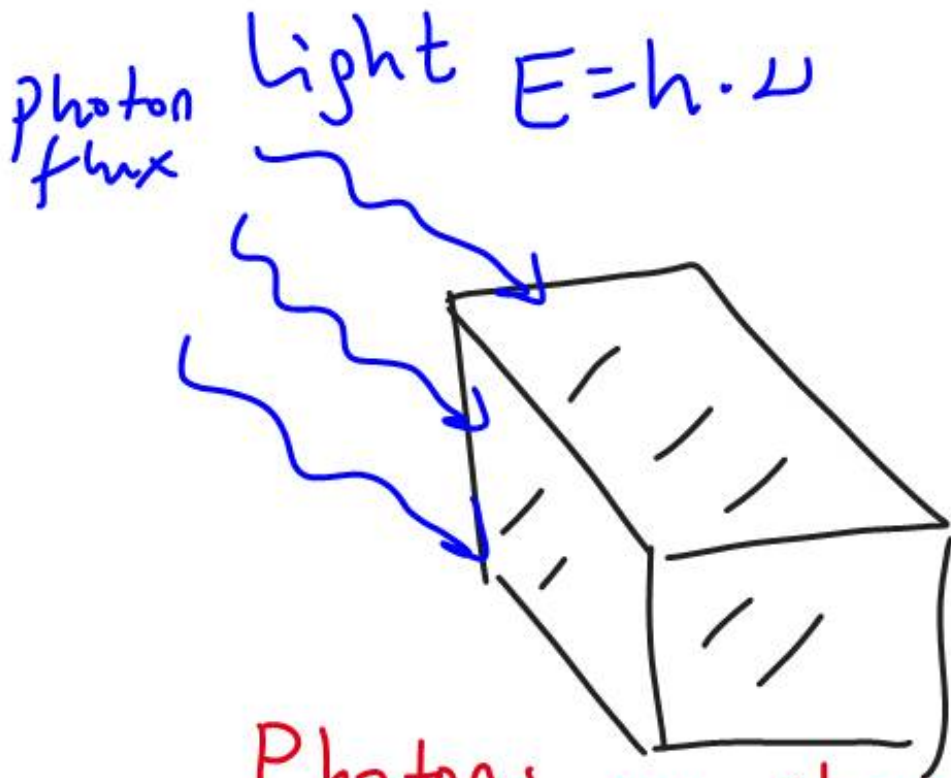


02.10.2012
ECE 631

Celal Zaim Çil
©

For Lasing \Rightarrow

- population inversion
- Stimulated emission



Photons are absorbed
transmitted
or reflected

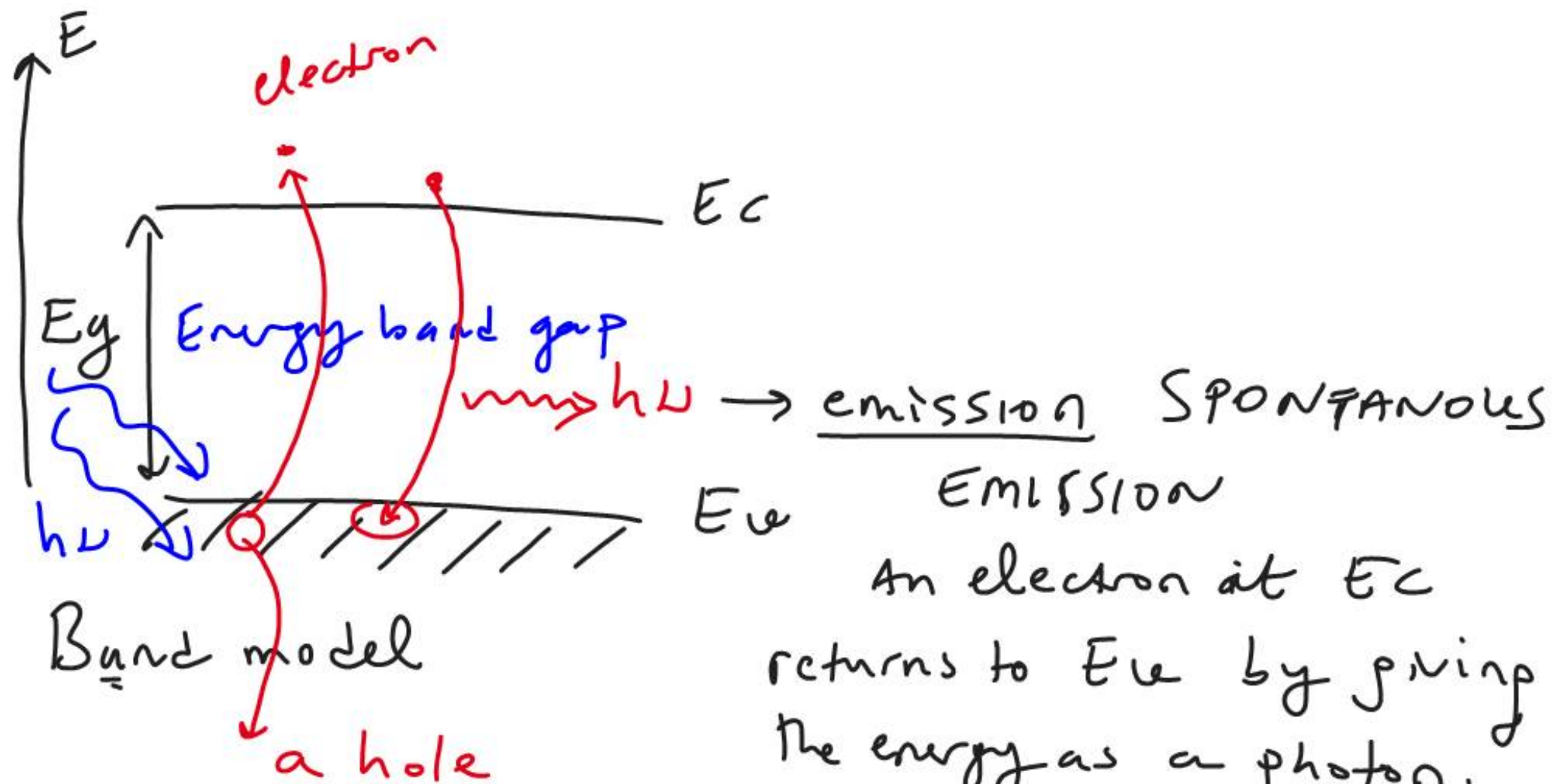
$$\text{Photon flux} = \frac{p \cdot h \nu}{t} \quad \left. \vphantom{\frac{p \cdot h \nu}{t}} \right\} \text{(Watt)}$$

p : # of photons

t : time

$\frac{p}{t}$ = # of photons
per second

h : Planck's constant
 ν = frequency (Hz)



