Fundamentals of Solid State Physics

Optical Emission

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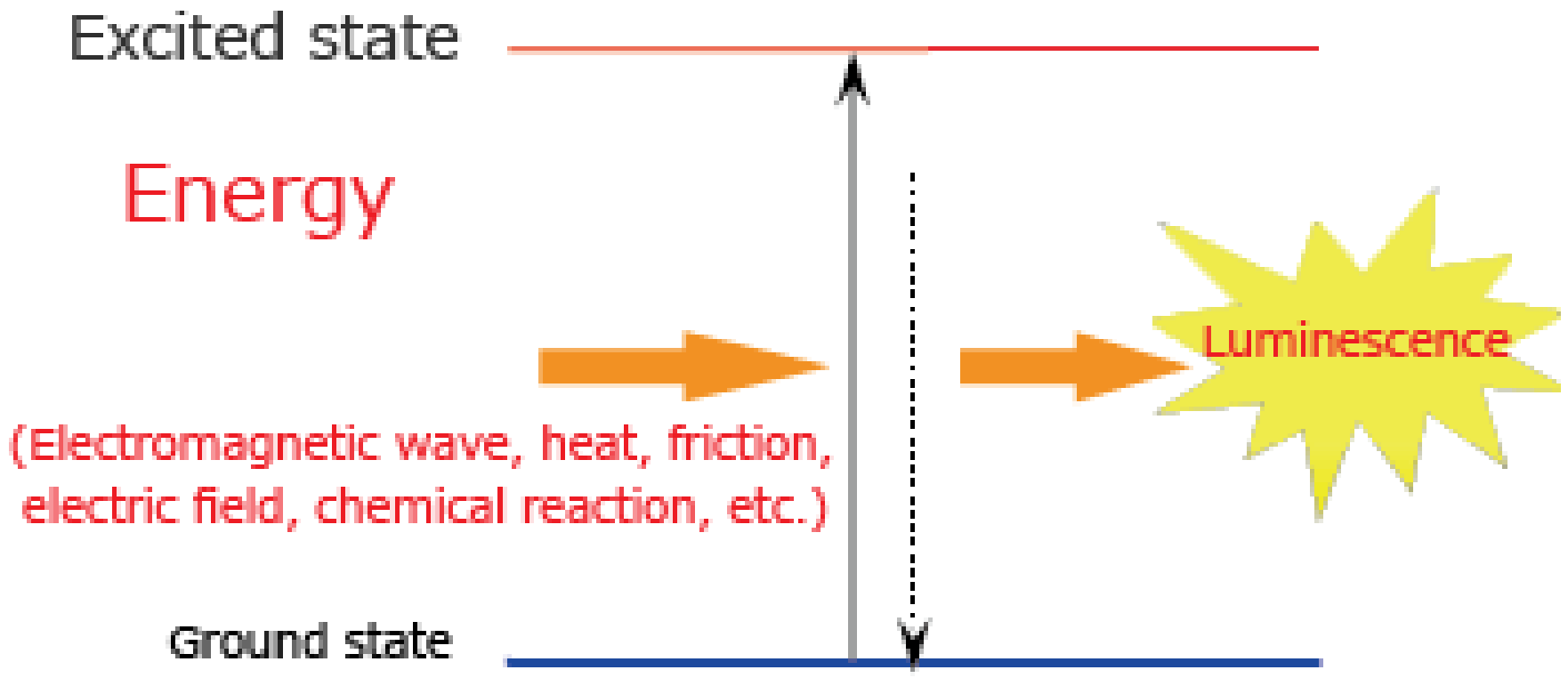
Optical Emission



