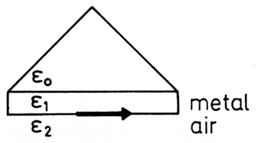
Field amplification

$$T^{el}_{\max} = \frac{\left|E\langle 2/1\rangle\right|^2}{\left|E\langle 0/1\rangle\right|^2} = \frac{1}{\varepsilon_2}\,\frac{2\left|\varepsilon_1'\right|^2}{\varepsilon_1''}\,\frac{\sqrt{\left|\varepsilon_1'\right|(\varepsilon_0-1)-\varepsilon_0}}{1+\left|\varepsilon_1'\right|}$$

with $\varepsilon_1 = \varepsilon_1' + i\,\varepsilon_1''$



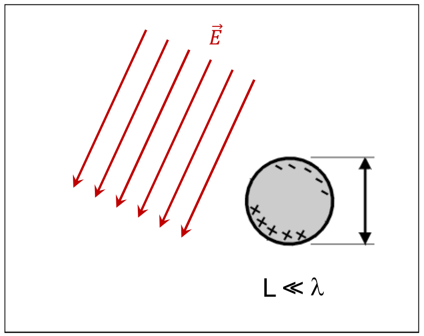
Examples:

Ag (600 nm) : T=200
Au (600 nm) : T=30
Al (600 nm) : T=40

H. Raether, Surface Plasmons

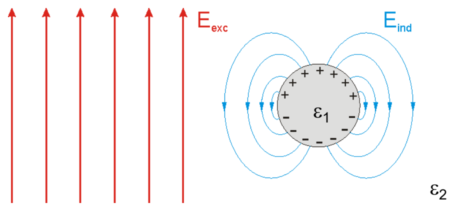
Localized plasmons

Metallic nanoparticle



Localized Plasmon

Induced electric dipole in a spherical metal particle with $\varepsilon_1(\omega) = \varepsilon_1' + \mathrm{i}\,\varepsilon_1''$



$$\vec{p}_{ind} = \alpha \cdot \vec{E}_{exc}\,, \qquad \alpha = 4\pi\varepsilon_0 \cdot R^3 \cdot \frac{\varepsilon_1(\omega)-\varepsilon_2}{\varepsilon_1(\omega)+2\,\varepsilon_2}$$

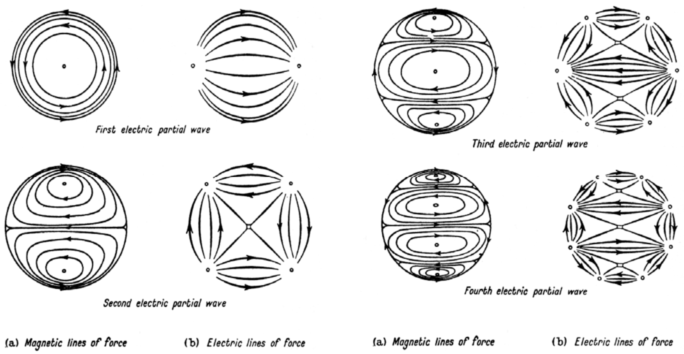
Resonance at $\varepsilon_1' \cong -2\varepsilon_2$ with

$$T_{el}^{\max} = \left|\frac{E_{ind}}{E_{exc}}\right|^2 \cong \left|\frac{3\varepsilon_2}{\varepsilon_1''}\right|^2$$

(= 480 for Ag in vacuum)

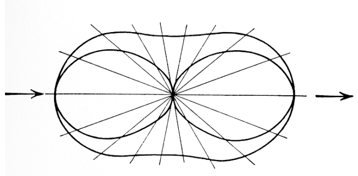
Mie scattering – partial waves

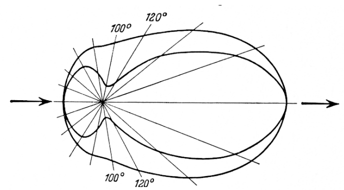
Multipole excitations. Resonances are at $\varepsilon_1(\omega) = -\varepsilon_2 \cdot \frac{l+1}{l} \quad ; \quad l = 1, 2, 3 \ldots$

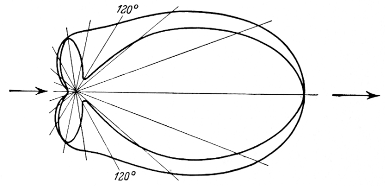


Born & Wolf, Principles of Optics

Radiation Pattern of a Au particle







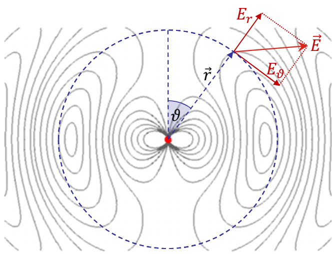
Excitation by natural light (unpolarized)

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

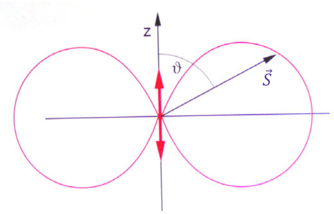
Inner curve: $I = I_\perp$

Born, Optik

Electric field



Emission to far-field (polar diagram)



Far- and Near-Field of a Point Dipole

Dipole moment

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

creates time-dependent electric field (spherical coordinates!)