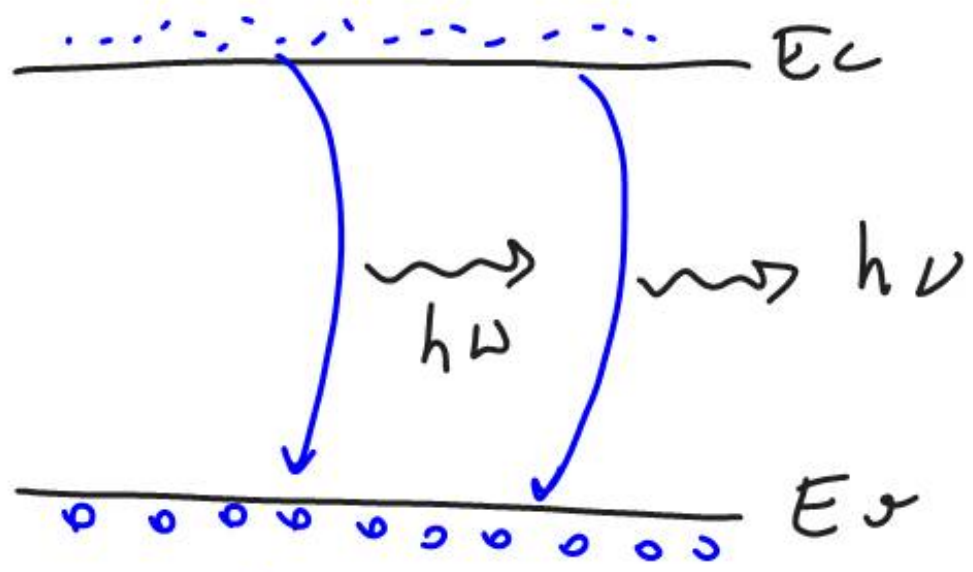
ABSORPTION

The energy of the photon
 is absorbed by the material
 and an electron-hole pair is created.
 An electron is excited to the E_c level.

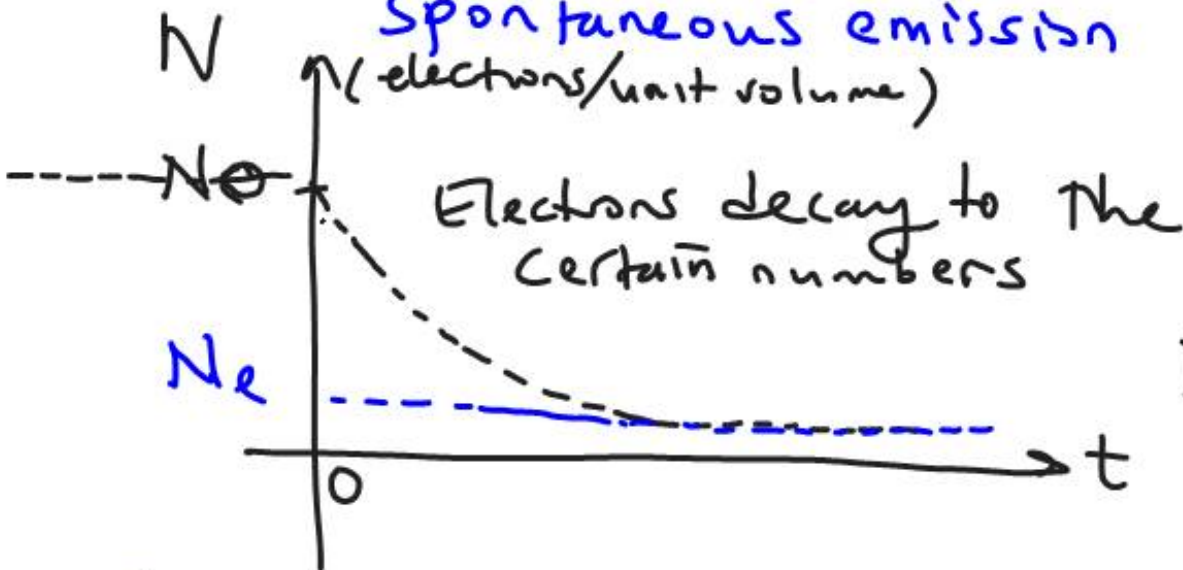
$$h\nu = E_g$$

E_g is a characteristic property of a material.

E_g	Material	Photons (light) h. ν
0.6 eV	Ge	Intra-red (IR) $E_g = h\nu$
1.1 eV	Si	IR $1.1 \text{ eV} = h\nu$
1.4 eV	GaAs	Red $\nu = \frac{1.1 \text{ eV}}{h}$
2.5 eV	GaN	Blue
5 eV	Glass	no photon
	⋮	



Spontaneous emission
(electrons/unit volume)

