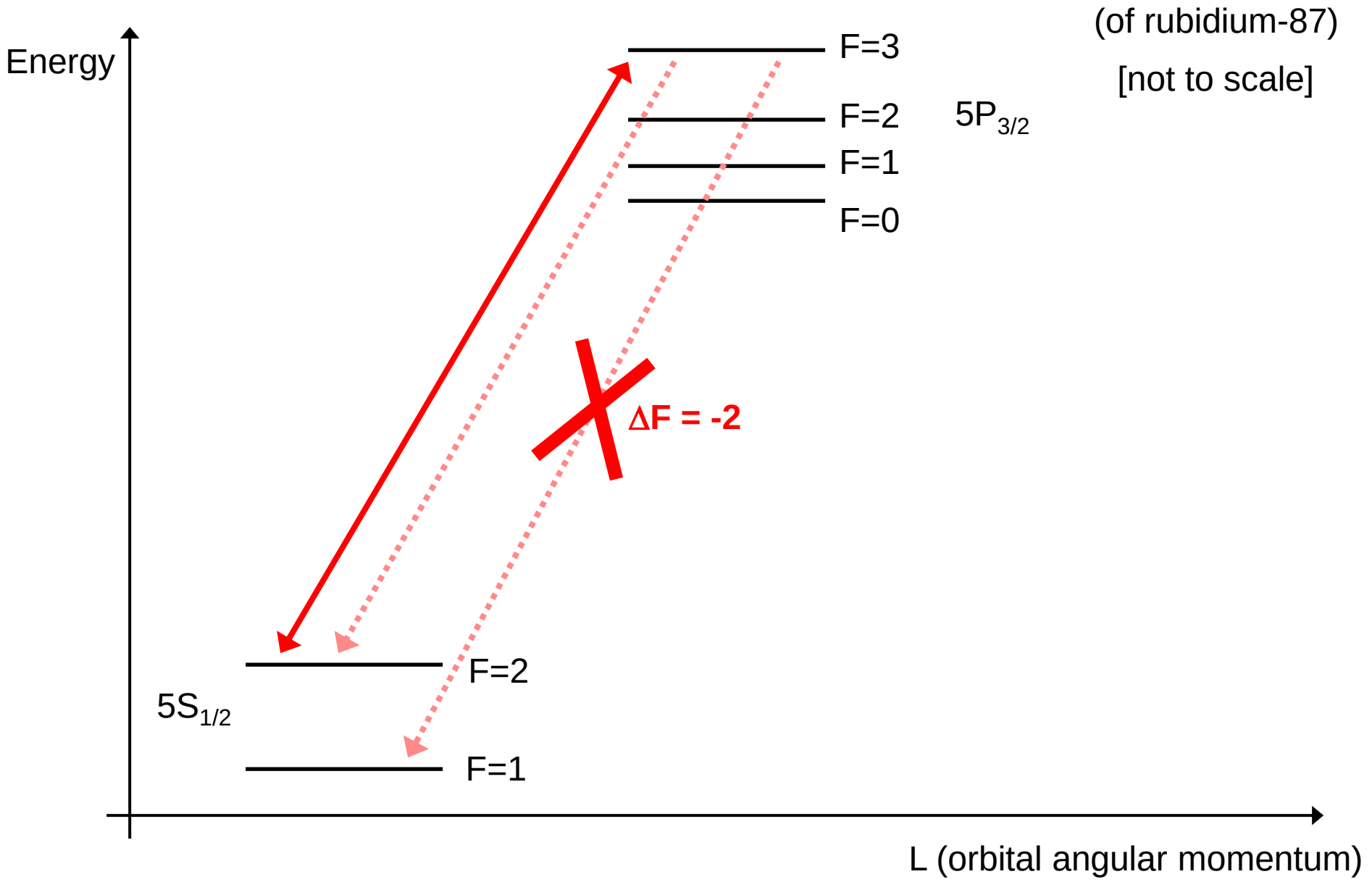
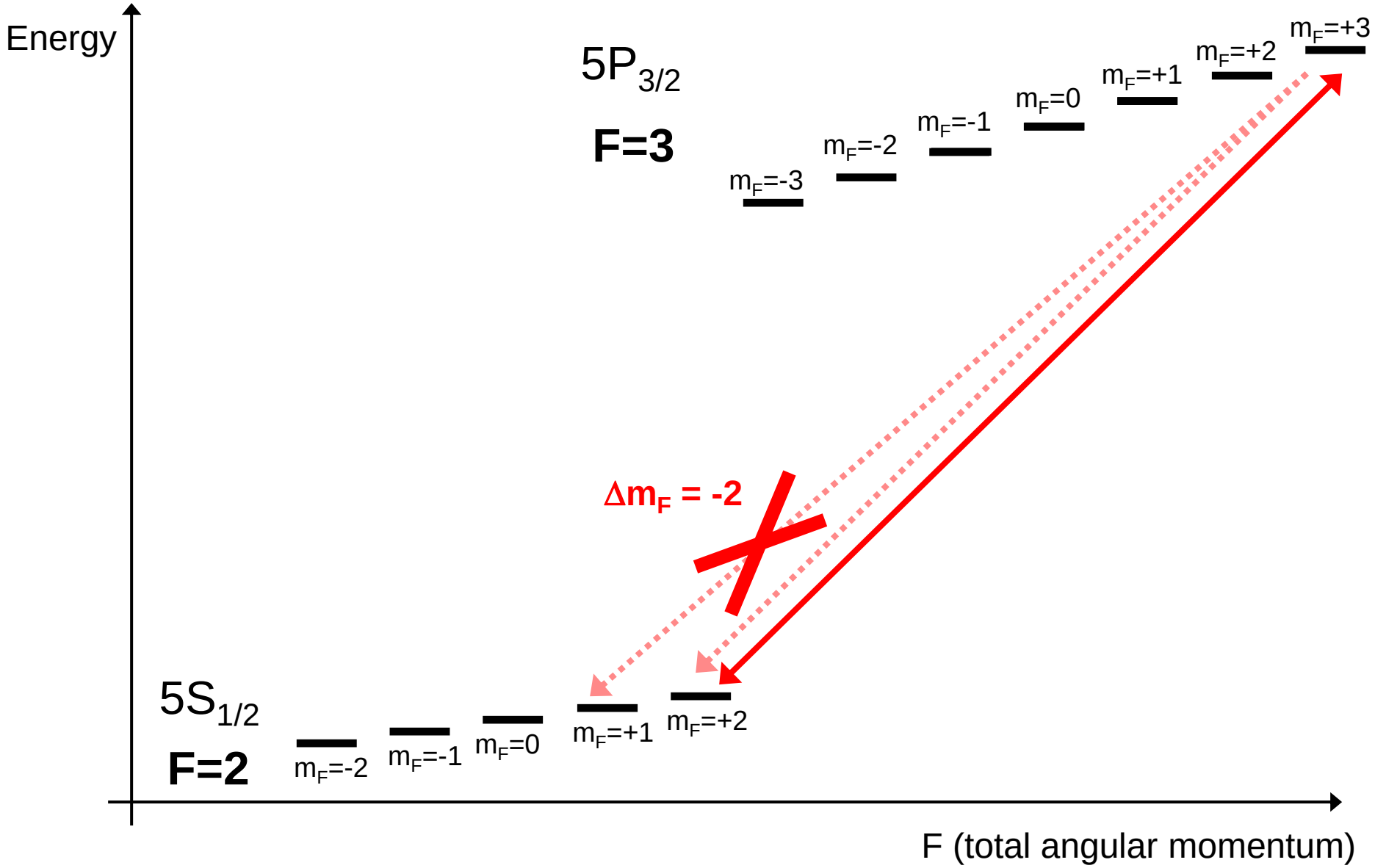
Why are Alkalis “2-level atoms” ?



