Modern Physics (Phys. IV): 2704

Professor Jasper Halekas
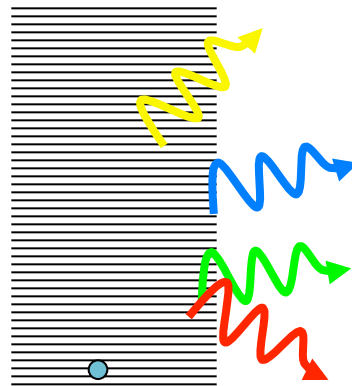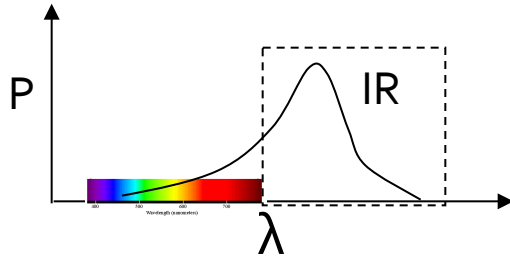Van Allen 70
MWF 12:30-1:20 Lecture

Lasers

"I have one simple request, and that is to have sharks with frickin' laser beams attached to their heads!" – Dr. Evil
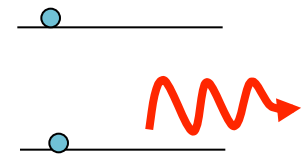
Lights

sources of light (traditional):

atom discharge lamps

light bulb filament

Hot electrons.
very large # close
energy levels (metal)
Radiate spectrum of
colors. Mostly IR.

Electron jumps
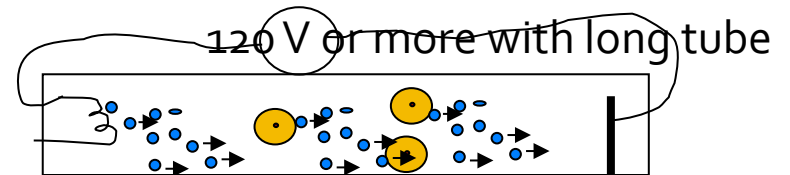to lower levels.

Only specific
wavelengths.

120 V or more with long tube

P

IR

λ

- Light from extended source
- Going different directions
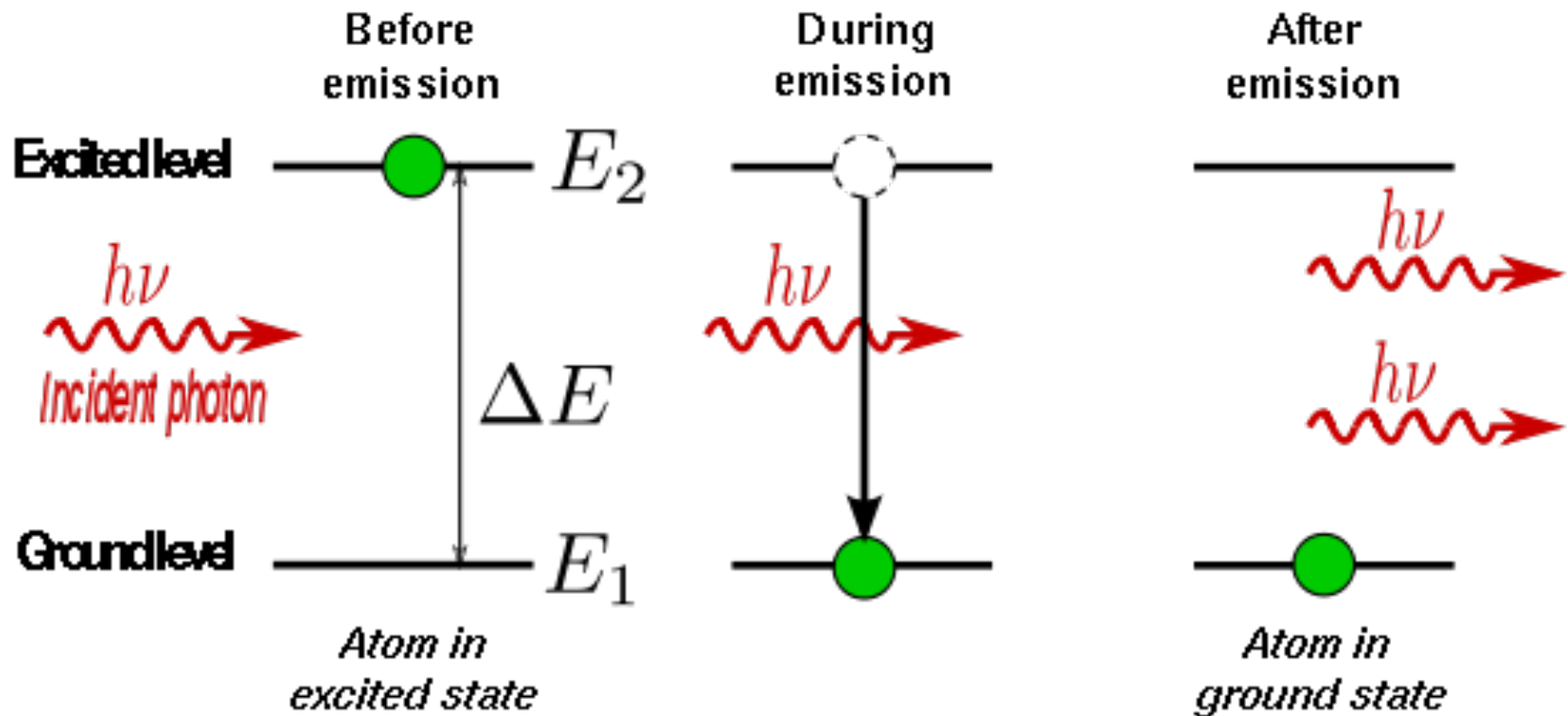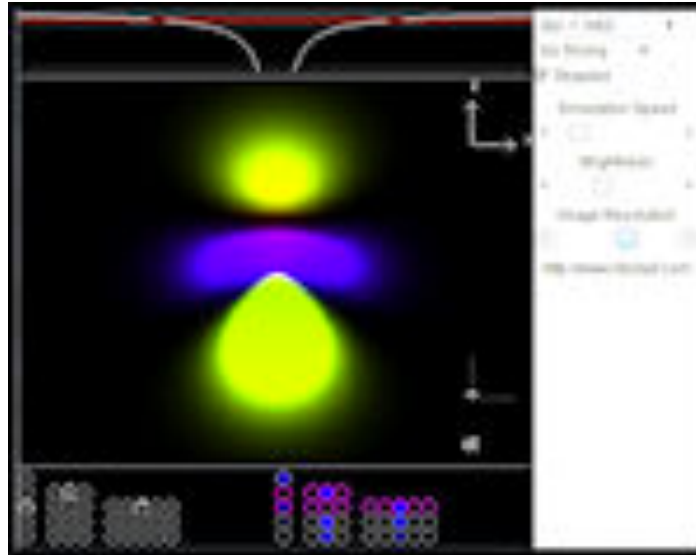- Range of wavelengths

