Farbe

Causes of Color
Causes of Color

- **made light**
  - light bulbs, fire, lightning, aurora, glowing

- **lost light**
  - water, plants, gold, emerald \([\text{Smaragd}]\)

- **moved light**
  - rainbow, sky & sunset, butterfly, opal

www.webexhibits.org/causesofcolor
Color from Incandescence

- „blackbody radiation“
- when heated, a blackbody emits energy
  - wavelengths in visible area \( \Rightarrow \) light
  - it “glows”
- heating source
  - electricity (light bulb, lightning)
  - chemical reactions (fire, sun)
Blackbody Radiation

- A blackbody has no color.
- Looks black because it absorbs all light.
- No radiation at –273°C = 0 K [Kelvin].
- When heated, a blackbody emits energy.
  - I.e. it becomes luminous.
  - Radiance depends on temperature.
  - Wavelengths depend on temperature.
  - Wavelengths in visible area $\Rightarrow$ light, color.
  - It “glows”
Blackbody Radiation

- = electromagnetic radiation spectrum of an object at a certain temperature
- all matter (regardless of composition) emits exactly the same spectrum at a given temperature
- at around 500 K objects start to glow red
- extremely hot iron furnaces [Öfen] can glow almost white
- plasma can glow blue at about 20,000 K (very bright and hot stars)
blackbody radiation

- radiation spectra at different temperatures
- peak of radiation given by Wien’s law

\[ \lambda_{\text{max}} = \frac{2897768 \text{ nm} \cdot \text{K}}{T} \]

Example:
\[ T = 2898 \text{ K} \rightarrow \lambda_{\text{max}} = 1000 \text{ nm} \]
Blackbody Radiation: 1200 – 2200 K

500 1000 1500 2000 nm
Blackbody Radiation: 3000 – 6000 K

3000 – 6000 K

500 1000 1500 2000 nm
Blackbody Radiation: 5000 – 50000 K
Blackbody Radiation & Color Temperature

Tungsten lamp [Wolfram]

1000 K 2000 K 3000 K 4000 K 4500 K 5500 K 7500 K

normalised (at 555 nm) relative radiance

400 450 500 550 600 650 700 nm

1800 K 4000 K 5500 K 8000 K 12000 K 16000 K

„color temperature“
Tungsten Lamp \([\text{Wolfram-Glühlampe}]\)

- also called *incandescent light* \([\text{Glühlicht}]\)
- tungsten is heated by electricity
  \[\Rightarrow\] blackbody radiation
- temperature
  \[\sim 2500^\circ C = \sim 2800 \text{ K}\]
- \[\Rightarrow\] yellowish light
- higher temperature would rapidly destroy the tungsten (melting point \(3695 \text{ K}\)) \([\text{iron} 1811 \text{ K}]\)
- filled with gas (e.g. N, Ar)
Spectrum of an Incandescent Lamp

Tungsten lamp (~2850 K)

noon sunlight (~5500 K)
Spectrum of the Sun

extraterrestrial sunlight
after ozone +
molecular scattering
after aerosol scattering +
water/oxygen absorptions =
= terrestrial sunlight
human visual sensitivity

\[
\begin{align*}
O_2 & \quad H_2O & \quad H_2O + CO_2 \\
200 & \quad 400 & \quad 800 & \quad 1200 & \quad 1500 \text{ nm}
\end{align*}
\]
Color from Gas Excitation

- emission of light by a chemical element present as a gas (e.g. neon) or vapor (e.g. of sodium [Natrium] or mercury [Quecksilber])
- electrical excitation raises atoms into higher energy states
- they decay back to ground state with the emission of photons
- fluorescent lamps
- aurora borealis
Gas Excitation – Sodium

- several different excitation paths
- each energy level corresponds to a wavelength band
- combination is spectrum of lamp:
Spectrum of a Vapor Lamp

noon sunlight (~5500 K)

mercury vapor lamp
[Quecksilberdampflampe]