TOPICS

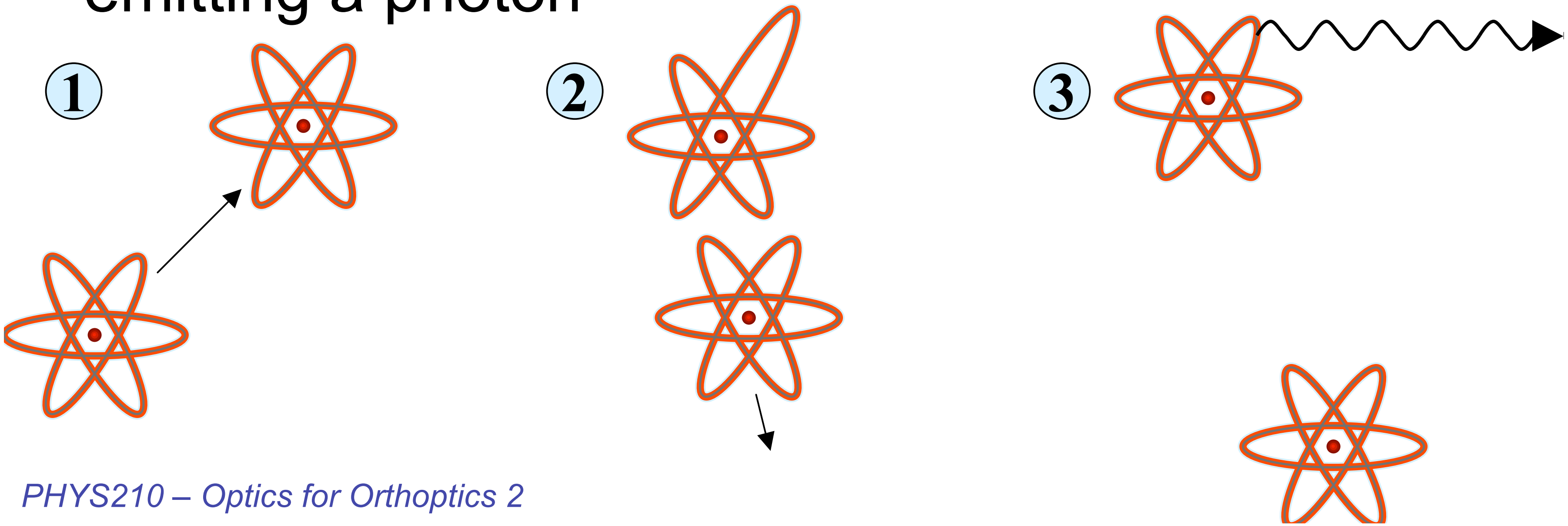
- Recap of PHYS110 *- 1 lecture*
- **Physical Optics** *- 4 lectures*
  - EM spectrum and colour
  - **Light sources**
  - Interference and diffraction
  - Polarization
- Lens Aberrations *- 3 lectures*
  - Spherical aberrations
  - Coma, astigmatism, field curvature, distortion
  - Chromatic aberrations
- Instrumental Optics *- 4 lectures*
  - Telescope, microscope
  - Stops, eyepieces
  - Instruments for the anterior eye
  - Instruments for the posterior eye

Lecture 3

- Light sources
  - Gaseous light sources
  - Solid light sources
  - Lasers

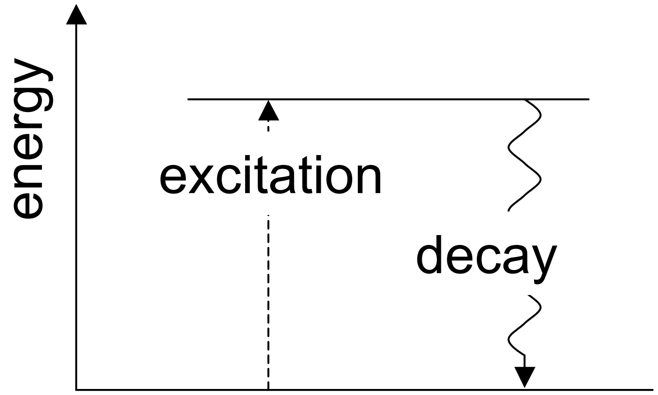
Origin of light

- Light arises from the motion of **electrons** within molecules
- If electrons are 'excited', for example from heating, or from an electric current, electrons are raised to higher energy states
- Shortly, electrons 'jump' down to a lower state, emitting a photon



