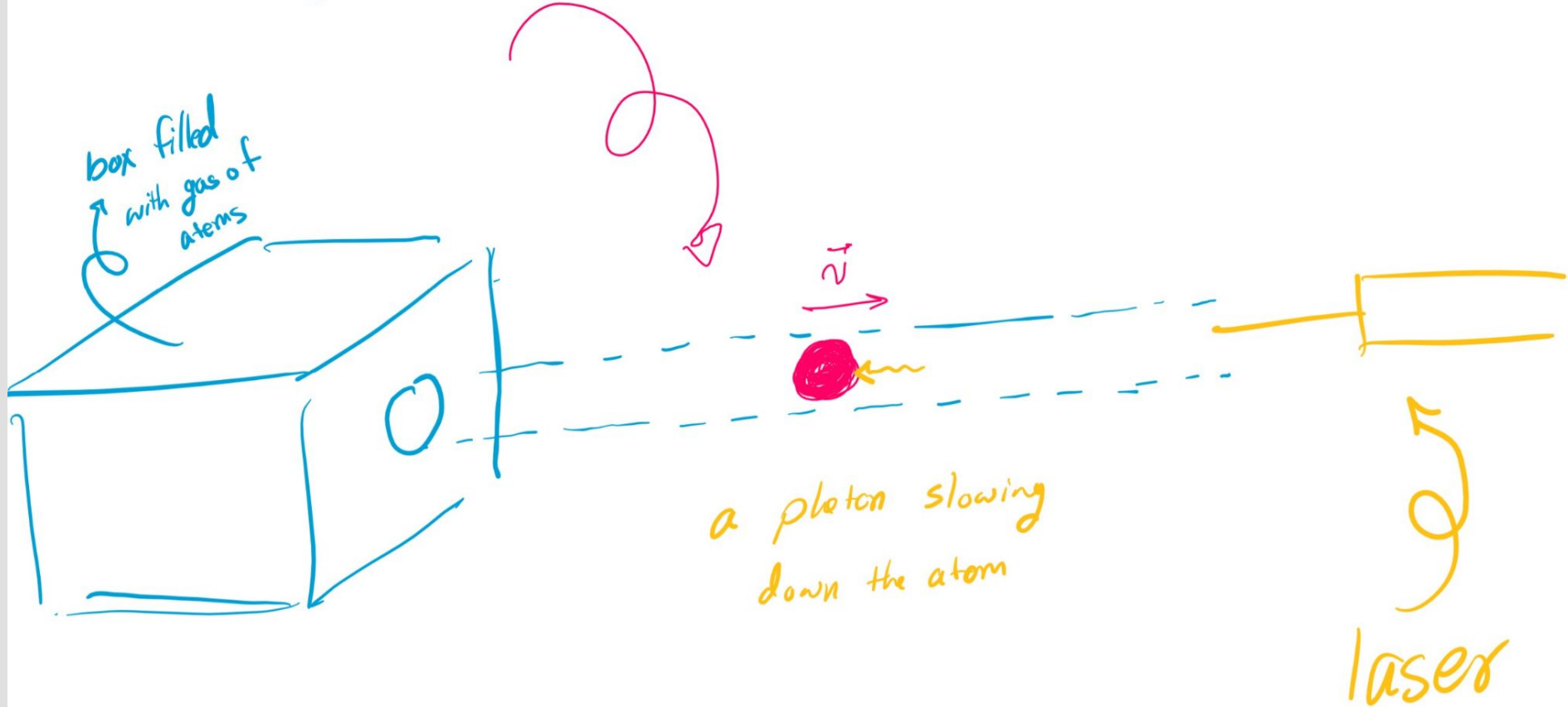
box filled
with gas of
atoms



$\hbar k$

a photon slowing
down the atom

laser



So how to fix?

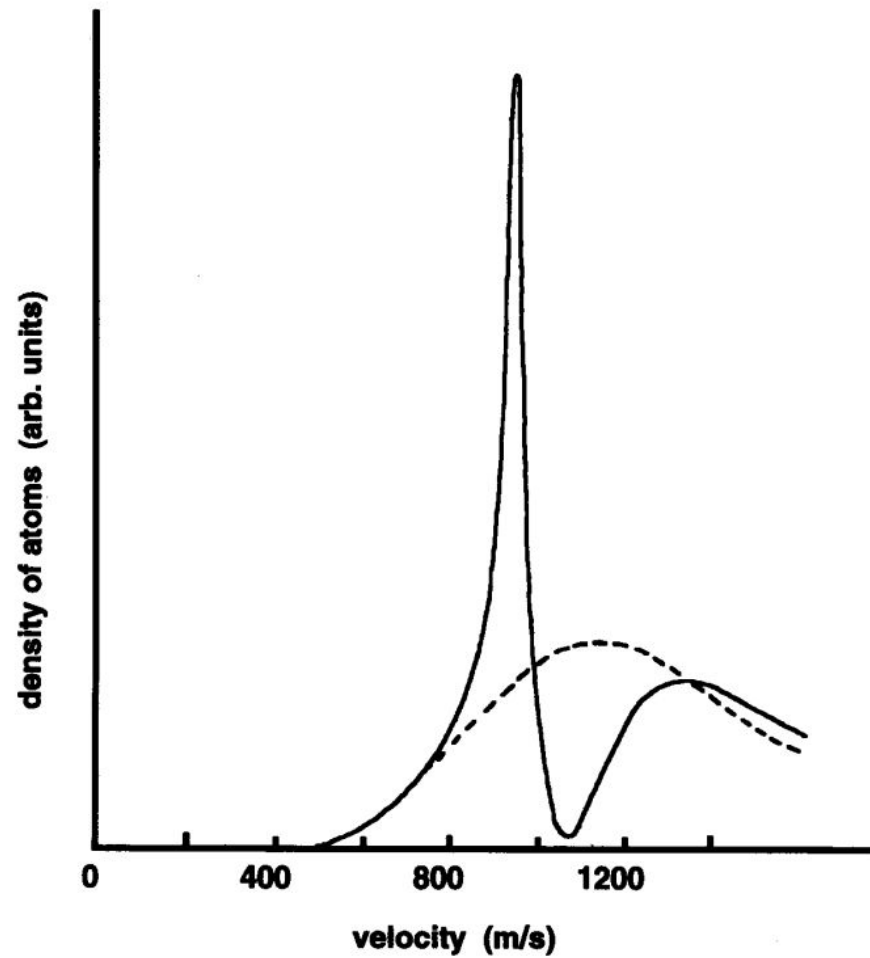
Doppler shift

- Down-shift ,in real time,the ENERGY of the ATOMIC RESONANCE
- Up-shift ,in real time, the FREQUENCY of the LASER

