Surface Plasmon Polariton on Thin Films
Leakage Radiation Microscopy

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EP 432 Physics of Nanostructures and Nanoscale Devices

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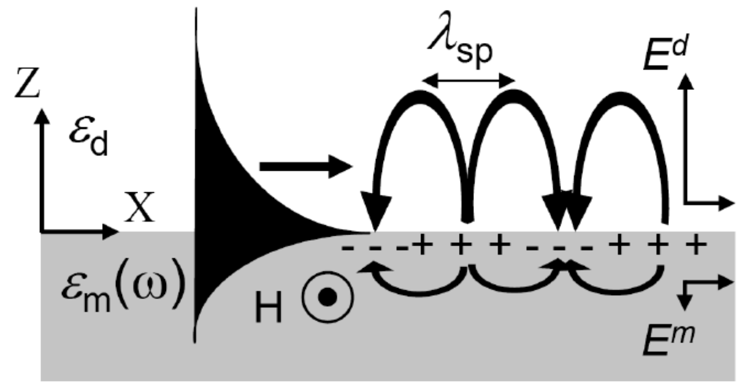
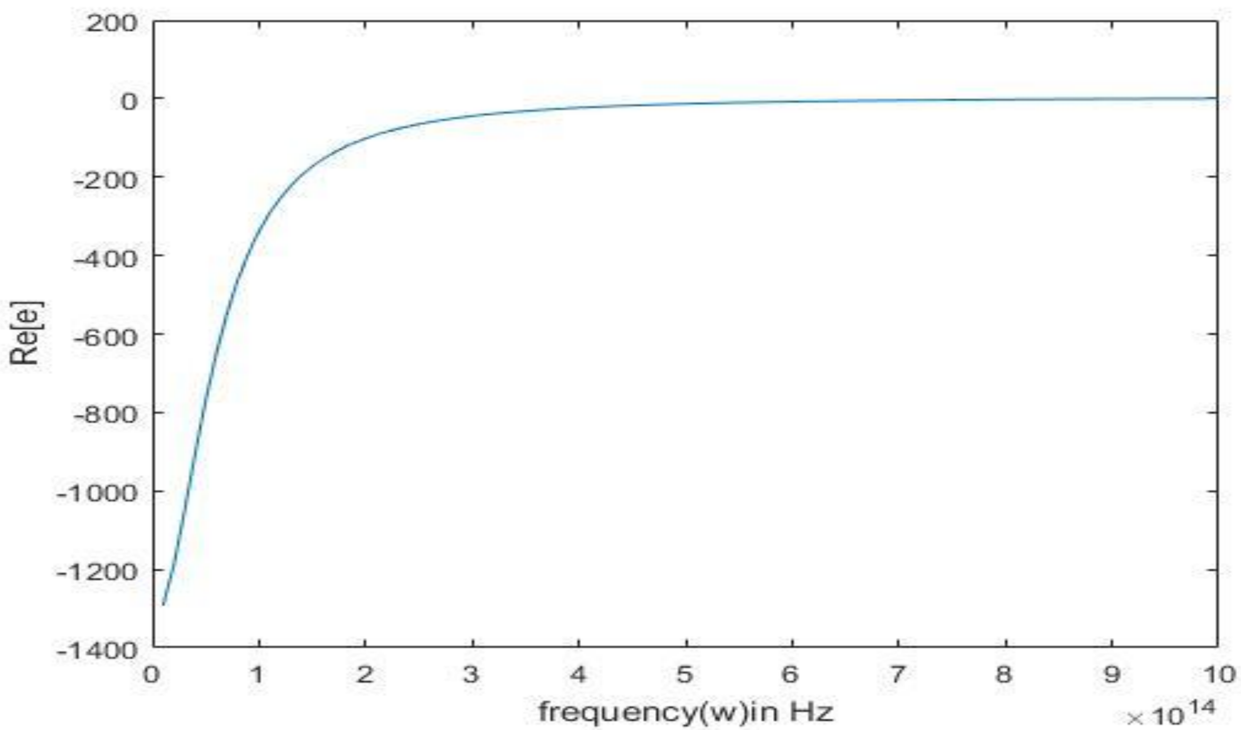
Dielectric Metal Interface