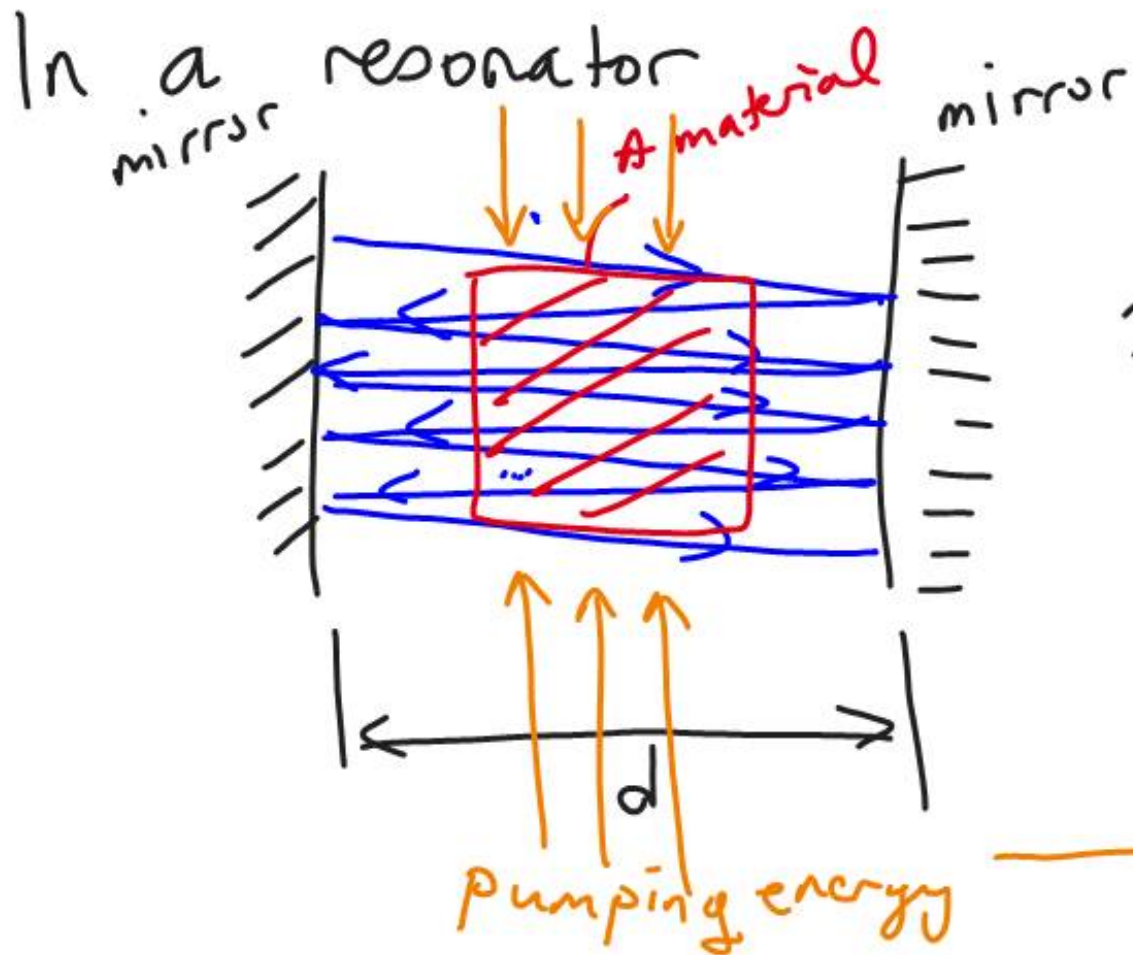


$$N = N_0 e^{-t/\tau} + N_e$$

N_e : equilibrium # of electrons

For STIMULATED EMISSION we need an OPTICAL FIELD.

How we generate the optical field?



We can obtain the required photon field with ~~a~~ parallel mirrors (resonator).

But we need more!

Population inversion

Classical Theory:

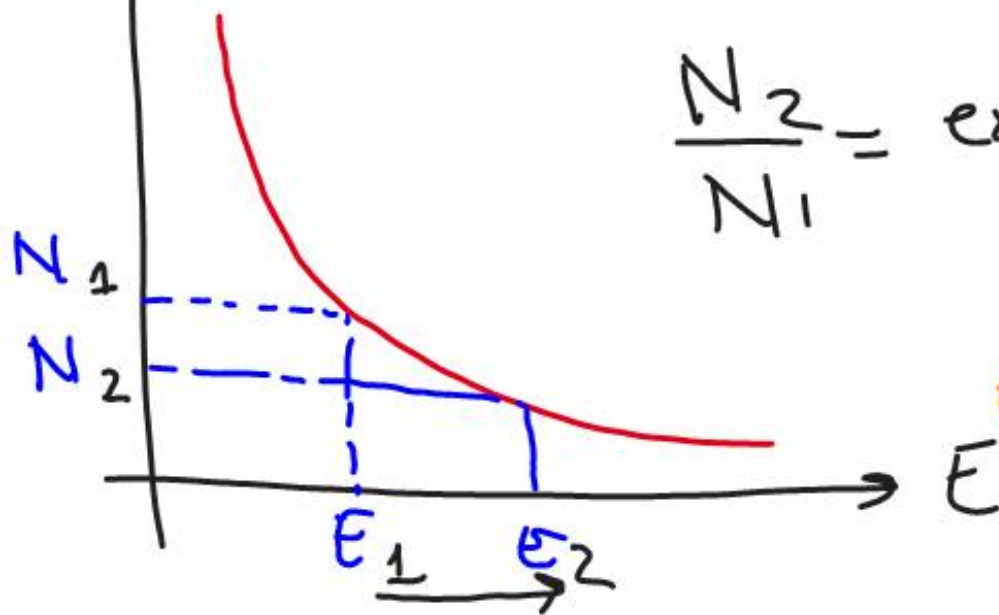
In a system there are always less number of carriers at the higher energy level than at the lower energy level.

k : Boltzmann Constant

BOLTZMANN STATISTICS

T : Absolute temp.

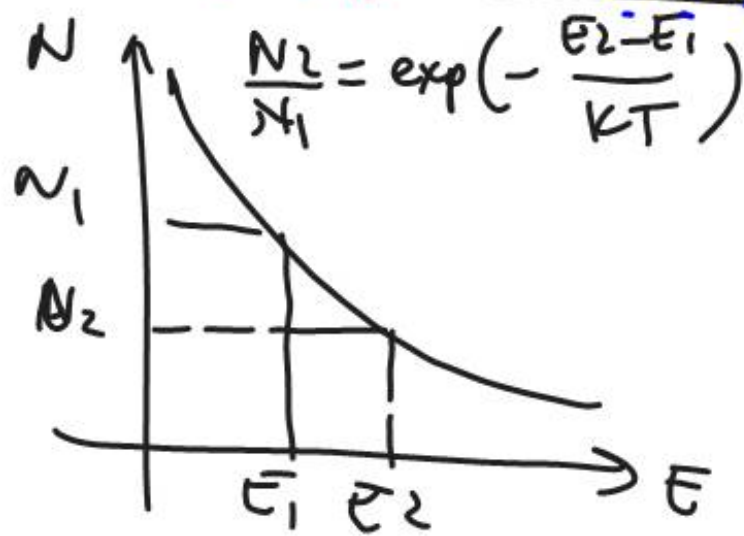
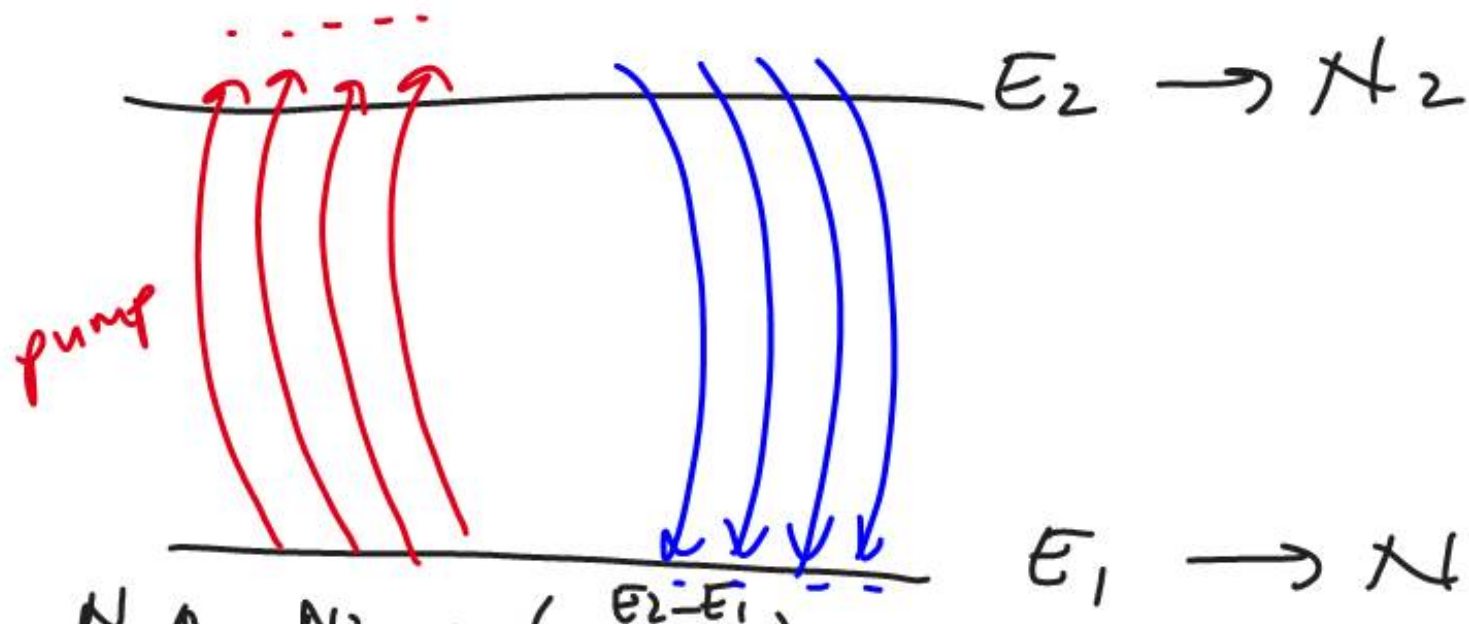
N ↑ # of carriers



