Electromagnetic Radiation: Characteristics

tranversal waves, velocity $c_0 \approx 3 \cdot 10^8$ m s^{-1}

1. Energy (eV, kJ mol^{-1})

-frequency ν ($\nu = c_0 / \lambda$; s^{-1}, Hz)

-wavelength λ ($\lambda = c_0 / \nu$; Å, nm, ..., m, ...)

-wavenumber $\tilde{\nu}$ ($\tilde{\nu} = 1/\lambda = \nu/c_0$; cm^{-1}, Kaiser)

energy ~ frequency ($E = h \cdot \nu$)

~ wavenumber ($E = h \cdot \tilde{\nu} \cdot c_o$)

~ $wavelength^{-1}$ ($E = h \cdot c_0 / \lambda$)

2. Intensity cross-section $I \sim |\vec{S}|^2 = |\vec{E} \times \vec{H}|$

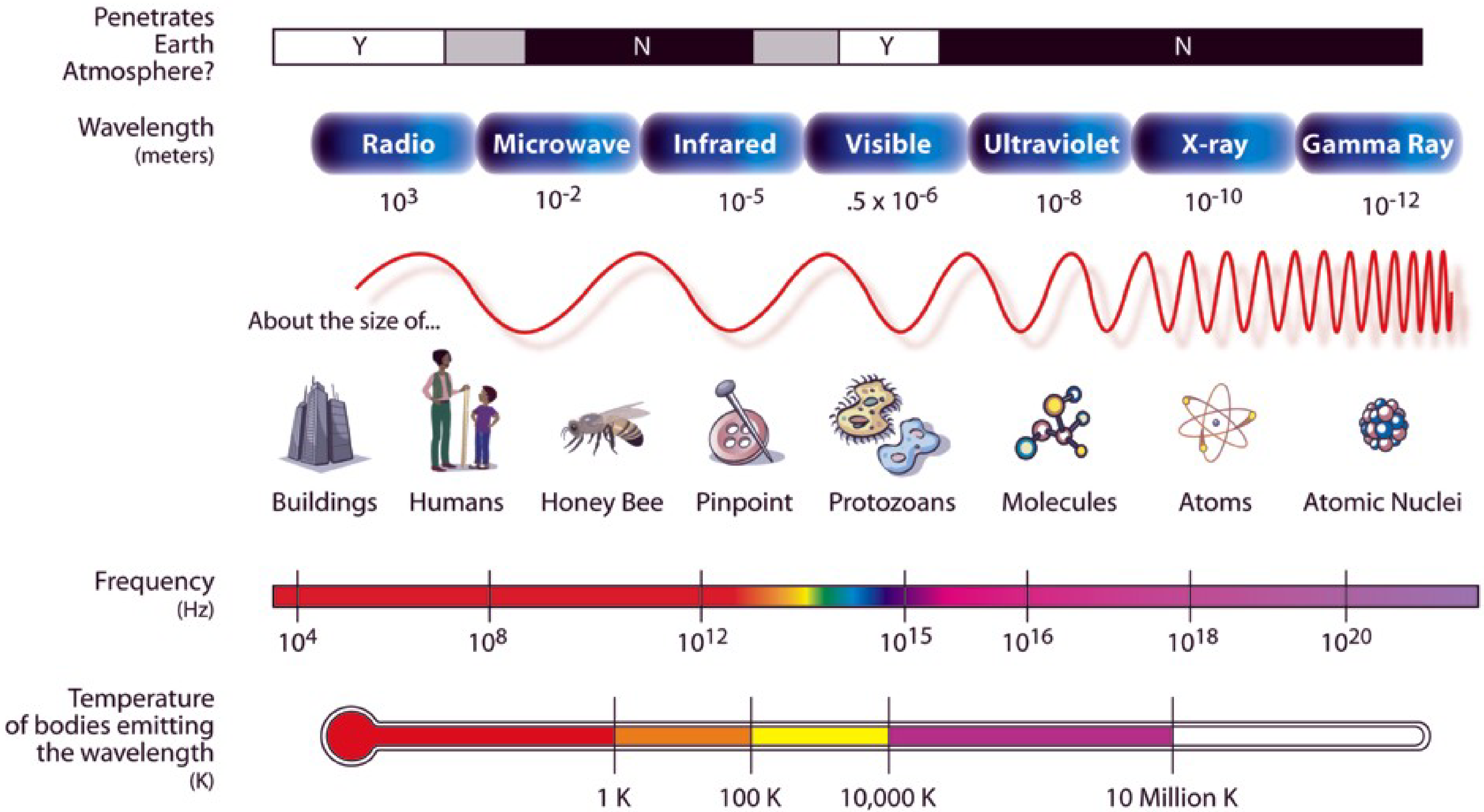
3. Direction wavevector $\vec{s}_0$

4. Phase phase φ

Range of frequencies for structural analysis: 10^6-10^{20} Hz, 10^2 -10^{-12}m, 10^{-8}-10^6 eV

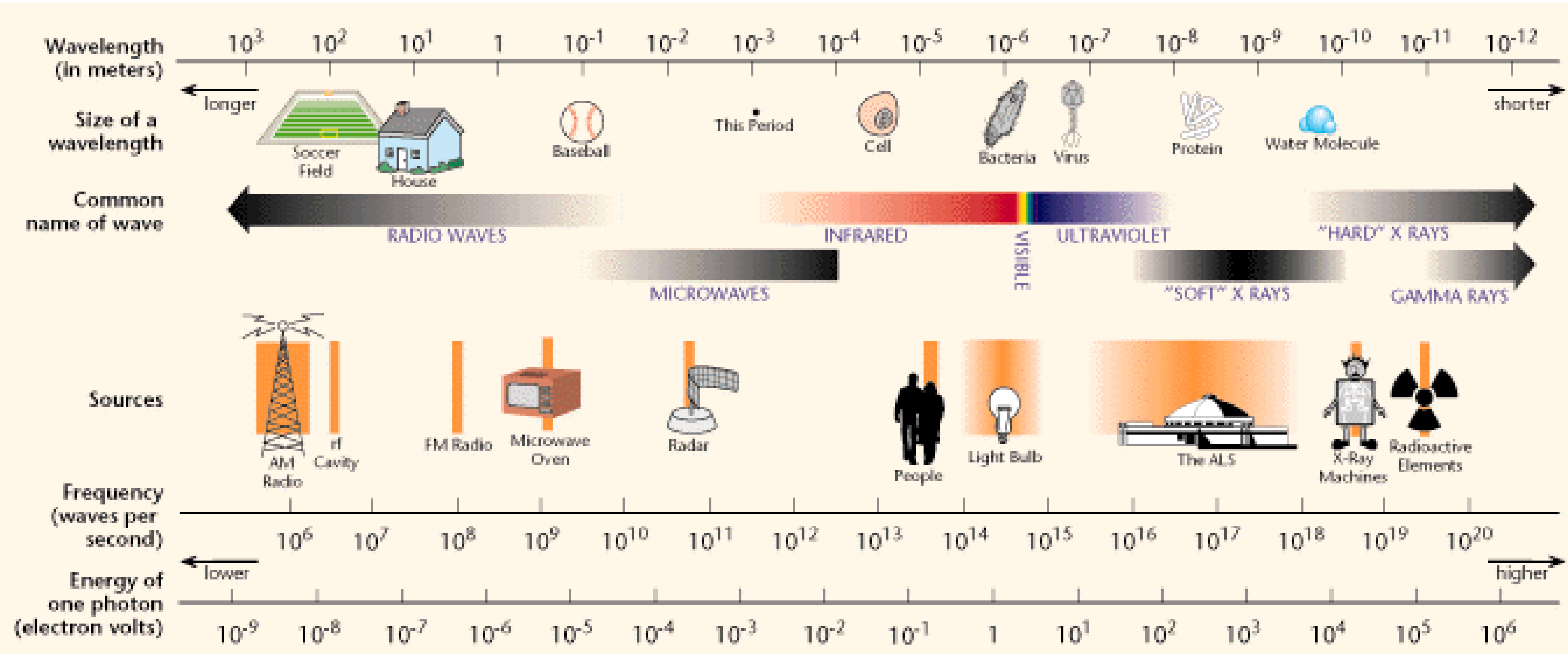
radio-, microwaves, infrared (IR), visible (VIS), ultraviolet (UV), X-ray, γ-ray[1]