- Surface Plasmons
  in TM mode



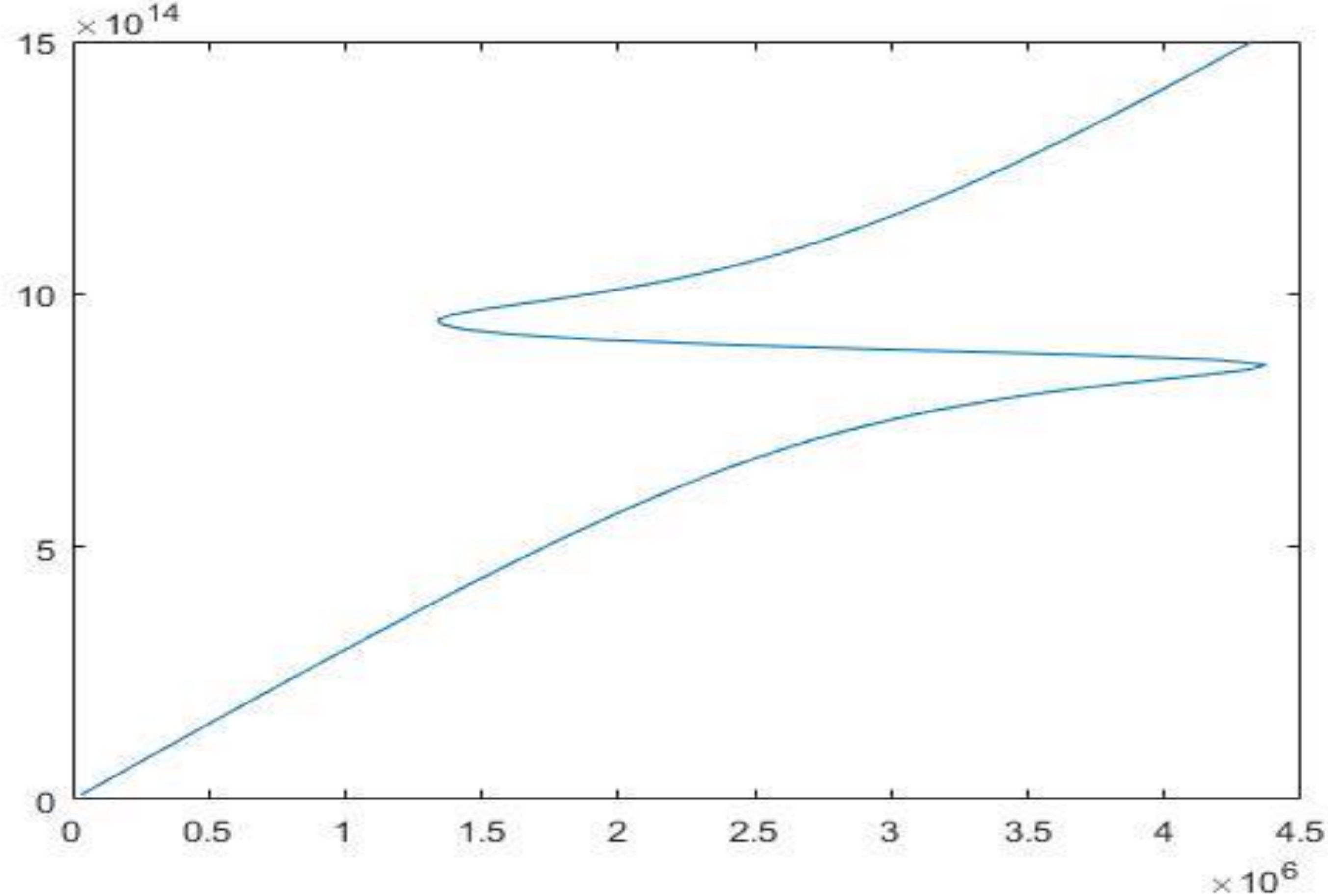
$$k_{SPP} = \frac{2\pi}{\lambda}\sqrt{\frac{\varepsilon_d \varepsilon_m}{\varepsilon_d + \varepsilon_m}}$$

