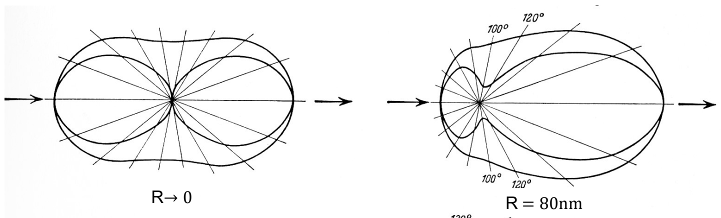
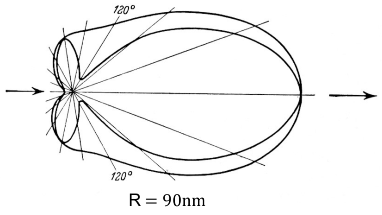
Radiation Pattern of a Au particle





Excitation by natural light (unpolarized)

Outer curve: $I = I_\perp + I_{||}$

Inner curve: $I = I_\perp$

Born, Optik

Far- and Near-Field of a Point Dipole

Dipole moment

$$p(t) = p_0 \cos(\omega t)$$

creates time-dependent electric field (spherical coordinates!)

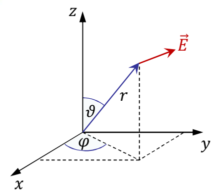
Far-field

Near-field

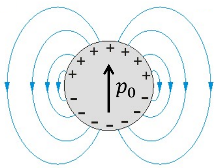
$$\vec{E}(r,\vartheta,\varphi,t) = \begin{pmatrix} E_r \\ E_\vartheta \\ E_\varphi \end{pmatrix} = \frac{p_0 k^3}{4\pi\varepsilon_0} \begin{pmatrix} \left(-\frac{2i}{(kr)^2} + \frac{2}{(kr)^3} \right) \cos\vartheta \\ \left(-\frac{1}{kr} - \frac{i}{(kr)^2} + \frac{1}{(kr)^3} \right) \sin\vartheta \\ 0 \end{pmatrix} \cos(kr - \omega t)$$

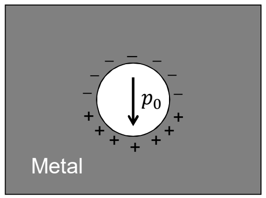
Emission to far-field

$$\langle |\vec{S}| \rangle = \frac{\omega^4 p_0^2}{32\pi^2 \varepsilon_0 c^3} \frac{\sin^2\vartheta}{r^2}$$



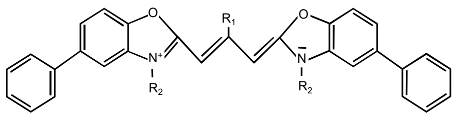
Nanostructures as electric dipole emitters

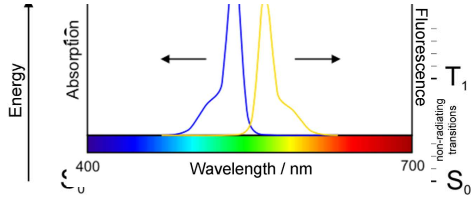




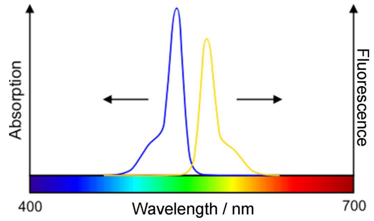
Absorption and Emission of Light by Molecules

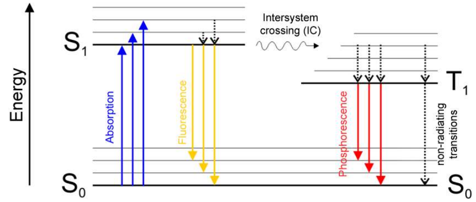
Cyanine dye





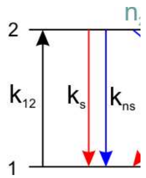
Absorption and Emission of Light by Molecules





Absorption- and Emission Rates

Simplified Sch



Absorption rate

$$R_{abs} = k_{12} \cdot n_1 = (\sigma \cdot I / h\nu) \cdot n_1$$

Emission rate

$$R_{em} = k_S \cdot n_2$$

Boundary conditions

$$n_1 + n_2 + n_3 = 1$$

$$\dot{n}_1 = \dot{n}_2 = \dot{n}_3 = 0$$

Rate equations

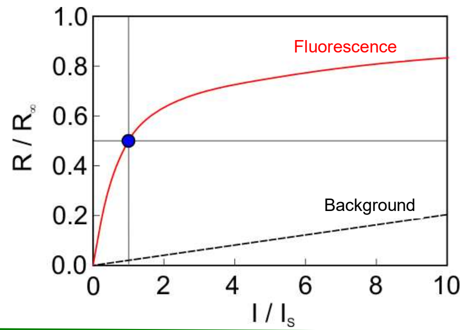
$$\dot{n}_1 = -k_{12} n_1 + (k_s + k_{ns}) n_2 + k_{31} n_3$$