Doppler shift

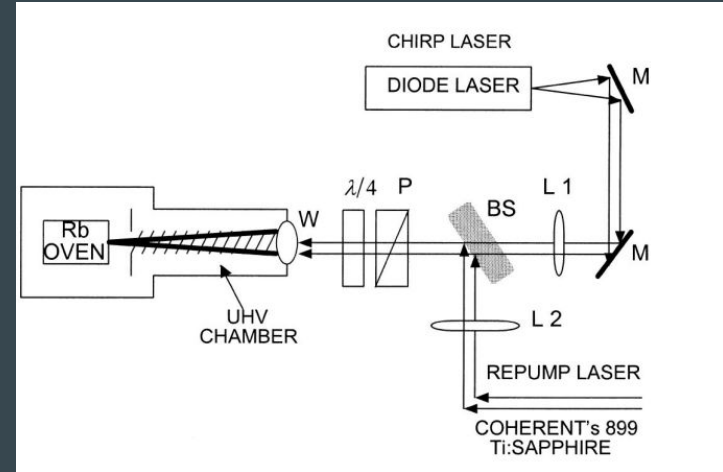
Example:

Doppler cooling slows Na by 4m/s and after absorbing 100 photons detunes...



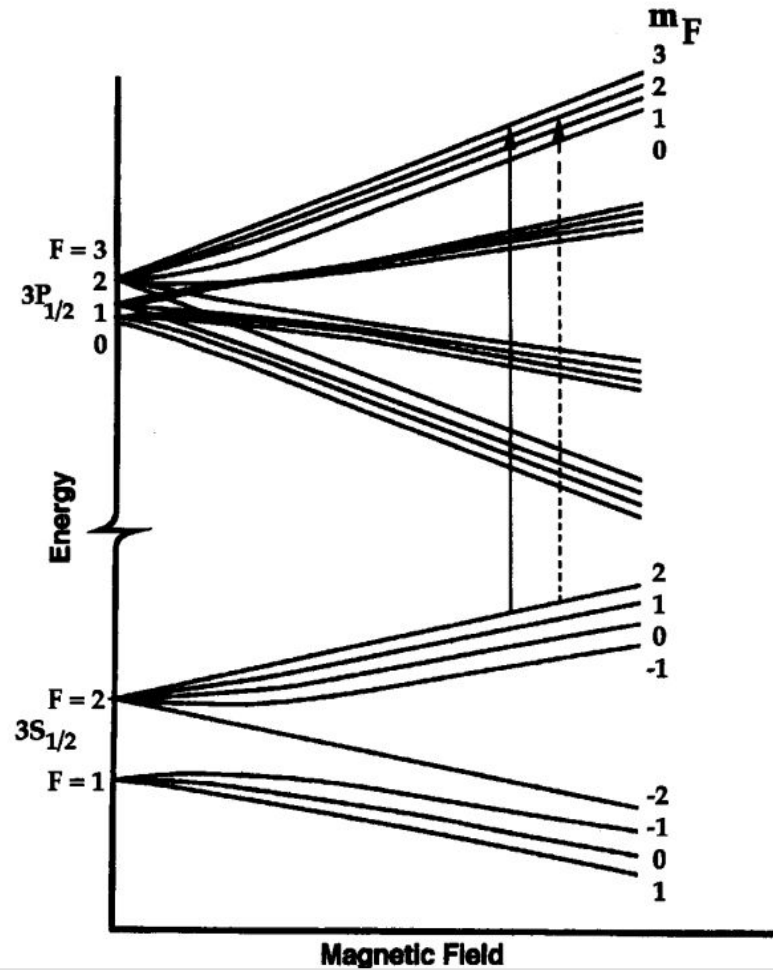
solutions:

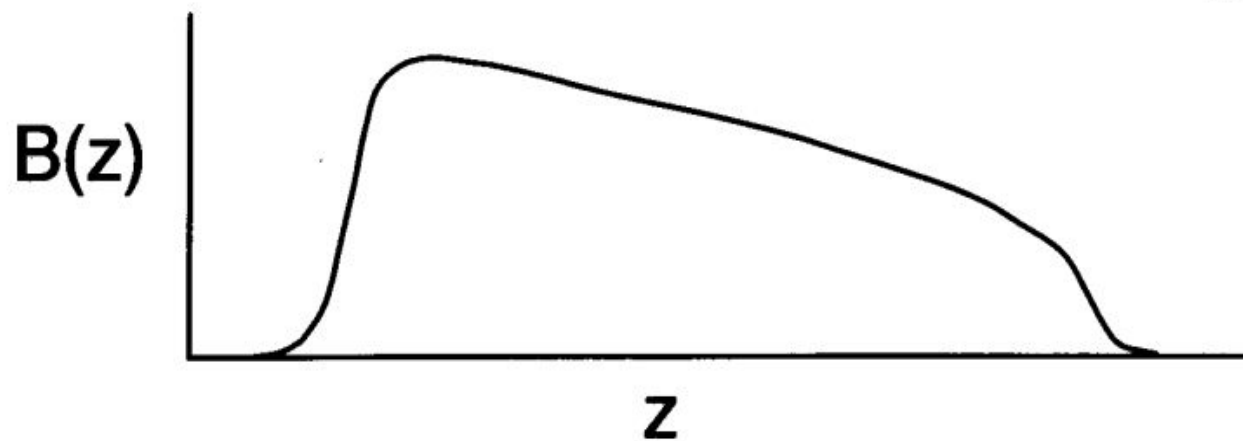
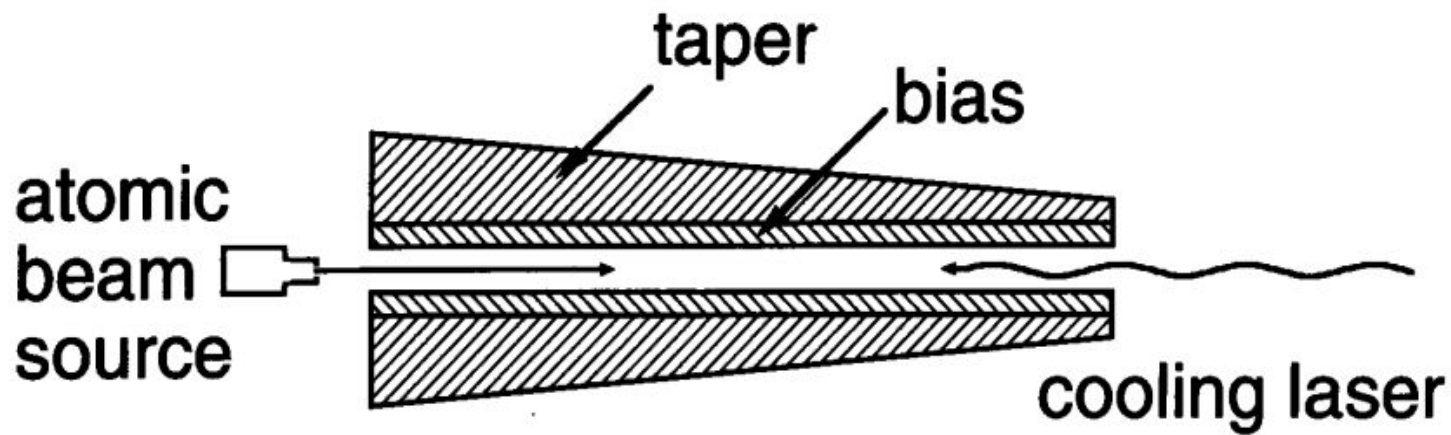
- a. Chirp cooling.
- b. Zeeman cooling