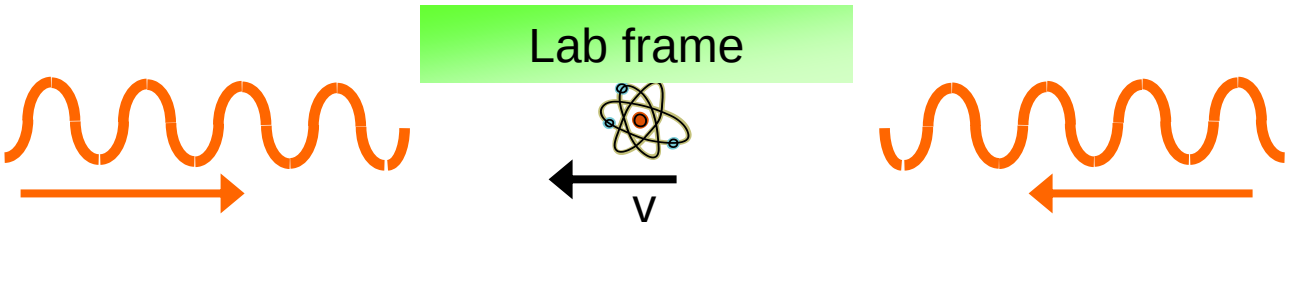
The D2 line Cycling Transition

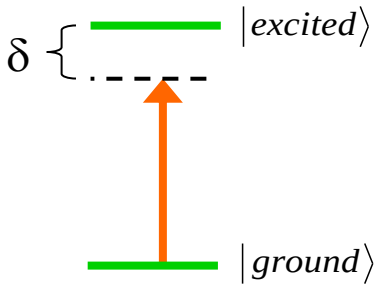


Laser Cooling

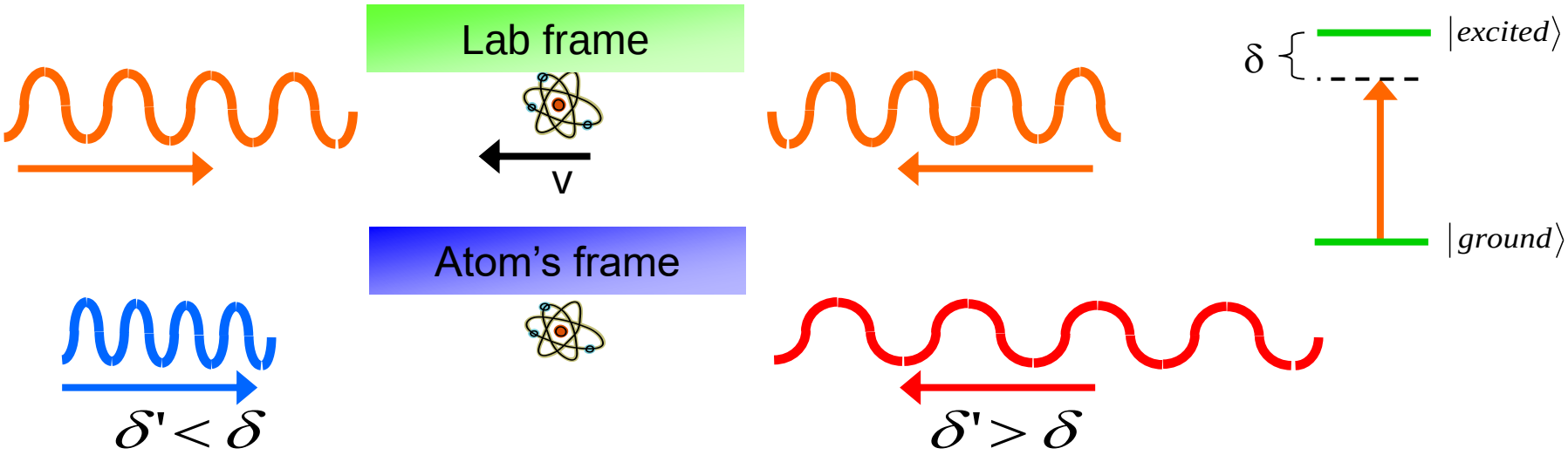
1. Doppler Cooling – optical molasses.
2. Doppler temperature.
3. Magneto-optical trap.

Doppler Cooling: How can a laser cool?





Doppler Cooling: How can a laser cool?



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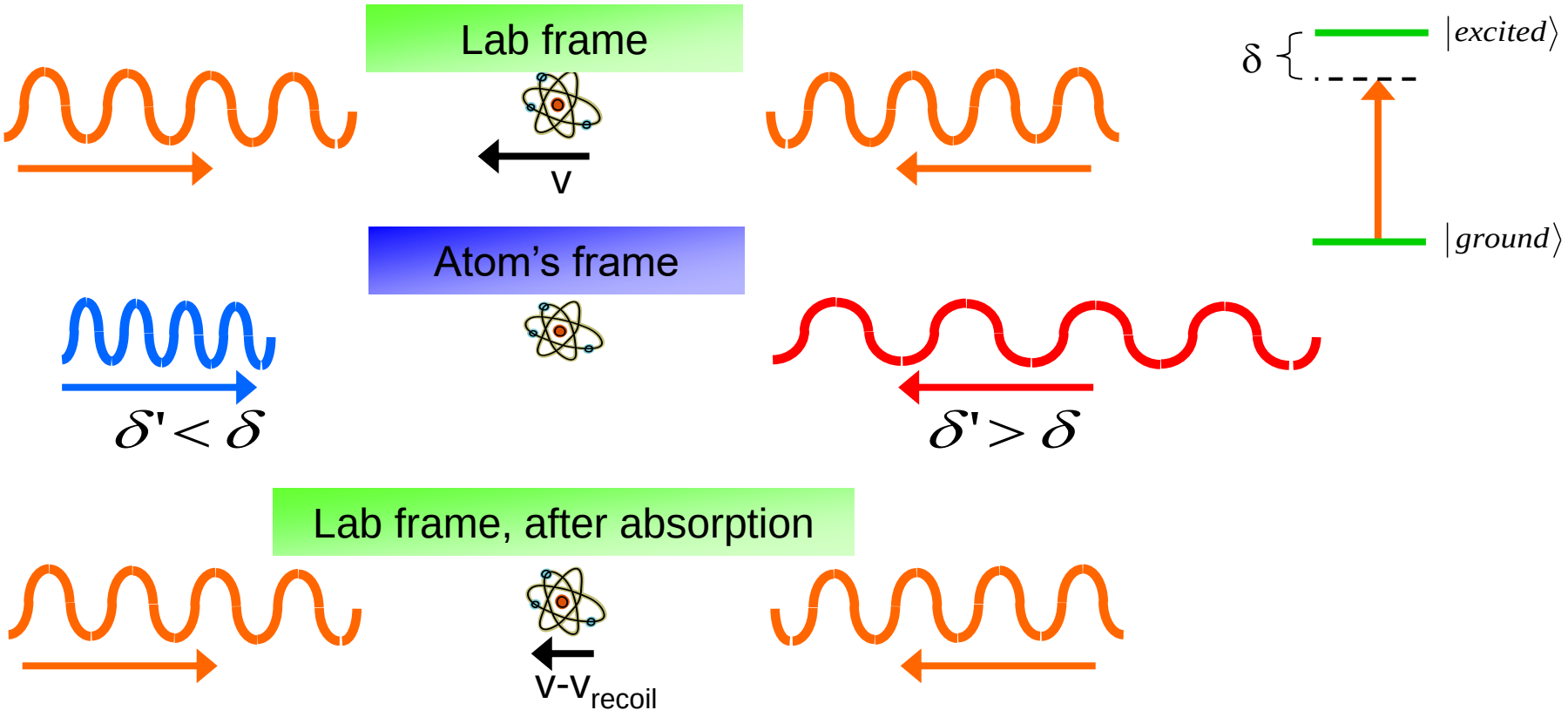