Electromagnetic radiation: Sprectral ranges



Orders of magnitude in wavelength, frequency, energy, temperature

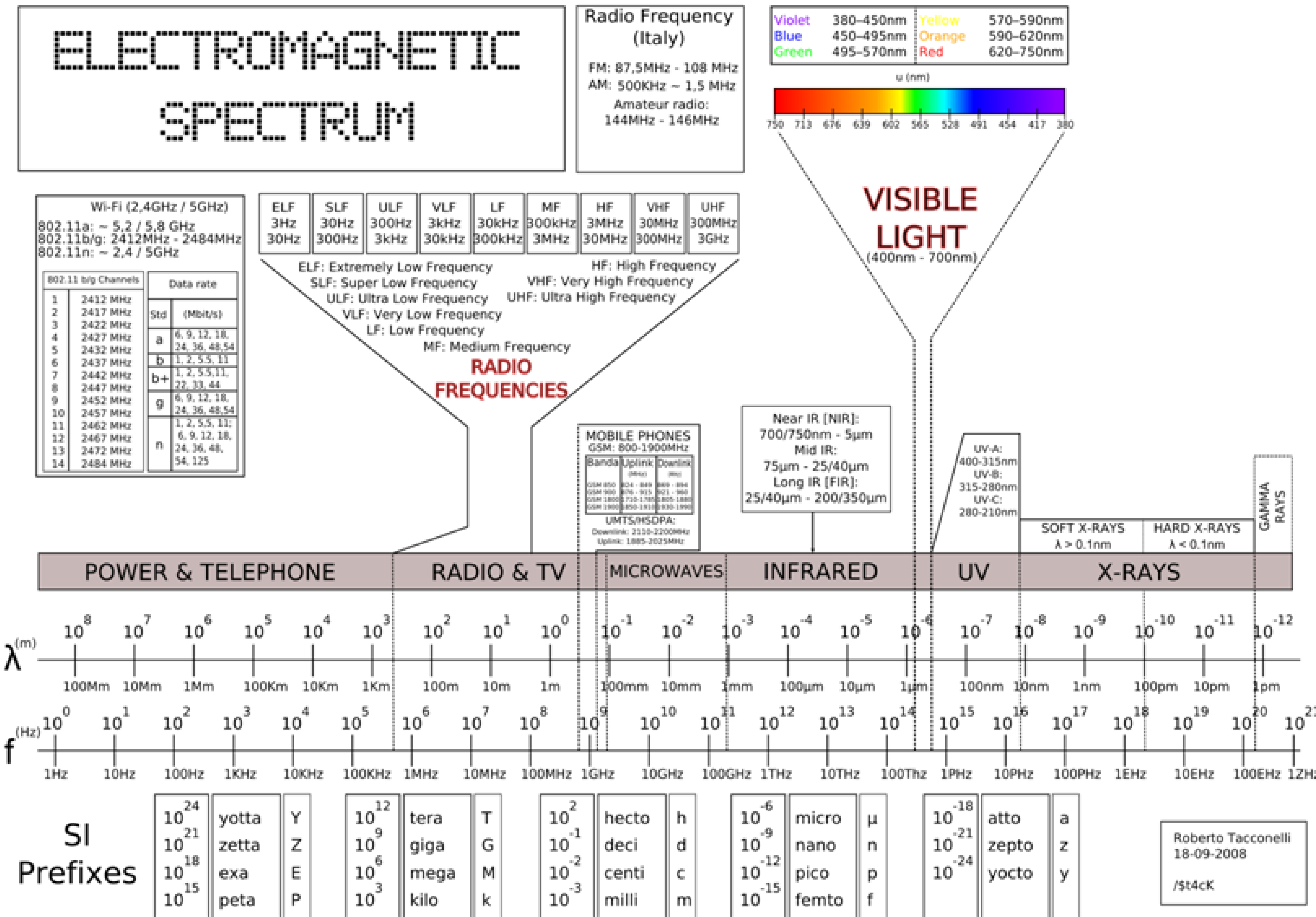
Electromagnetic radiation: Sprectral ranges



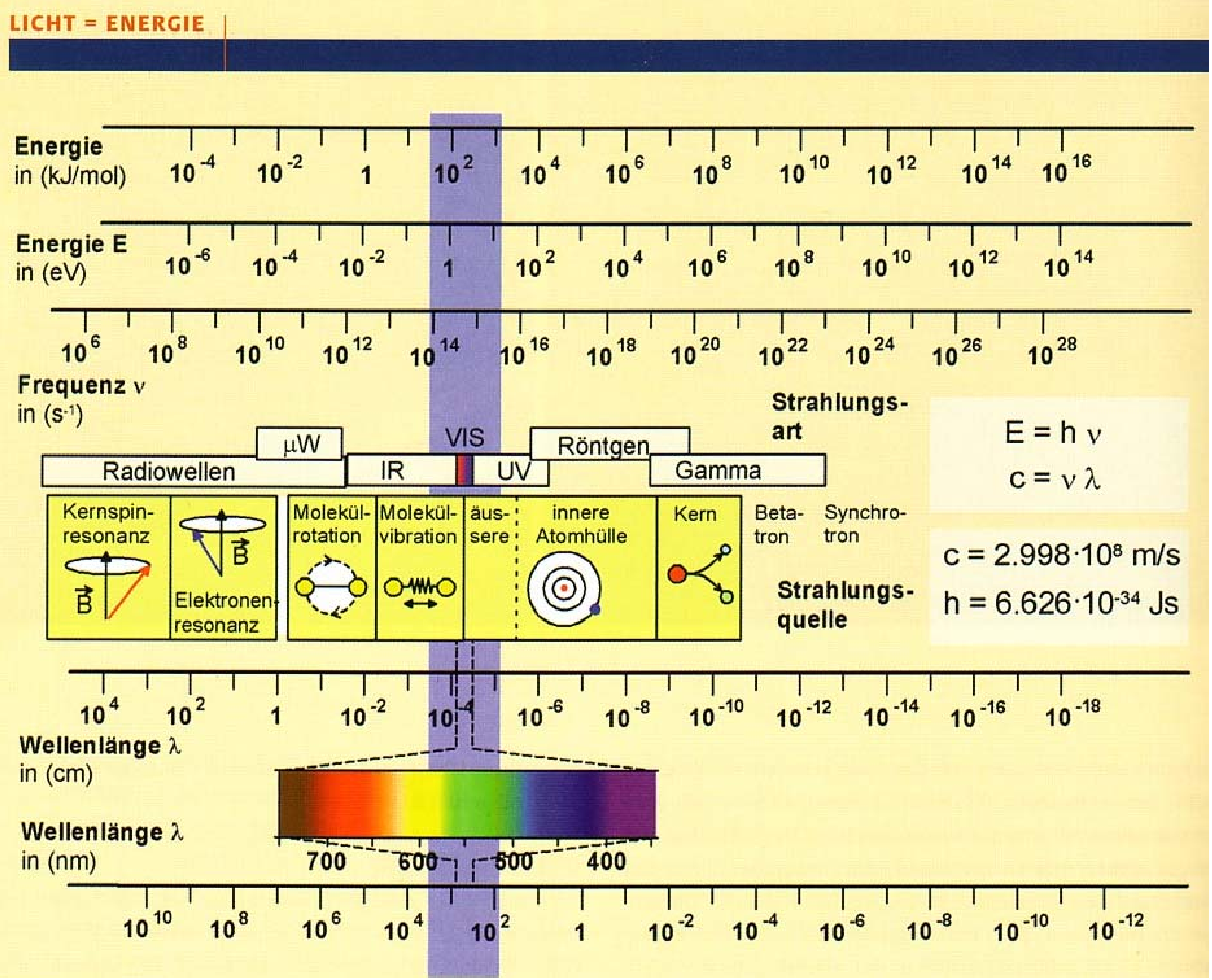
$$1\ eV = 1{,}602 \cdot 10^{-19}\ J = 96{,}485\ kJ\ mol^{-1} = 8065{,}5\ cm^{-1}$$