Atomic Transitions
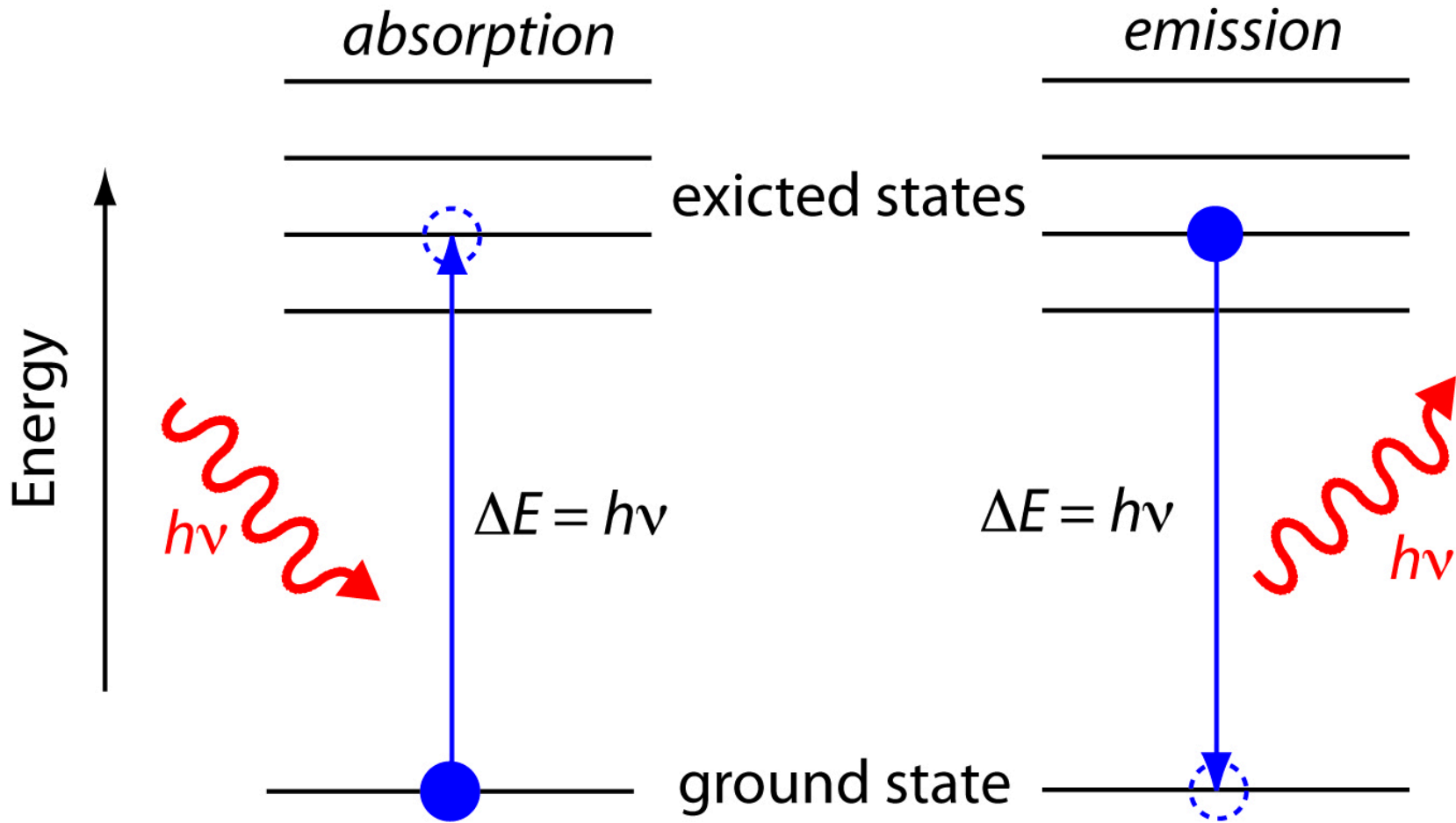
Stimulated Emission

$$E_2 - E_1 = \Delta E = h\nu$$

Atomic Dipole Transitions
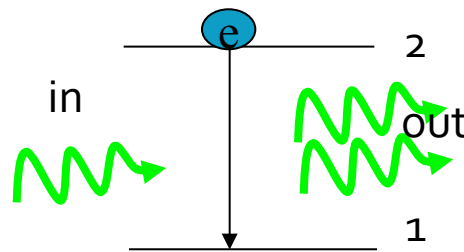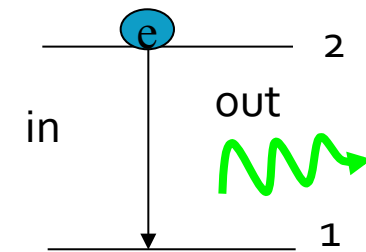
http://www.falstad.com/qmatomrad/