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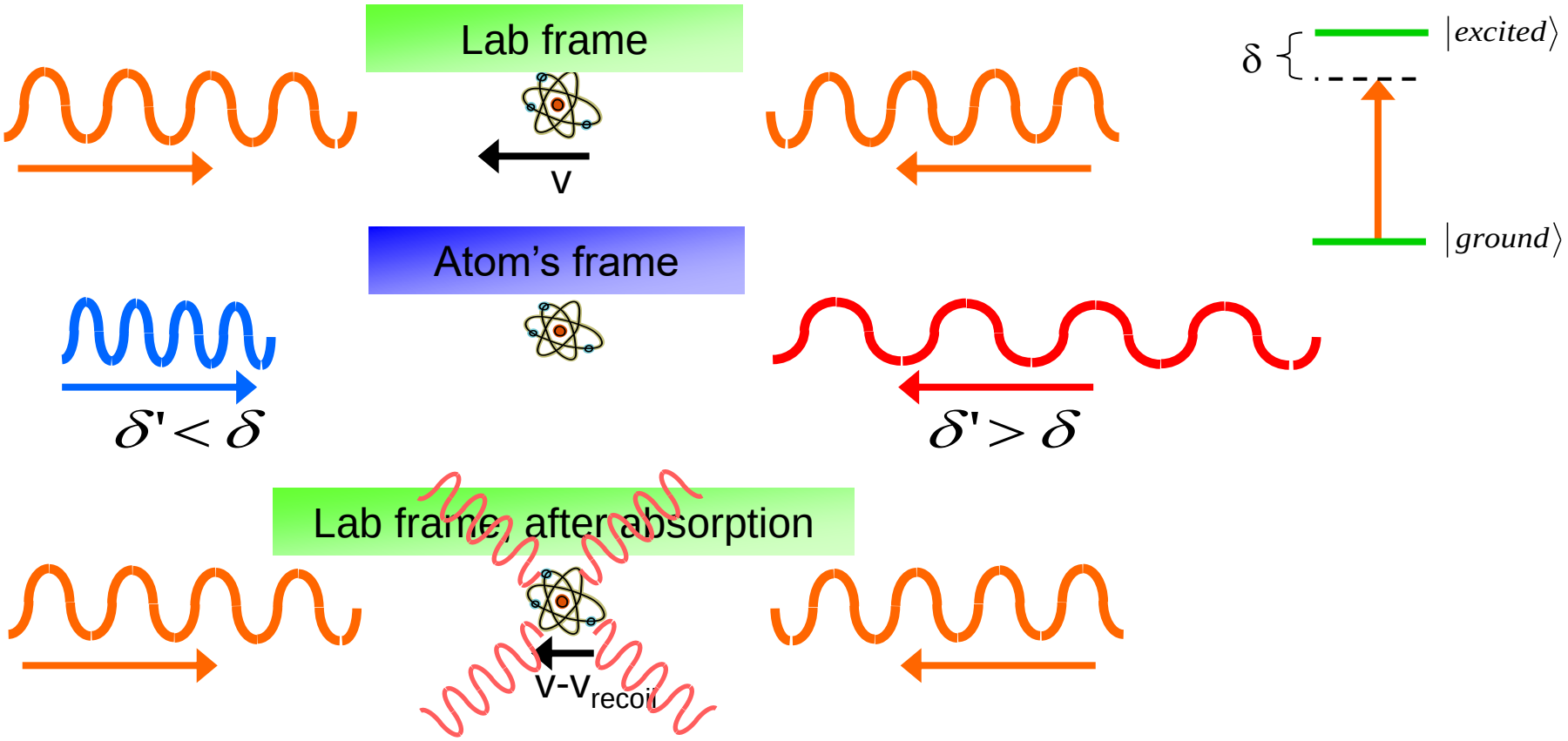
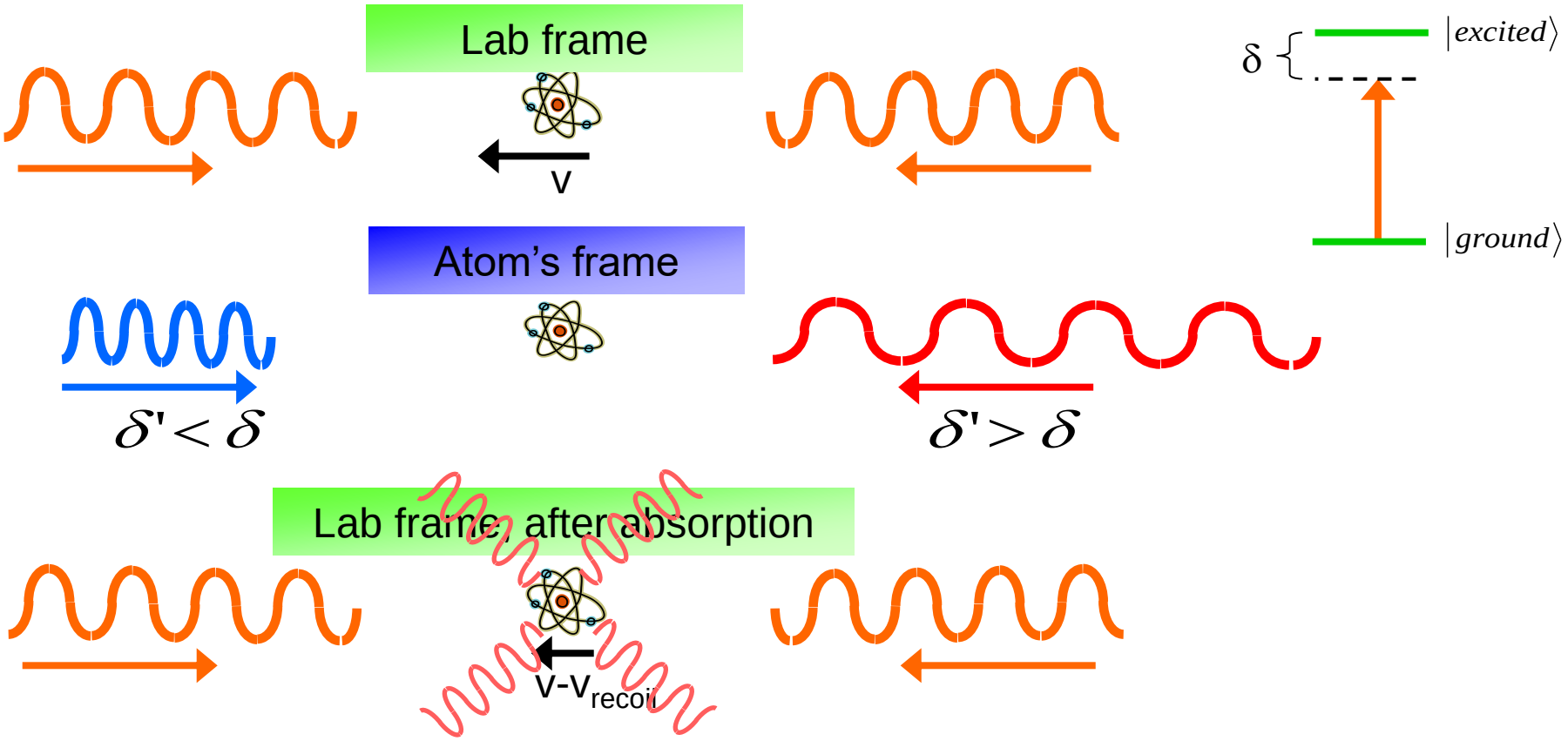
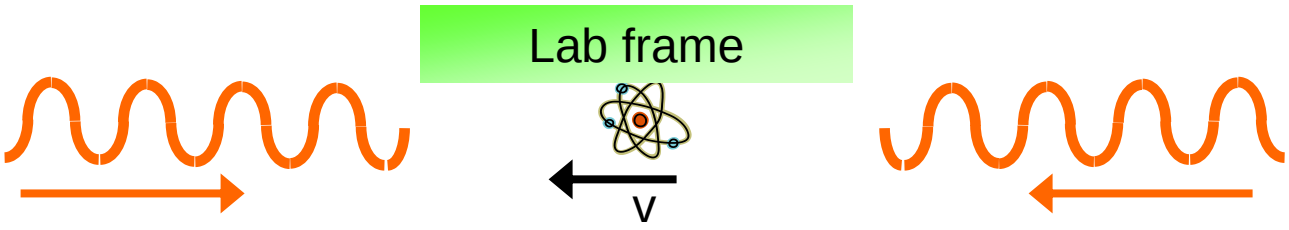


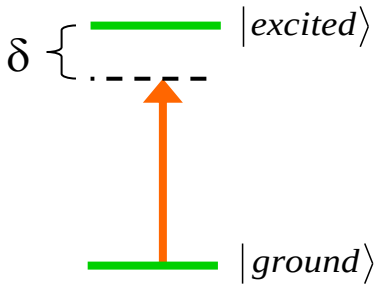
Doppler Cooling: How can a laser cool?

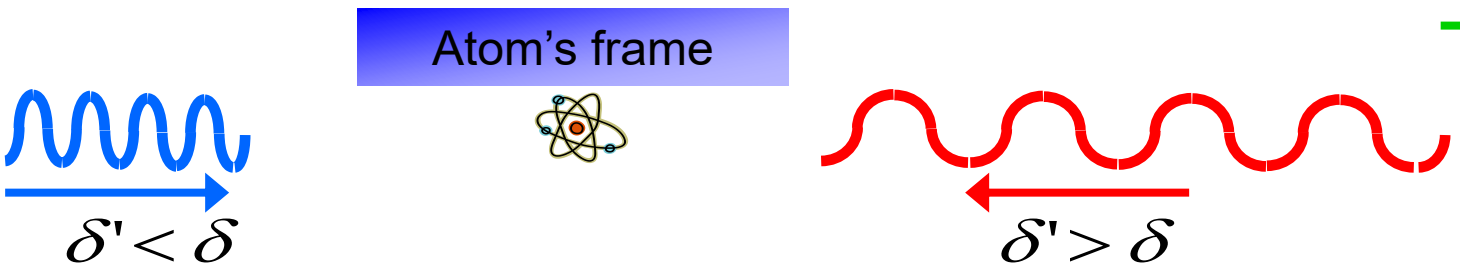


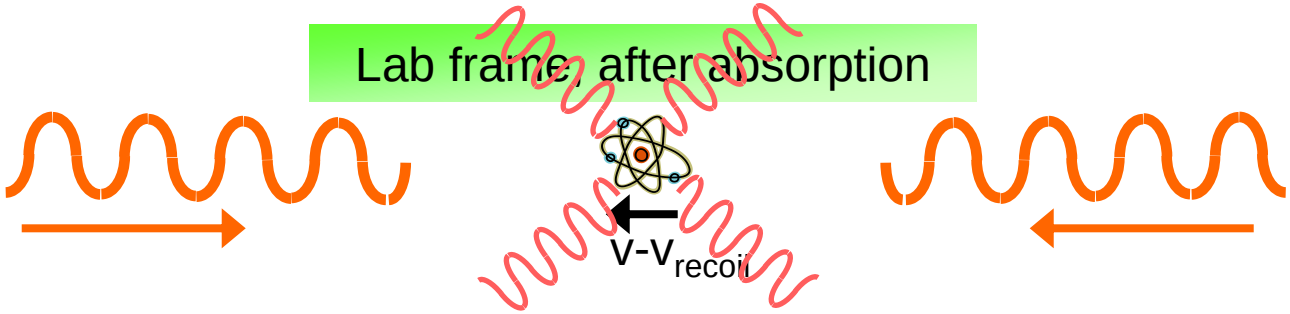
- Absorb a photon → atom gets $\hbar\vec{k}$ momentum kick.
- Repeat process at 10^7 kicks/s → large deceleration.
- Emitted photons are radiated symmetrically
  → do not affect motion on average

Doppler Cooling: How can a laser cool?