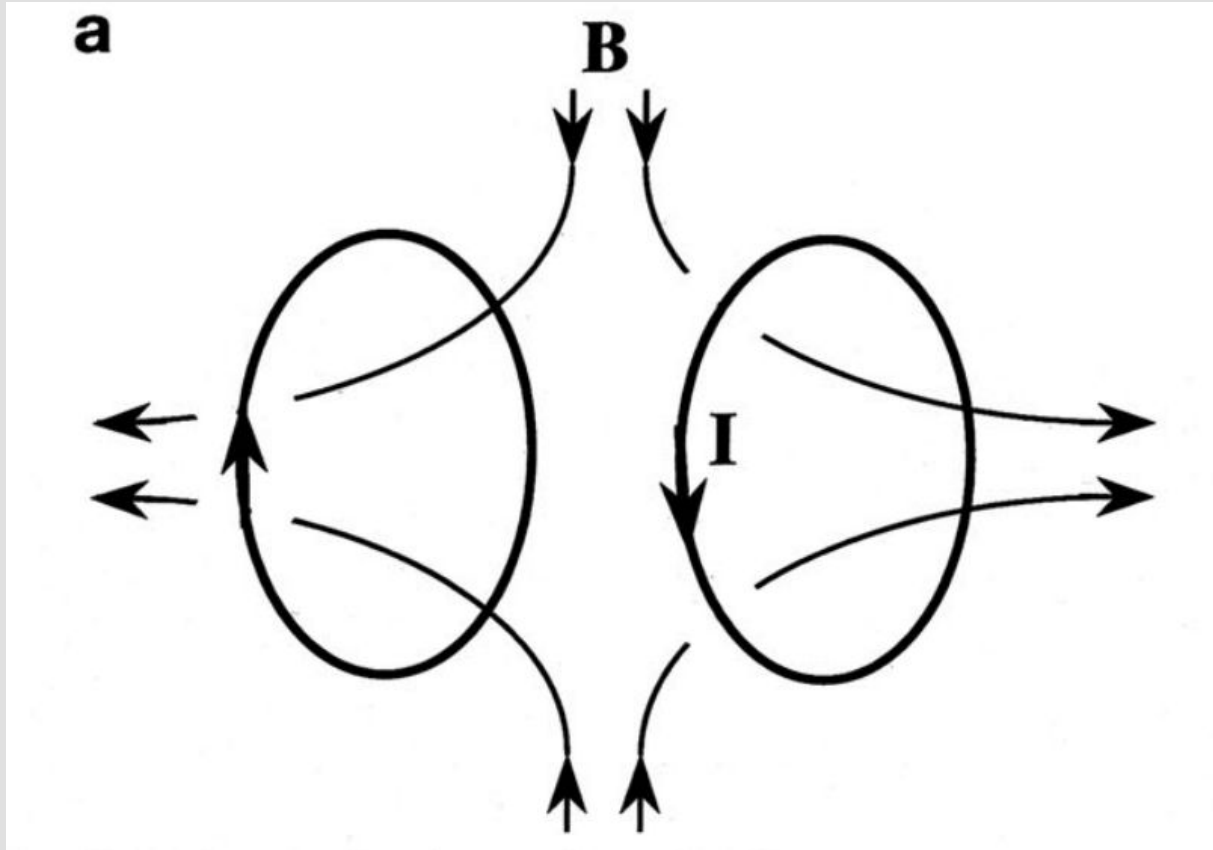


$$E = -M.B$$



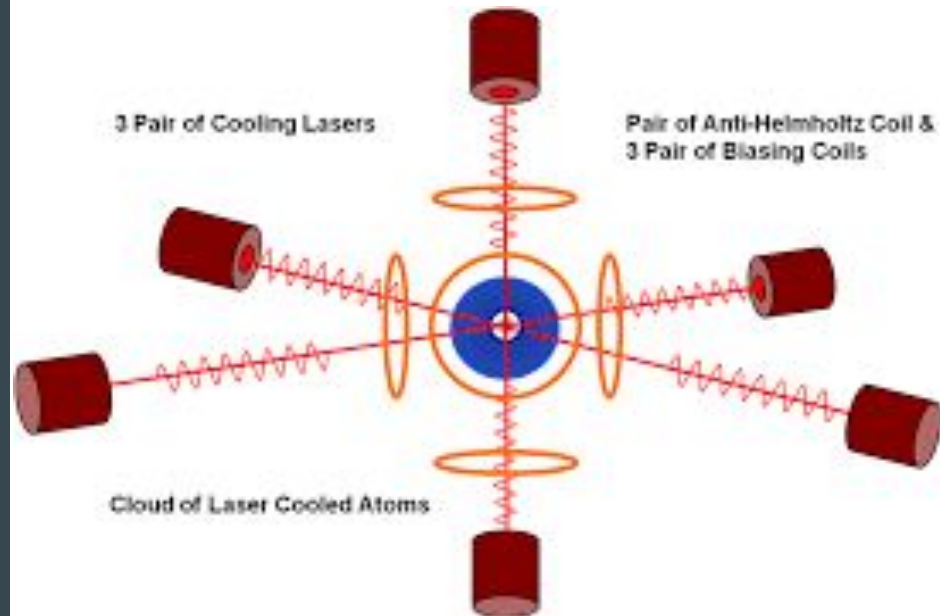


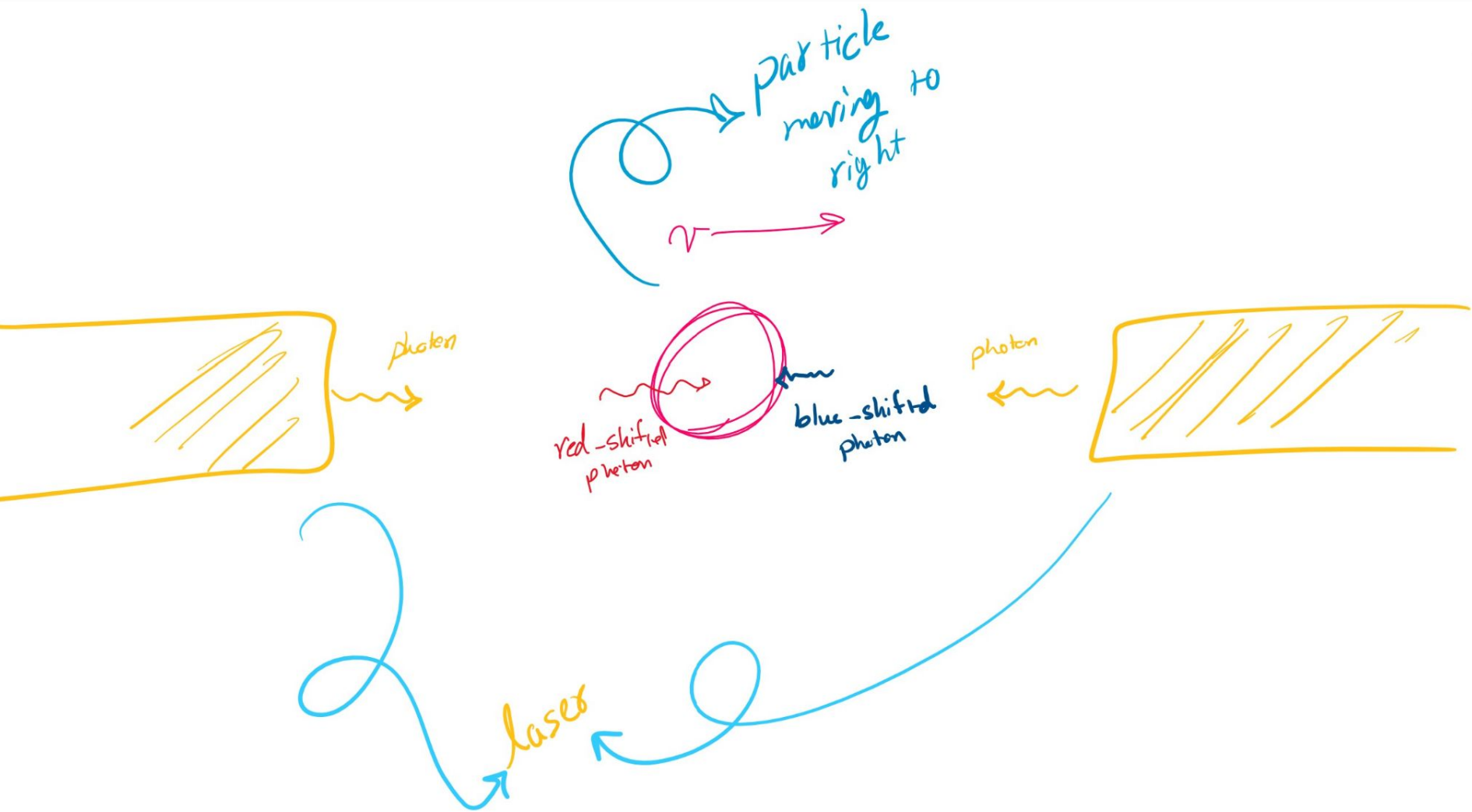
Magnetic trap



Doppler cooling

Optical trap

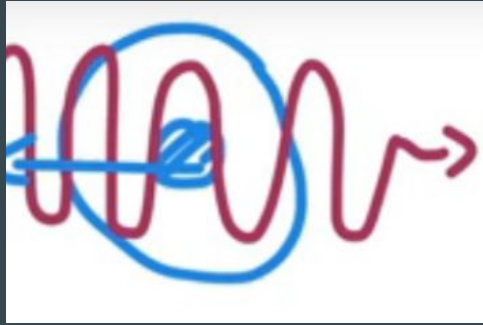




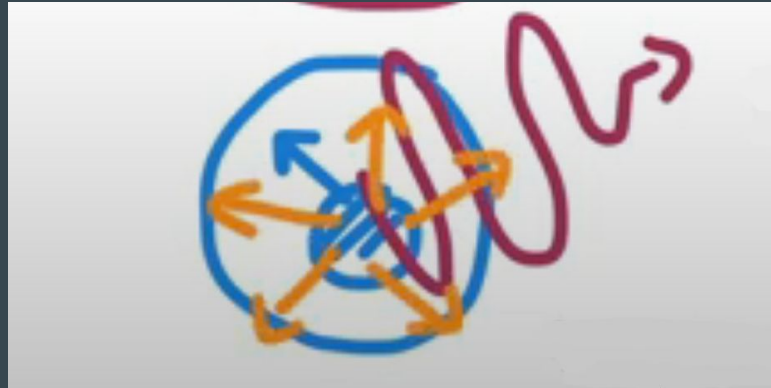
Problems of doppler cooling

- Doppler limit
- Sensitivity to laser detuning and intensity $\rightarrow$ Doppler shift
- Recoil heating $\rightarrow$ optical pumping
- Difficulties in cooling certain atomic specie