$$\dot{n}_2 = k_{12} n_1 - (k_s + k_{ns} + k_{23}) n_2$$

$$\dot{n}_3 = k_{23} n_2 - k_{31} n_3$$

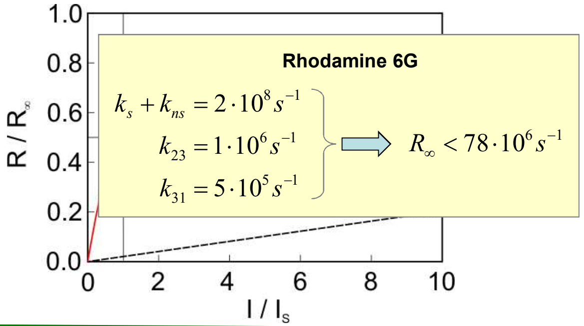
Saturation

$$R_{em} = R_\infty \frac{I / I_S}{1 + I / I_S} \quad \text{with} \quad \begin{cases} R_\infty = \dfrac{k_s}{k_{23} + k_{31}} \cdot k_{31} \\ I_S = \dfrac{h\nu}{\sigma} \cdot \dfrac{k_{23} + k_s + k_{ns}}{k_{23} + k_{31}} \cdot k_{31} \end{cases}$$



Saturation

$$R_{em} = R_\infty \frac{I/I_S}{1+I/I_S} \quad \text{with} \quad \begin{cases} R_\infty = \dfrac{k_s}{k_{23}+k_{31}} \cdot k_{31} \\ I_S = \dfrac{h\nu}{\sigma} \cdot \dfrac{k_{23}+k_s+k_{ns}}{k_{23}+k_{31}} \cdot k_{31} \end{cases}$$



1 Theoretical aspects

⋮

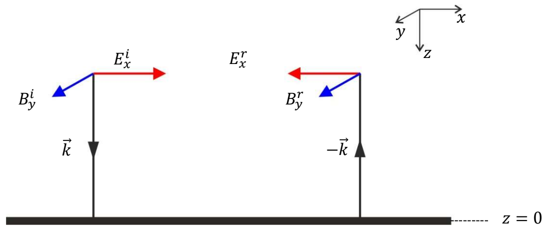
1.3 Light scattering and emission by particles

1.3.1 Localized Plasmons – Mie scattering
1.3.1 Far- and near-field of a radiating (point-) dipole
1.3.2 Fluorescence of molecules
1.3.3 Fluorescence Quenching and Enhancement
1.3.4 Stimulated Emission

Reflection at an ideally conducting metal

$$\vec{k} = \begin{pmatrix} 0 \\ 0 \\ k \end{pmatrix}$$

$$\vec{B} = \frac{1}{\omega} \vec{k} \times \vec{E}$$



Assumption: Only $\vec{E}$ interacts with metal (electrons). Then the fields are given by

$$\vec{E}^i = \begin{pmatrix} E_x^i \\ 0 \\ 0 \end{pmatrix} ; \quad E_x^i = E_0 e^{i(kz-\omega t)} \qquad \vec{E}^r = \begin{pmatrix} E_x^i \\ 0 \\ 0 \end{pmatrix} \quad E_x^i = -E_0 e^{i(-kz-\omega t)}$$

$$\vec{B}^i = \begin{pmatrix} 0 \\ B_y^i \\ 0 \end{pmatrix} ; \quad B_y^i = B_0 e^{i(kz-\omega t)} \qquad \vec{B}^r = \begin{pmatrix} 0 \\ B_y^r \\ 0 \end{pmatrix} \quad B_y^r = +B_0 e^{i(-kz-\omega t)}$$

Reflection at an ideally conducting metal

Due to the ideal conduction, $\vec{E} = \vec{E}^i + \vec{E}^r$ must vanish at the surface ($z = 0$).

Thus we get

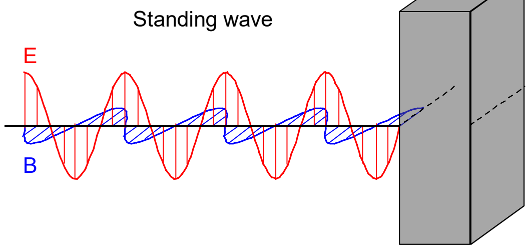
$$E_x = E_x^i + E_x^r = i \cdot 2E_0 \sin(kz)\, e^{-i\omega t}$$

$$B_y = B_y^i + B_y^r = 2B_0 \cos(kz)\, e^{-i\omega t}$$

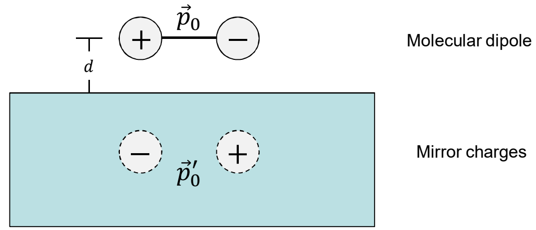
The current density $\vec{j}$ in the slab is created by the incident electric field E_x. Then the inductance prevents the current to increase infinitely. The current j_x produces a magnetic field H_y^r which in turn creates the reflecting electric field. Thus

$$\vec{j} = \operatorname{curl} \vec{H}^r \quad \Rightarrow \quad j_x = -\frac{\partial H_y^r}{\partial z} = i\, k\, H_0\, e^{-i\omega t}$$

Reflexion at a Metallic Surface



Molecule in Front of a Metal Surface: Fluorescence Quenching



- Damping through ohmic losses (current in metal)
- Damping through the excitation of SPPs
- Weaker or even forbidden dipole emission (depending on distance)
  → change of spontaneous emission rate!