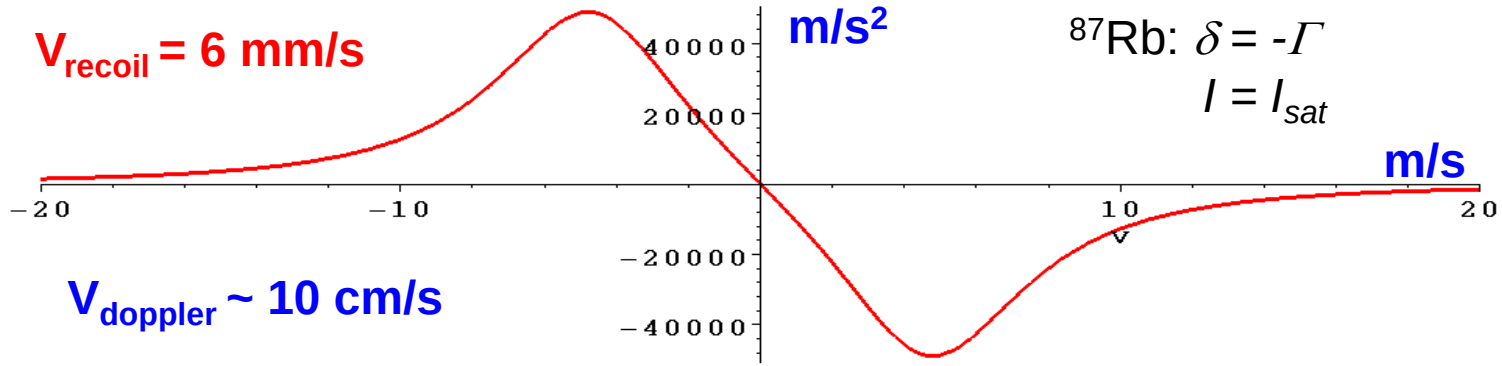






V_{recoil} = 6 mm/s

$V_{doppler}$ ~ 10 cm/s



^{87}Rb: $\delta = -\Gamma$

$I = I_{sat}$

Magneto-Optical Trap (MOT)

Problem:

Doppler cooling reduces momentum spread of atoms only.

→ Similar to a damping or friction force (optical molasses).

→ Does not reduce spatial spread.

→ Does not confine the atoms.

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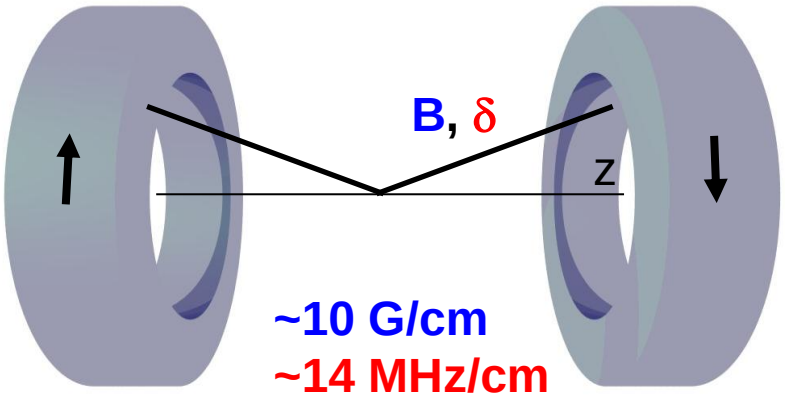
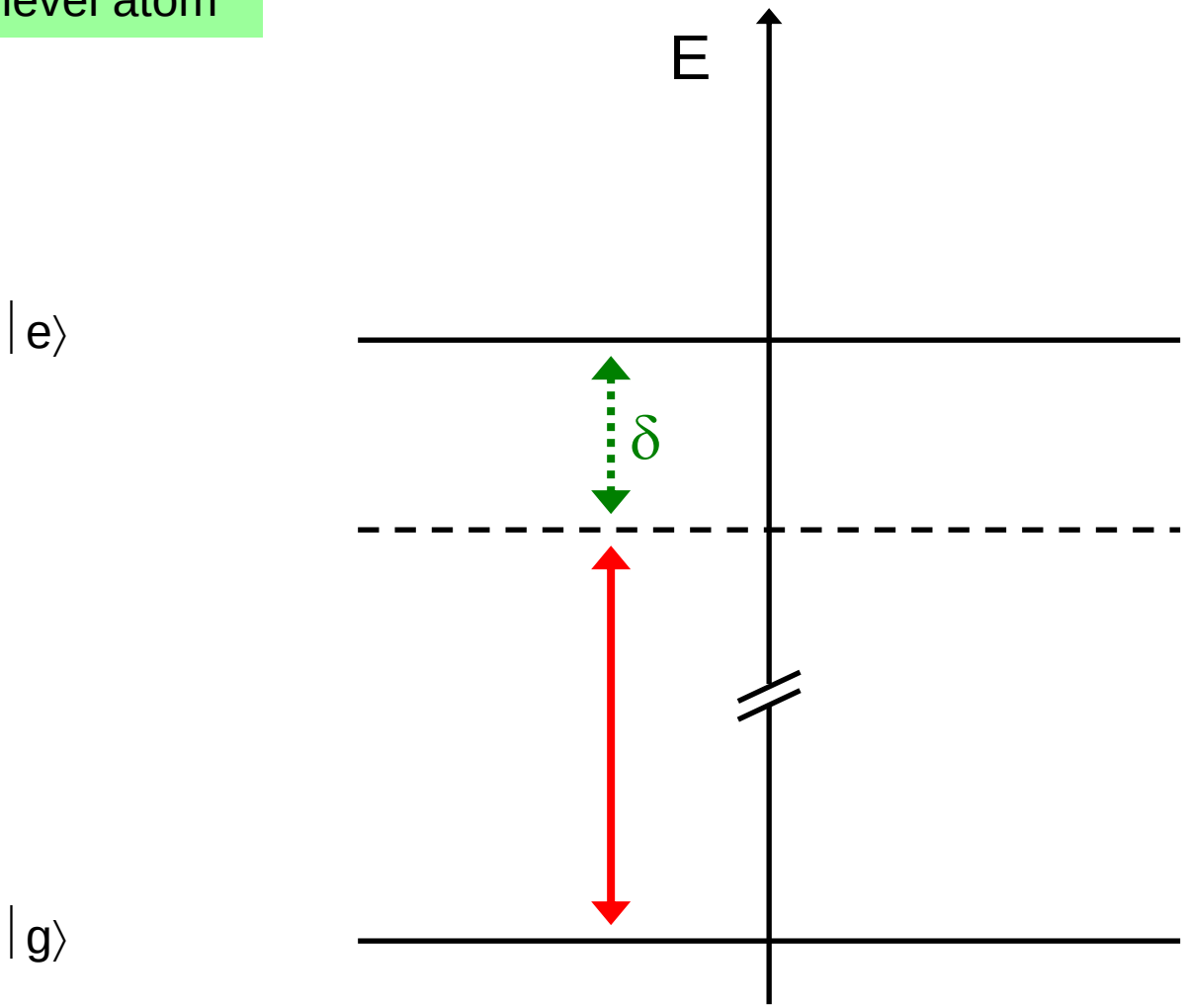
Solution:

Spatially tune the laser-atom detuning with the Zeeman shift from a spatially varying **magnetic field**.