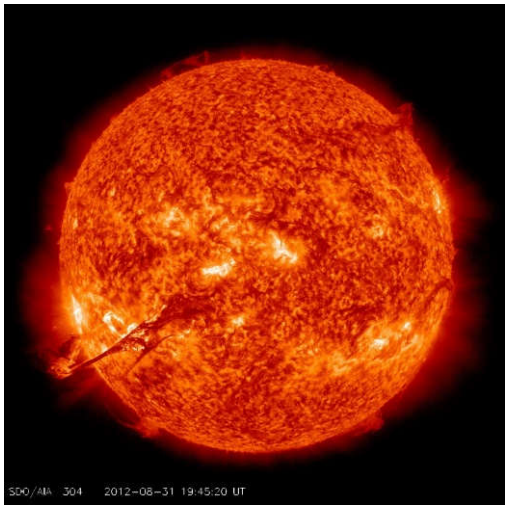
Optical Emission

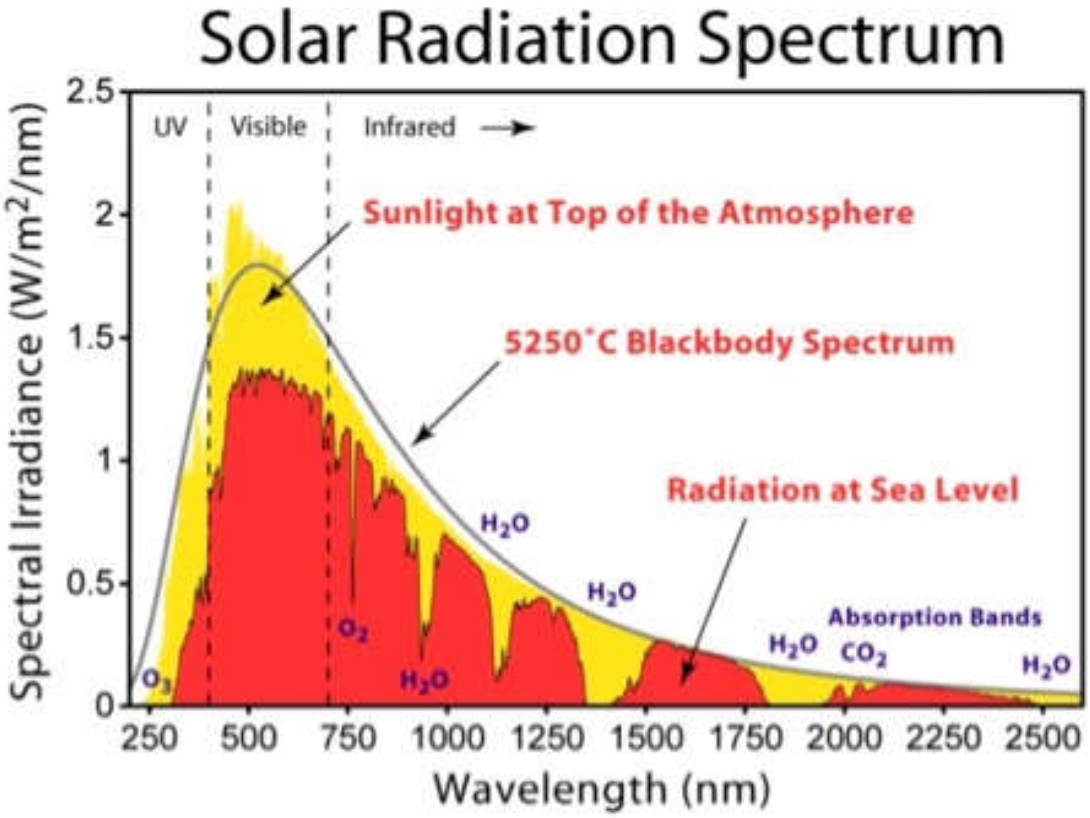
- Thermal radiation 热辐射
- Photoluminescence 光致发光
- Electroluminescence 电致发光
- Others
  - Chemiluminescence 化学发光
  - Bioluminescence 生物发光
  - Sonoluminescence 声致发光
  - ...

Thermal Radiation 热辐射

- **Blackbody Radiation 黑体辐射**
  - **$S(\lambda)$ - radiation power per unit area per unit wavelength ($W/m^2/nm$)**

$$S(\lambda) = \frac{2\pi hc^2}{\lambda^5 (e^{hc/\lambda k_B T} - 1)}$$





Thermal Radiation 热辐射

- **Blackbody Radiation 黑体辐射**
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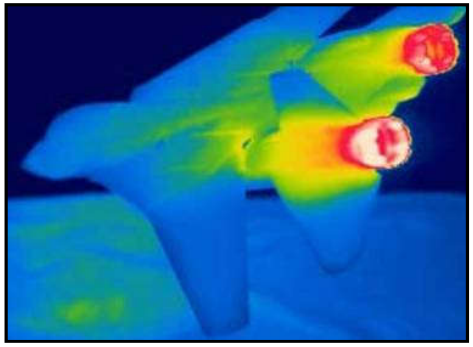
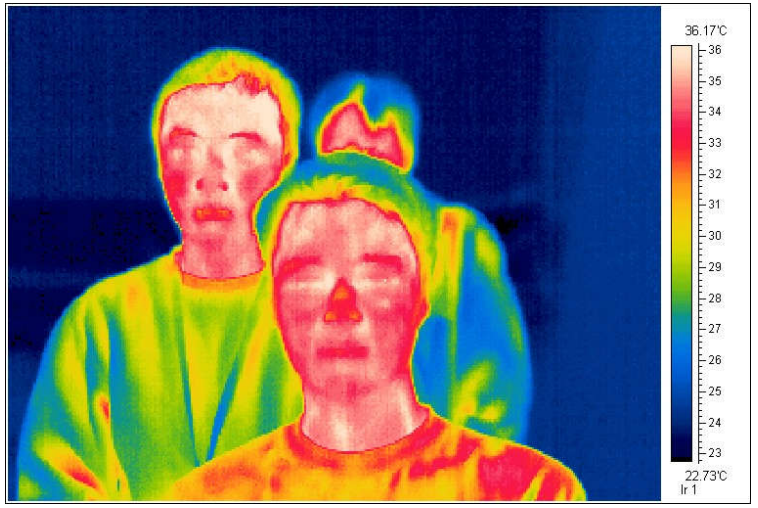
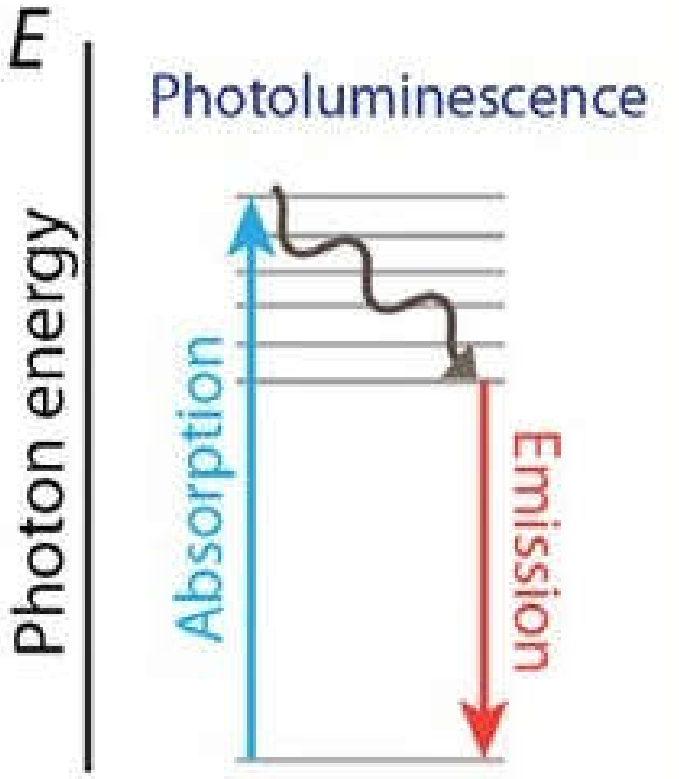