Emission/Absorption Processes
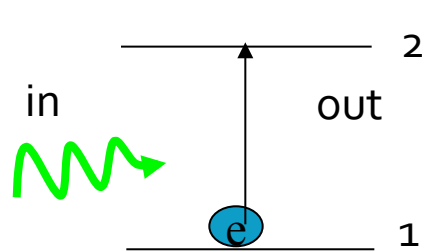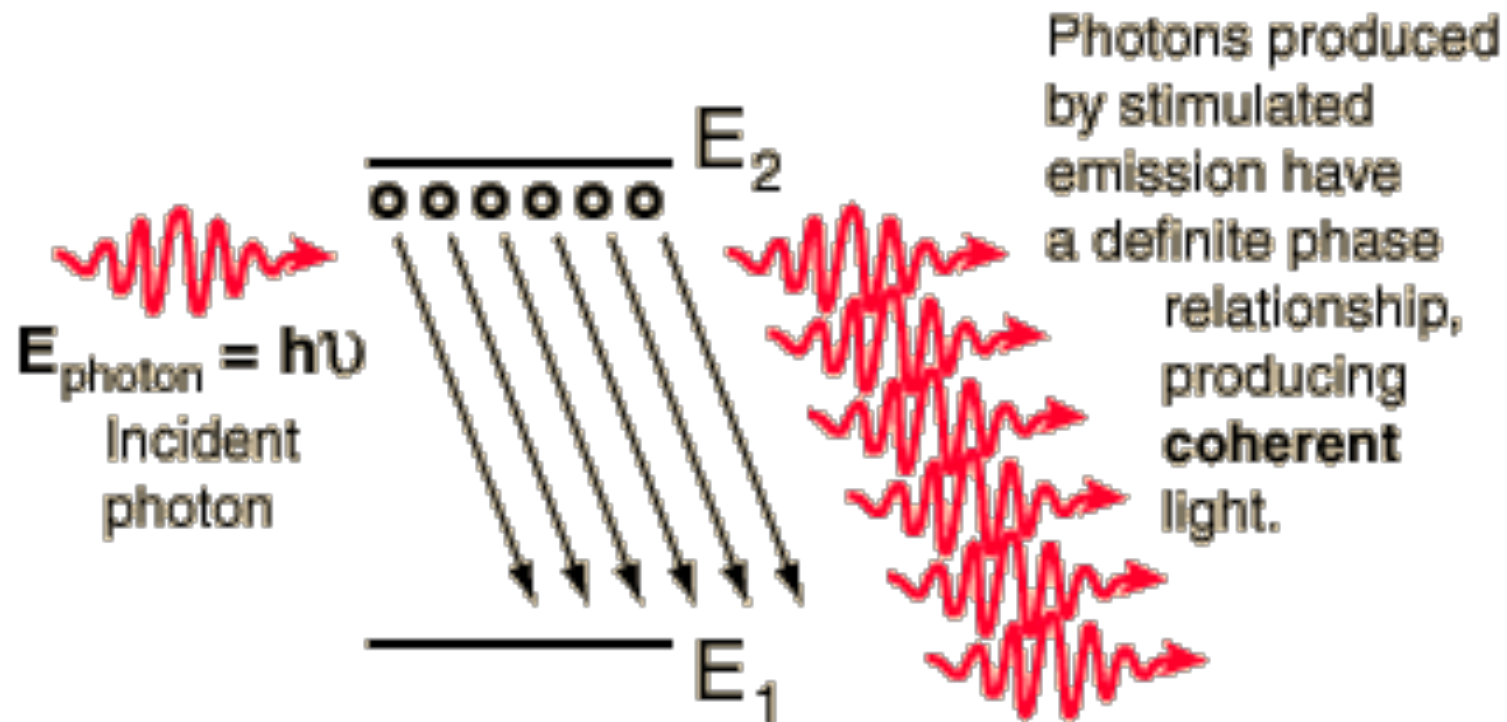
absorption
(of light)

stimulated
emission
(of light)

spontaneous
emission (of light)
(After elec. coll. or
light excited atom)

Surprising fact. Chance of stimulated emission of excited atom **EXACTLY** the same as chance of absorption by lower state atom. Critical fact for making a laser.

Coherence

E_2

$E_{photon} = h\upsilon$

Incident photon

E_1

Photons produced by stimulated emission have a definite phase relationship, producing **coherent** light.