Magneto-Optical Trap

2-level atom

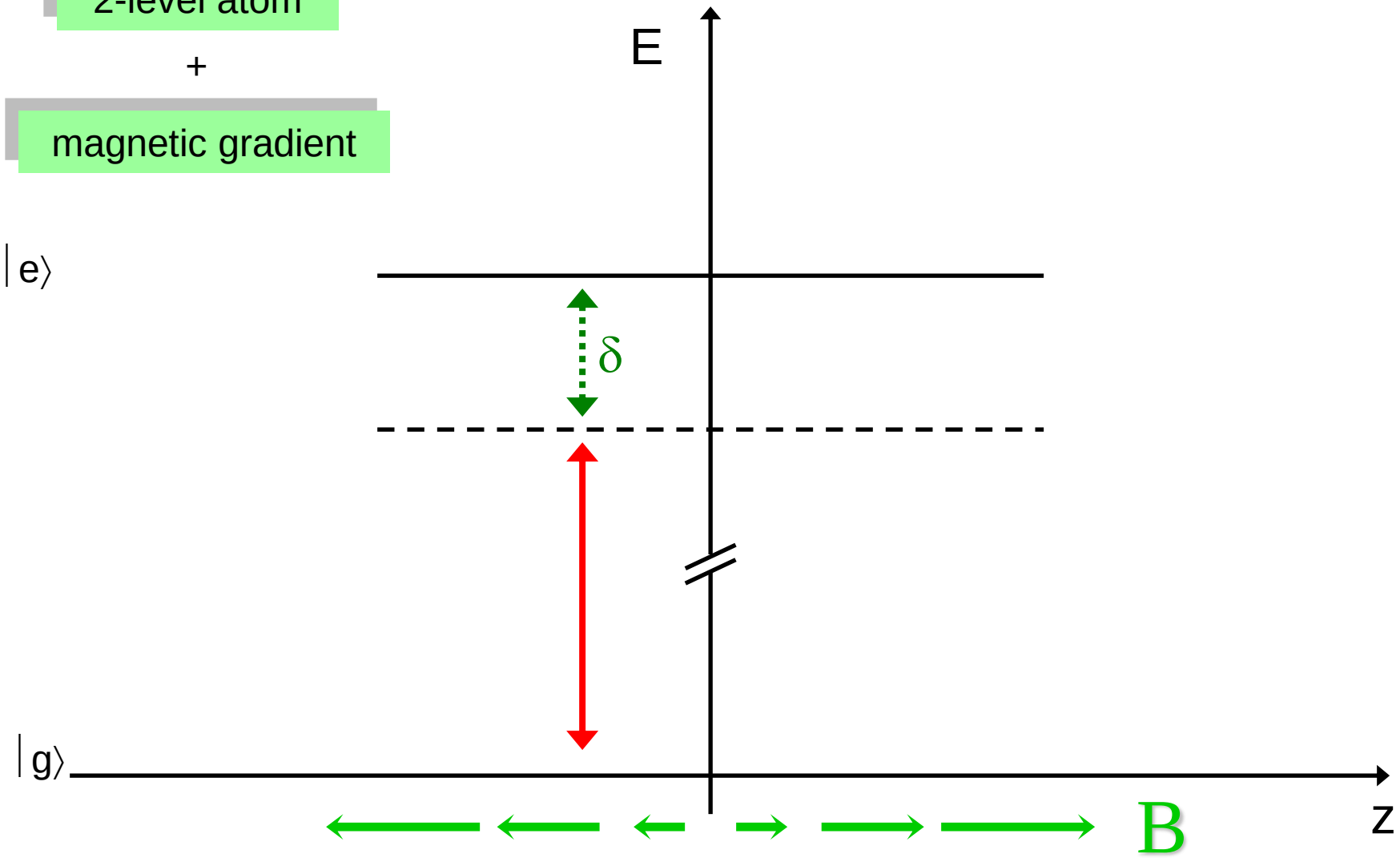


Magneto-Optical Trap

2-level atom

+

magnetic gradient



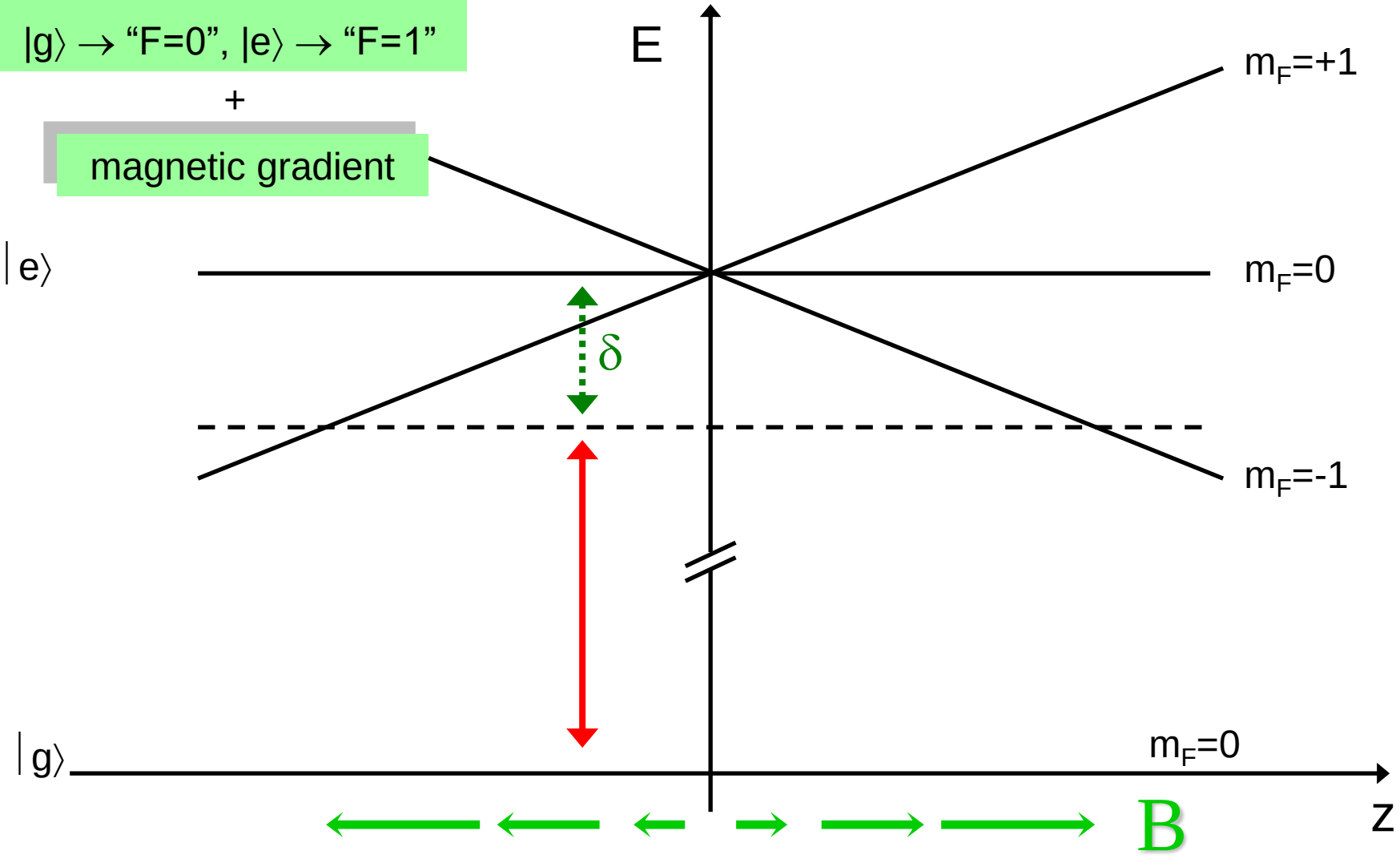
Magneto-Optical Trap

4-level atom

$|g\rangle \rightarrow$ “F=0”, $|e\rangle \rightarrow$ “F=1”

+

magnetic gradient



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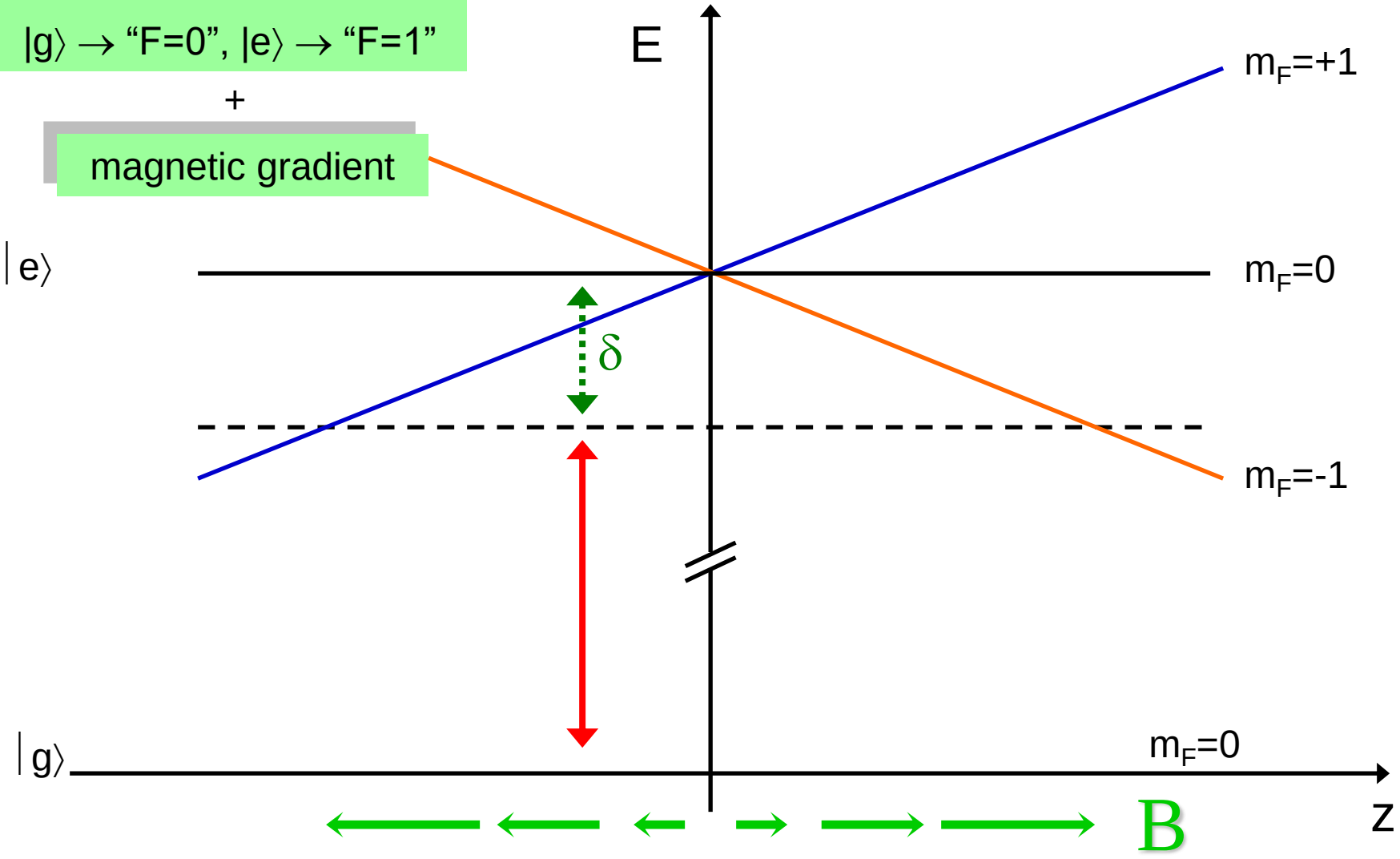