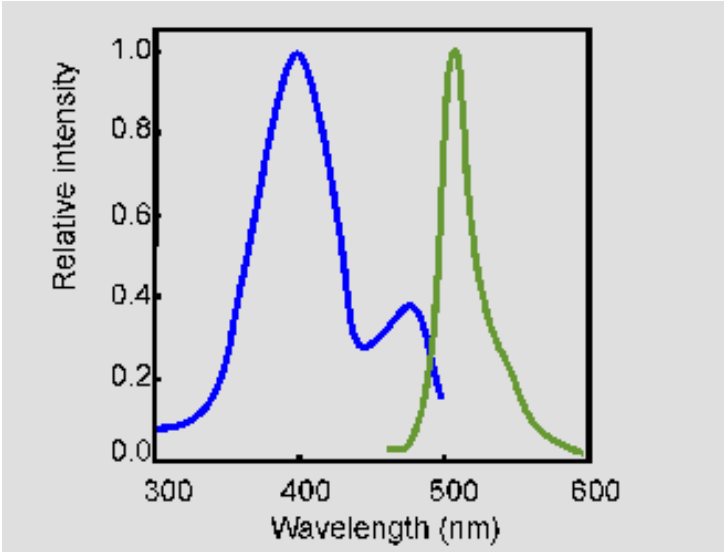
Photoluminescence 光致发光

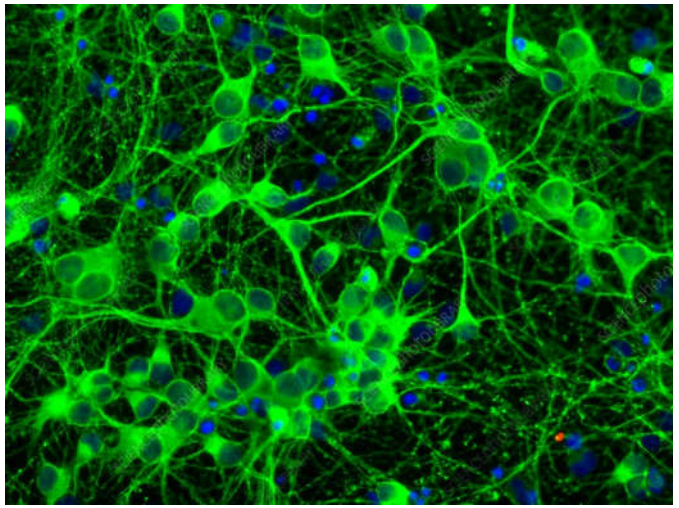


GFP
绿色荧光蛋白

M. Chalfie, *et al.*, *Science* 263, 802 (1994)

absorption **emission**



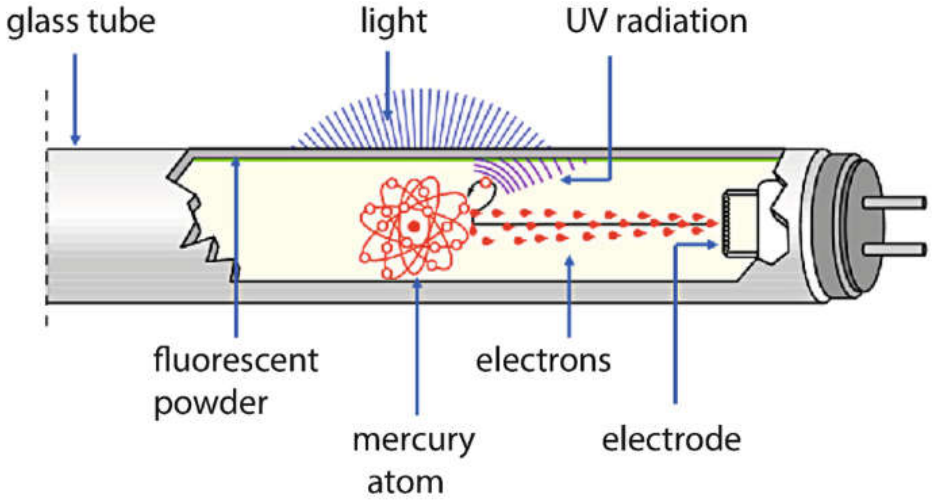


neuron cells

Electroluminescence 电致发光

lightning

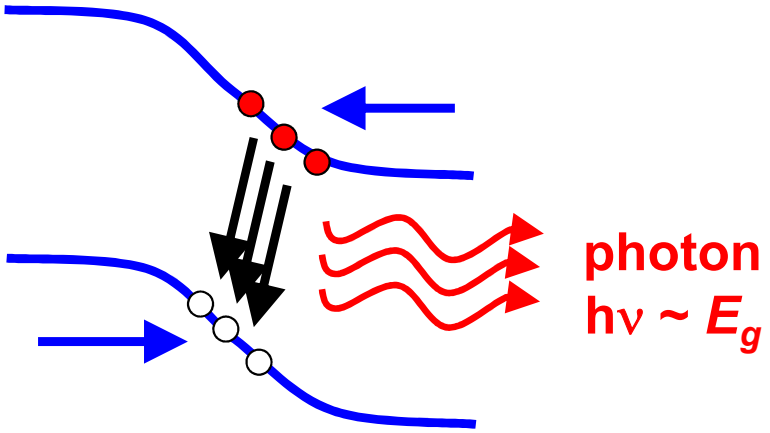
cathode ray tube (CRT)