Orders of magnitude in wavelength, frequency, energy, temperature

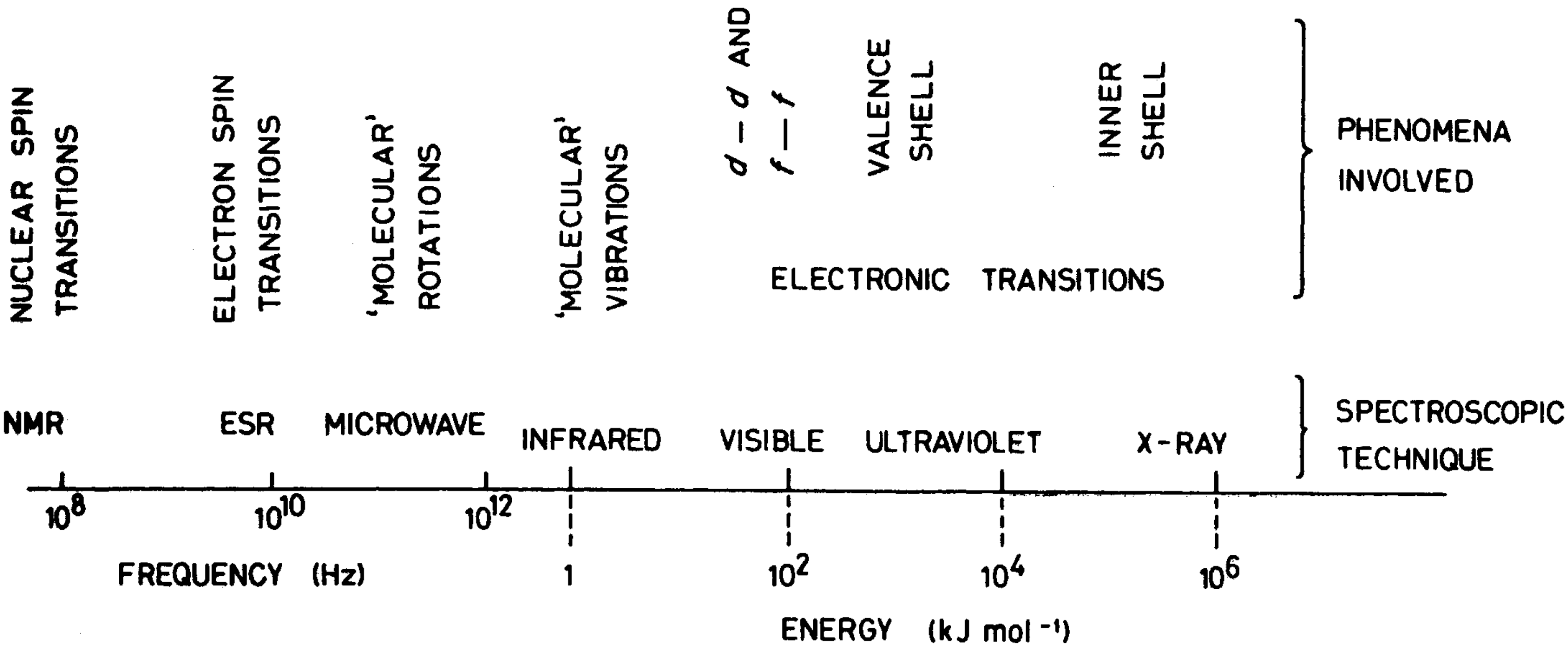
Electromagnetic radiation: Sprectral ranges



Electromagnetic radiation: Sprectral ranges



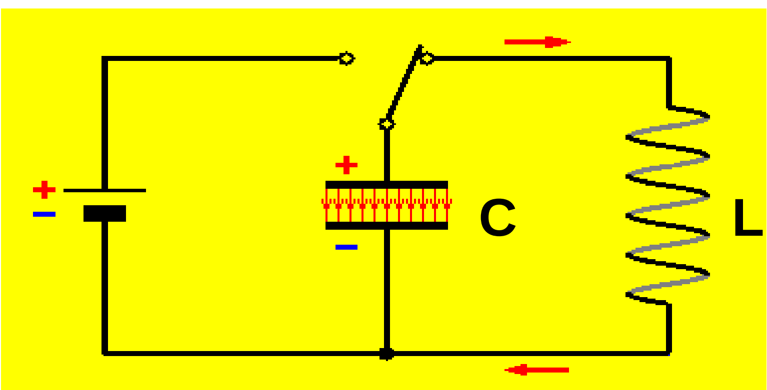
Electromagnetic radiation: Origins and techniques

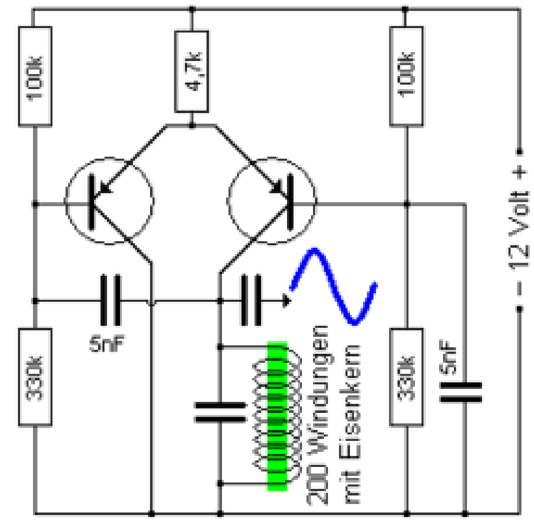


Electromagnetic radiation: Sources
Radio waves/NMR

Radio valve, 500 W graphite anode

Anode



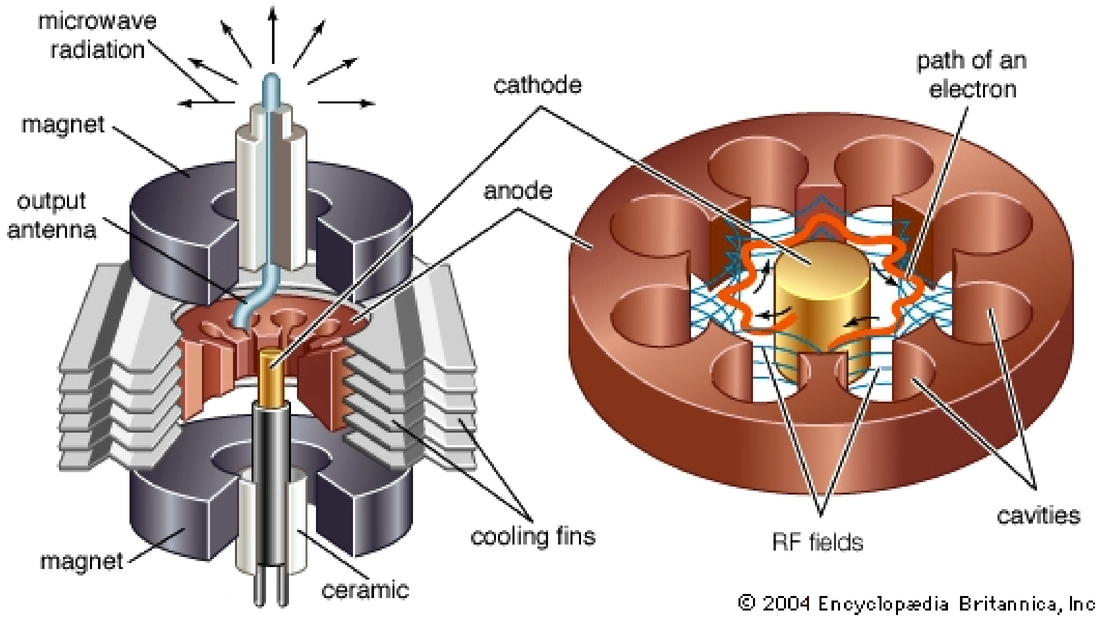


Sinus-Oszillator für etwa 1 kHz mit PNP-Transistoren.

