LASER

Light **A**mplification by **S**timulated

Emission of **R**adiation

Characteristics of Laser Light

INTENSE

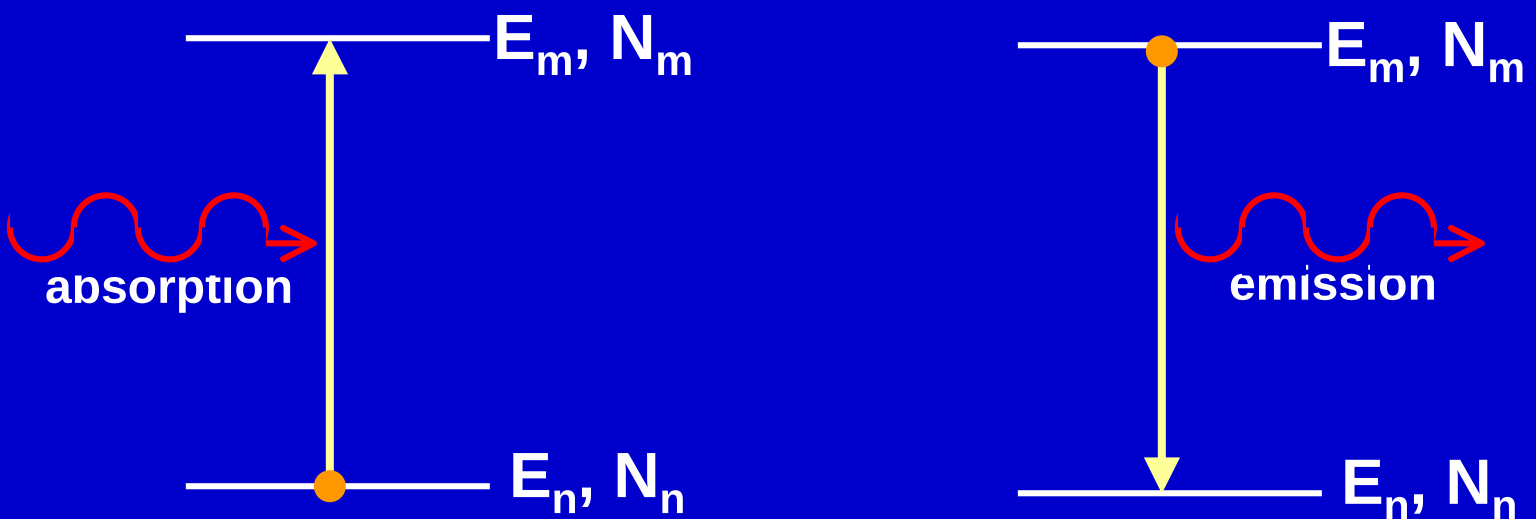
MONOCHROMATIC

COLLIMATED

COHERENT

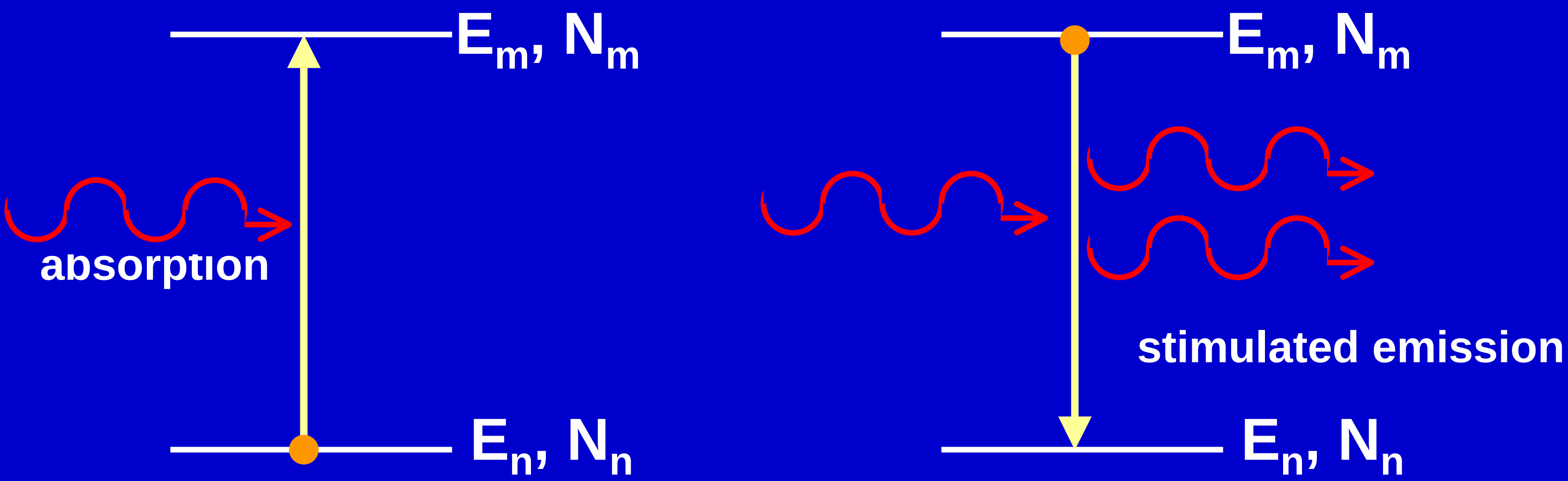
Absorption and Spontaneous Emission

Consider a two-level system



Light from bulbs are due to spontaneous emission

Absorption and Stimulated Emission



Laser light results from stimulated emission

Stimulated vs Spontaneous Emission

Stimulated emission requires the presence of a photon.
An "incoming" photon stimulates a molecule in an excited state to decay to the ground state by emitting a photon.
The stimulated photons travel in the same direction as the incoming photon.

Spontaneous emission does not require the presence of a photon.
Instead a molecule in the excited state can relax to the ground state by spontaneously emitting a photon.
Spontaneously emitted photons are emitted in all directions.

When light travels through an absorbing medium, the medium absorbs the light; the amount of light absorbed is determined by Beer's Law.

For a medium to operate as a lasing medium, the transmitted light intensity should be greater than the intensity of light incident on the material.

When an atom or molecule in the lasing medium absorbs light it is excited

The excited molecule then decays to a lower level either through emission of a photon (stimulated or spontaneous) or via a non-radiative loss of the energy.

For lasing action, stimulated emission must dominate.

As determined by the Boltzmann factor, the population of the ground state > population of excited state.

Hence, typically absorption dominates.

For stimualted emission to be the dominant process, the excited state population must be larger than the lower state population.

In other words, for a medium to produce laser light, there must be a "population inversion" where $N_{upper} > N_{lower}$

How can a population inversion be created when the population in the ground state is always greater that the population in the excited state?

What kinds of materials will "allow" for an inversion of population in its electronic states?