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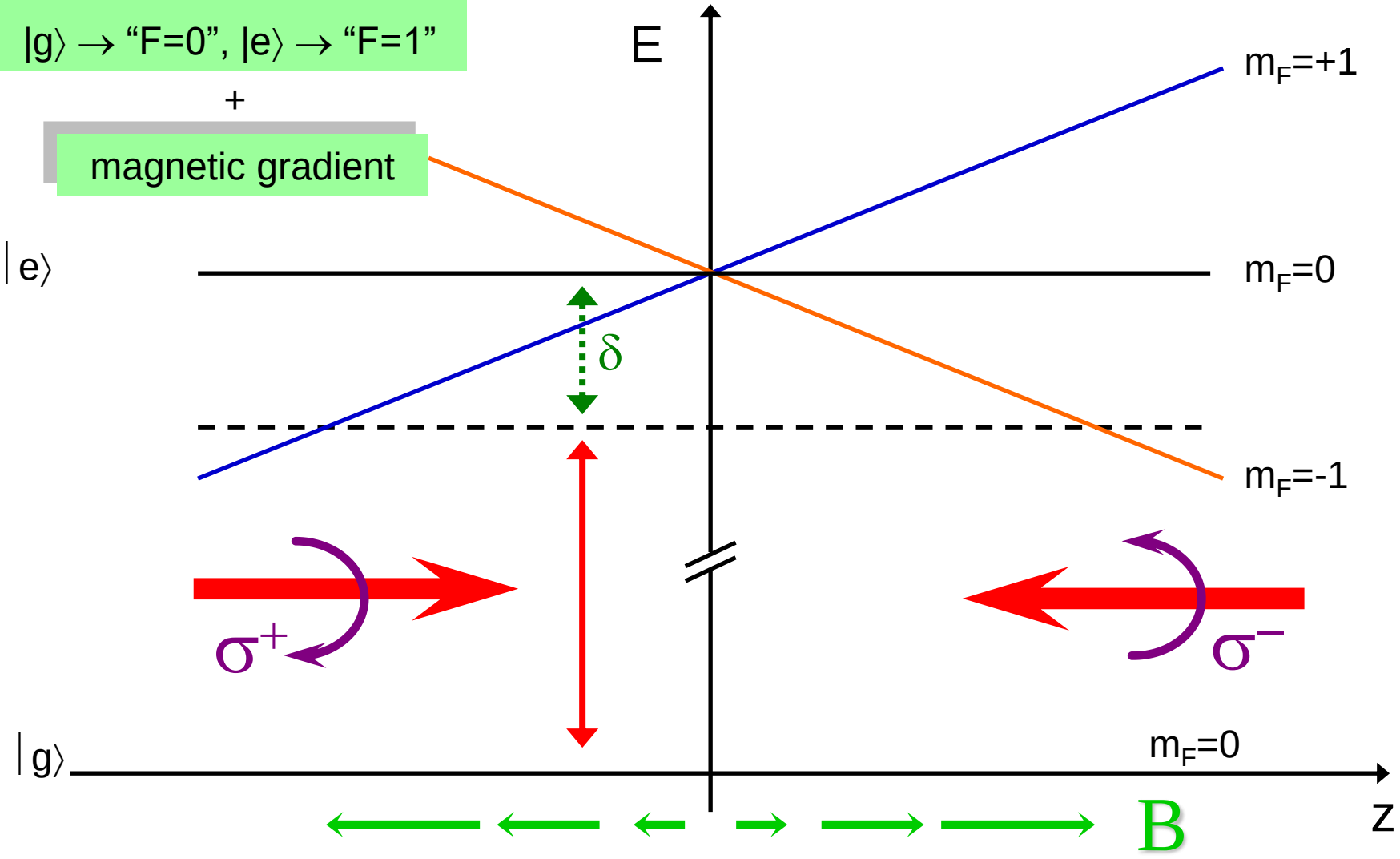

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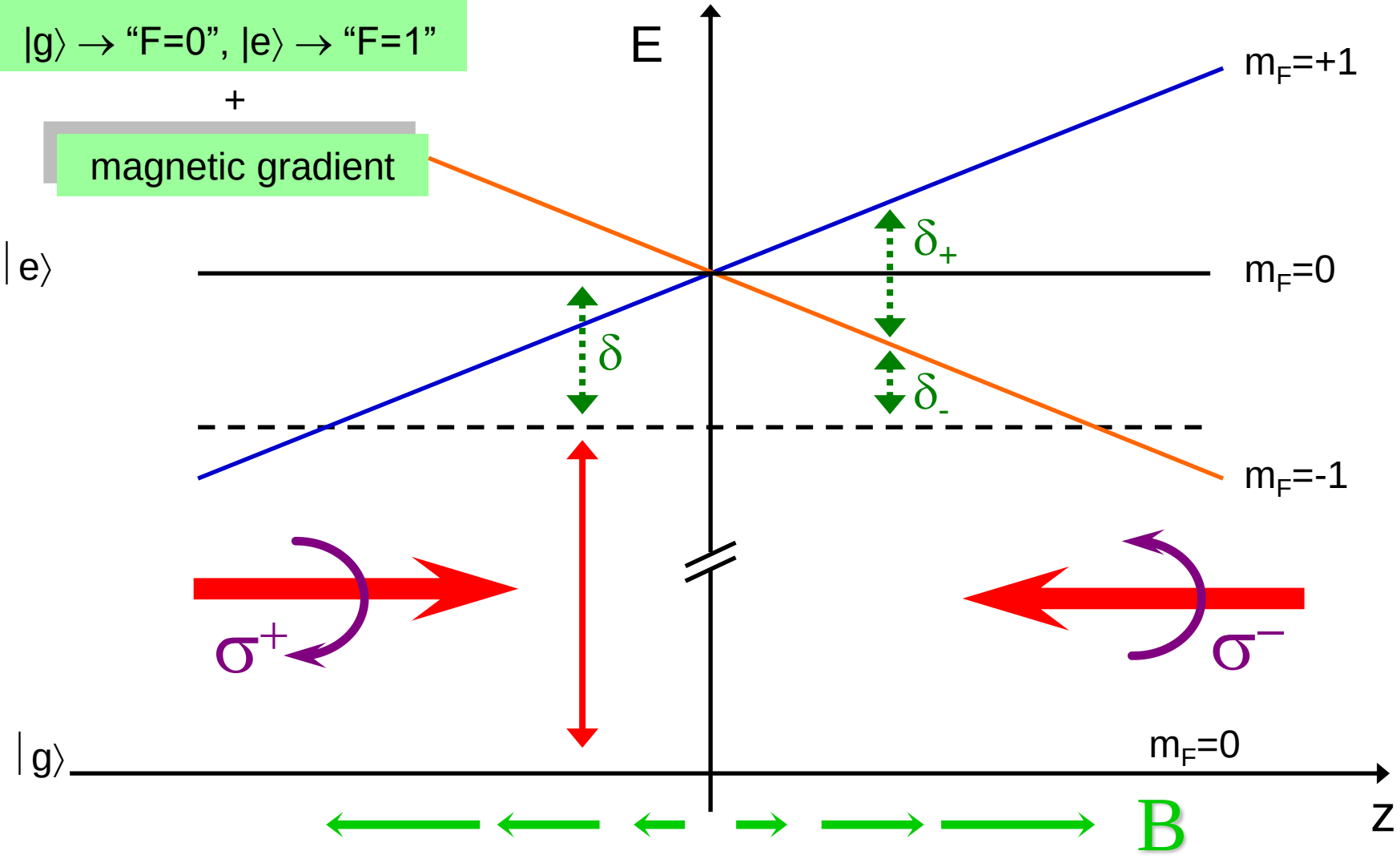

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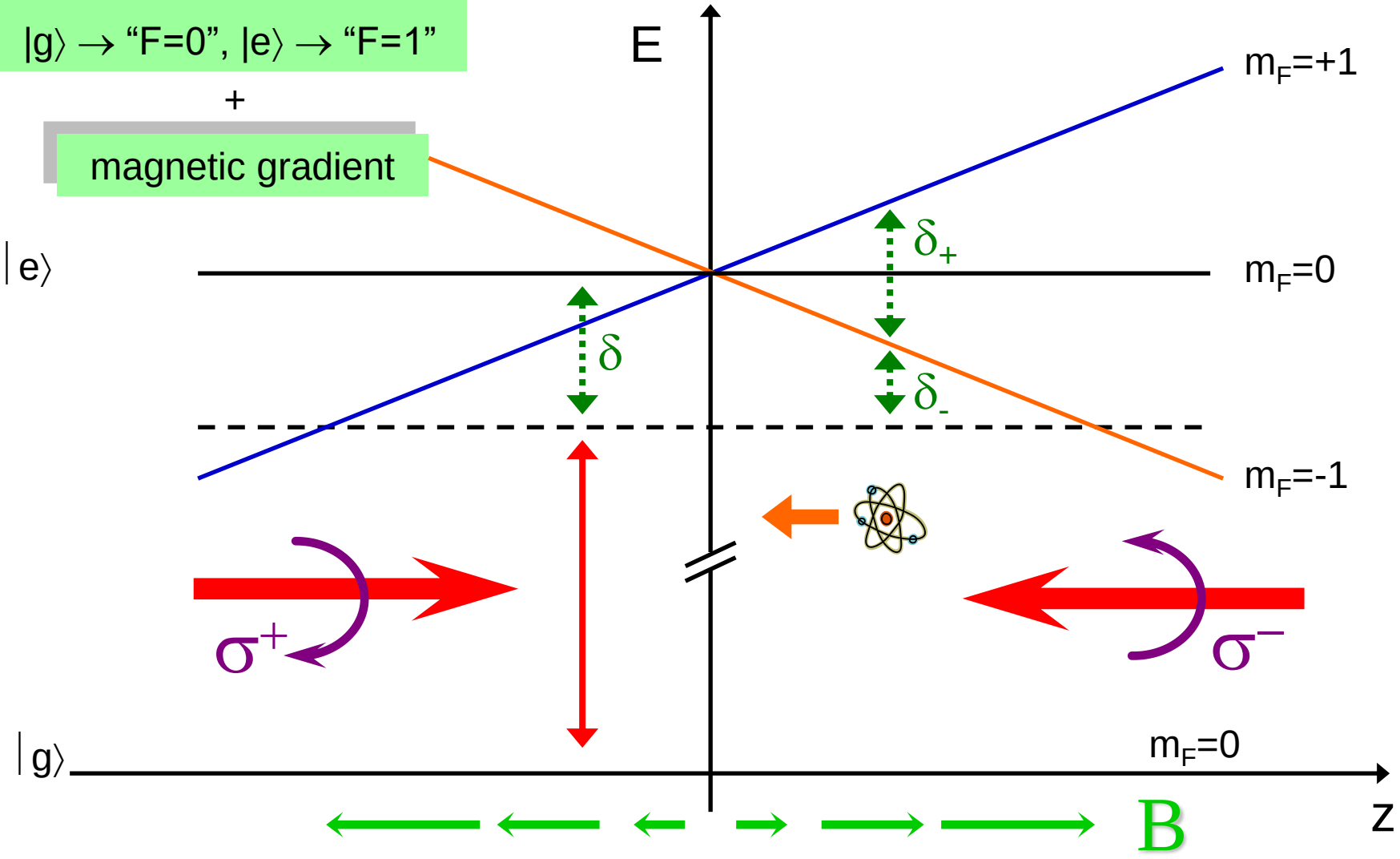