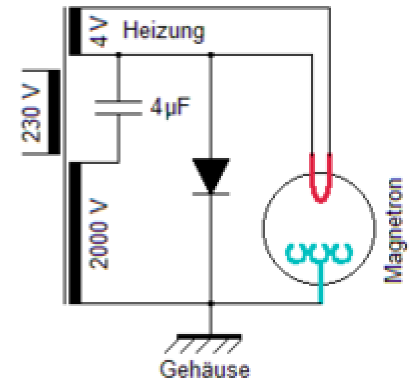
$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

Electromagnetic waves are produced (a.o.), when charges or charged or dipolar species are oscillating with frequencies in the respective range.
For **microwaves**, the charges oscillate in a **resonance or tank circuit**, consisting of a capacitor with **capacitance *C*** and a coil with **self-inductance *L***.

Electromagnetic radiation: Sources
Microwave radiation



Schematic view of a magnetron for the production of microwaves (left) and the anode with an even number of anode vanes (right)

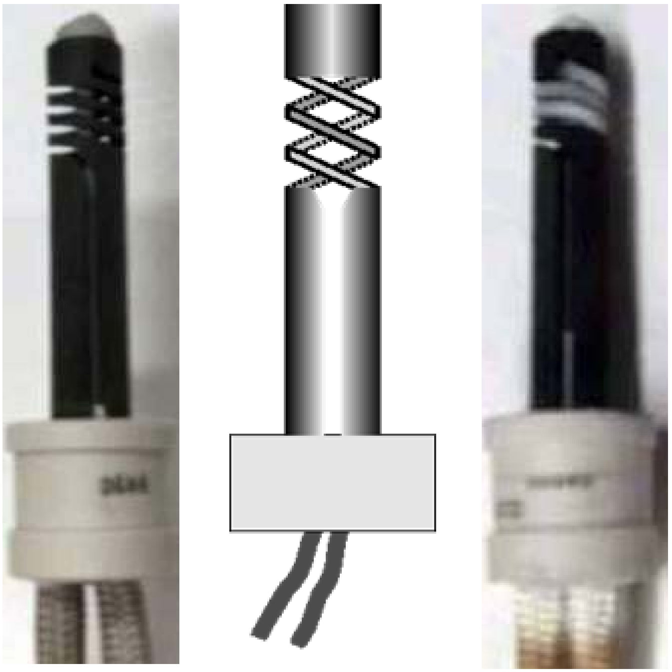


Principal circuit of a magnetron

Impulsmagnetron MI-189W (ca. 9 GHz)
Bordradar, Russia

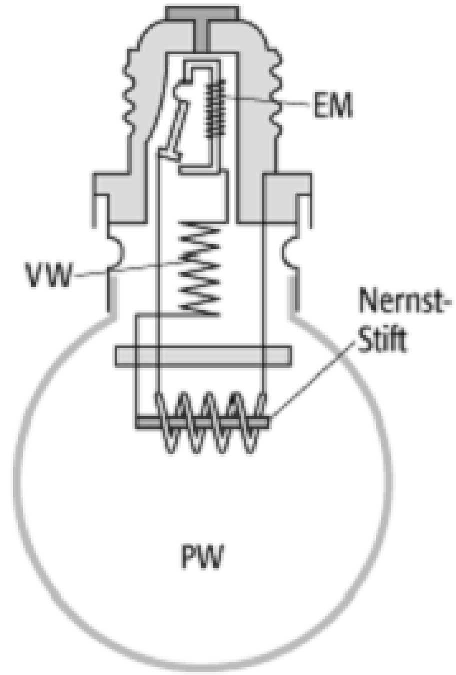
Magnetrons and Gyrotrons are diode-type electron tubes (~ 1-10 kV) with a trapezoid anode (*resonant cavities*) surrounded by permanent magnets producing an axial magnetic field. Under the combined influence of the electric and the magnetic field, the electrons are forced in a circular motion of travel to the anode resulting in electromagnetic radiation of 0.3 - 300 GHz .

Electromagnetic radiation: Sources
IR-Sources, Globar, Nernst lamp



new sketch used

Globar (SiC, ~1.500 K)

