Enhanced Surface Plasmons Polaritons Induced by Active Dielectrics

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Introduction: At optical frequencies the metal's free electrons can sustain oscillations, called Surface Plasmon Polaritons (**SPPs**). The existence of plasmons is characteristic for the interaction of metals with light. The aim of this work is to investigate with COMSOL Multiphysics® the plasmon dispersion relation as well as propagation and the role of active dielectrics (gain).

Configuration: A metal film of thickness d and permittivity ε_2 is sandwiched between two dielectric layers with permittivity ε_1 and ε_3 (Kretschmann-Raether configuration). The permittivity of the metal is frequency dependent and is taken using the Drude-Sommerfeld theory (Drude model) given by Eq. (1)

$$\varepsilon_2(\omega) = \varepsilon_h - \frac{\omega_p^2}{\omega^2 - i\omega\Gamma} \qquad (1)$$

- ε_h the high frequency permitivity
- ω_p the plasma frequency
- Γ the collision frequency
- κ the gain parameter

Parameter	Value
ε_1	2.25
ε_3	$(1.3+i\kappa)^2$
d	50 nm
Γ	$1.018\ 10^{14}$ rad/sec
ω_p	$1.367\ 10^{16}$ rad/sec
ε_h	9.84

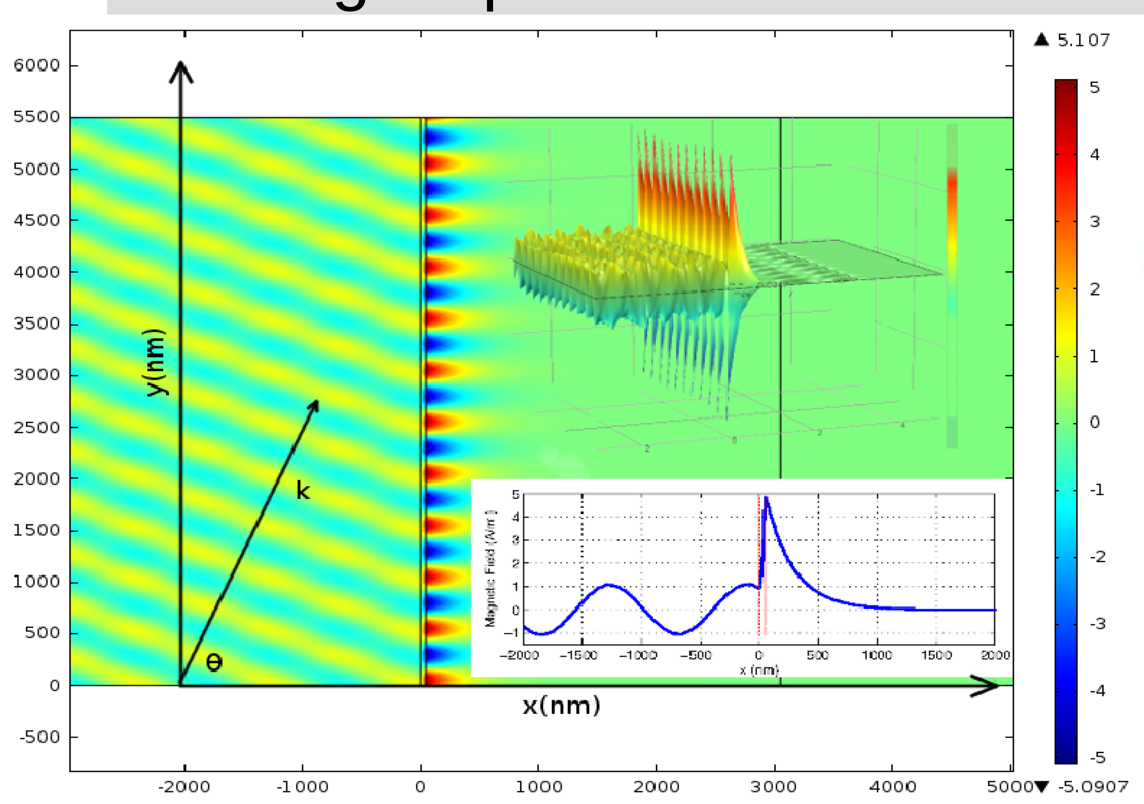

Figure 2. Magnetic Field Hz(x,y) at the SPP resonance angle

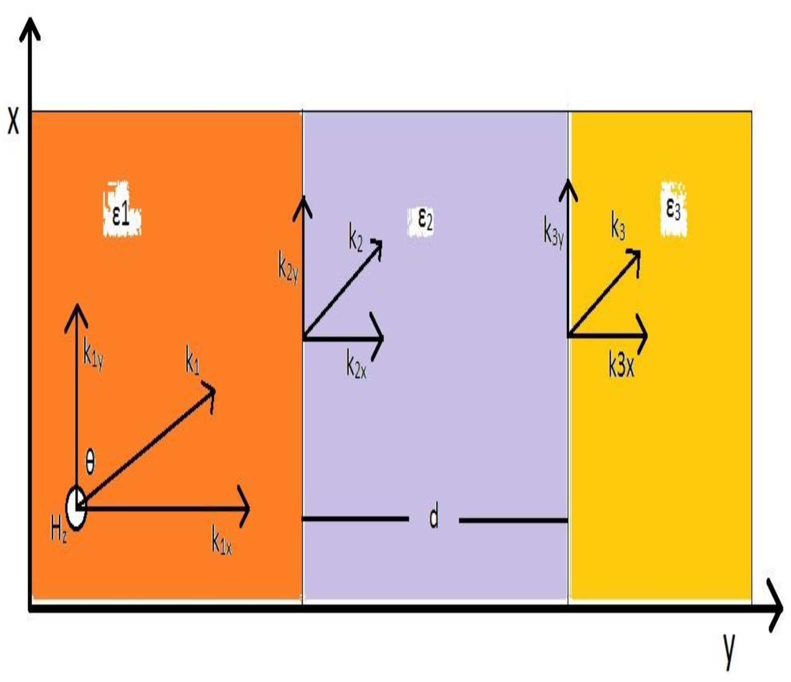

Figure 1. Kretschmann-Raether configuration

Dispersion Relation: The relation between the SPP wavevector β along the interface and the angular frequency is called dispersion relation given by Eq. (2) We compare COMSOL results with theory and investigate the role of gain.

$$\beta = \sqrt{\frac{\varepsilon_2 \varepsilon_3}{\varepsilon_2 + \varepsilon_3}}\,\frac{\omega}{c} \qquad (2)$$