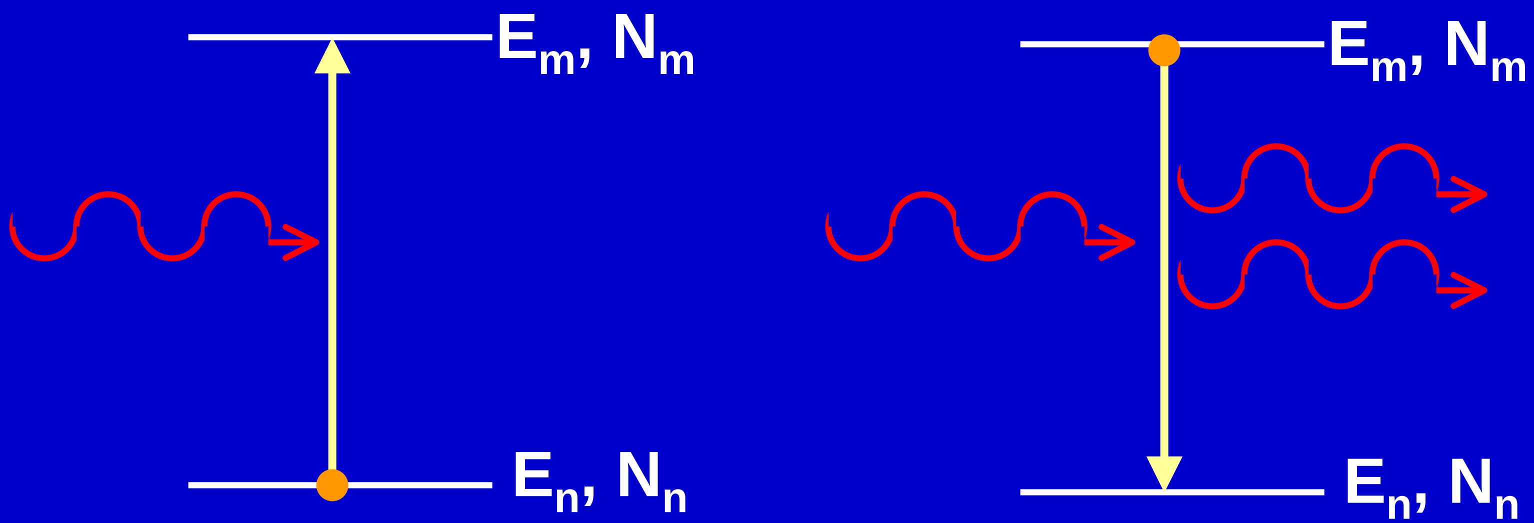
How can a population inversion be created?

By excitation of the lasing atoms or molecules - this is called PUMPING.

If the pump source is very intense, the number of atoms or molecules excited can be large.

However, once excited, the atoms and molecules must say in the excited state long enough to create an excited population > ground state population