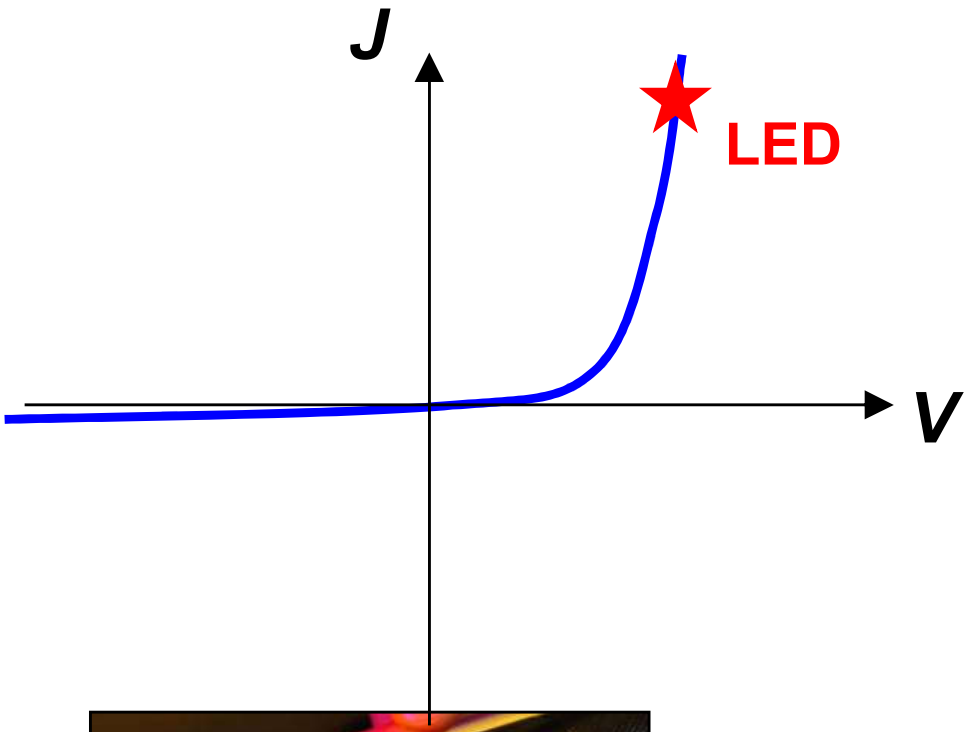


fluorescent lamp

W. von Bommel, *Interior Lighting* Springer (2019)

Electroluminescence 电致发光

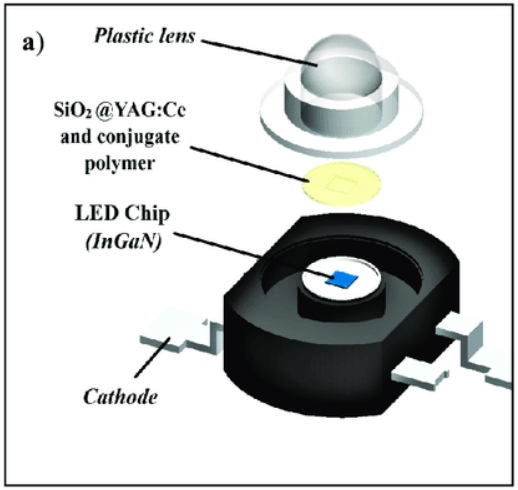


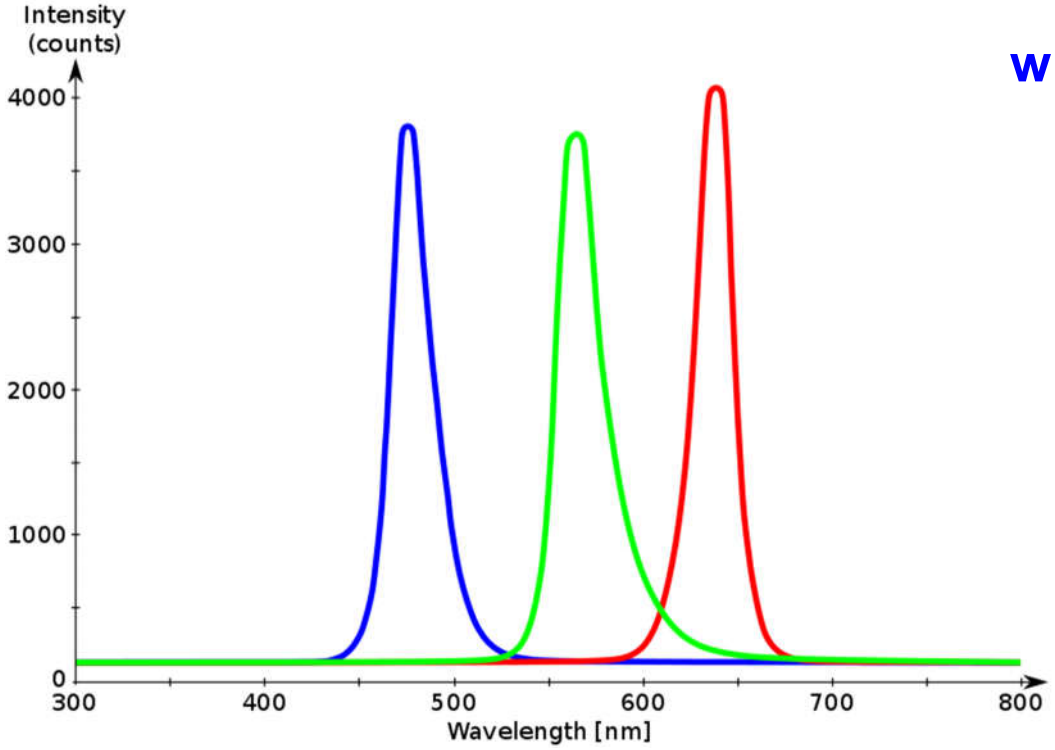


LEDs

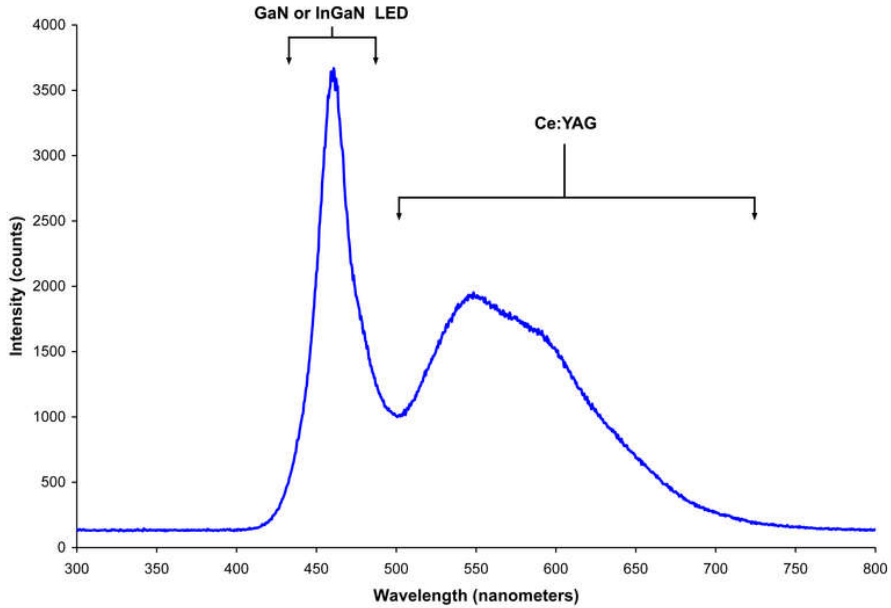
lasers

