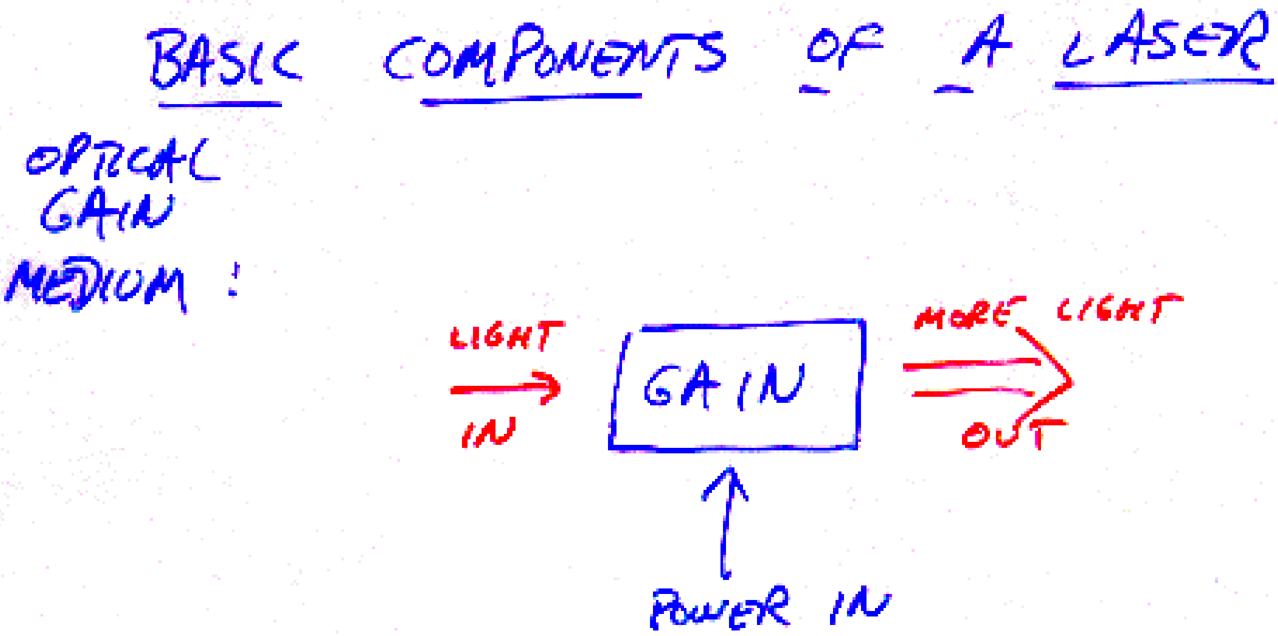
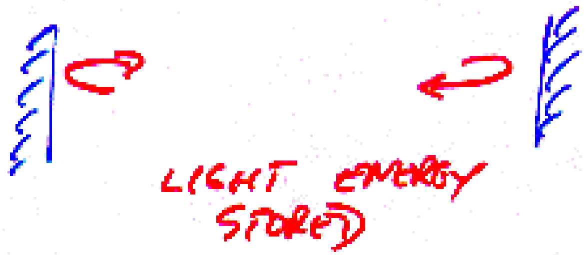
Lasers are a natural choice as a Spectroscopic tool. But what exactly are they?



OPTICAL RESONATOR:

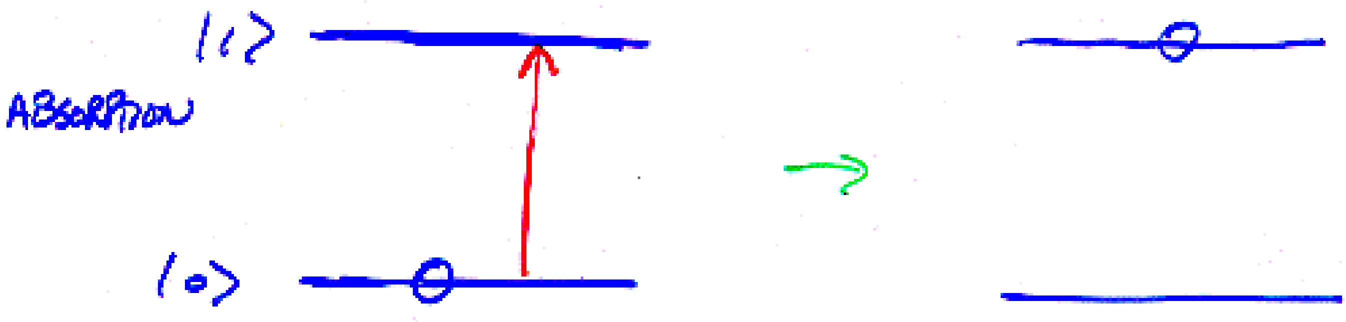


LASER:

CIRCULATING POWER $\Rightarrow$ GAIN = LOSS

HOW TO GET OPTICAL GAIN

CONSIDER A TWO-LEVEL SYSTEM CONNECTED BY AN ELECTRIC DIPOLE MOMENT OPERATOR

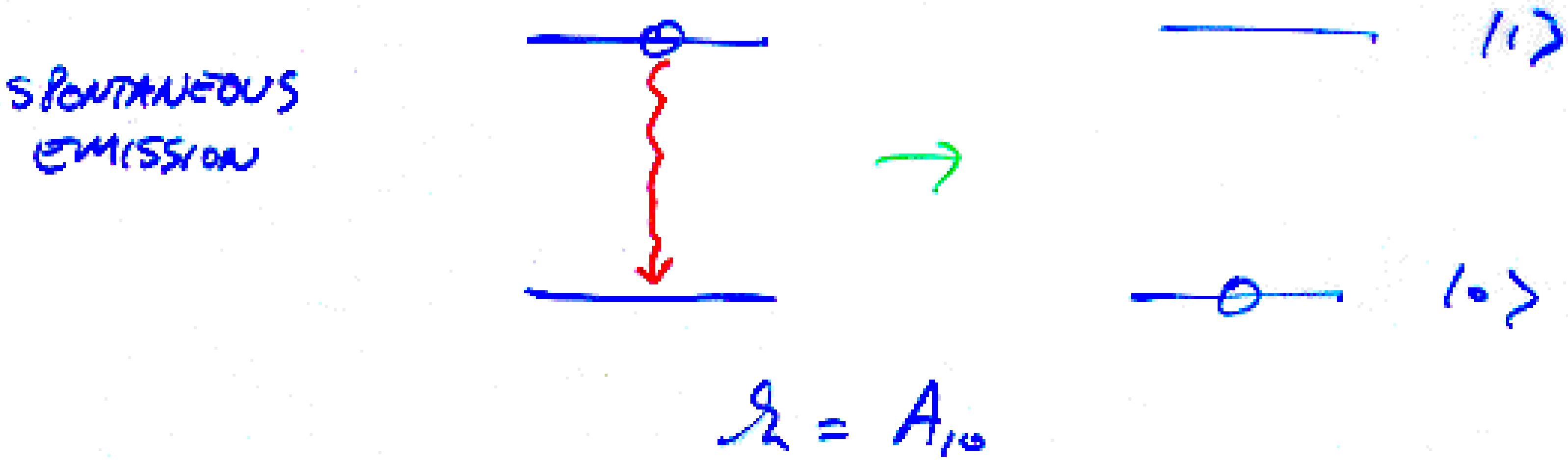


$$h\nu = E_2 - E_1 \qquad R = B_{01} I$$

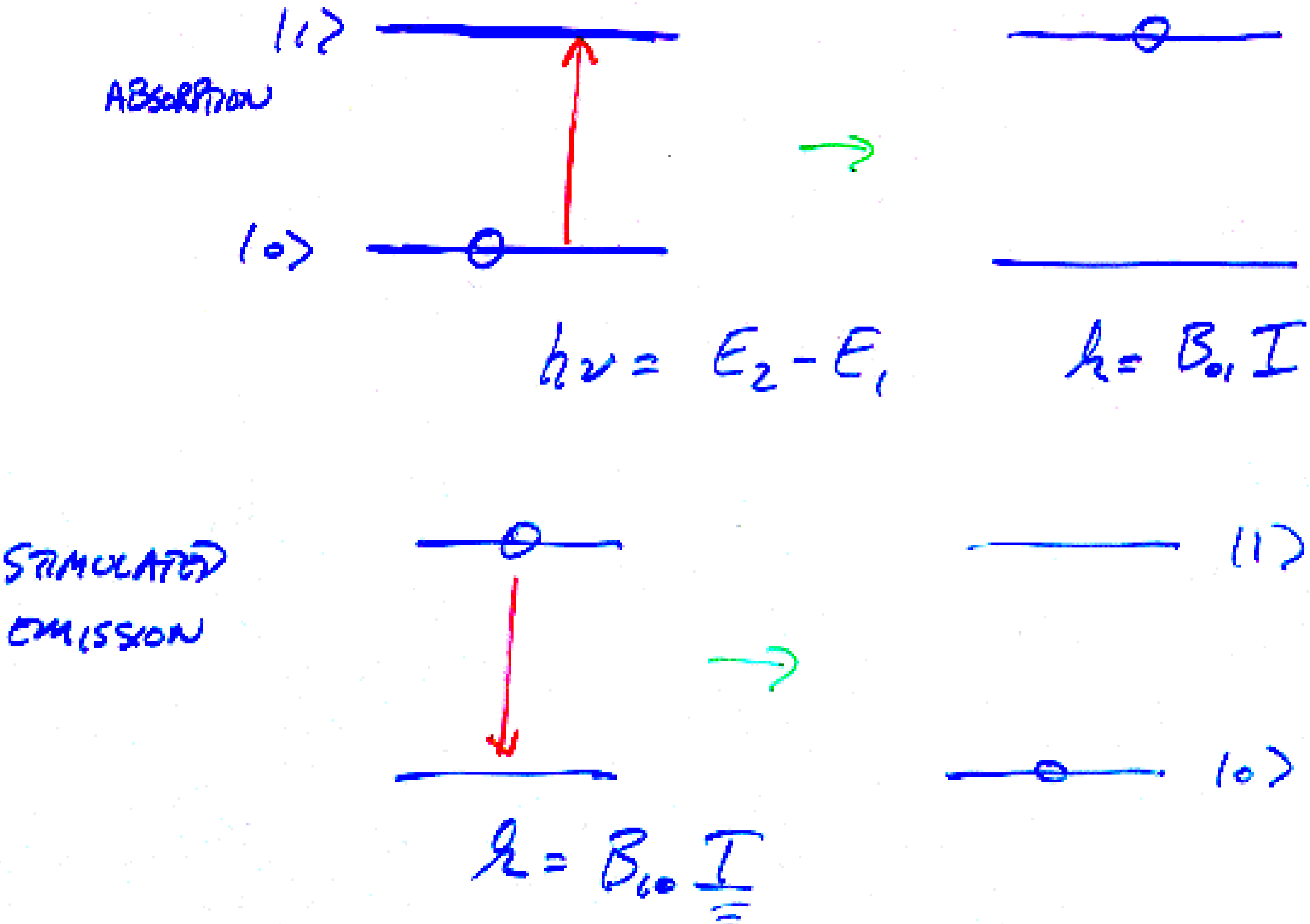
We can put energy into matter to 'store' it for amplification (gain)

What goes up must come down: Spontaneous emission!

But you can't use this to amplify light --- this is incoherent!