Two-Level System

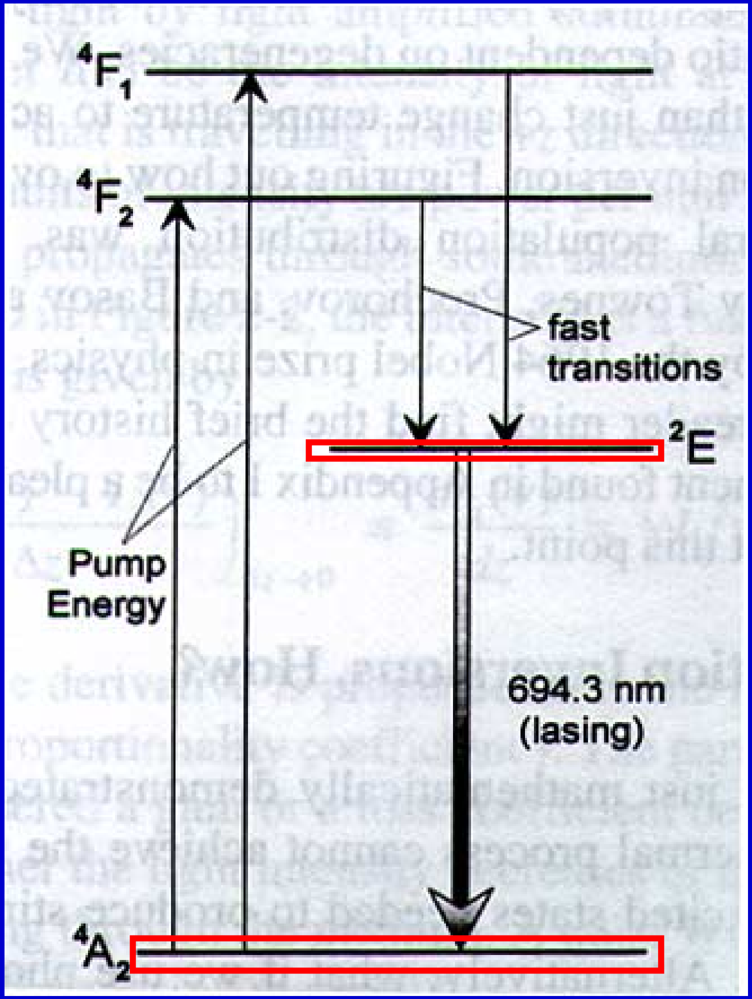


Even with very a intense pump source, the best one can achieve with a two-level system is