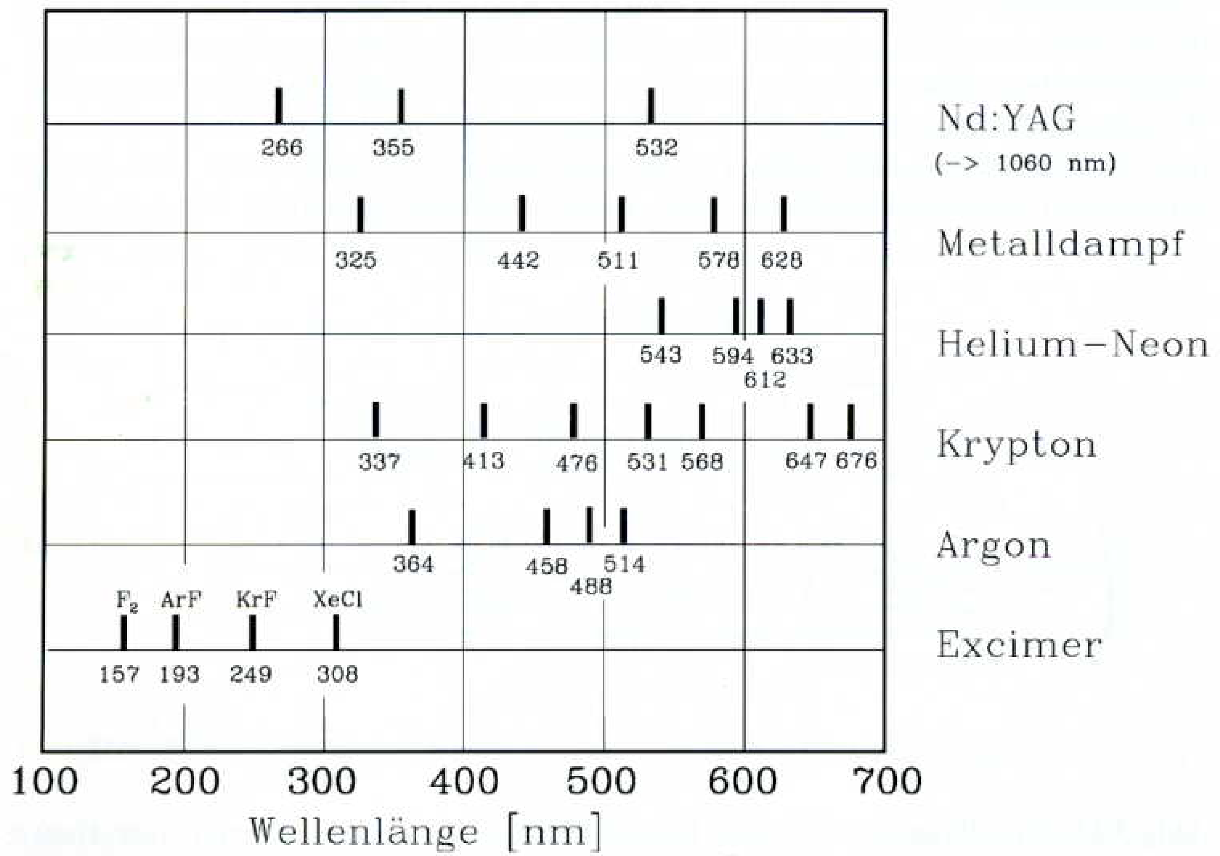


Nernst lamp with Nernst rod, a ZrO_2/Y_2O_3 ion conductor 1.900 K

Any heated material will produce infrared radiations

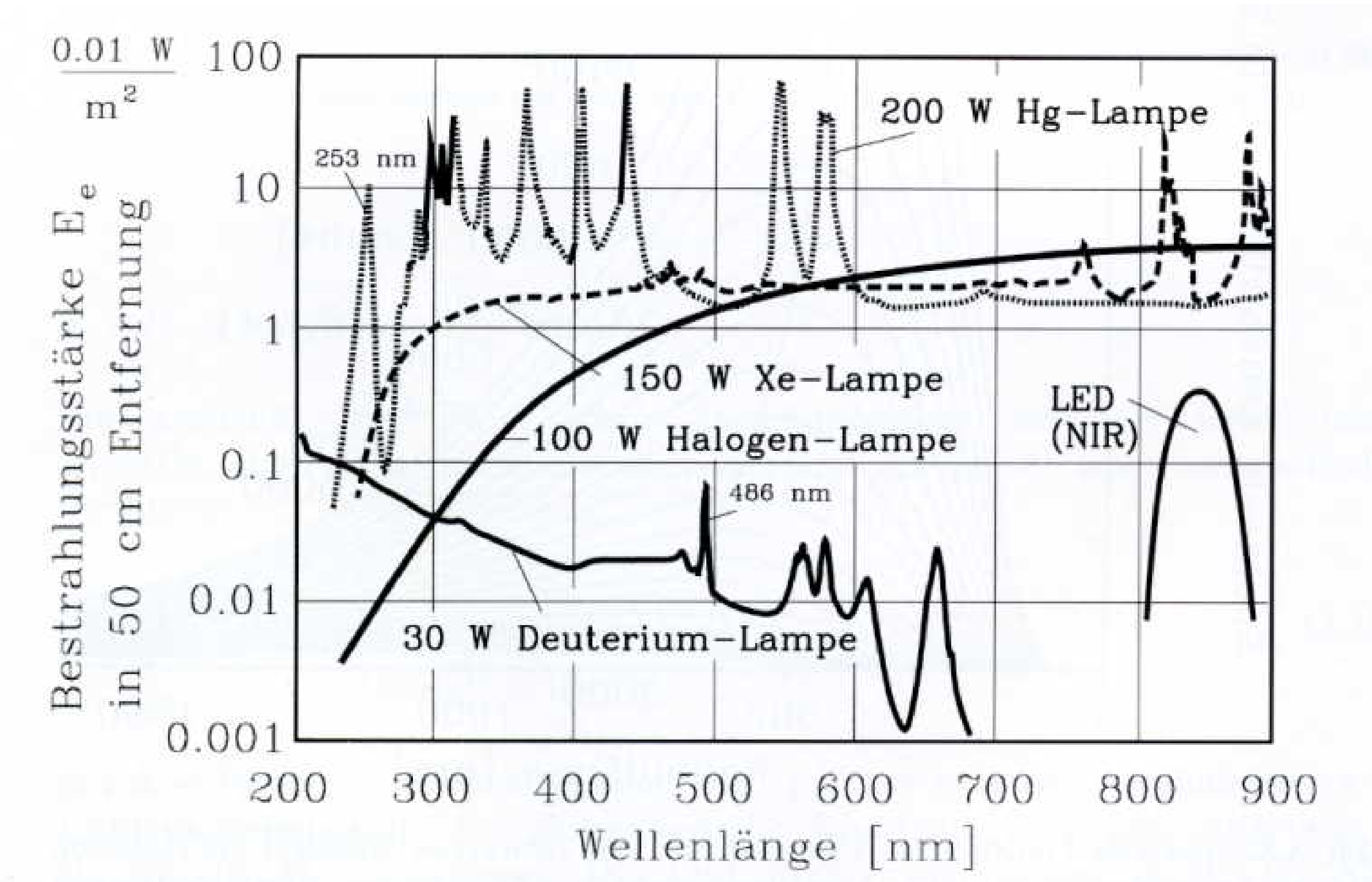
http://www.techniklexikon.net/d/nernst-brenner/nernst-brenner.htm

Electromagnetic radiation: Sources UV and NIR radiation

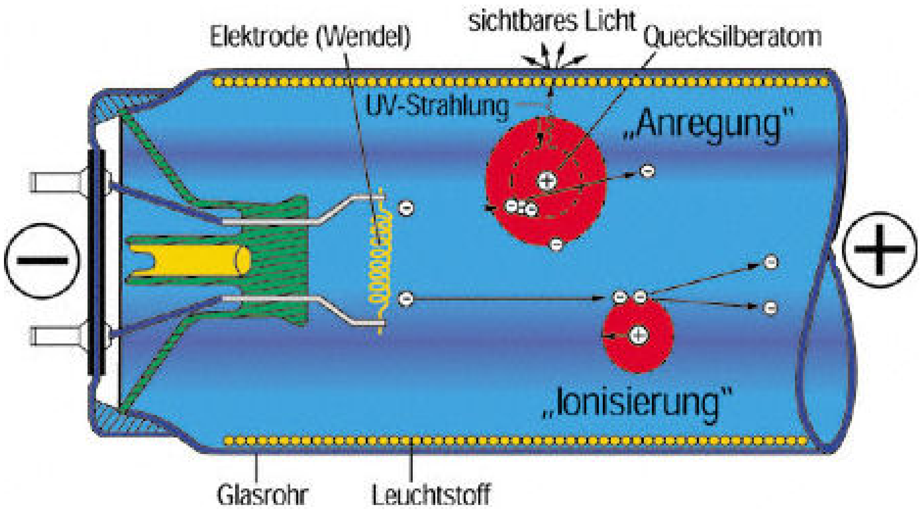


Wave lengths of some lasers for UV, visible and Raman specroscopy

Electromagnetic radiation: Sources
UV and NIR radiation



Electromagnetic radiation: Sources
UV radiation

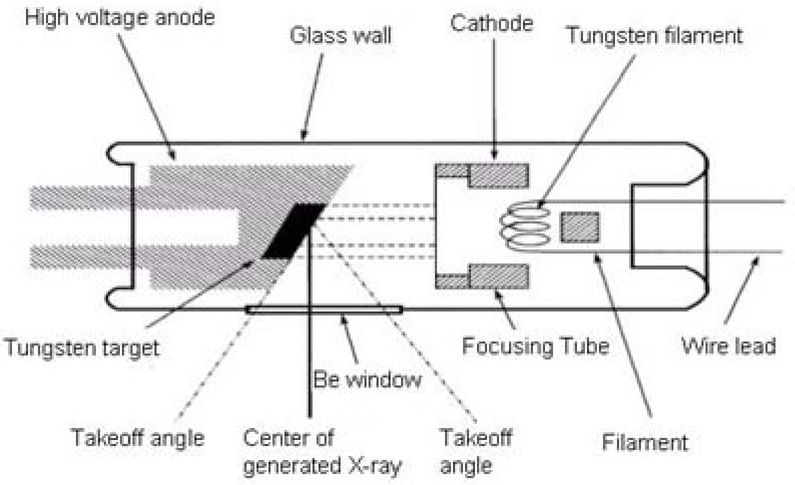


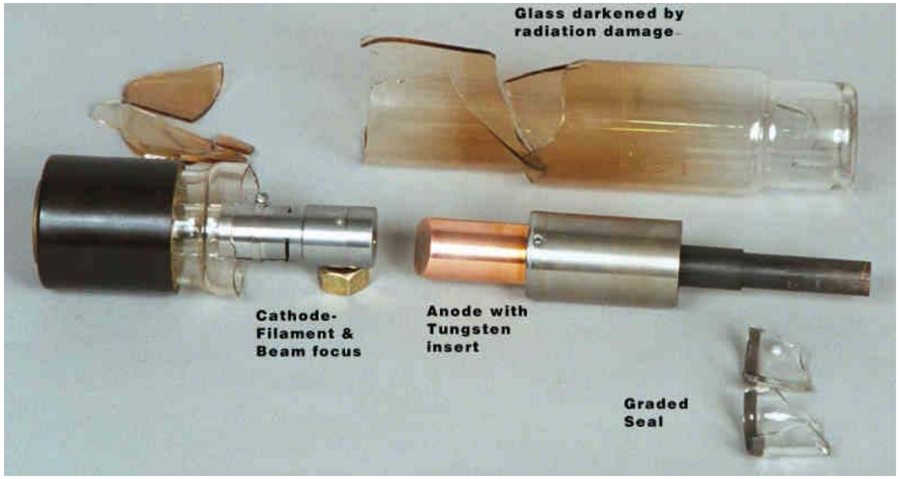
Sketch of a mercury (low pressure) lamp
Excitation/ionisation of Hg by fast electrons
(Importent Hg lines are 313 nm, 365 nm (i line), 405 nm (h line), 434 nm (g line), 546 nm (e line) and 577/579 nm und nm (orange dubble line)).