$$\frac{N_2}{N_1} = \exp\left(-\frac{E_2 - E_1}{kT}\right)$$

The higher the energy level, the lower the population

a 2-level energy system:



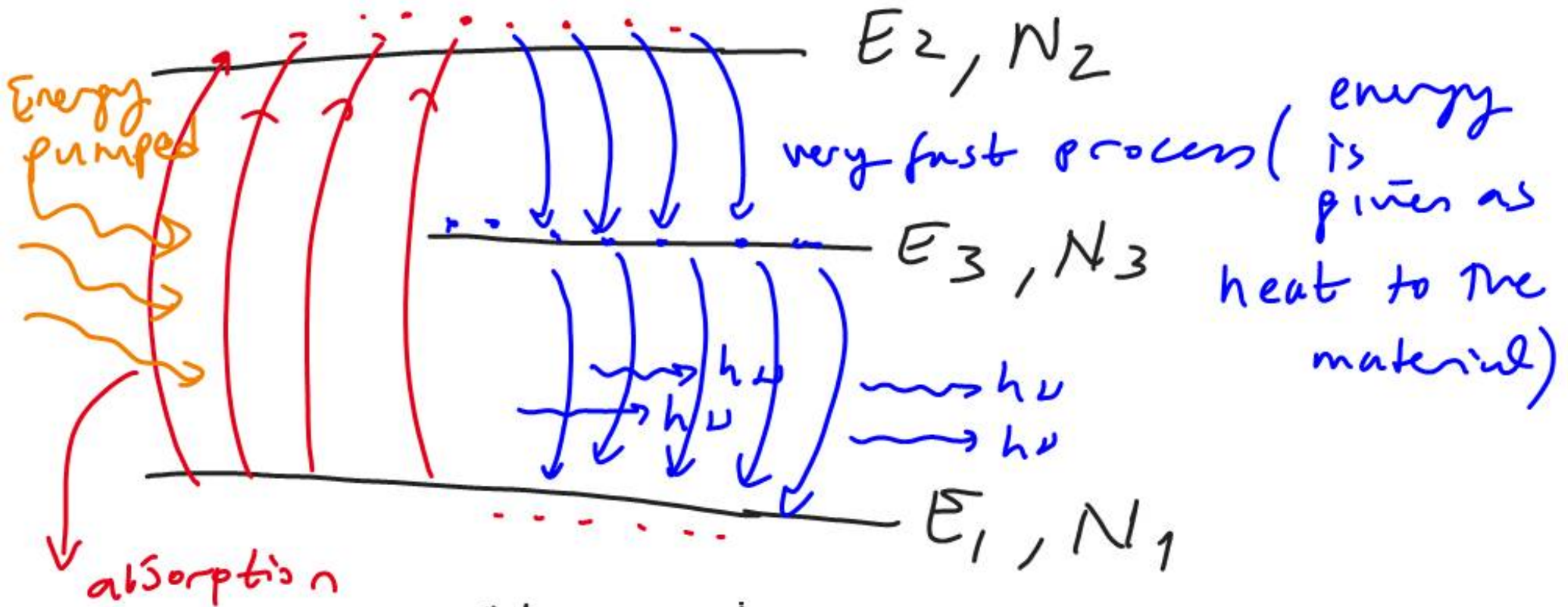
It is not possible to get population inversion in a 2-level system