Recoil heating



Doppler limit



- The photon scattered has a:
- Momentum(energy)
 - time(duration of scattering)

Principle:

**An atom radiate and absorb photons
at half the radiative decay rate of
the excited state**

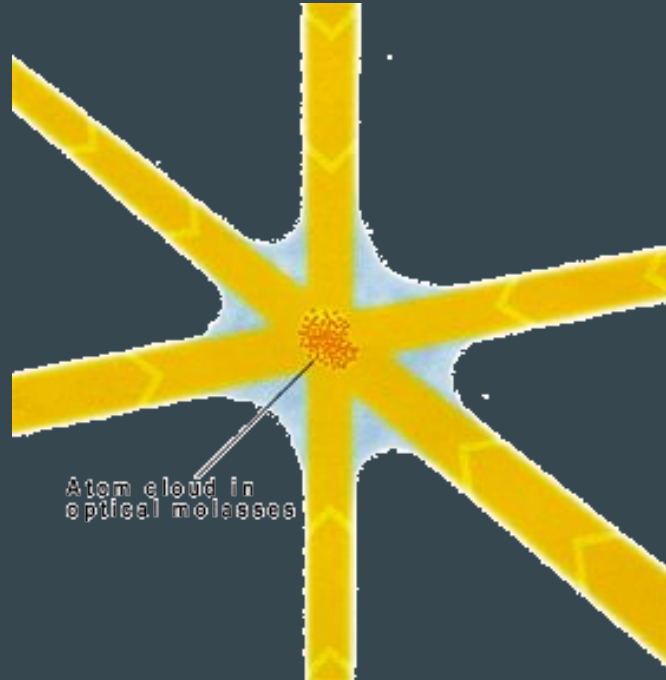
Duration of scattering time is limited!