Concept Check

Glass tube below, full of atoms, like discharge lamp. Some excited, some not excited.
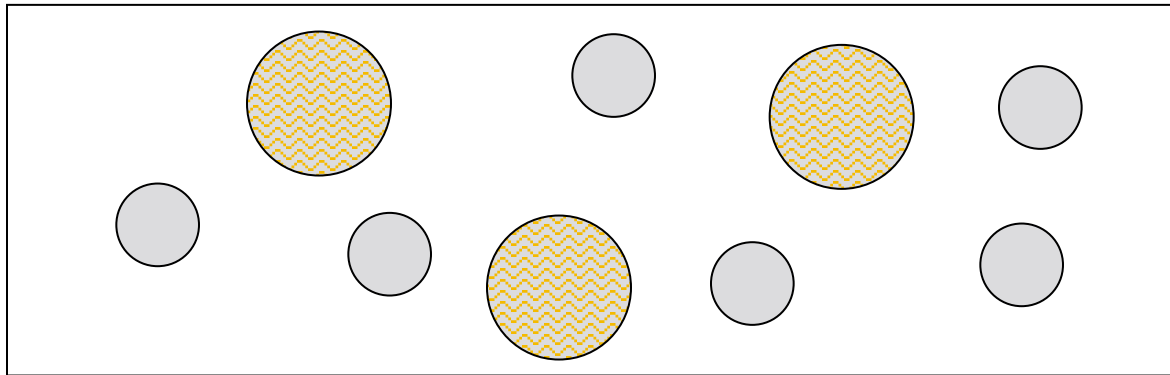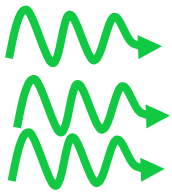
For the condition above (3 atoms excited, 6 atoms not excited): what do you expect?

a.   More photons will come out right hand end of tube,
b.   Fewer photons will come out right hand end of tube
c.   Same number as go in,
d.   None will come out.

Concept Check

Glass tube below, full of atoms, like discharge lamp. Some excited, some not excited.
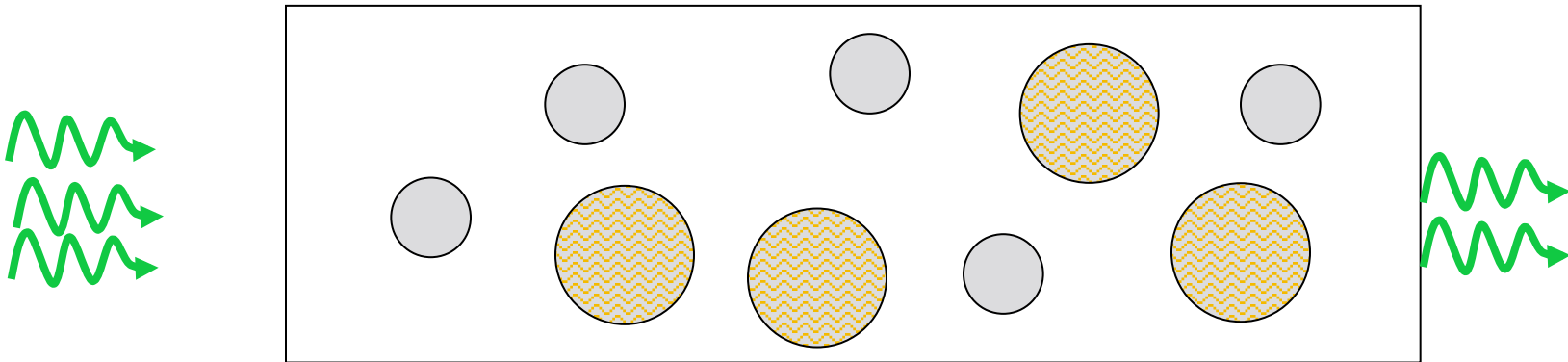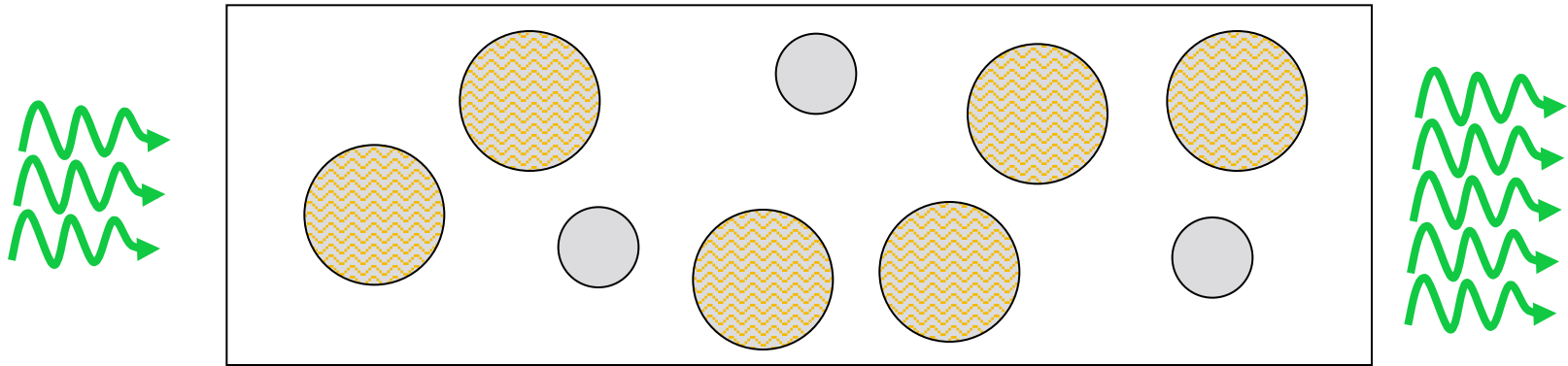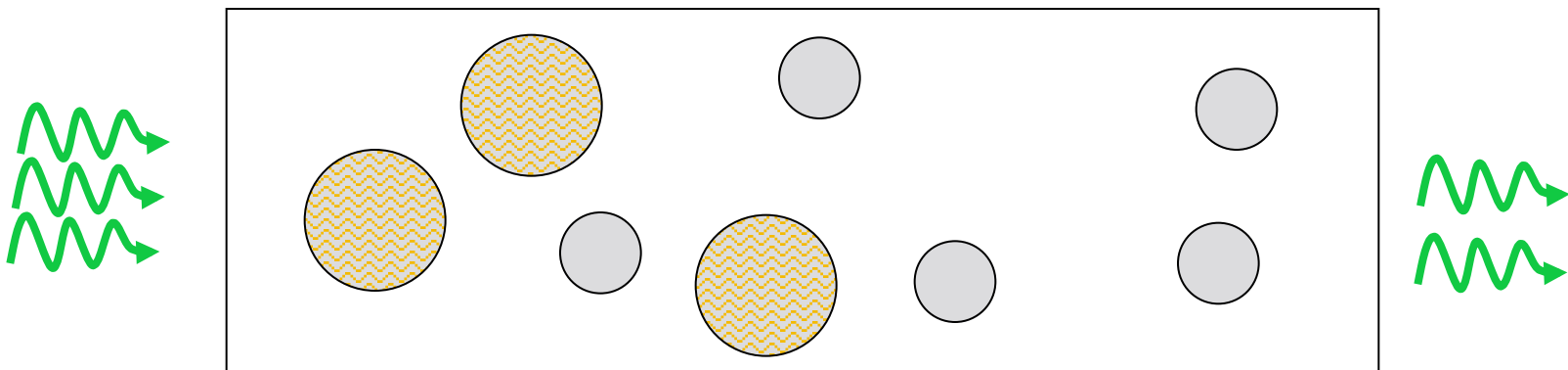