You need $kT < 0$

($T < 0$) negative temp. !!!
absolute

$$N_1 > N_2$$

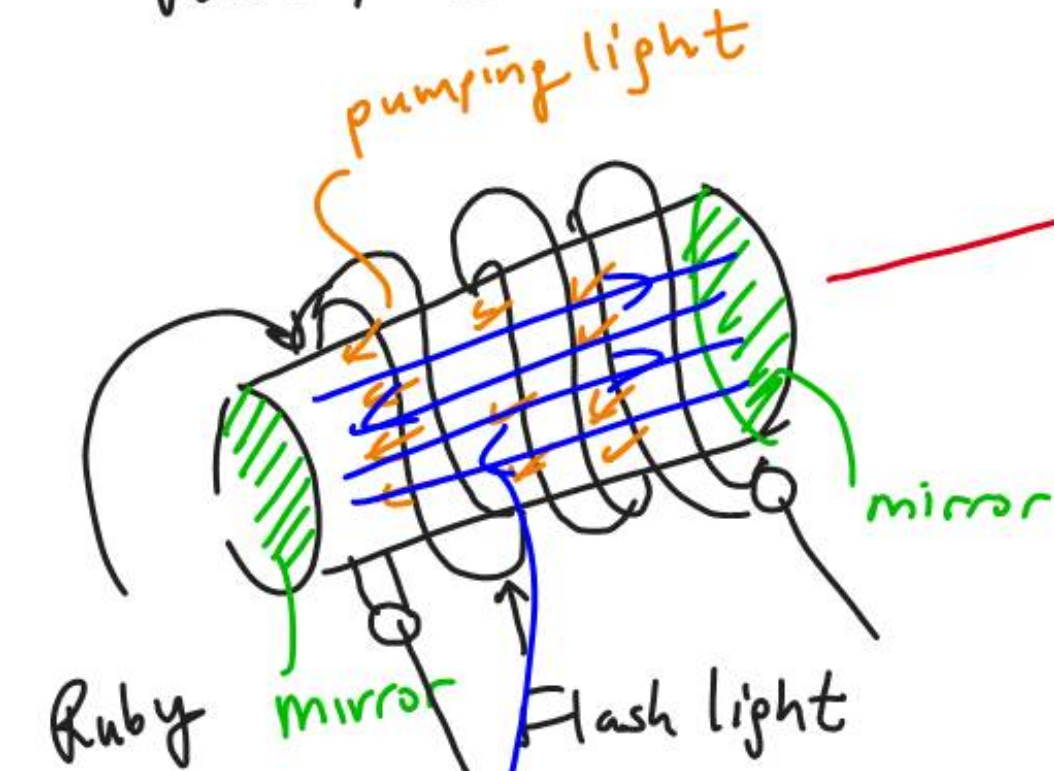
a 3-level system:



N_3 can be bigger than N_1
($N_3 > N_1 \Rightarrow$ POPULATION INVERSION)

Example: a 3 level Laser

RUBY CRYSTAL



Laserlight
of photons

- same energy
- same direction
- same phase
etc.

population
inversion
is obtained
by 3 energy levels
of Cr atoms in RUBY.

photon field
in the resonator.

pulse operation is
possible only
and the crystal is heated
up to high temperatures:
It should be COOLED.