LED Spectrum



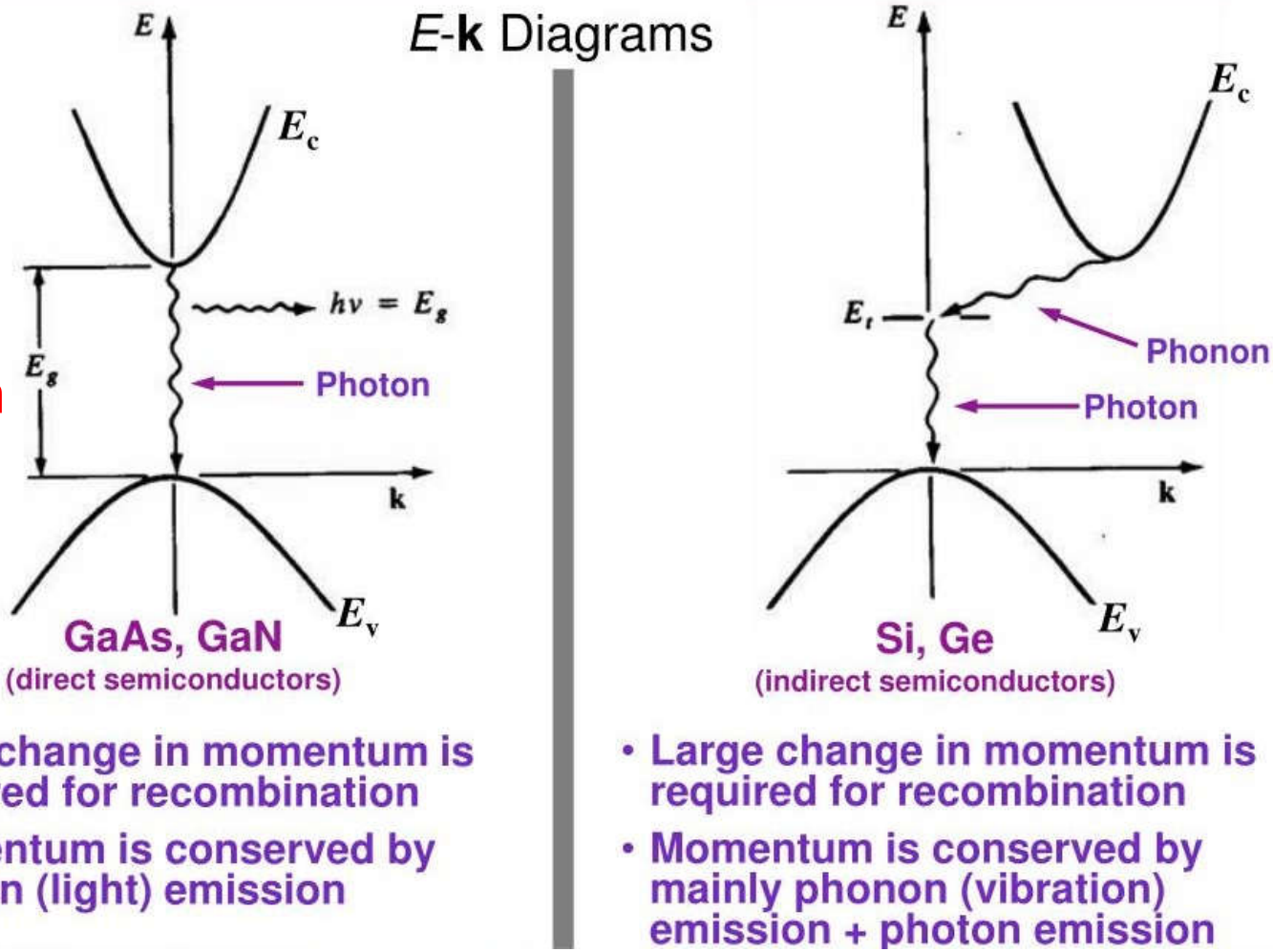


white LED = blue LED + yellow phosphor



Light Emission Efficiency

radiative recombination



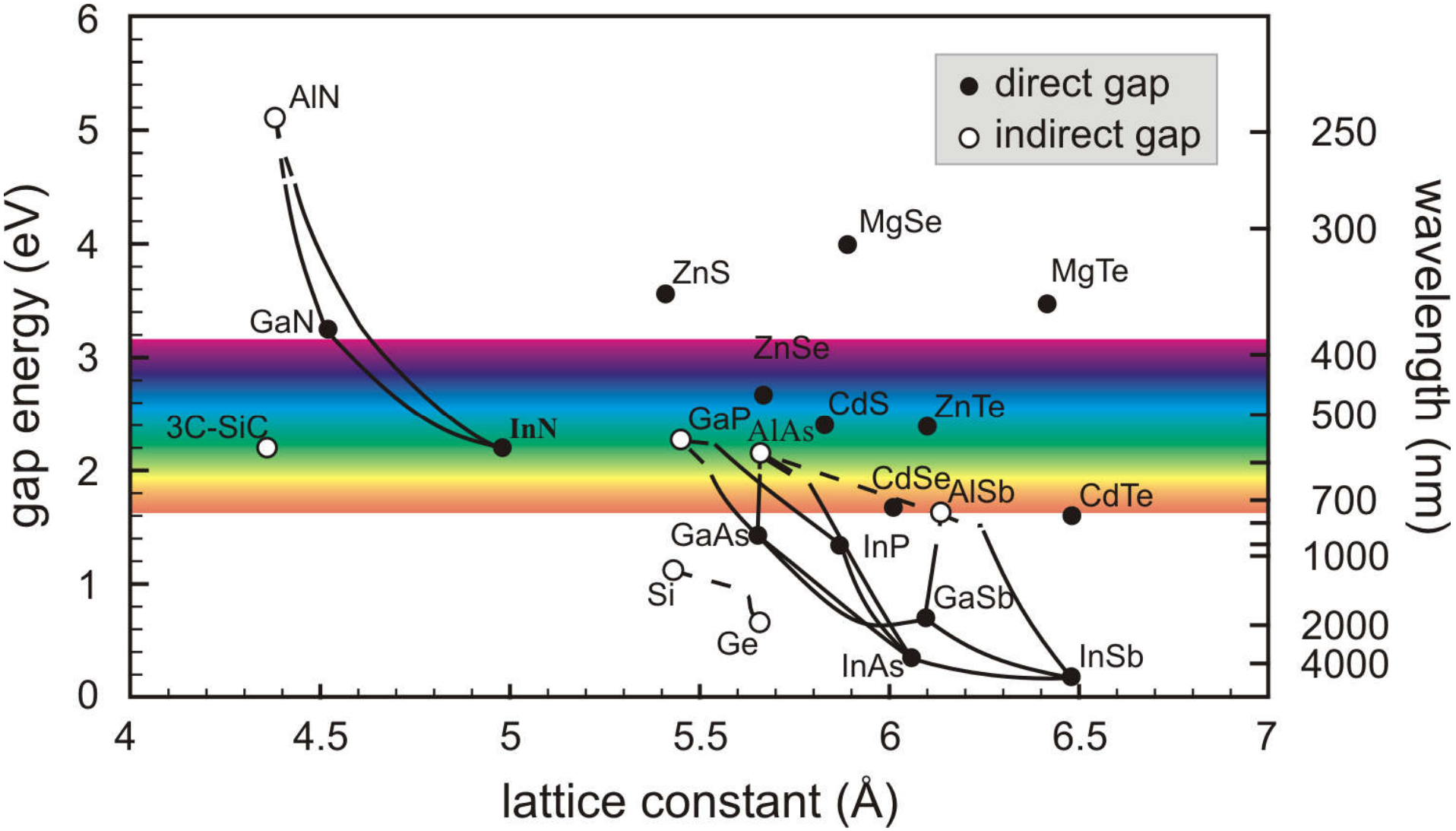
- Little change in momentum is required for recombination
- Momentum is conserved by photon (light) emission