Energy levels

- This can be indicated with a diagram of energy levels



- The amount of energy emitted in the decay determines the wavelength and thus the colour of the emitted light (remember $E=h \cdot f$)

Gaseous light sources

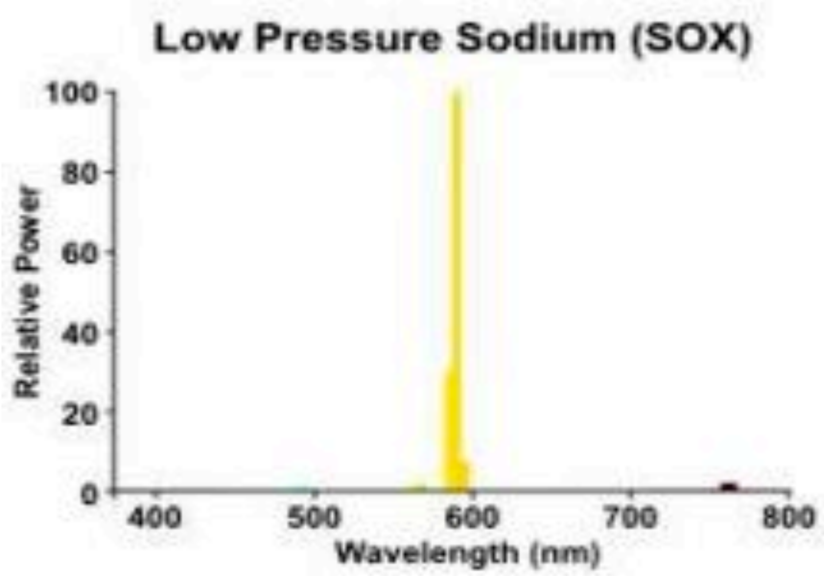
- In gaseous light sources, the energy levels of the molecules are well-defined
- Only certain energy transitions are allowed

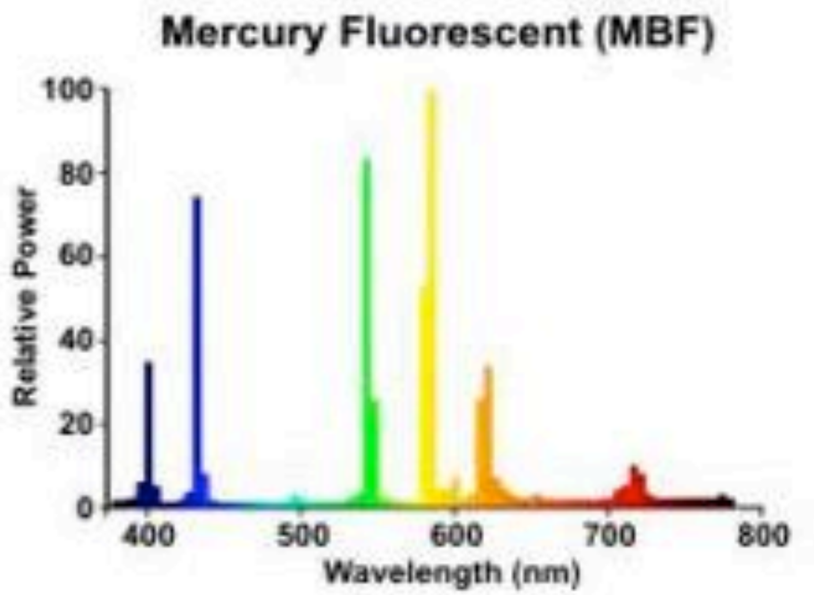
$\Rightarrow$The produced light only has certain wavelengths