UV or black light lamp

Electromagnetic radiation: Sources
X-rays

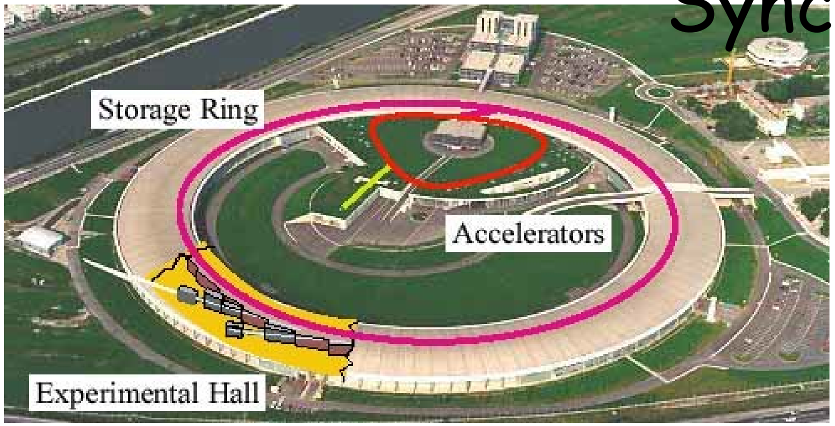
X-rax tube

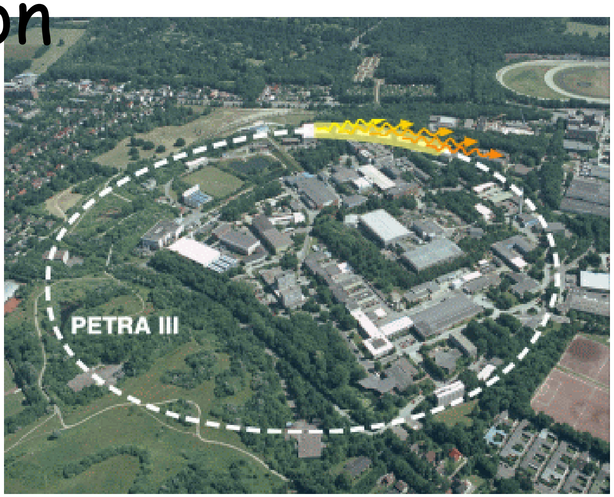




X-rax tube: sketched and dashed

Electromagnetic radiation: Sources
Synchroton





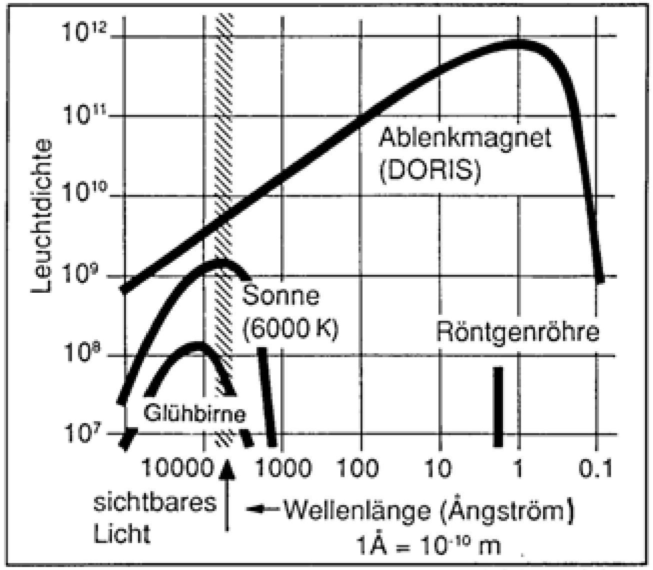
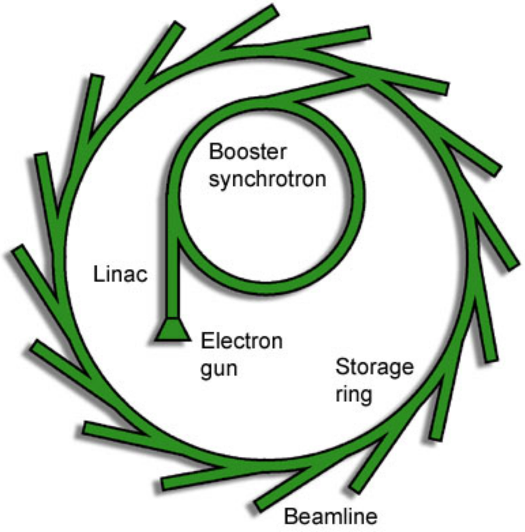
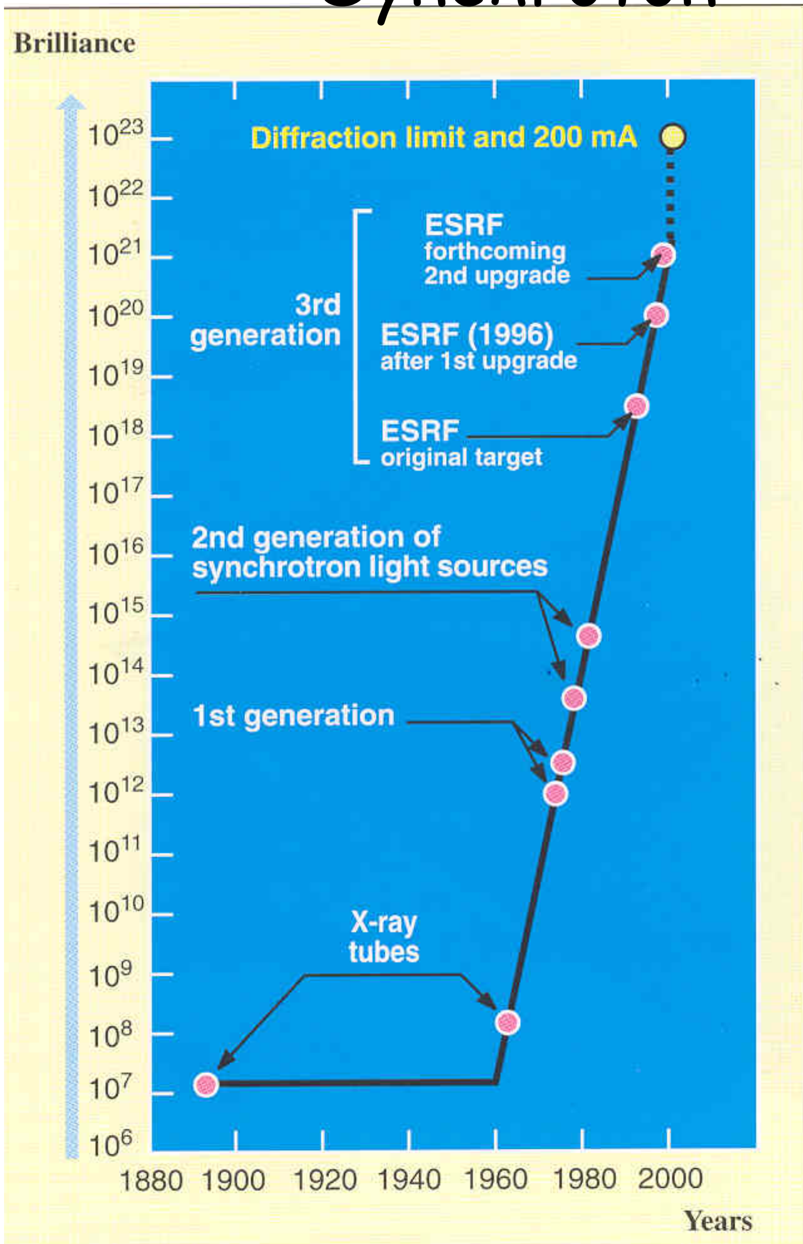