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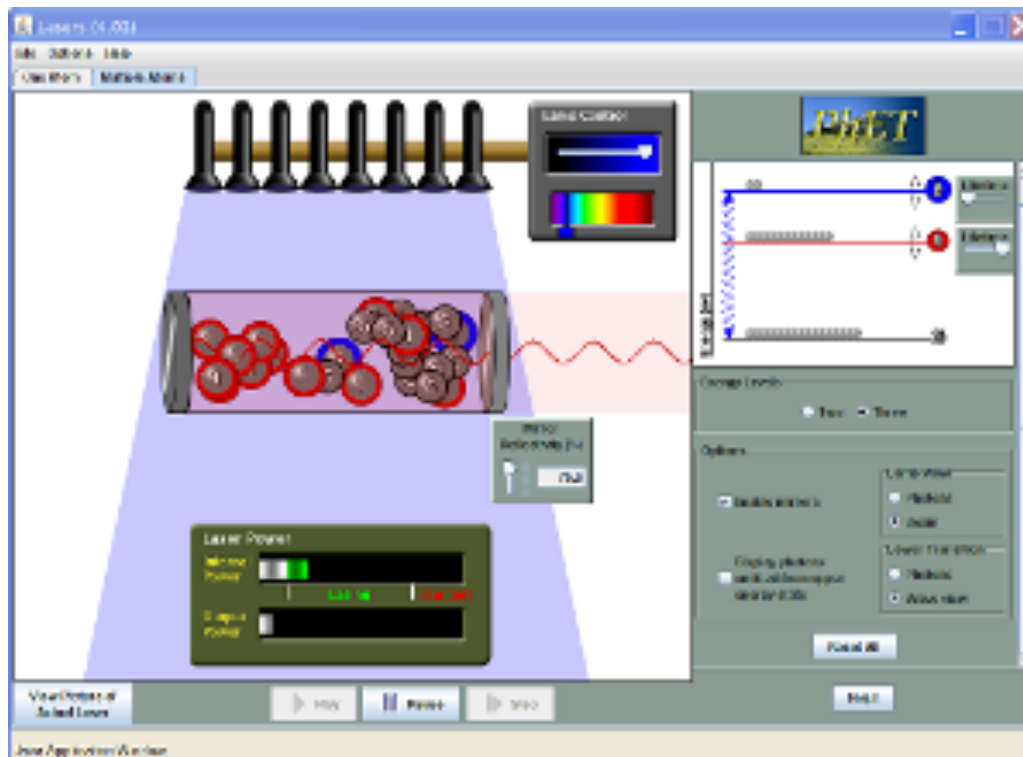d.   None will come out.

Population Inversion

$N_{upper} > N_{lower}$ (more reproduced than eaten)

$N_{upper} < N_{lower}$ fewer out than in.
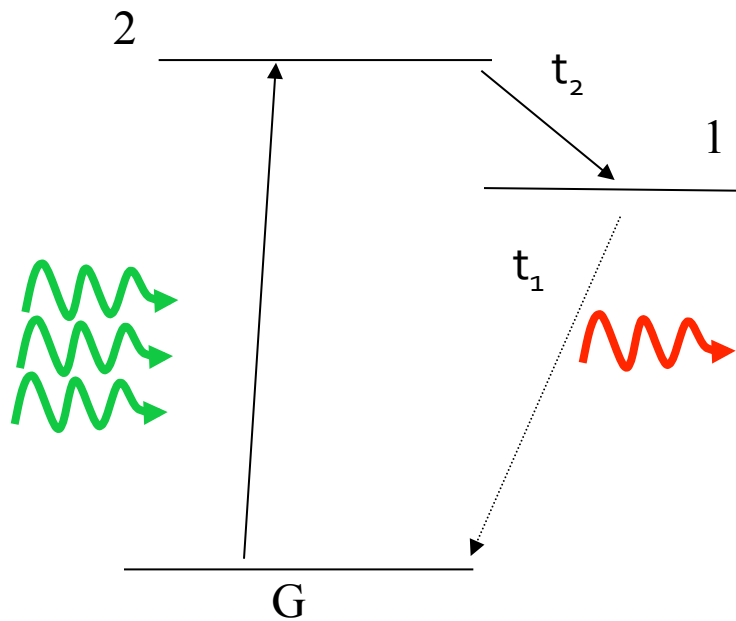
Laser Simulation