excited state population = ground state population

Three-Level System

The first laser, the ruby laser, was a three-level system



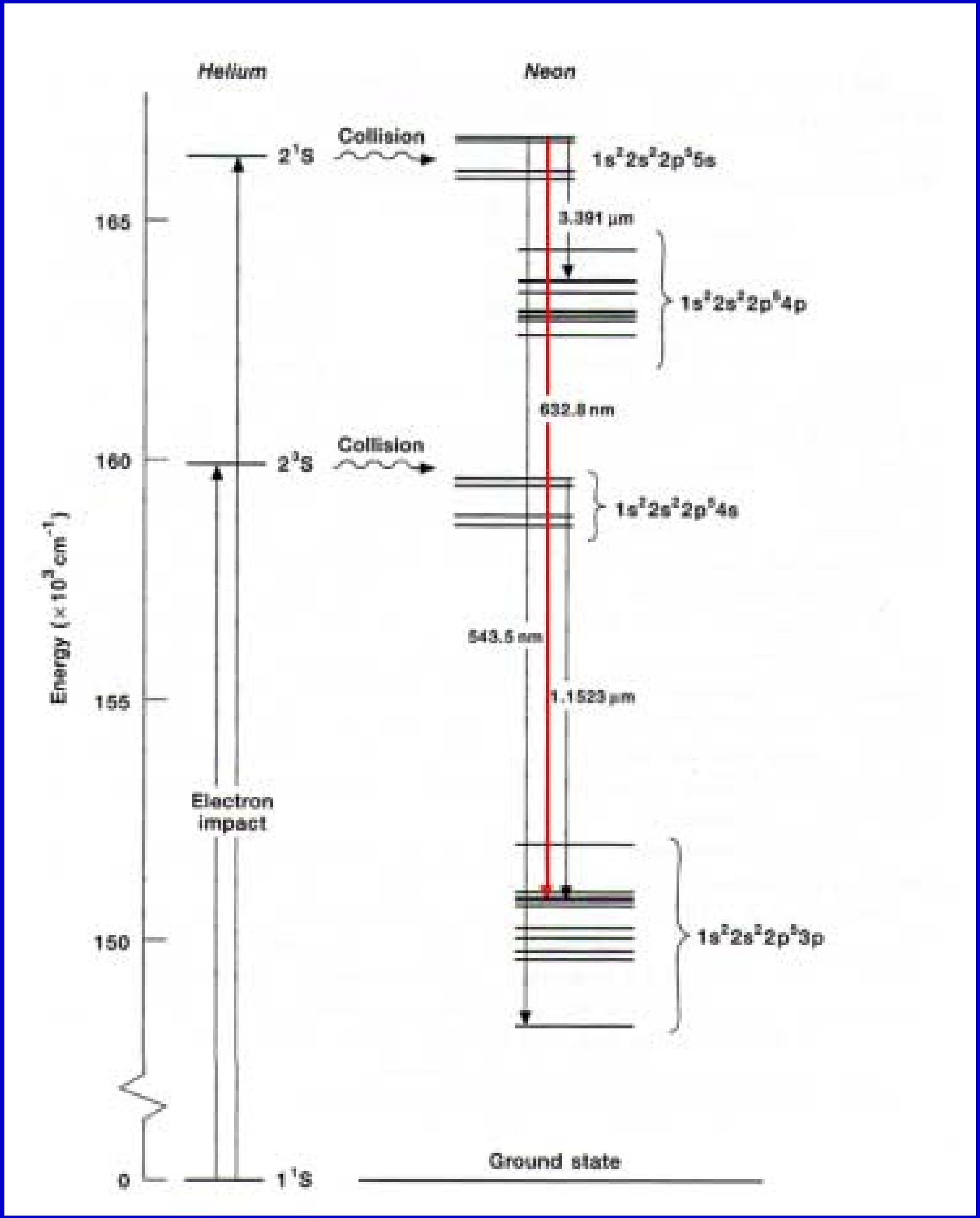
upper lasing state

lower lasing state

Laser light due to transition from ^2E state to $^4A_2$ state

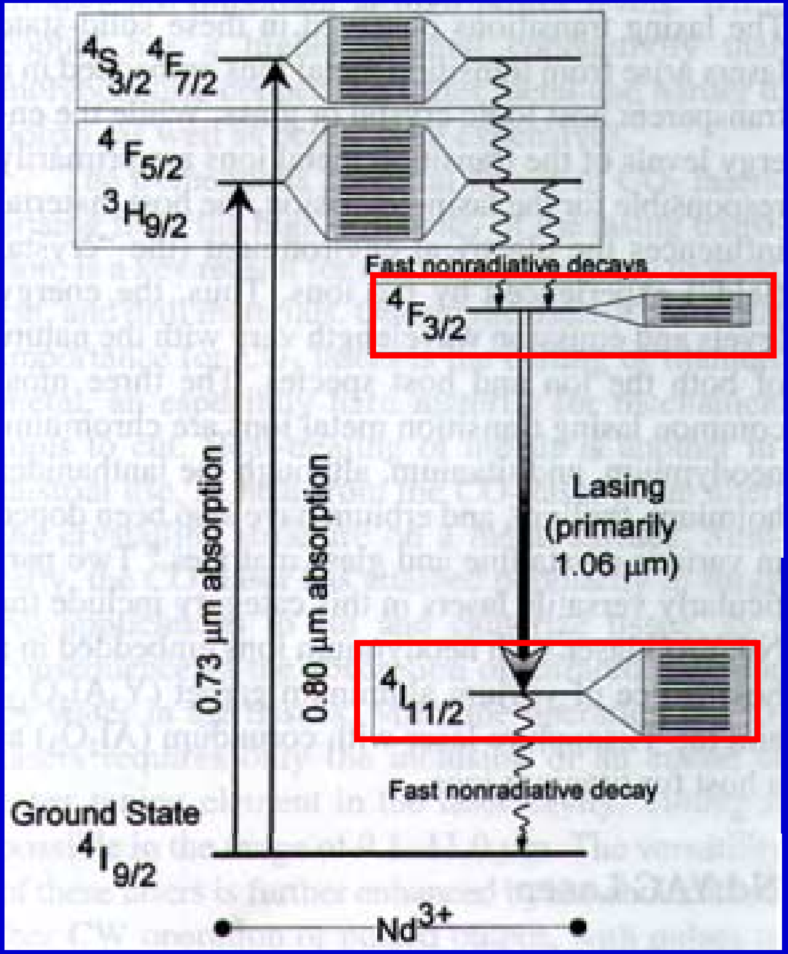
Four-Level System

He-Ne laser