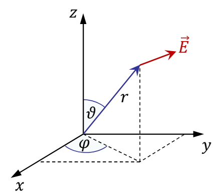
Far-field

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

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



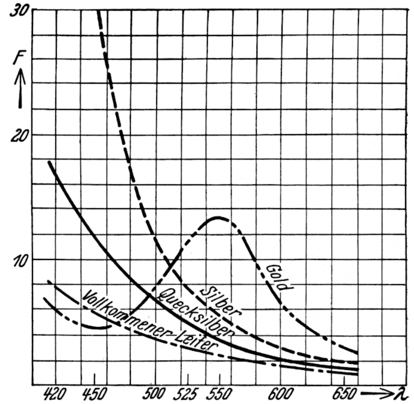
Near-fields

Comparison of far- and near-fields:

$$\left|\frac{E_{Nearfield}}{E_{Farfield}}\right|^2 \sim \left|\frac{kr}{(kr)^3}\right|^2 \sim \frac{1}{(kr)^4} \sim \left(\frac{\lambda}{r}\right)^4$$

The intensity in the near-field (kr ≪ 1 ⇒ r ≪ λ) of an antenna (or, e.g., a molecule) is very large as compared to the far-field!

Total scattering cross section



Translation

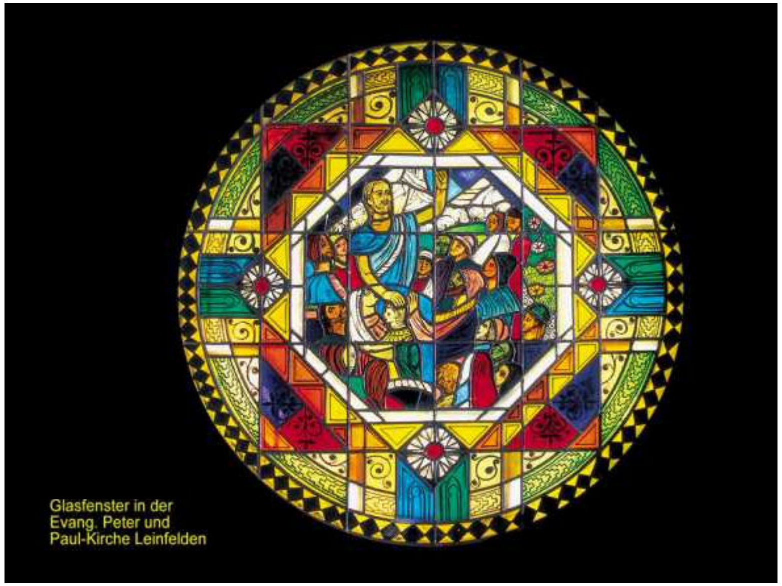
Gold = Gold

Silber = Silver

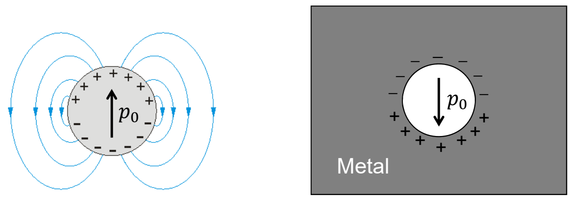
Quecksilber = Mercury

Vollkommener Leiter = Ideal Conductor

Born, Optik



Nanostructures as electric dipole emitters



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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*

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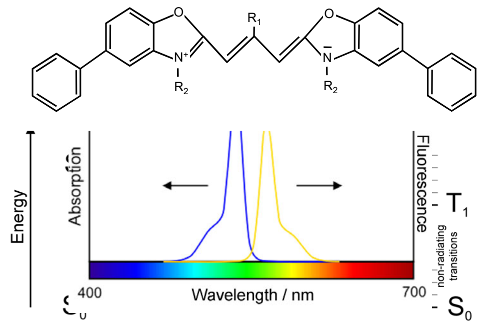
Absorption and Emission of Light by Molecules

Cyanine dye



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Absorption and Emission of Light by Molecules