Determined by interaction time

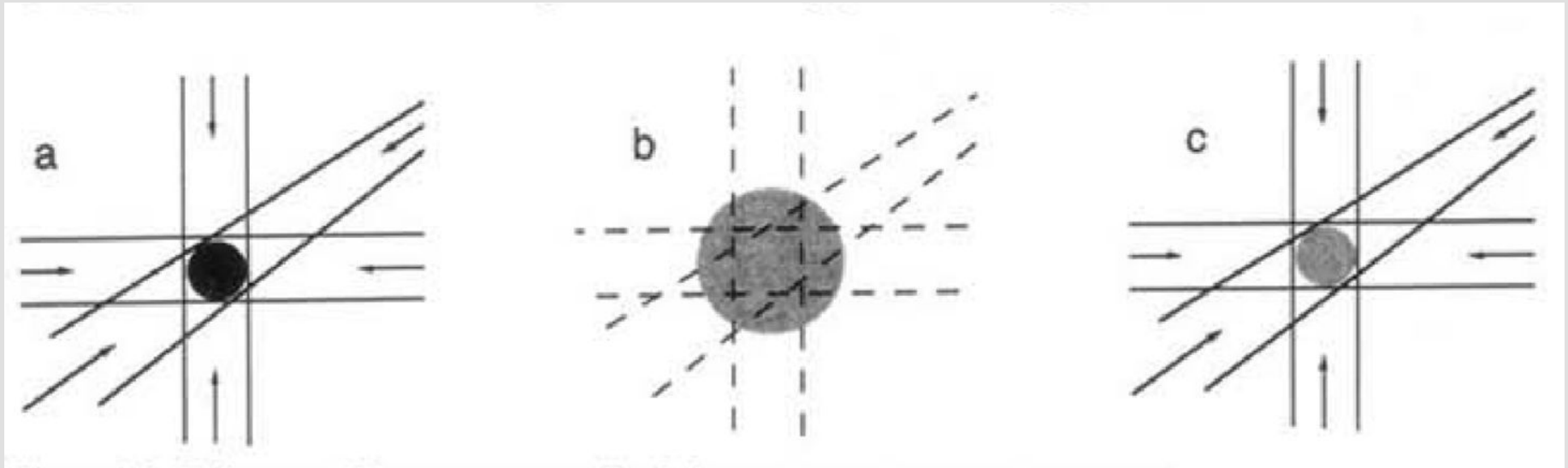
Uncertainty principle

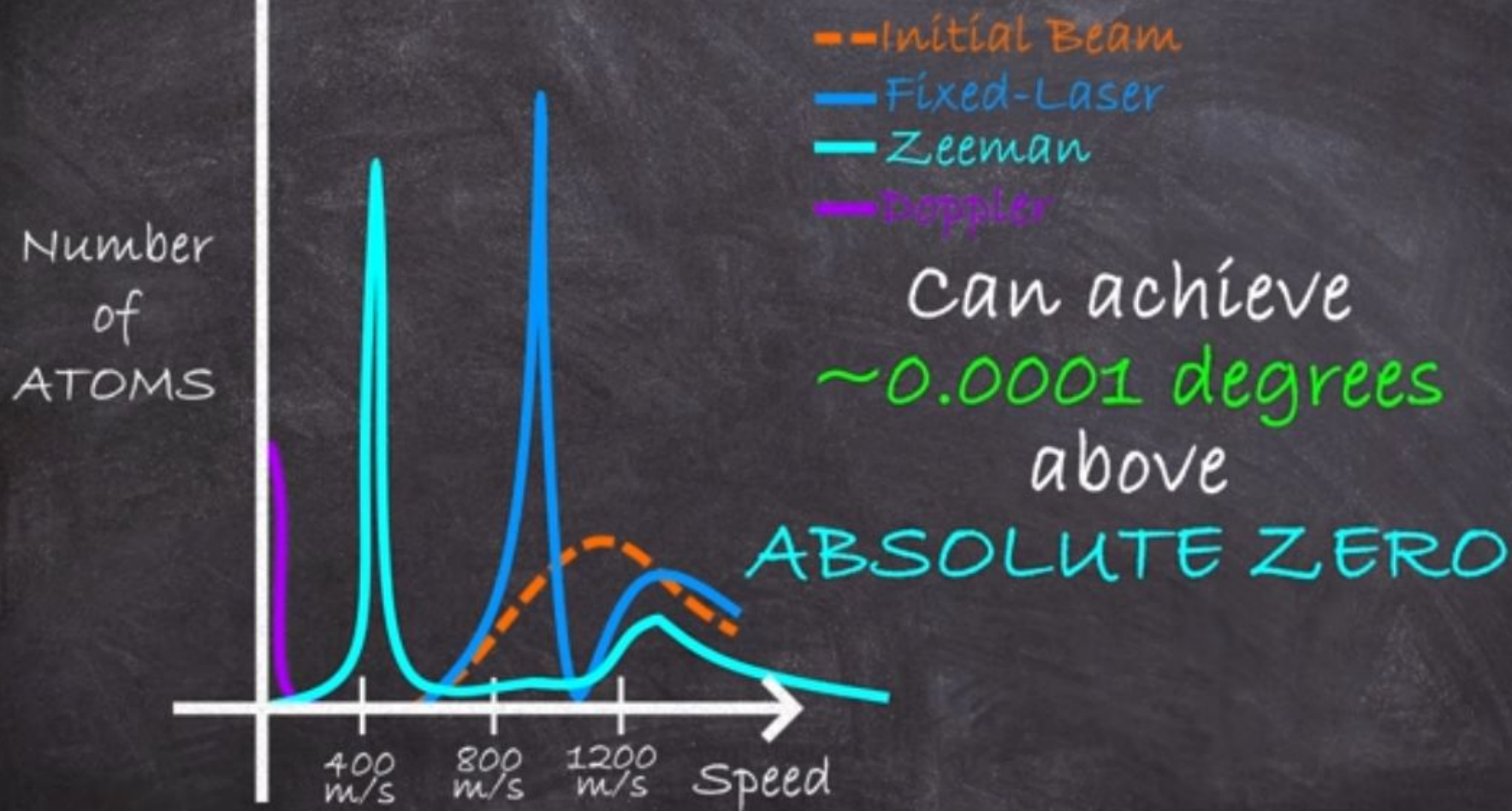
A longer interaction time allows for a more precise measurement of the photon frequency and, consequently, the momentum transfer.

Optical molasses ?!?



Release and capture





The Sisyphus Effect

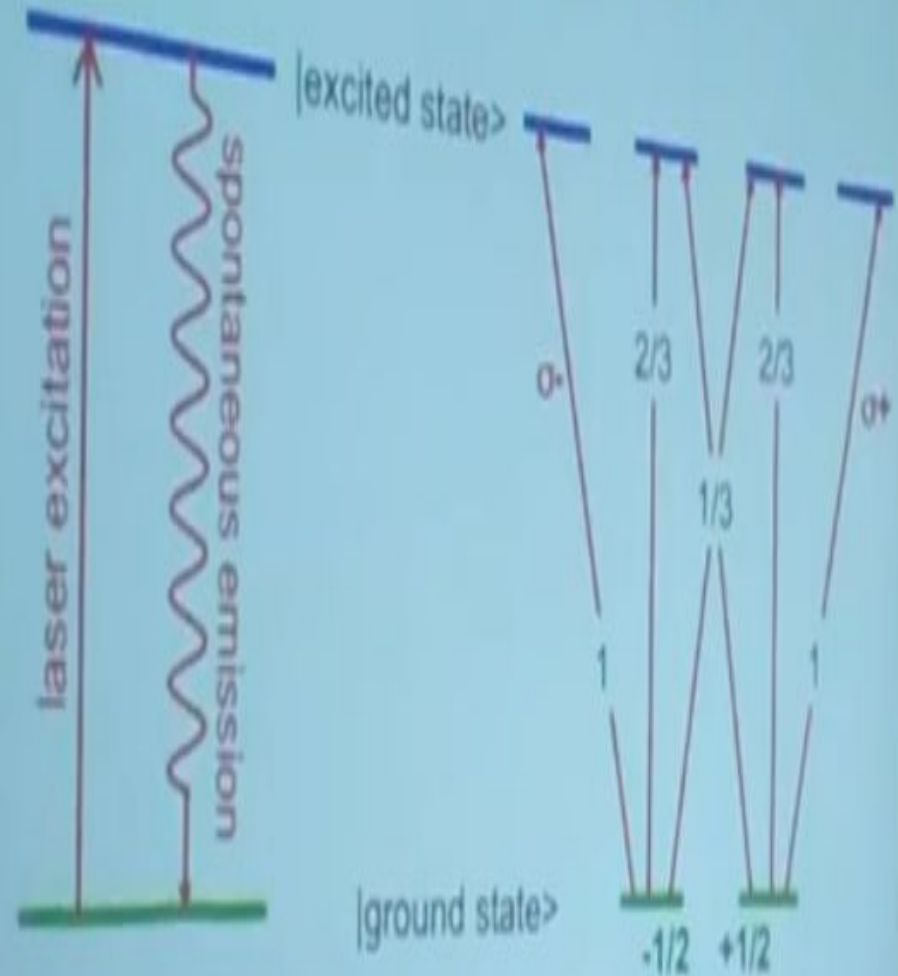
Jean Dalibard and Claude
Tannoudji 1989

مجازاتى كه سيزيف گرفتار آن شد، نمادِ كارِ پوچ و بى معنا است.
اين پوچى به خاطر تكرر ابدى يك فعاليت مشخص نيست؛
بلكه به علت بى نتيجه بودن اين فعاليت است.
هر بار كه سنگ به پايين كوه مى غلتد،
همه چيز به نقطه‌ي صفر بازگشته و مانند گذشته است؛
جز اين كه سيزيف، فرسوده تر از قبل است.