- Large change in momentum is required for recombination
- Momentum is conserved by mainly phonon (vibration) emission + photon emission

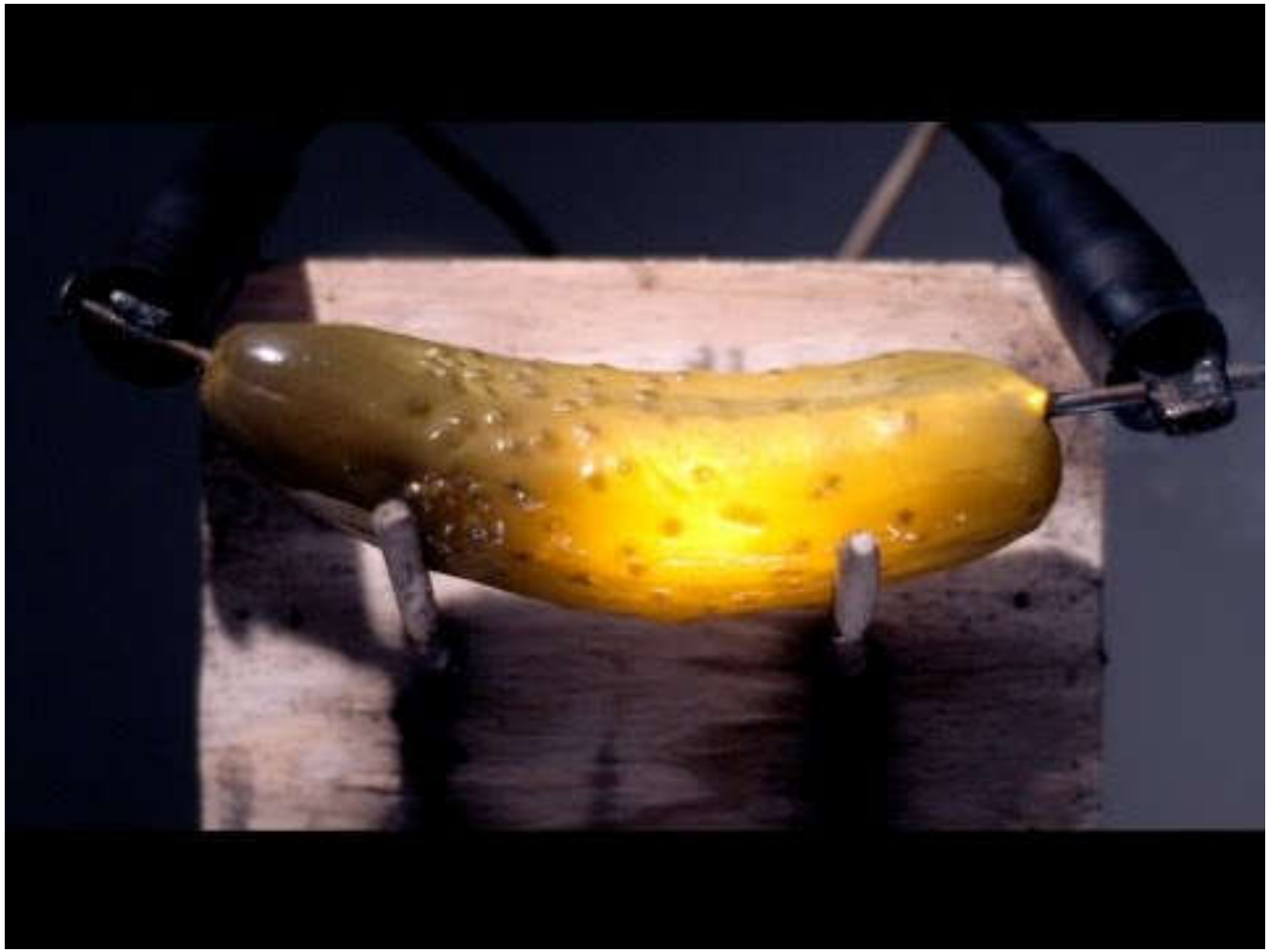
Direct bandgap semiconductors like GaAs, GaN are more suitable for LEDs and lasers