Magneto-Optical Trap (MOT)

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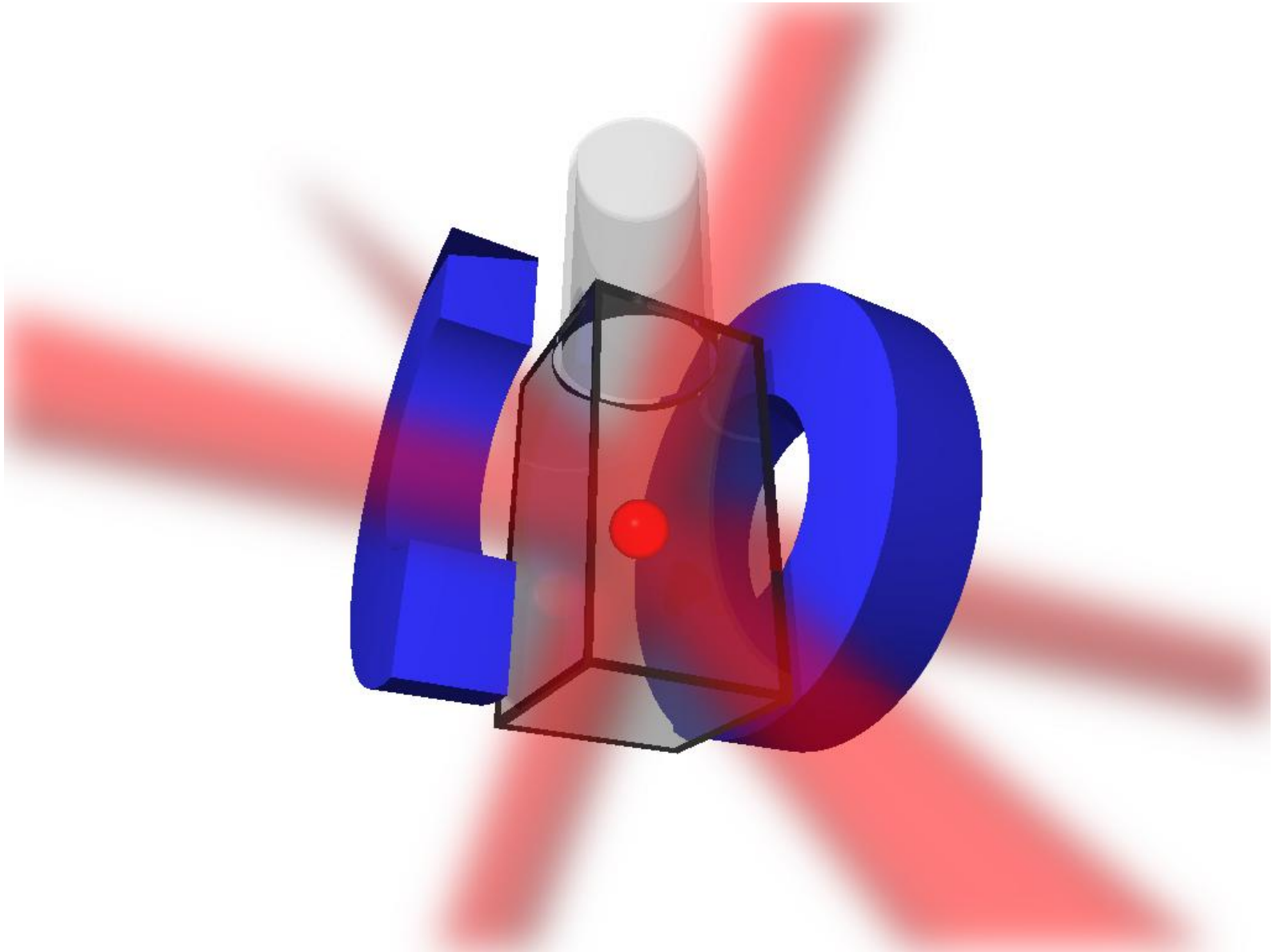

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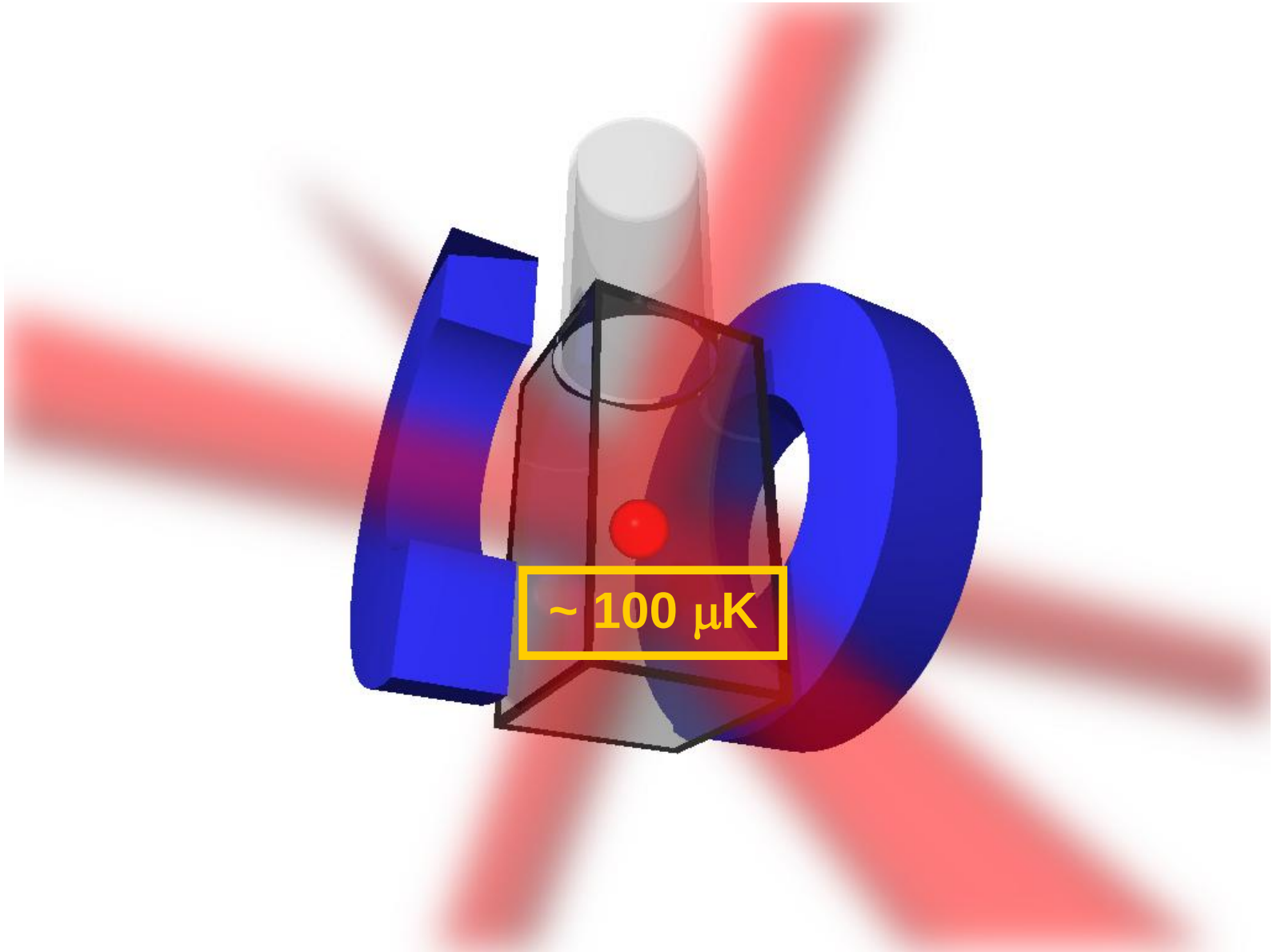