Four-Level System

Nd:YAG laser

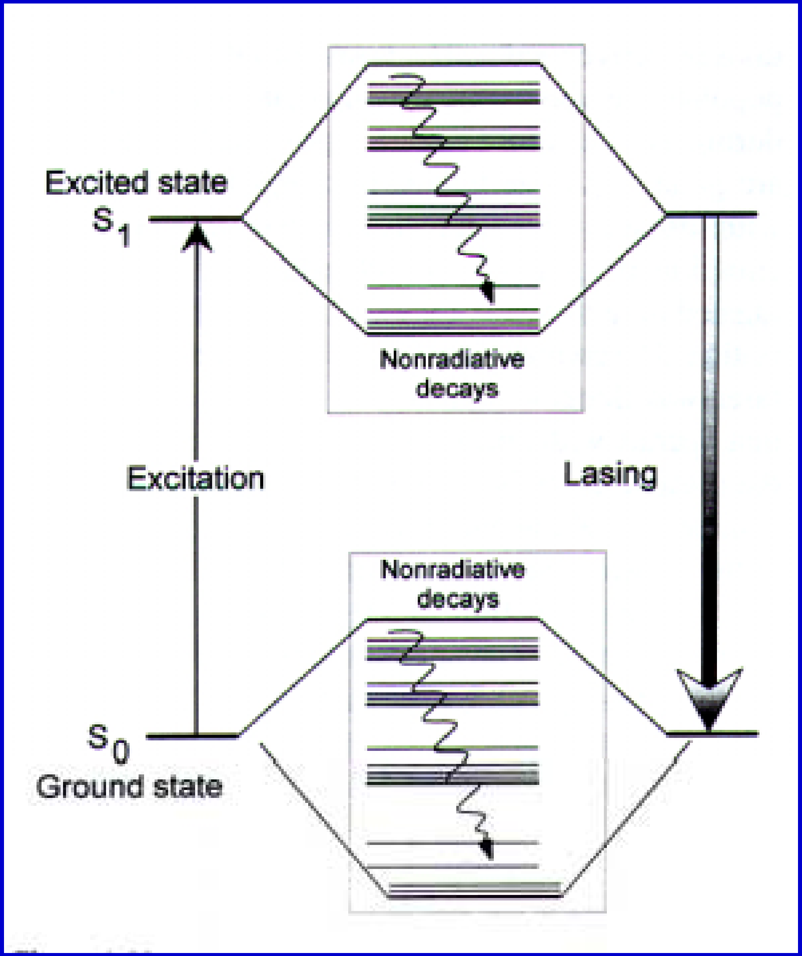


upper laser state

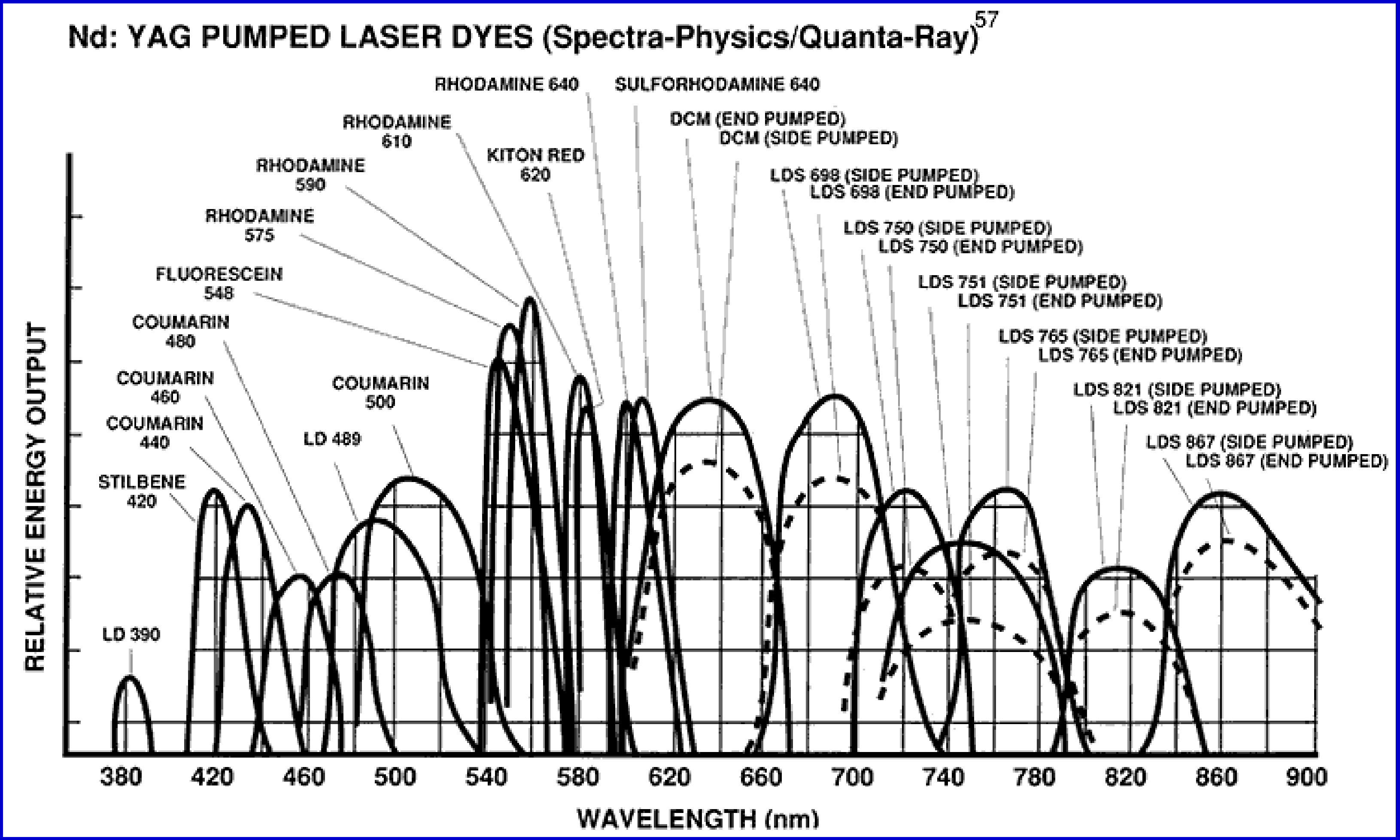
lower laser state

Laser light due to transition from ^4F to ^4I

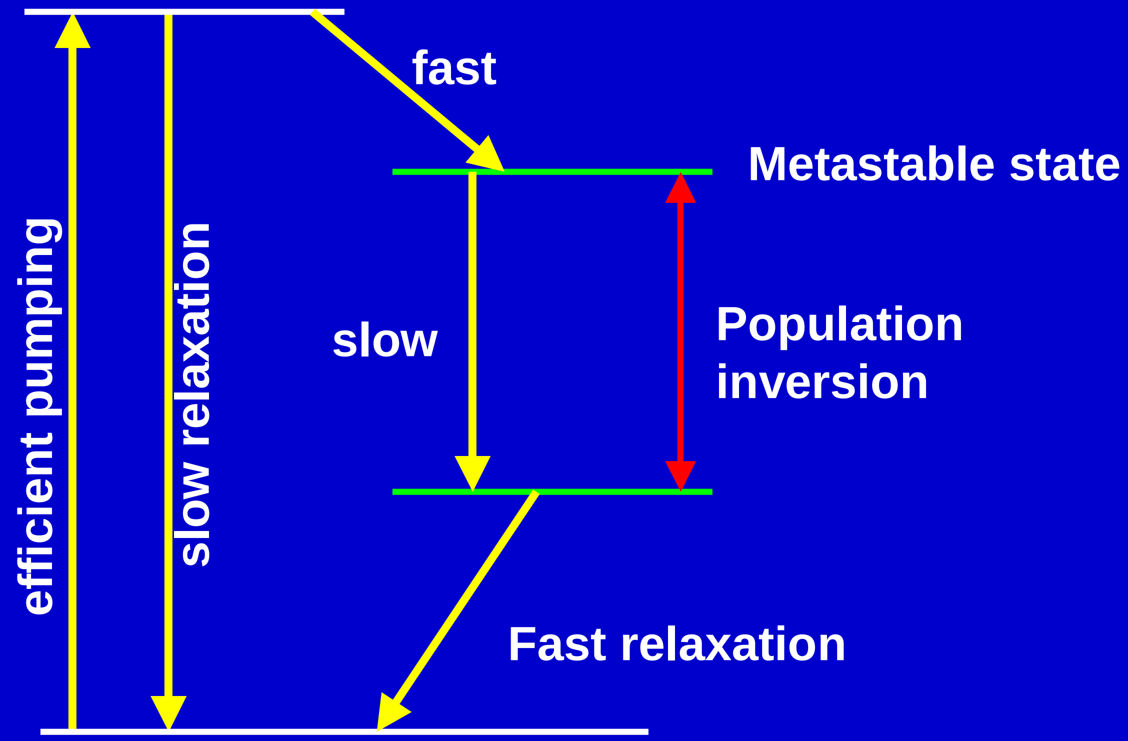
Dye Lasers: Four-level systems



Dye Tuning Curves

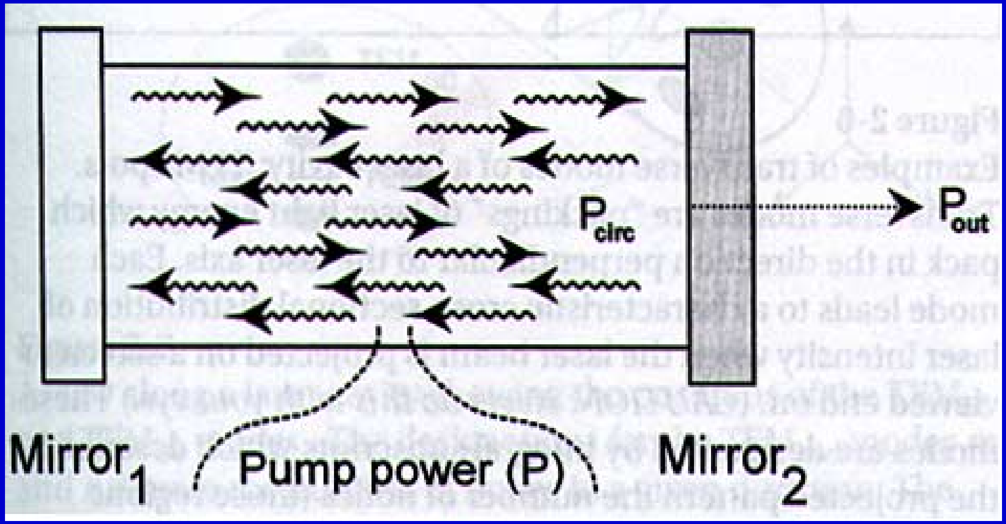


Requirements for Laser Action



Light Amplification

Create a laser cavity, which consists of the lasing medium and two highly reflective mirrors.



Continuous vs Pulsed Lasers

Excitation of the lasing atoms or molecules is by using external sources of light, examples flashlamps or another laser - PUMPING

The output of the laser light can be a continuous wave (cw) if the pumping is continuous or pulsed if the pumping is pulsed.

Pulsed lasers have very high intensities because the laser intensity is concentrated in a very short time duration.

Lasers in Chemistry

Lasers being monochromatic, with short pulse durations, and high intensity allow detailed studies in chemical dynamics.

Can do very fast kinetic studies – femtosec (10^{-15} s) studies – “look” at bond dissociation, bond formation, study kinetics in the liquid phase

Spectroscopy – monochromaticity allows detailed information on small molecules

High intensity – allows investigation of processes which which depend on light intensity and have very small probabilities of occuring e.g. Raman scattering