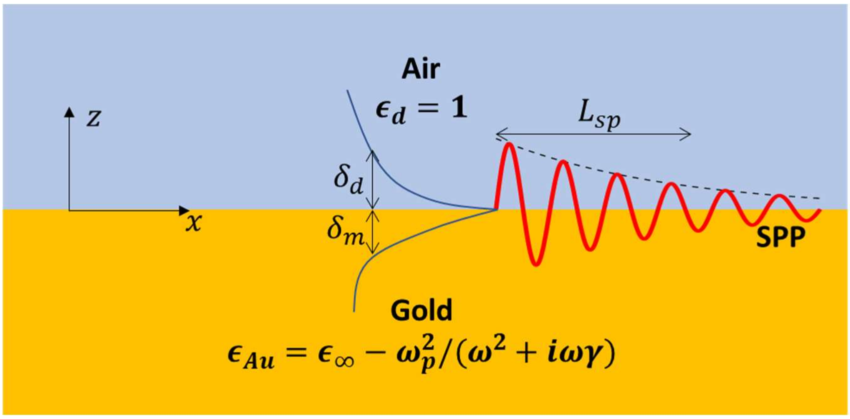
LAB EXERCISE: Understanding the physics of surface plasmon polaritons (SPPs)

The goal of this exercise is to understand the physics of a surface plasmon polariton propagating along the x-direction of a Gold-Air interface (see figure).



Air has refractive index equal to 1, while the relative permittivity of Gold is modeled as a Drude function (as described in figure).

The Drude parameters for Gold are: $\epsilon_\infty = 9.5, \omega_p = 1.36 \times 10^{16} \frac{rad}{s}, \gamma = 1.05 \times 10^{14} \frac{rad}{s}$.

Step 1. Use MATLAB to plot the real and the imaginary parts of the gold relative permittivity in the range of wavelengths from 300 nm to 2000 nm. Hint: start by defining in MATLAB the vector of wavelengths as lam=linspace(300e-9,2000e-9,1000).

Step 2. Once ϵ_{Au} is known, calculate the SPP wavevector $k_x = k_{sp} = \frac{\omega}{c}\sqrt{\frac{\epsilon_{Au}\epsilon_d}{\epsilon_{Au}+\epsilon_d}} = \frac{\omega}{c} n_{sp}$. Plot the dispersion relation of the SPP, i.e., the plot with $Re(k_{sp})$ on the x axis and the angular frequency ω on the y axis. Plot on a different graph also the real part of the effective refractive index as a function of the angular frequency (put on the x axis $Re(n_{sp})$ and on the y axis ω).

Step 3. Verify that the *surface plasmon resonance*, i.e., the condition in which $Re(k_{sp}) \to \infty$ or it is maximum, therefore when $Re(\epsilon_{Au}) + \epsilon_d = 0$, occurs at $\omega_{SPR} \cong \omega_p/\sqrt{\epsilon_\infty + \epsilon_d}$.

Step 4. Consider the wavelength $\lambda = 500\ nm$. Calculate the effective index of the SPP and its propagation length in the x direction, $L_{sp} = \frac{1}{2I\ \ (k_{sp})}$ (see figure).

[$n_{sp} =$]

[$L_{sp} =$]

Step 5. Consider the wavelength $\lambda = 500\ nm$. In reference to the figure, calculate the penetration depth of the SPP on the air side (calculated as $\delta_d = 1/|k_z^d|$) and on the metal side (calculated as $\delta_m = 1/|k_z^m|$).

[$\delta_d =$]

[$\delta_m =$]