Einstein was the first to recognize that there must also be a another way for the stored energy to be released, the microscopic reverse of absorption: Stimulated Emission!



So:

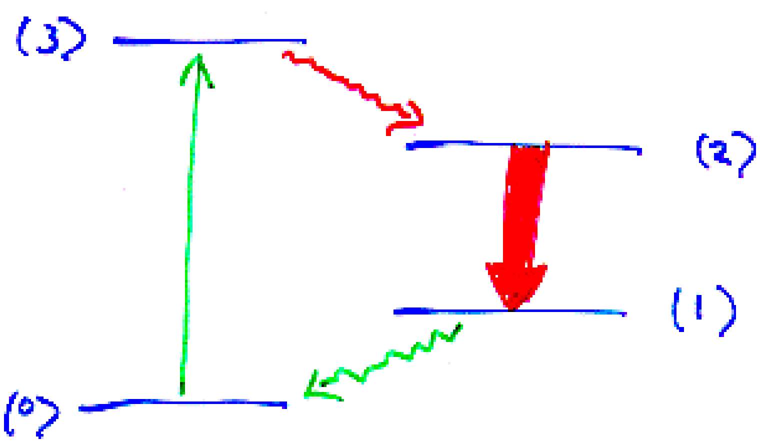
Light **A**mplification by **S**timulated **E**mission of **R**adiation

Seems simple, but how do you get ***net*** amplification if absorption is ALWAYS present, and competes with the Stimulated Emission?

Need more population in upper level than the lower level: a population **inversion**, intrinsically a non-equilibrium condition.