Abb. 5: Die Leuchtdichte von DORIS im Vergleich zu einigen bekannten Strahlungsquellen. (Die Leuchtdichte ist die Zahl der Photonen, die pro Sekunde und Wellenlängenintervall in eine bestimmte Richtung abgestrahlt wird.)



tunable electromagnetic radiation

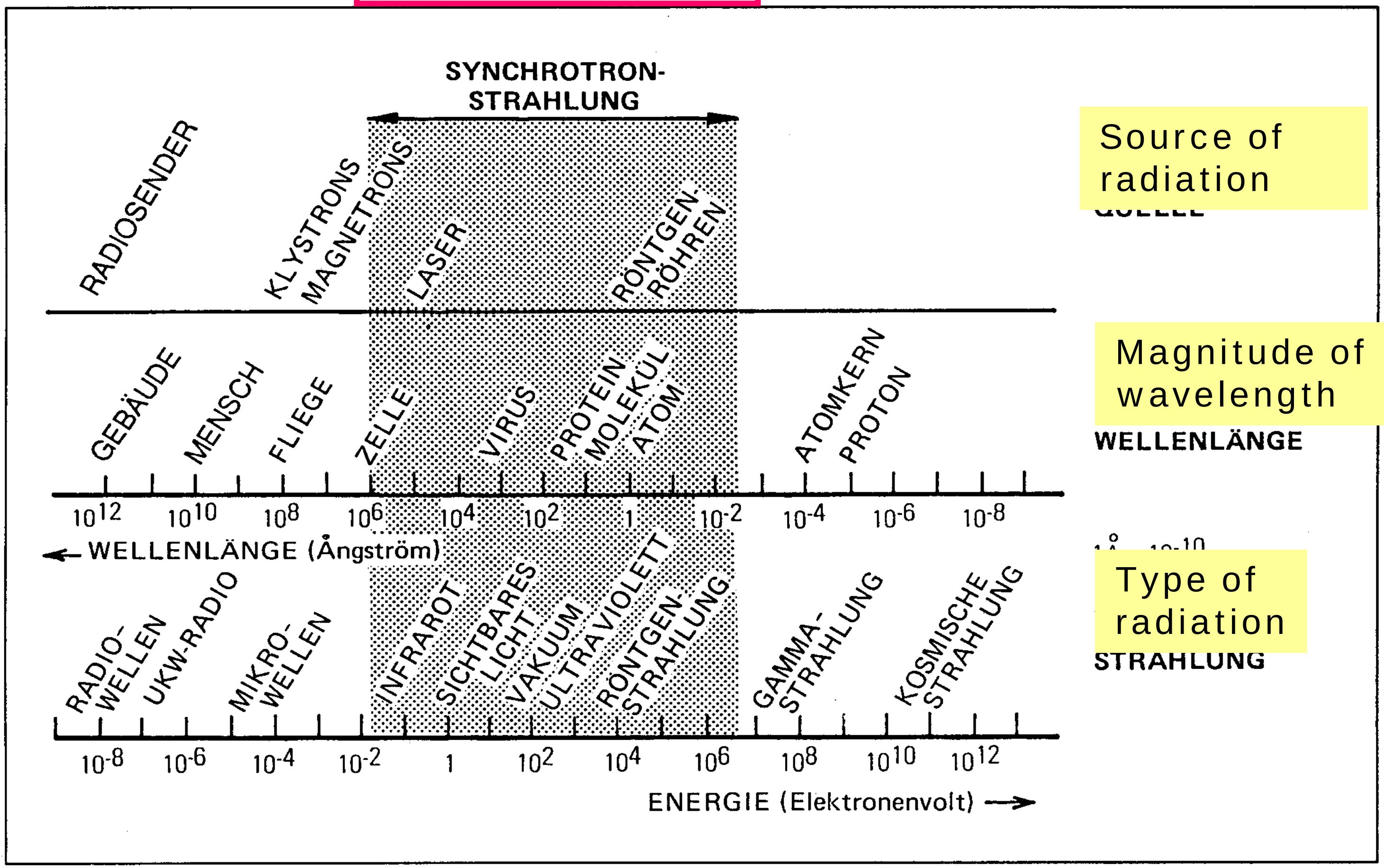
Electromagnetic radiation: Sources Synchroton



increase of brilliance over the years

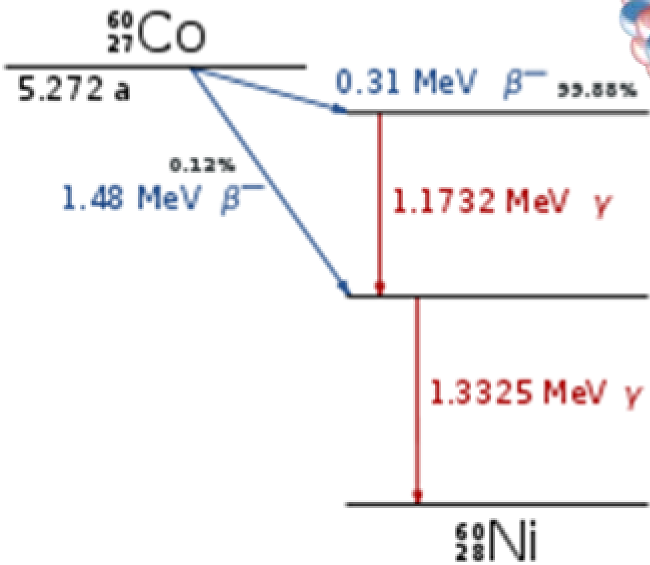
Electromagnetic radiation: Sources
Synchroton

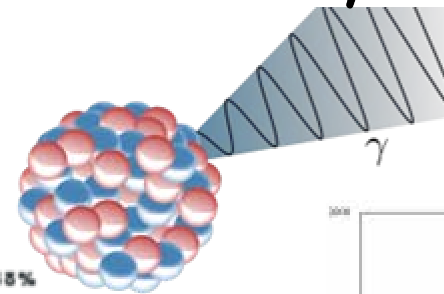
(range of tunability)