- https://phet.colorado.edu/en/simulation/lasers

Trick Number One

- Two-level systems won't work
  - If you get a population inversion, more atoms fall back to ground state
  - Need (at least) a three-level system

"pumping" process to
produce population inversion

To create population inversion between G and level 1 would need:

a. time spent in level 2 (t_2) before spontaneously jumping to 1 is long, and time spent in level 1 (t_1) before jumping to G is short.

b. $t_1 = t_2$

c. t_2 short, t_1 long

d. does not matter

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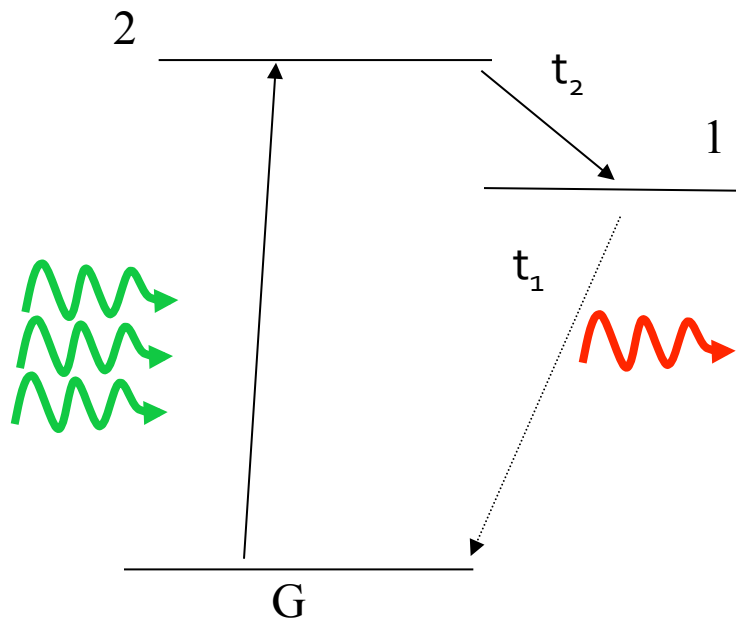 - Need (at least) a three-level system

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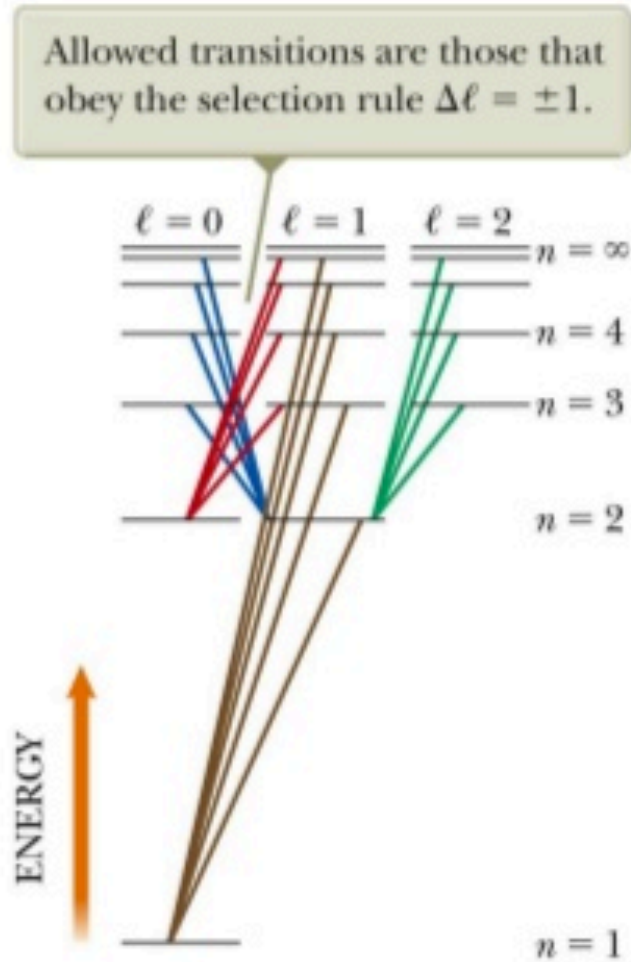To create population inversion between G and level 1 would need:

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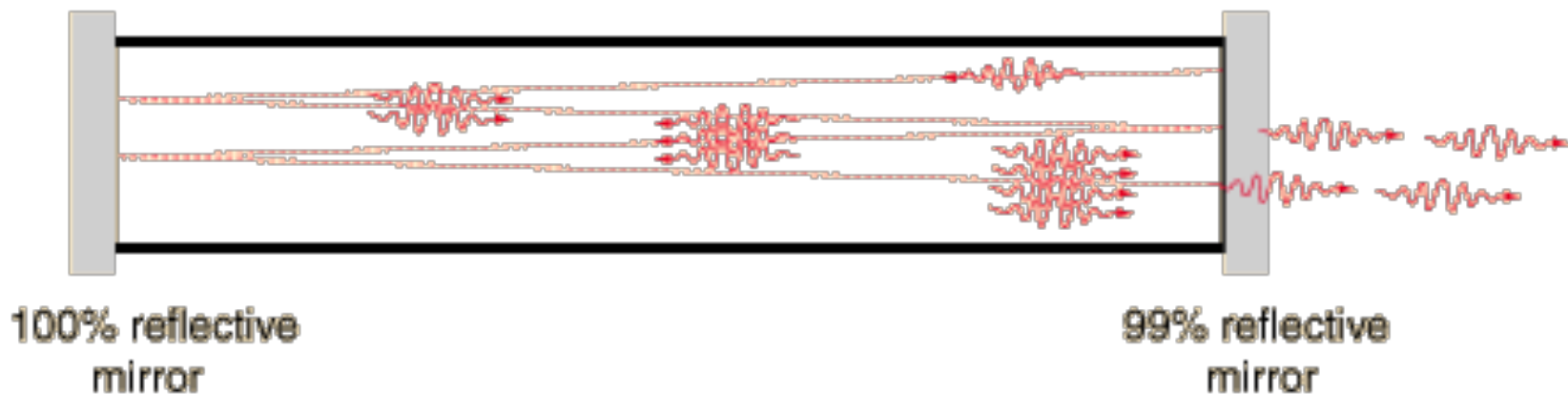
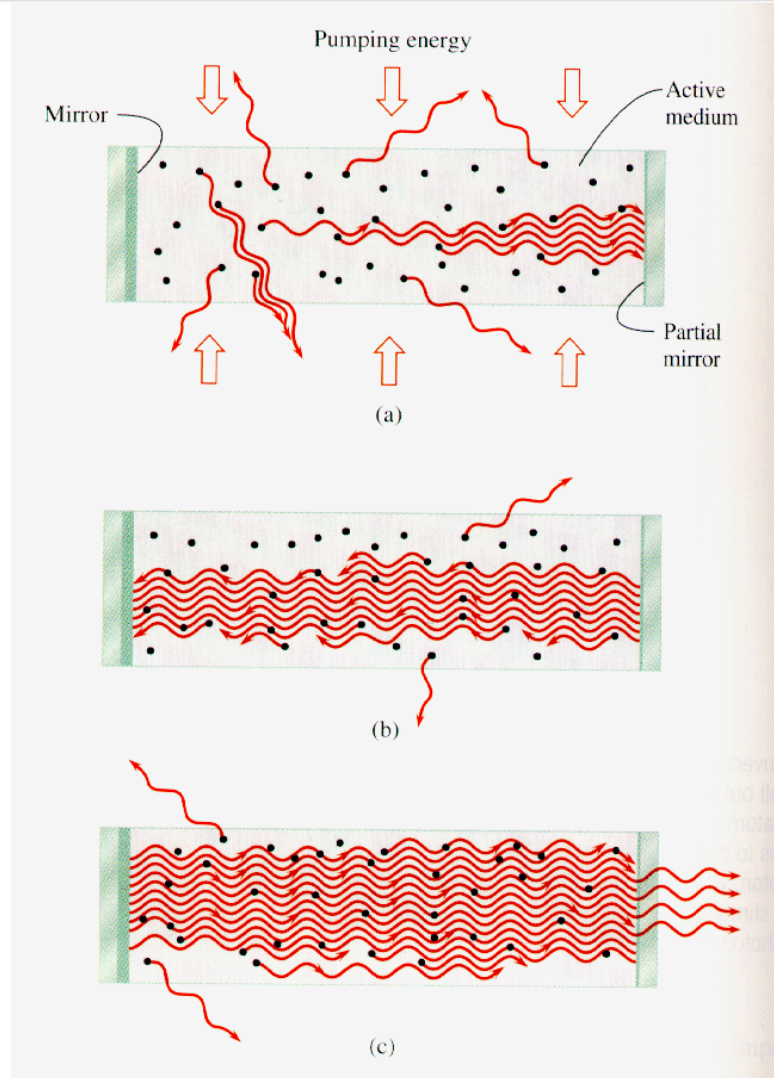c. t_2 short, t_1 long

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Metastable States

Allowed transitions are those that obey the selection rule $\Delta\ell = \pm 1$.

Trick Number Two

- Use your photons more than once!

Light Amplification by Stimulated Emission of Radiation
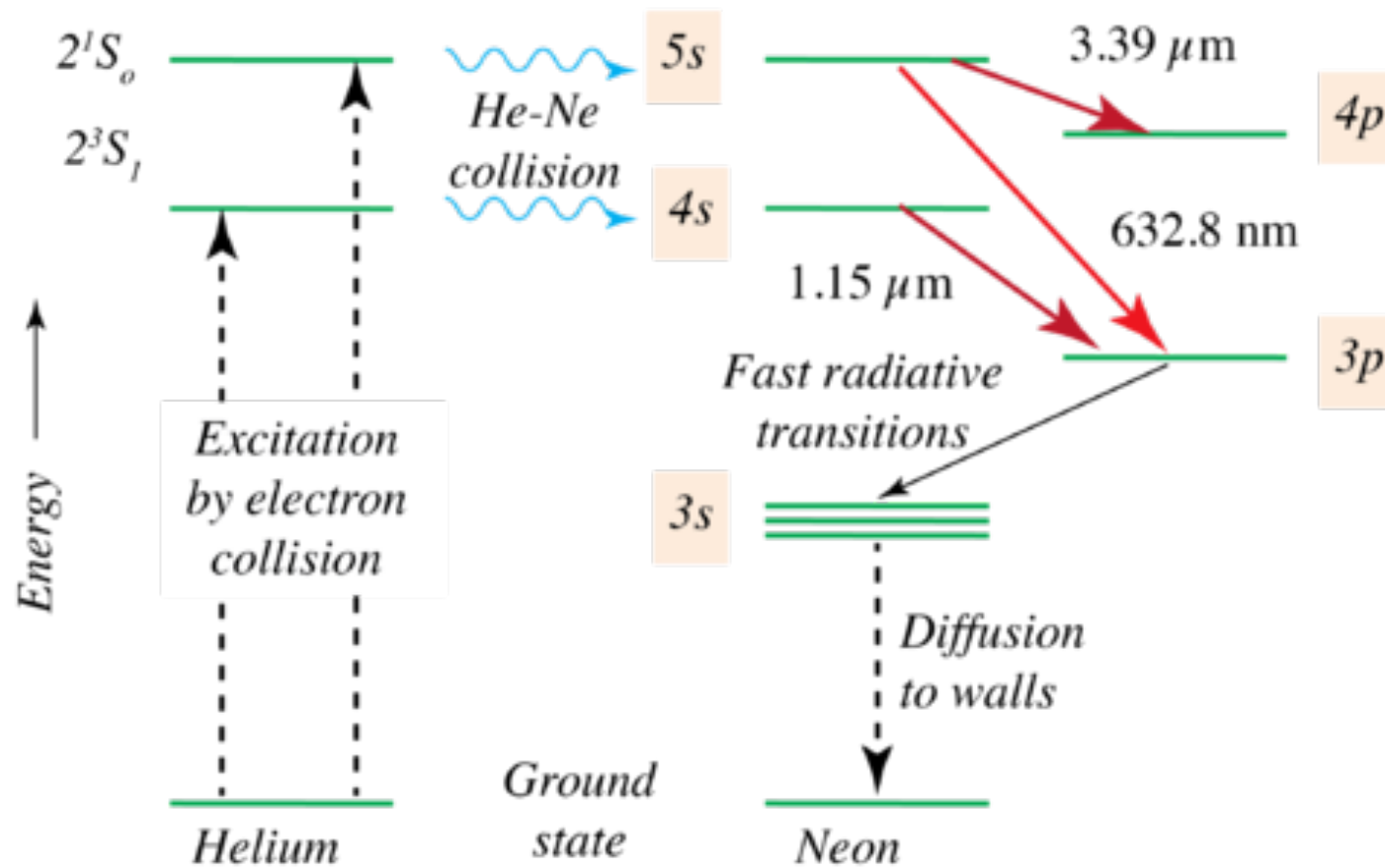
100% reflective mirror