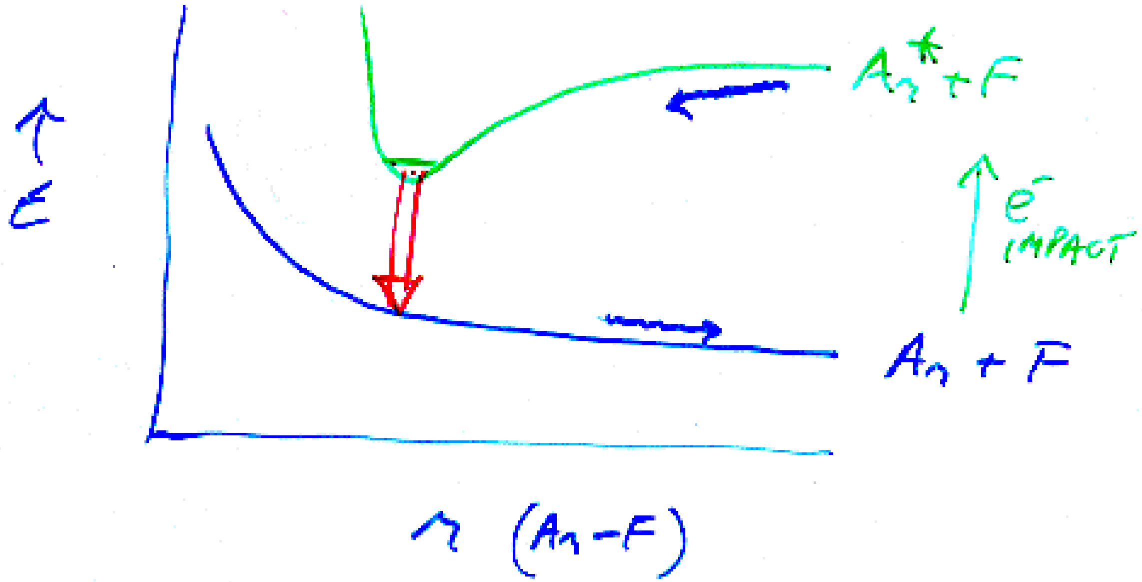
Negative Temperature??? How do you do that?

TYPES OF POPULATION INVERSIONS



LEVEL |2> IS INVERTED WRT |1> BUT NOT |0>

EXCIMER GAIN:

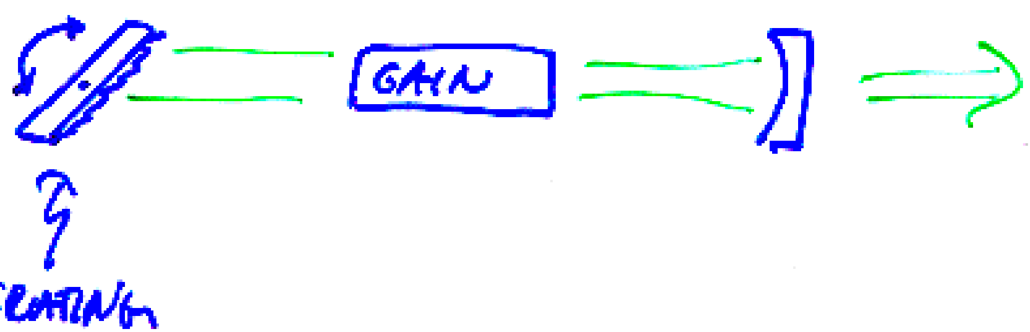


REMOVAL OF GROUND STATE BY DISSOCIATION INTO ATOMS!

What determines the photon energy of the LASER? It could be the characteristic of the gain medium, or, it could be determined by the cavity (resonator) if the gain is broad enough.

TUNABLE LASERS

IF THE GAIN CAN FUNCTION OVER A RANGE OF PHOTON ENERGIES THE LASER CAN BE TUNED



The 'storage time' of the laser cavity can make this wavelength selection very precise!