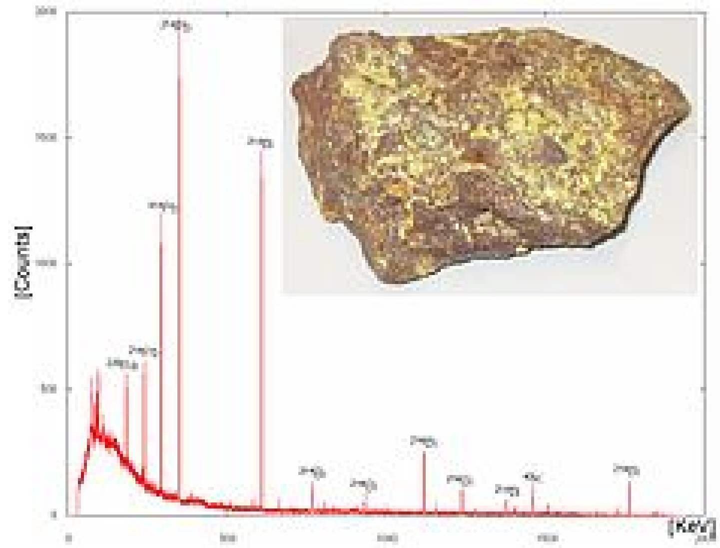


Use of Synchroton Radiation in materials science

Electromagnetic radiation: Sources
Gamma-rays





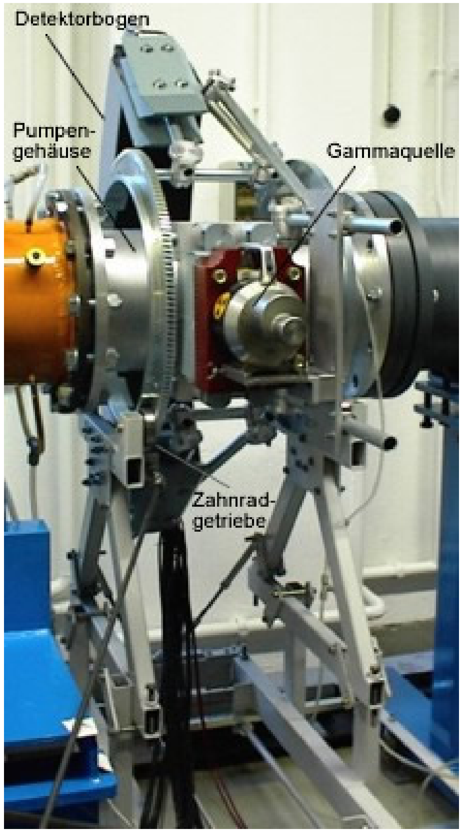


Decay scheme of ^{60}Co

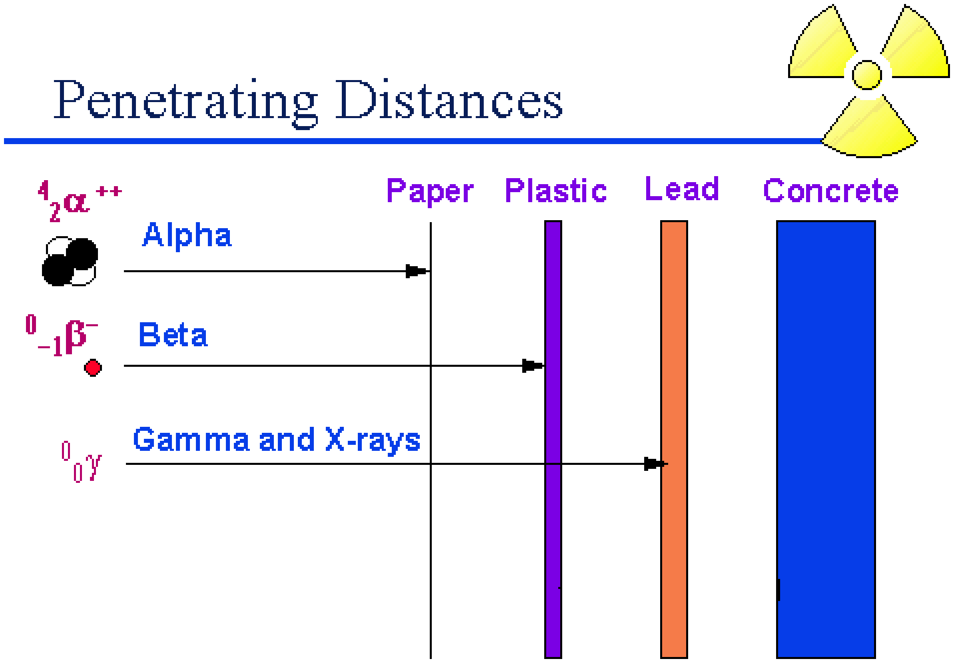
Gamma-ray spectrum of ^{238}U

Gamma rays can occur whenever charged particles pass through magnetic fields or pass within certain distances of each other or by nuclear reactions (e.g. fusion or decay processes)

Electromagnetic radiation: Sources
Gamma-rays

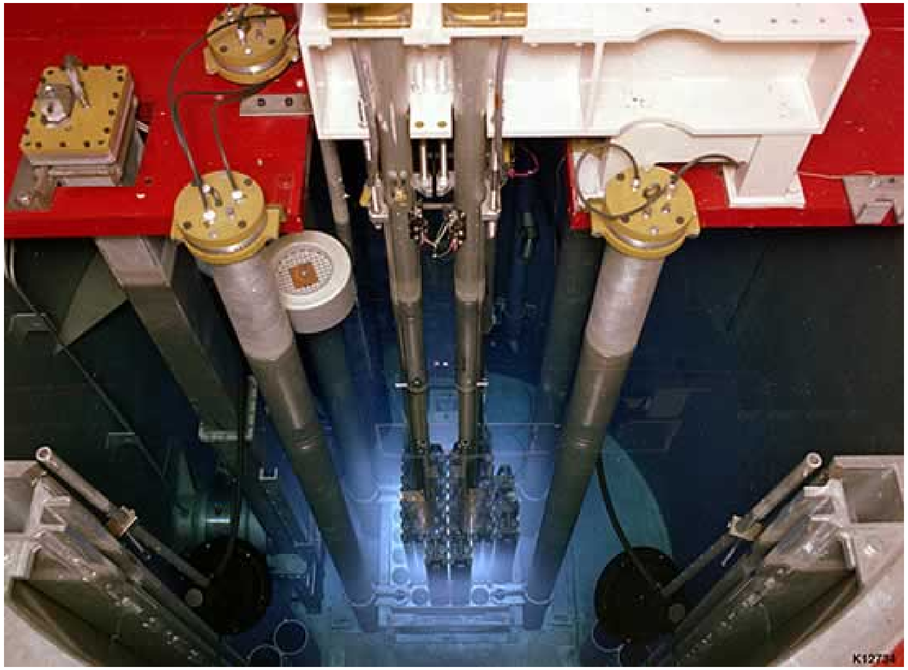


Gamma-radiation source

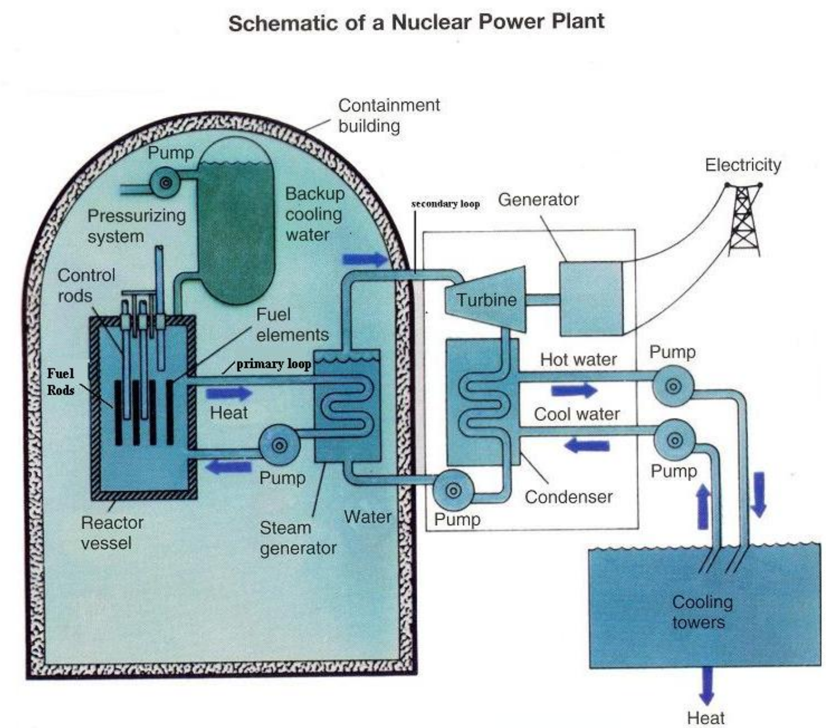


Nuclear decay products

Electromagnetic radiation: Sources
Neutrons



View into a nuclar reactor with Cherenkov radiation



Scetch of a nuclear power plant

De Broglie wave length: $\lambda = h/(m \cdot v)$

e.g. n with v = 3.300 m/s → 0,05 eV → 1,2 Å (0,12 nm)