99% reflective mirror

Laser Process

Helium Neon Laser
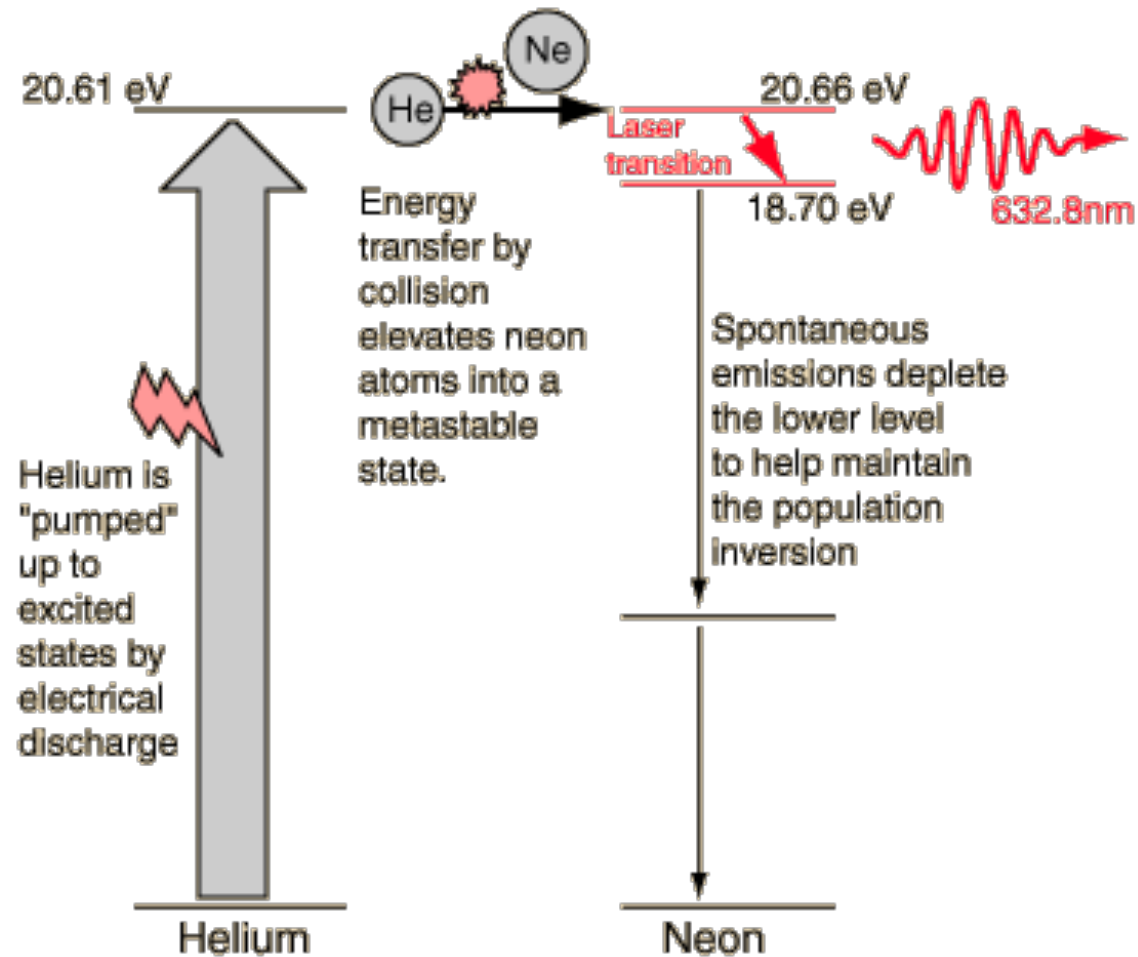
Helium Neon Energy Levels

Helium & Neon Visible Lines