- This results in a **line-spectrum**
- Each gas produces a unique spectrum

Examples

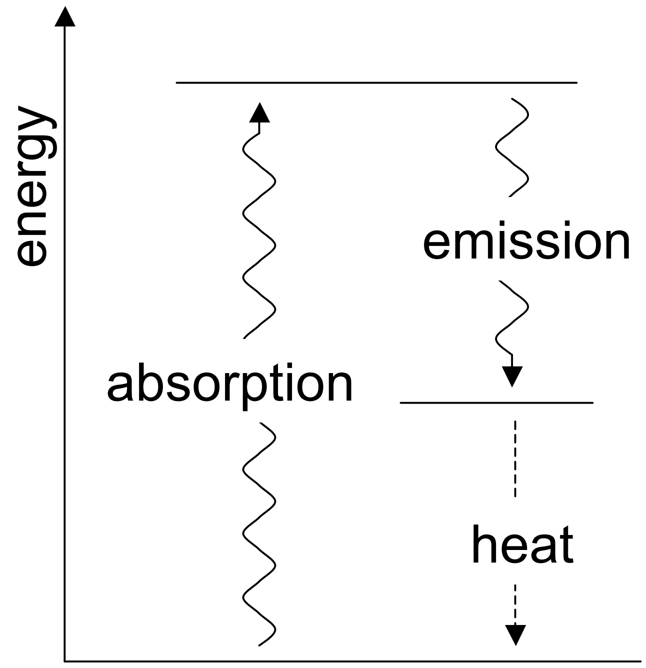
- Sodium lamp
  - used for example in street lights
  - heated to evaporate sodium
  - one spectral line at 589 nm
  - appears yellow-orange
- Mercury lamp
  - 5 spectral lines, one in UV
  - fluorescence is used to transform the UV light to visible light





Fluorescence

- Some molecules can absorb a high-energy photon, and re-emit it as a lower-energy photon.
  - The energy difference ends up as molecular vibrations (heat).
- The wavelengths of the emitted photons are larger than the wavelength of the absorbed photon
- This way, ultraviolet light can be absorbed and re-emitted as visible light



Solid light sources

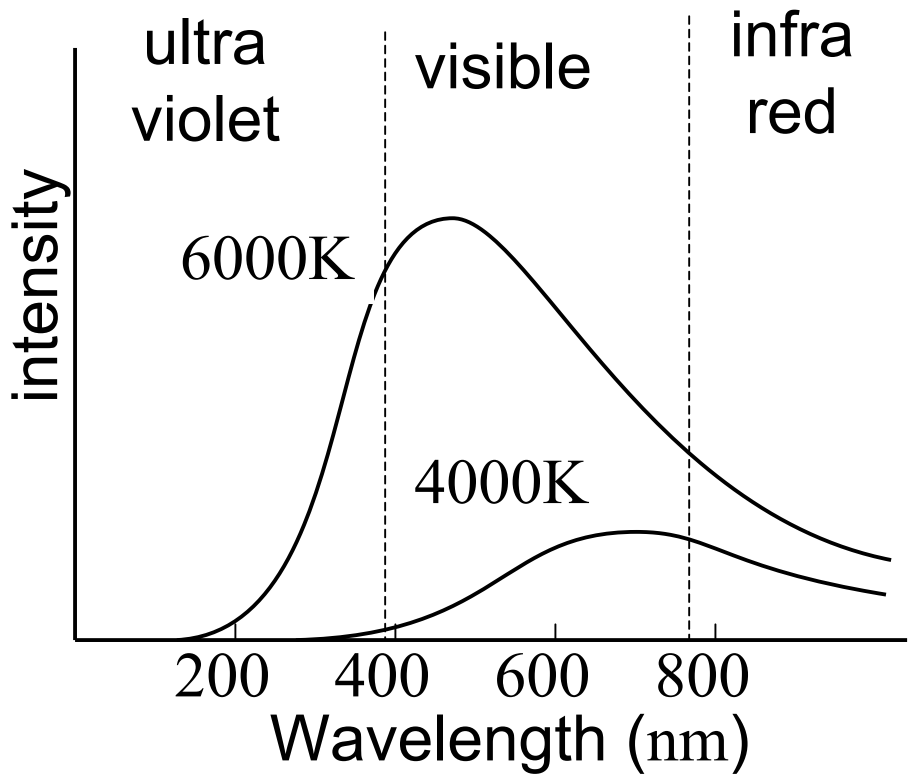
- In solids (and liquids), molecules interact with each other continuously
- Therefore, the energy transitions are not restricted to a small number

  ⇒ **continuous** spectrum is emitted
- The spectrum depends predominantly on the **temperature**, not on the material

Solid light sources

- At **low temperatures** , (<1000K) a solid radiates predominantly **infrared.** *The radiation is invisible, but can be felt as heat*
- At **higher temperatures**, (≈2000K) the tail of intensity moves to the visible spectrum and a **red glow** will be visible
- At **very high temperatures** (≈4000K) the solid radiates in the whole visible spectrum and appears **white**
- **Above** 5000K, a solid radiates significantly in **ultraviolet**.