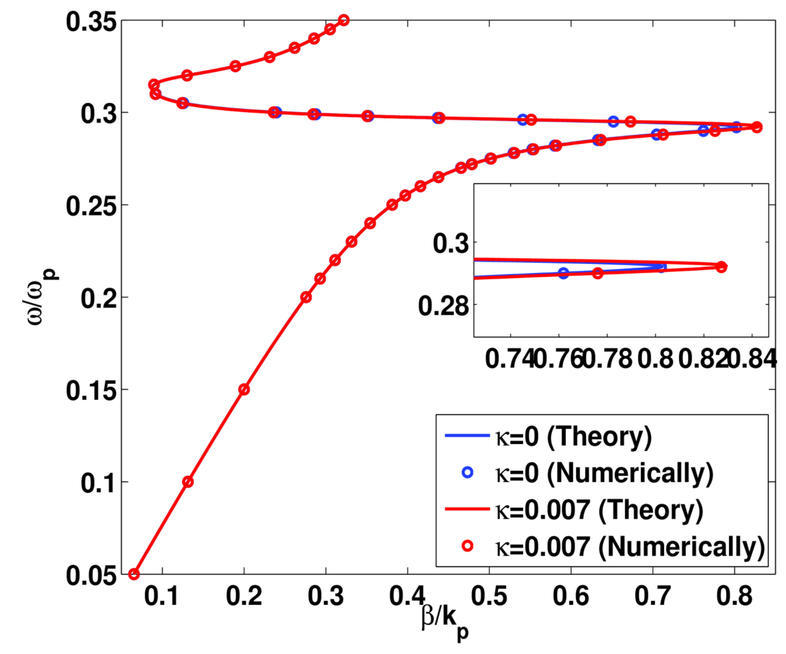

Figure 3a. Real part of β

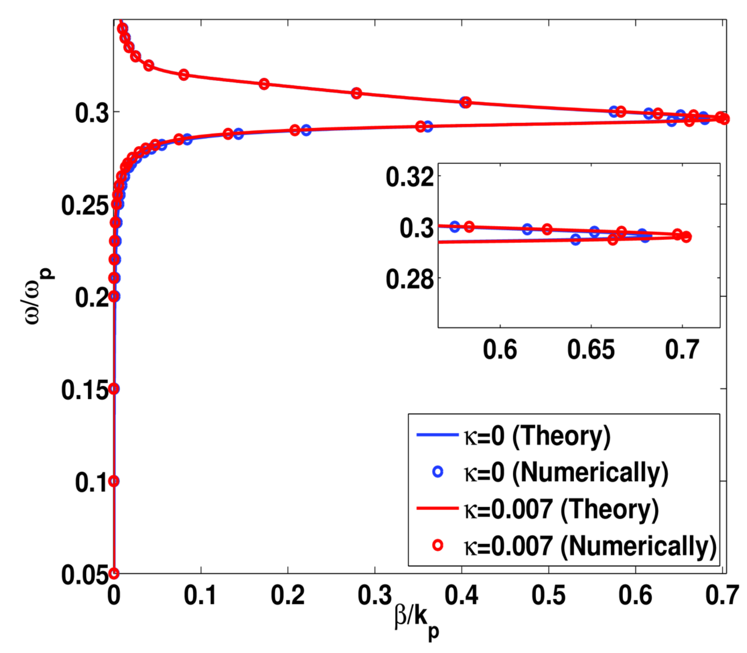

Figure 3b. Imaginary part of β

Plasmon Propagation length: The length traveled by the SPP up to 1/e decrease of the intensity is called propagation length L.

$$L = \frac{1}{2\mathrm{Im}[\beta]} \qquad (3)$$

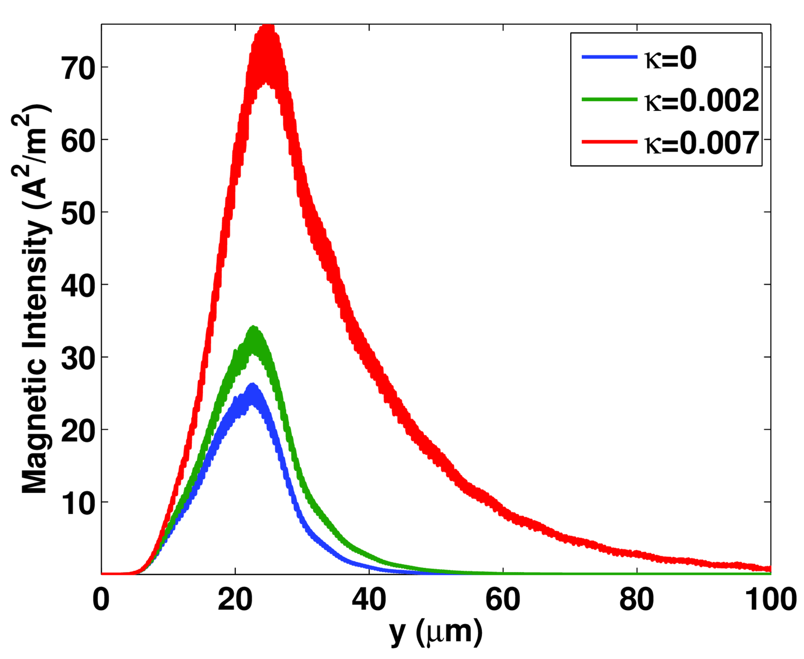

Figure 4a. Intensity of magnetic field (COMSOL)