Indirect bandgap semiconductors like silicon do not emit light efficiently more non-radiative recombinations

Materials Choices for Light Emission



Everything can emit light

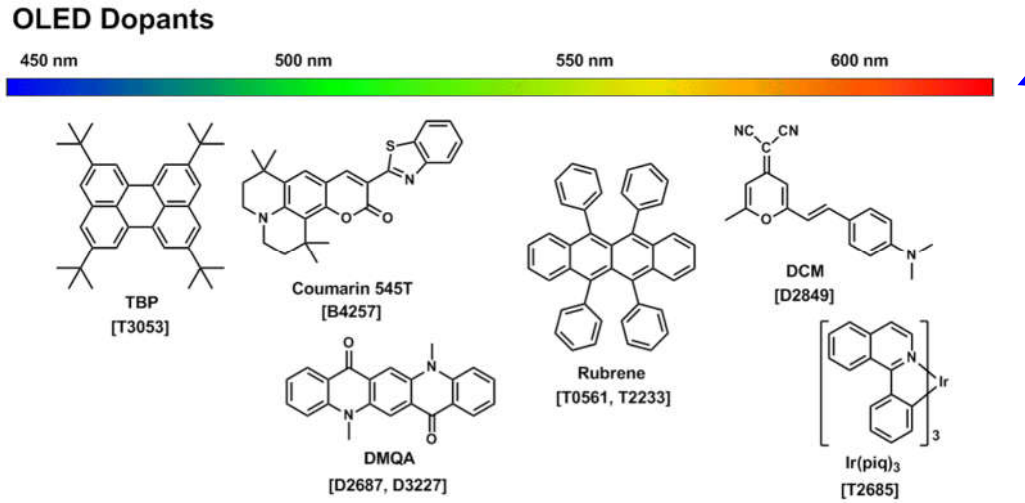


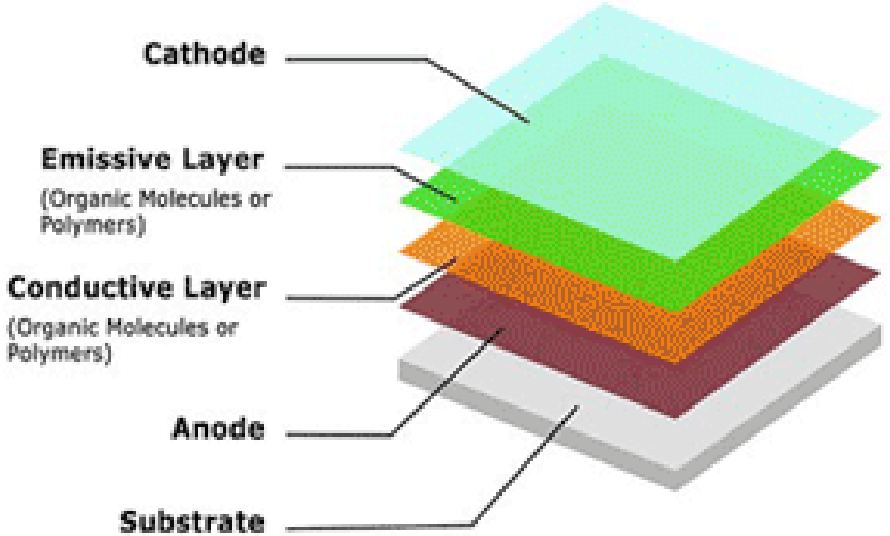
Pickle (腌黄瓜)
at 120 V

Video

Organic LED

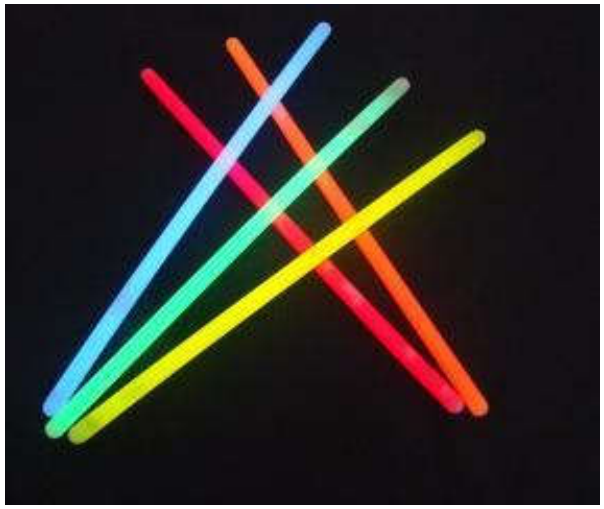
- **Small Molecules**



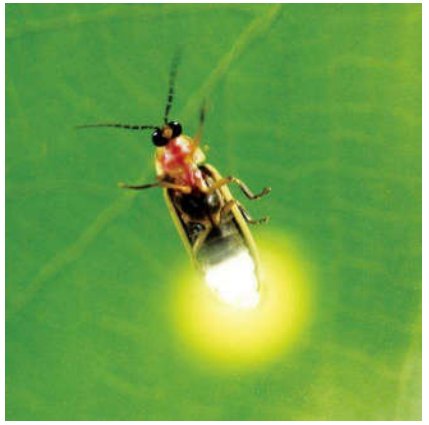


OLED

Others

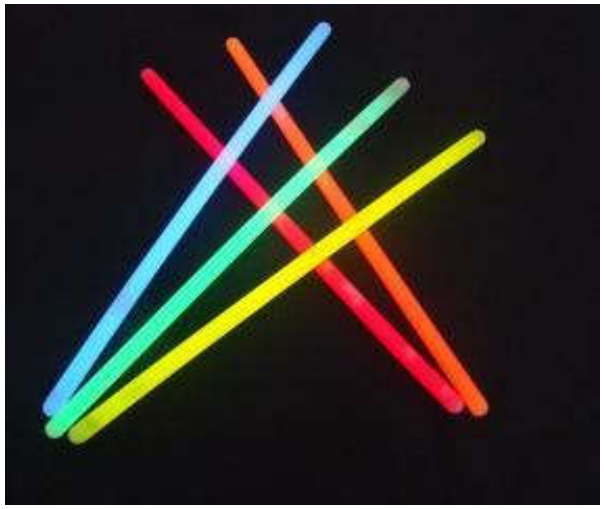


Chemiluminescence

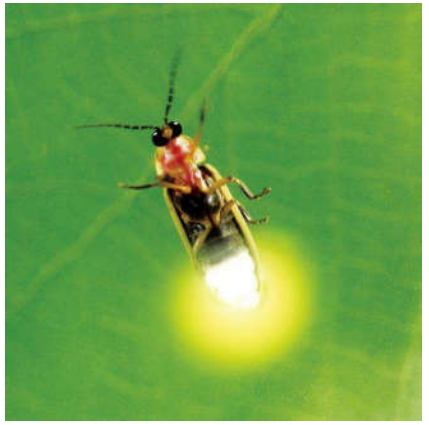


Bioluminescence

Others

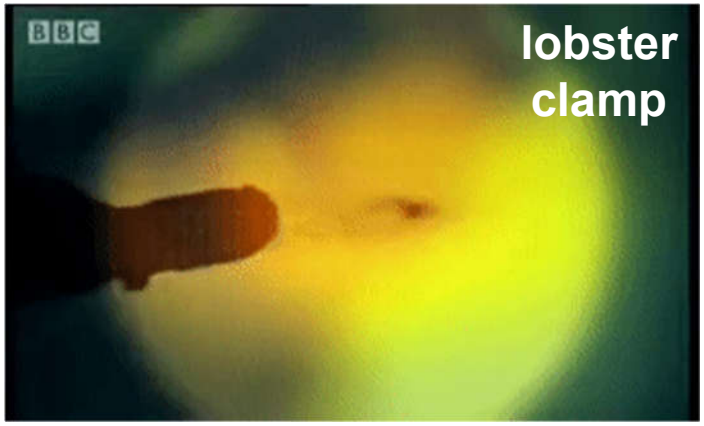


Chemiluminescence 化学



Bioluminescence 生物

Triboluminescence 摩擦



Sonoluminescence 超声

Lighting 照明技术

Incandescent bulb
白炽灯

Fluorescent lamp
荧光灯

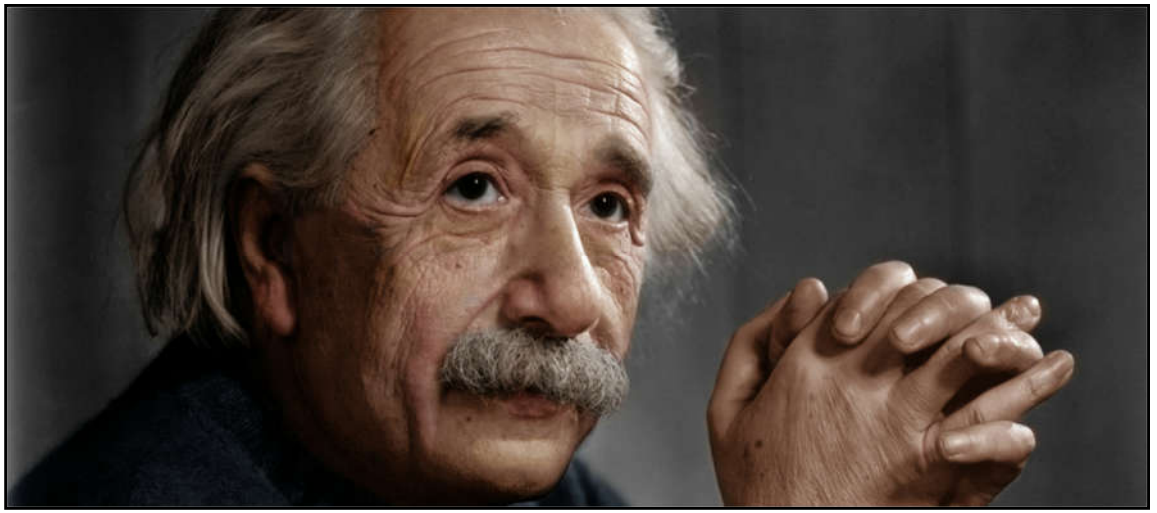
LED lamp

Q: What are the differences?

Mysteries Remain

"All these 50 years of pondering have not brought me any closer to answering the question, 'what are light quanta?' "

---- Albert Einstein in 1951



This Class

- Introduction (Week 1)
- Materials and Crystal Structures (Week 2–3)
- Electronic Properties (Week 4–12)
- Thermal Properties (Week 13)
- **Optical Properties (Week 14)**
  - **Origin of Dielectric constant (ε) and Refractive index (n)**
  - **Optical absorption, reflection, refraction, emission**
- Magnetic Properties (Week 15)

Next Class

- Introduction (Week 1)
- Materials and Crystal Structures (Week 2–3)
- Electronic Properties (Week 4–12)
- Thermal Properties (Week 13)
- Optical Properties (Week 14)
- **Magnetic Properties (Week 15)**
  - **Origin of Magnetics**
  - **Diamagnetism, Paramagnetism, Ferromagnetism**
  - **Superconductivity**

Thank you for your attention