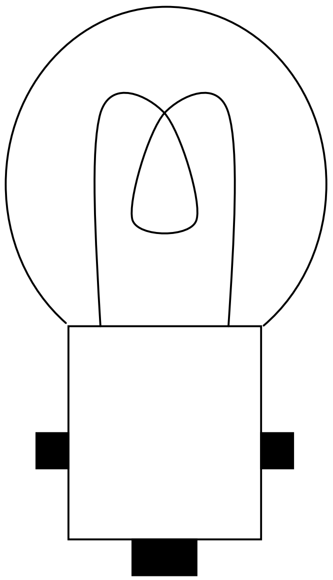
Example spectra from hot solids



- Wavelength of the peak intensity is inverse proportional with temperature: λ_{peak}=2,898,000nm/T
  - *Temperature in Kelvin = 273 + temperature in ^{o}C*

The incandescent light bulb

- In a light bulb, an electrical current flows though a thin tungsten wire
- The tungsten wire heats up to a temperature of $\approx 3500K$
- Inside the bulb is an inert gas (e.g. Argon or Nitrogen), otherwise the wire would burn
- Only $\approx 10\%$ of the energy is emitted as visible light
- Halogen lamps have a higher temperature than normal bulbs
  - They appear less yellow and have a higher efficiency

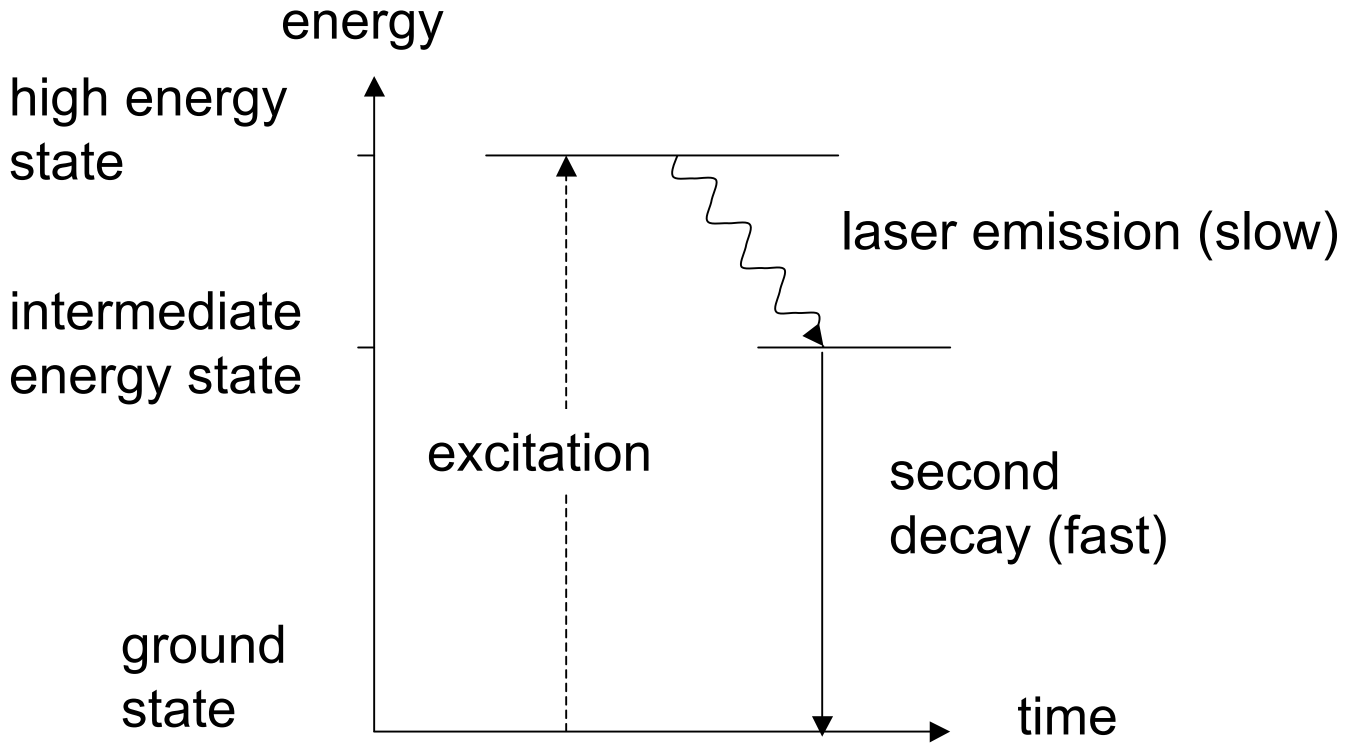


Lasers

- Acronym for
  - **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation
- Gives a **collimated** beam
  - Can be focused to very small area with very high energy density
- Gives **monochromatic** light
- Can be a **continuous** or **pulsed**

Laser principle

- Atoms are brought into excited state