IF THE CAVITY HAS A HIGH Q
THEN THE PHOTONS BOUNCE OFF
THE GRATING MANY TIMES BEFORE
EXITING THE CAVITY

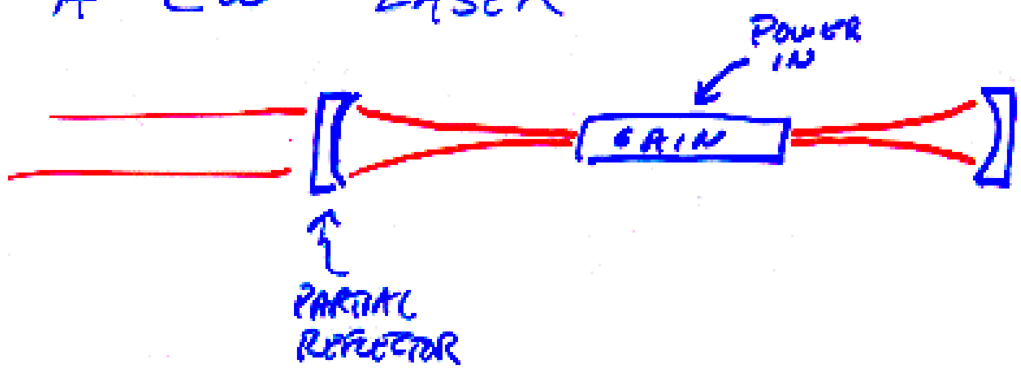
VERY HIGH RESOLUTION

$$\frac{\Delta E}{E} = \frac{\Delta \nu}{\nu} = 10^{-6} \ldots 10^{-12}$$

MUCH BETTER THAN A CONVENTIONAL
SPECTROMETER (MONOCHROMATOR)

What is thing called Q??

A CW LASER

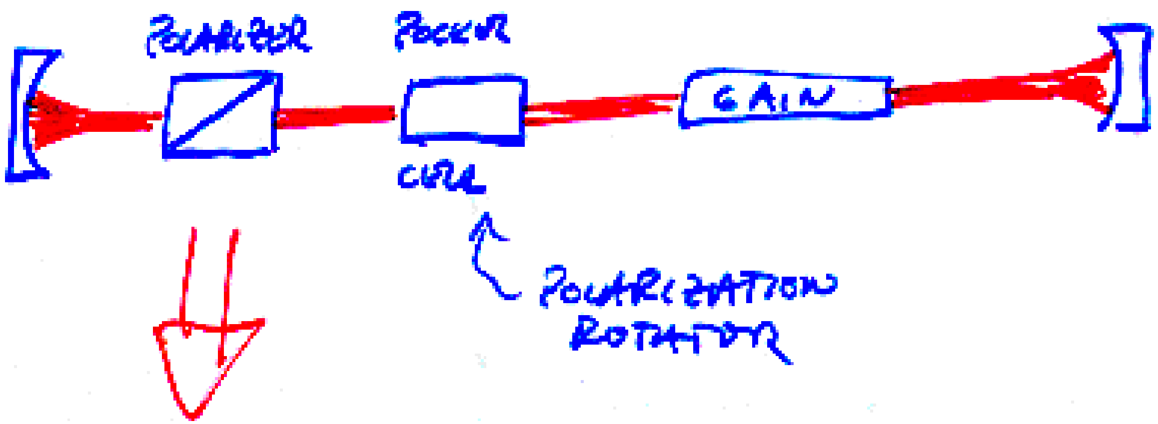


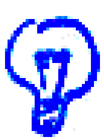
OUTPUT POWER = INPUT POWER TO GAIN
(CONSERVATION OF ENERGY)

CIRCULATING POWER = INPUT POWER · Q

$$Q \equiv \frac{\text{POWER STORED}}{\text{POWER IN}} \qquad 1 \leq Q \leq 1000$$

PULSED LASERS AND THE Q-SWITCH





LET POWER BUILD UP AT HIGH Q
THEN ROTATE POLARIZATION (Q-SWITCH)
AND GET A GIANT PULSE

A Q-switch (pulsed) or Output Coupler (CW) is necessary to get the light out of the laser cavity so that it can be used for spectroscopy.