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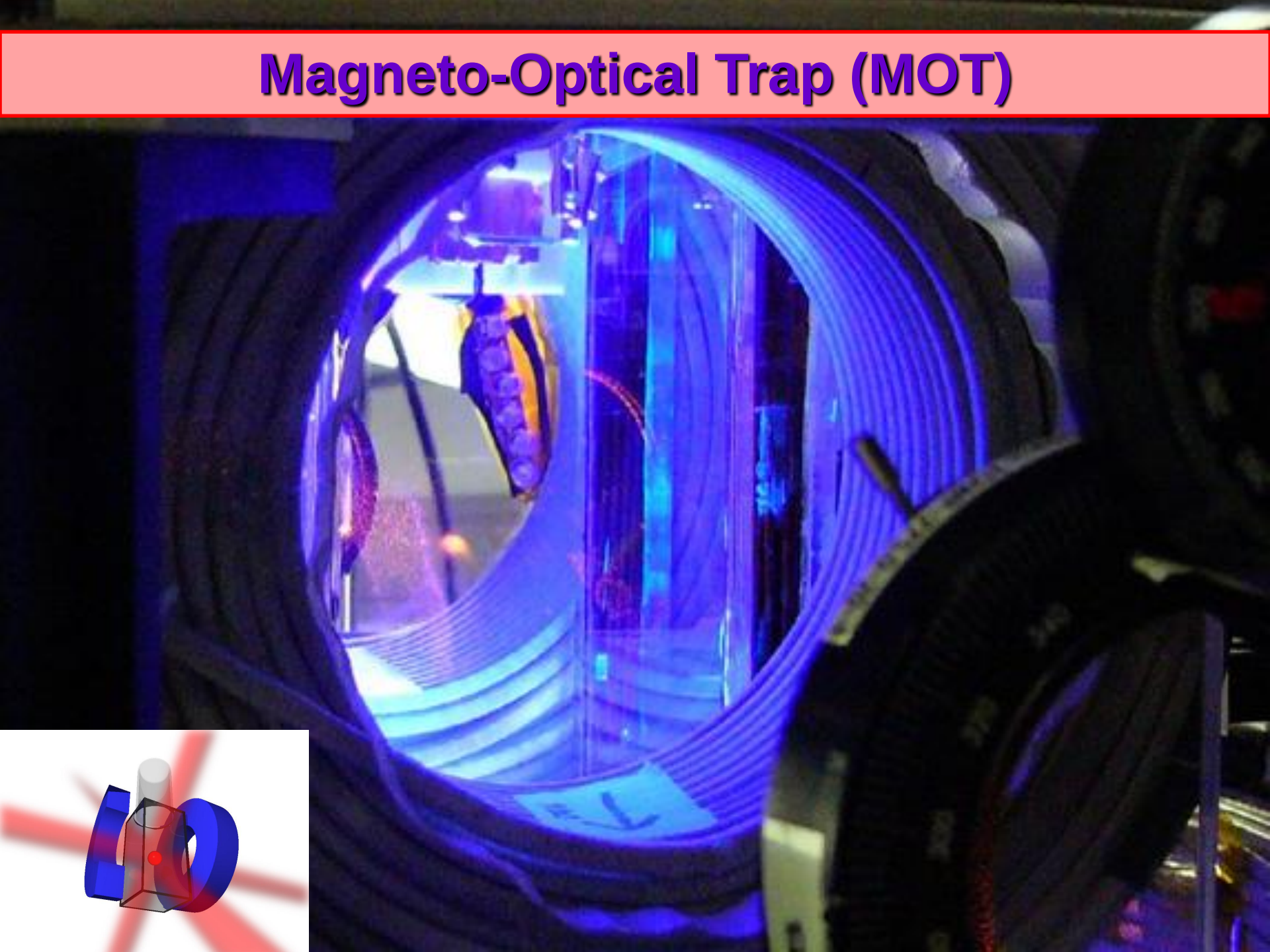

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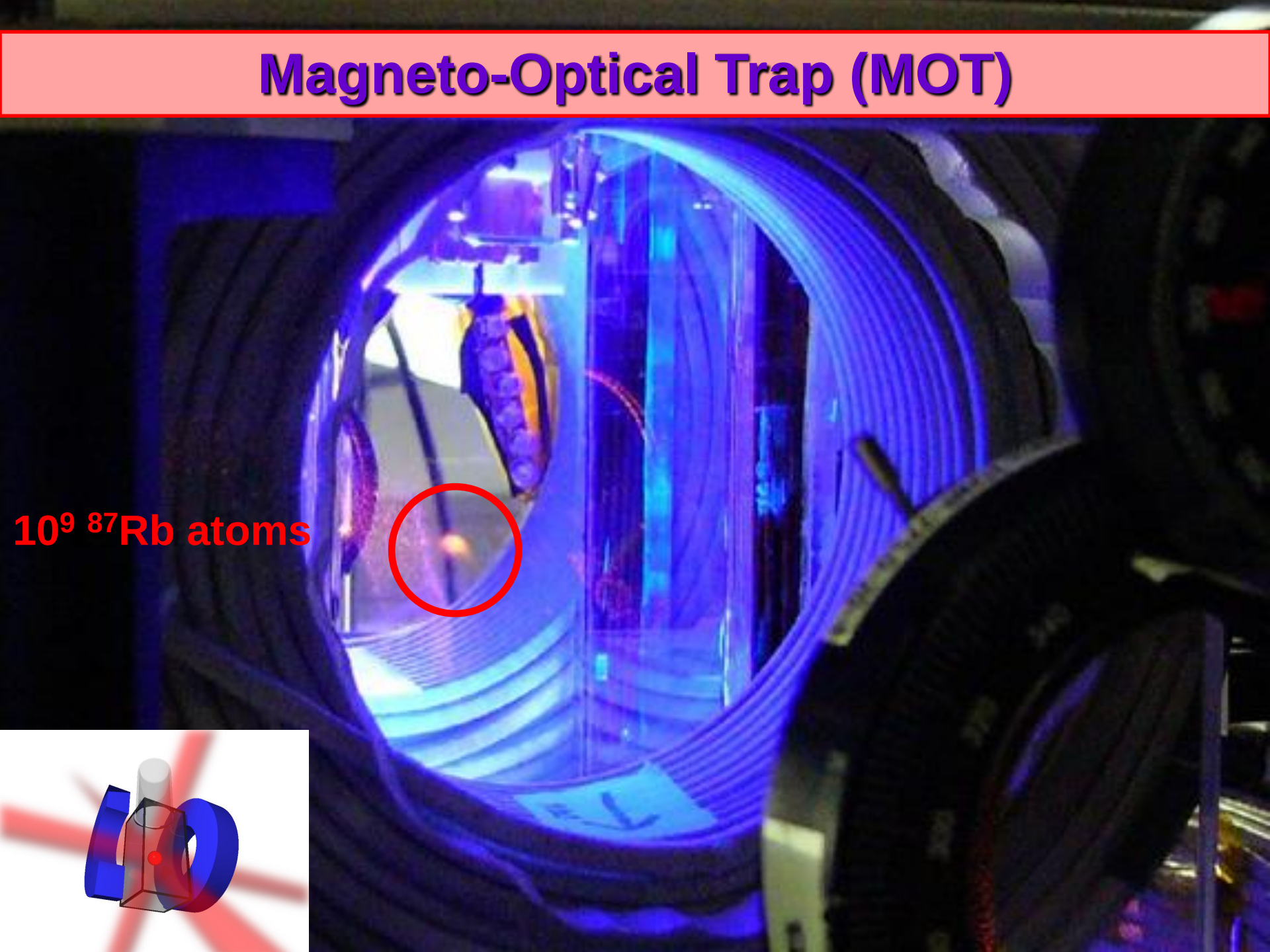

Francium MOT

PROBLEM: Accelerator produces only **10^6 Fr atoms/s**.

→ Very difficult to work with.

SOLUTION: **Attach a Francium Magneto-Optical Trap to the accelerator.**

→ Cold Francium is concentrated in **~1 mm^3** volume.

→ With **T < 100 μK**, Doppler broadening is negligible.

→ Long integration times.

→ Minimally perturbative environment (substrate free).

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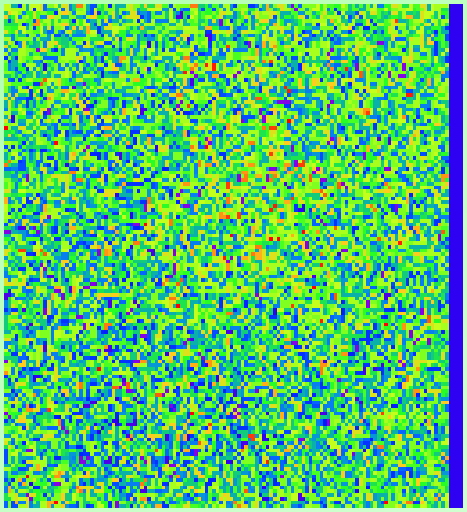

MOT collection efficiency ~ 1 %

MOT with ~10^5 ^{210}Fr atoms