  - 'pumping' : another light source or electric current
- Instead of decaying immediately to the ground state, some molecules stay some time in the excited state, then decay to an intermediate energy state and then immediately to the ground state

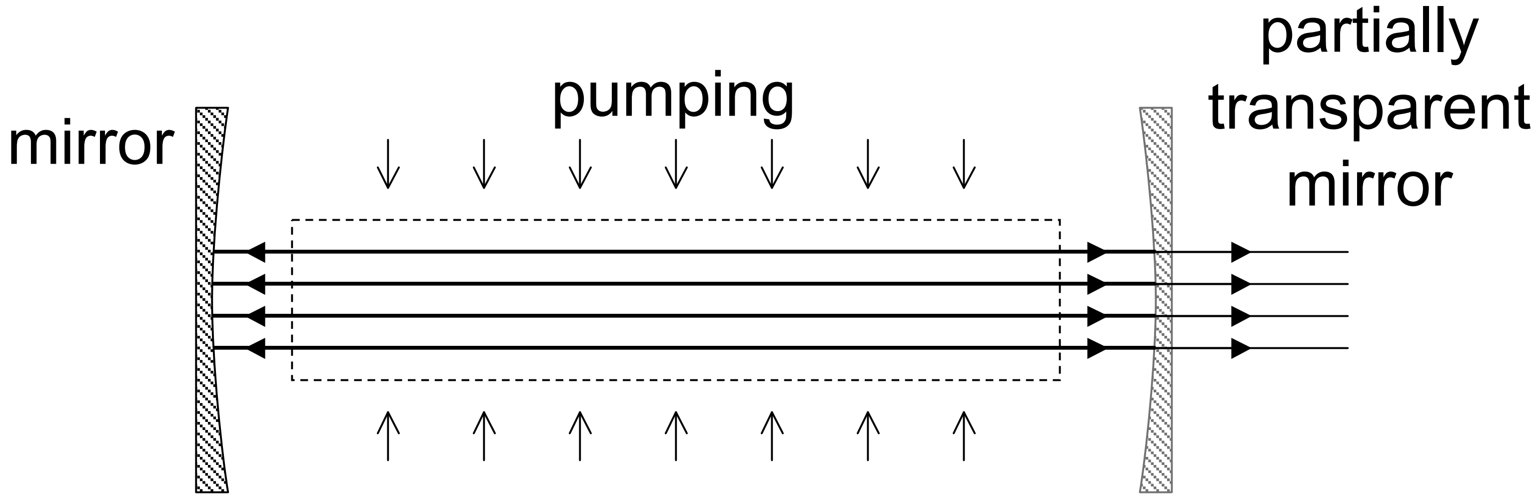


Stimulated emission

- Apart from spontaneous emission, an atom can also be stimulated by another photon to emit
- This process is called stimulated emission
- The result is two photons
- If pumping is fast and the photon density high, stimulated emission dominates spontaneous emission

A laser

- A very high photon density is achieved using two mirrors with the active medium in between



- By making one mirror semitransparent, the laser light can escape
  - It is monochromatic and collimated

Examples of lasers

type	*wavelength*	*application*
excimer (ArF)	193 nm	corneal surgery
Argon blue-green	488 nm and 514 nm	photocoagulation
diode	810 nm	CD player
CO_2	10600 nm	welding, cutting

CO_2 Laser in Action