Components of a Laser

4) Gain

5) Resonator

6) Output Coupler / Q-switch

FACTS & MYTHS ABOUT LASERS

- LASERS ARE POWERFULL

  AVERAGE POWER $< 100\ W$

  PEAK POWER $> 10^9\ W$

- LASERS ARE COLLIMATED (BEAMS)

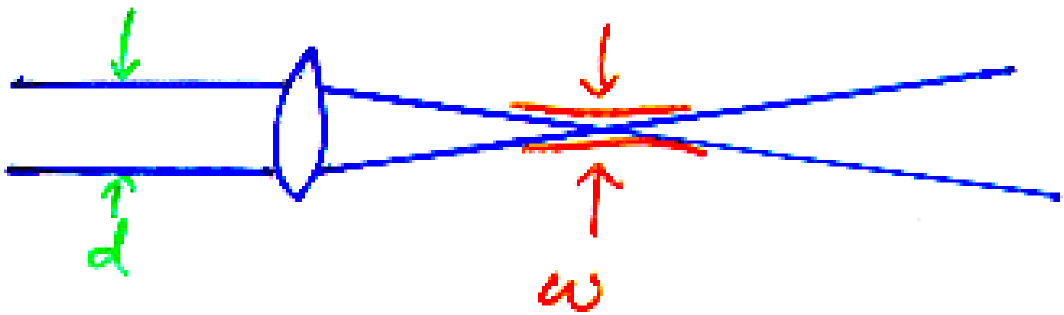
  ALL LASERS ARE DIFFRACTION LIMITED

  $$\sin \Delta\theta = m\lambda / D \qquad D = \text{BEAM SIZE}$$

  ↓

  DIVERGENCE

- LASERS FOCUS TO A POINT



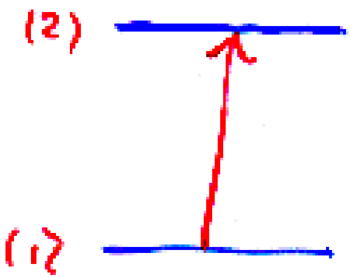
$$\omega = 2f / \pi d$$

- LASERS ARE COHERENT

  POLARIZATION IS A HARBINGER OF COHERENCE

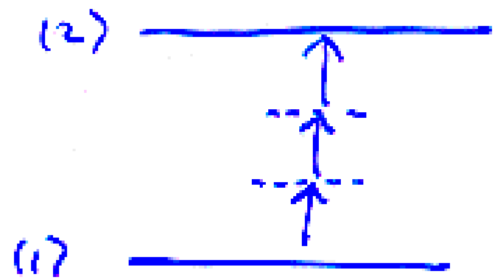
What can you use a LASER for?

NON-LINEAR SPECTROSCOPY



LINEAR ABSORPTION

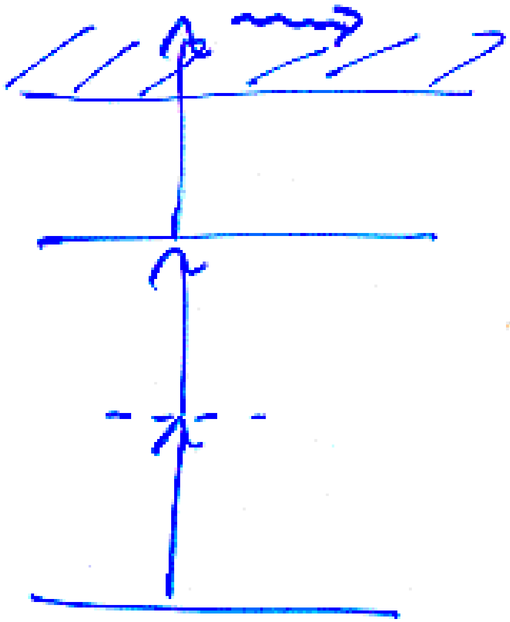
$E_2 - E_1 = h\nu$



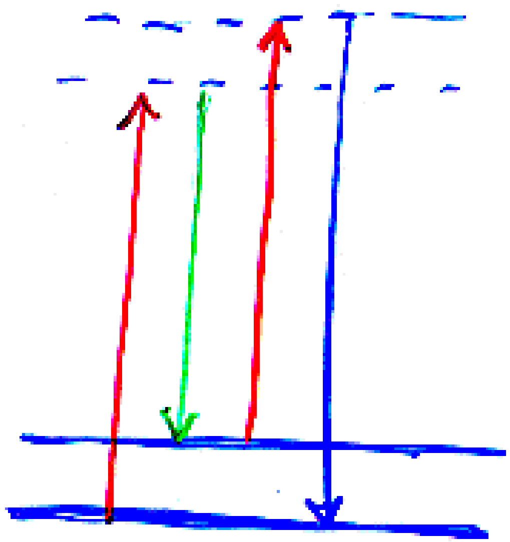
NON-LINEAR ABSORPTION

$E_2 - E_1 = (n)h\nu$

↑ PHOTON 'ORDER'



MPI



CARS

Fin