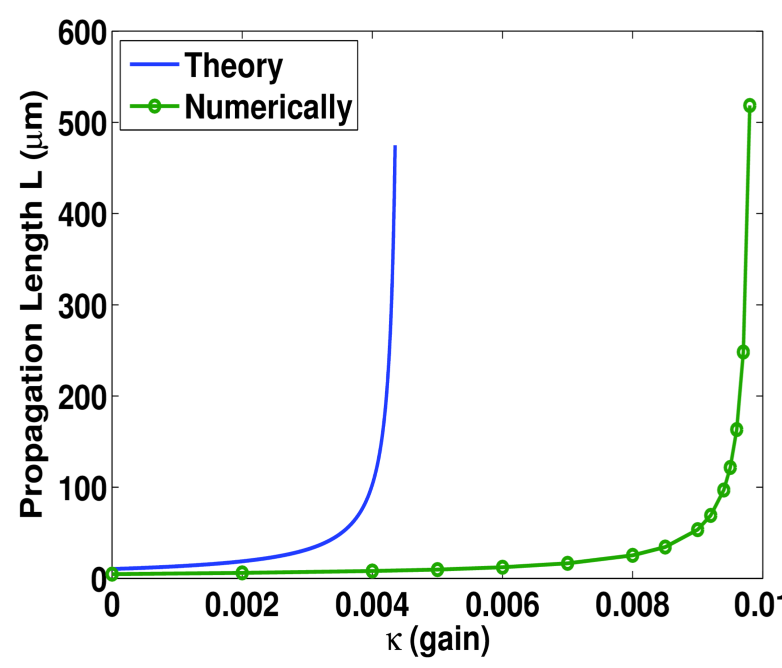

Figure 4b. Plasmon propagation length for different values of κ

Conclusion: We introduce active dielectric in order to overcome metal losses. We show that gain enhances SPP propagation length and there is a critical gain for which the SPP propagates without losses (infinity L)

References:

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