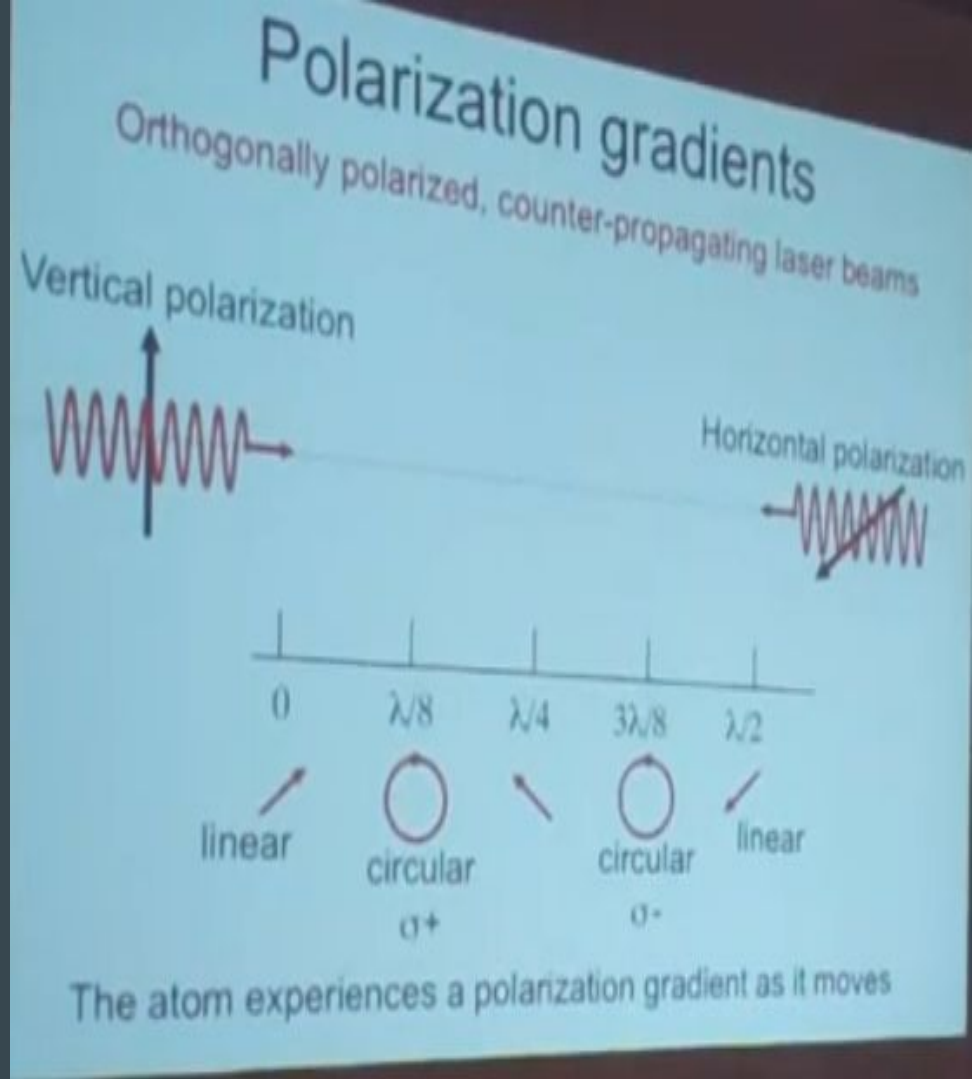
نم



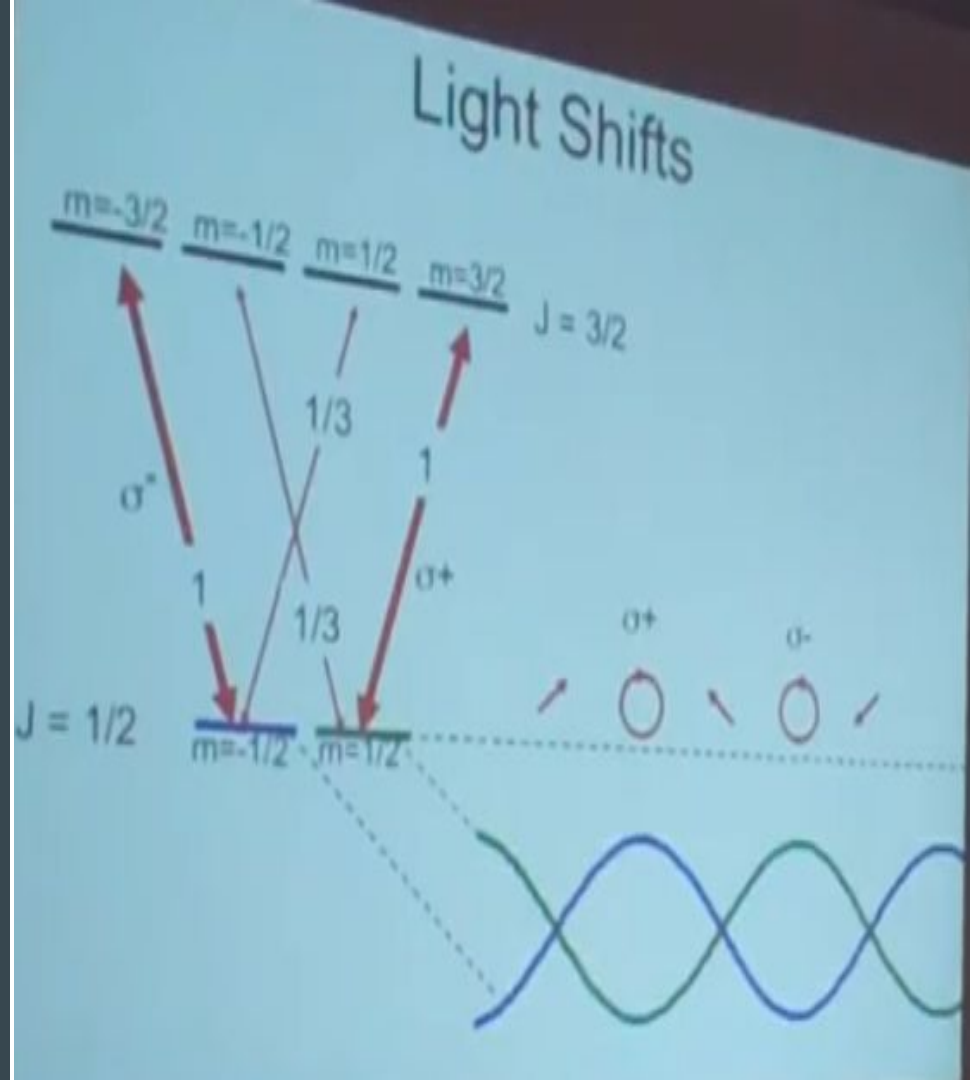
Multilevel atoms



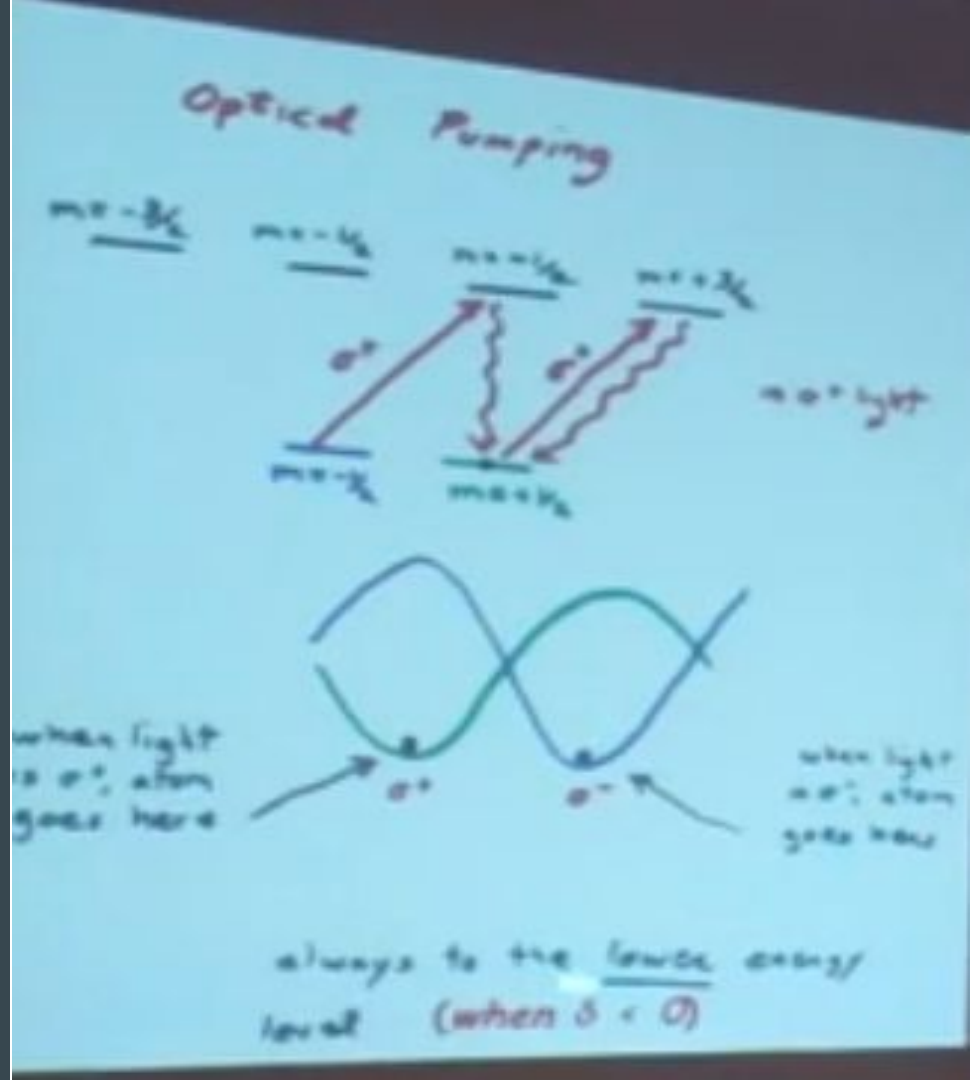
Polarization gradients



Light shift

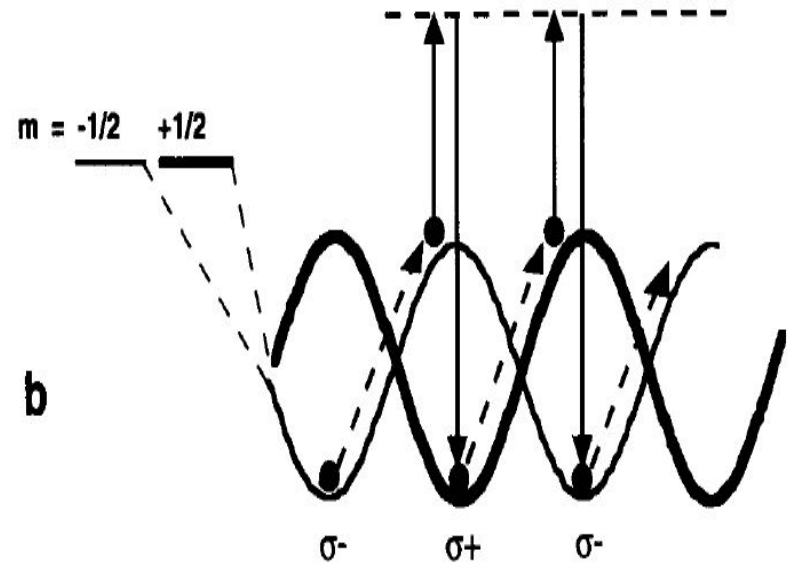
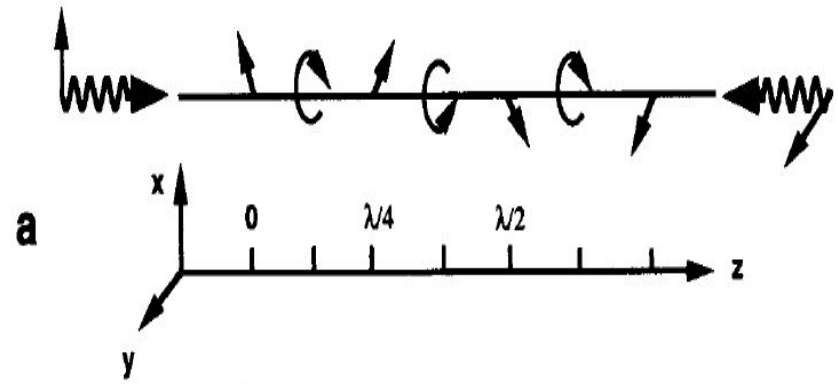


Optical pumping



How laser cooling really works?

“Sisyphus cooling”



Any questions?

Hope you have learned how to be cool by laser cooling ;)