Silver Dielectric function based on Drude model Re[ε(ω)]

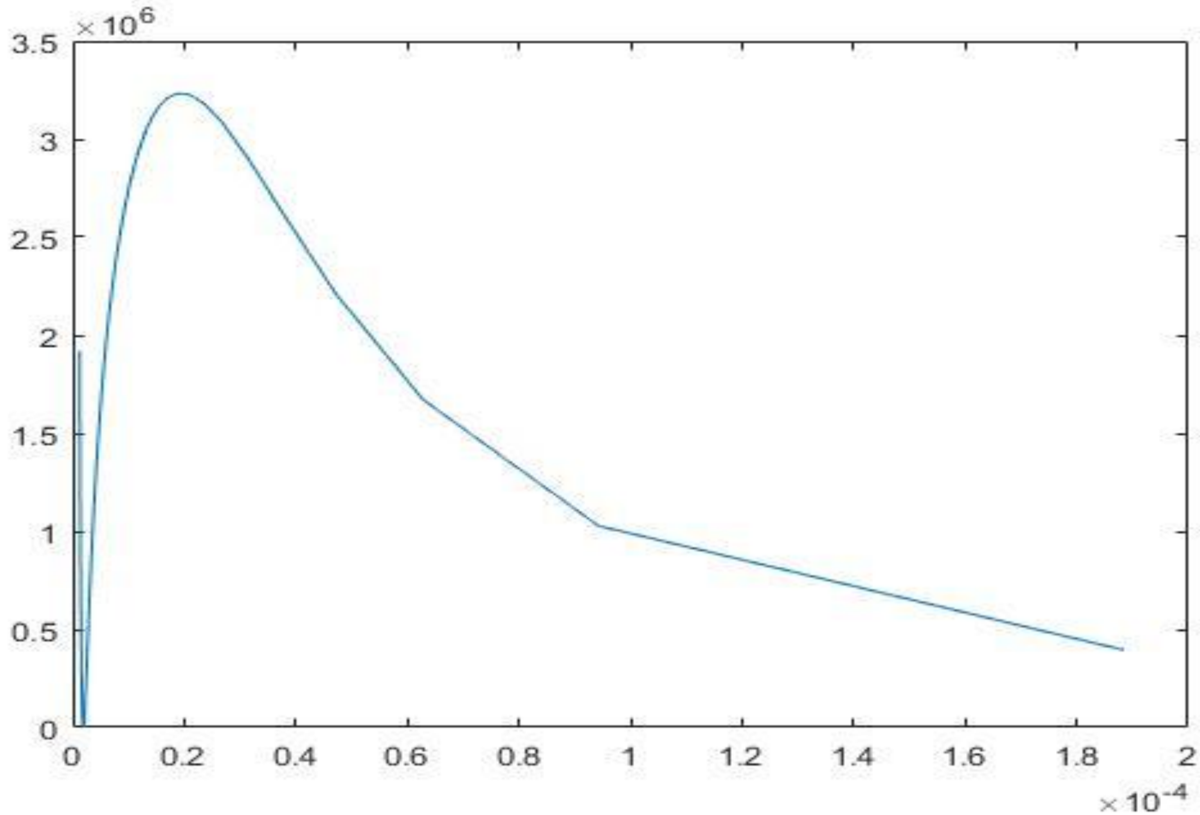


Data for Drude parameters from Johnson and Christy 1972

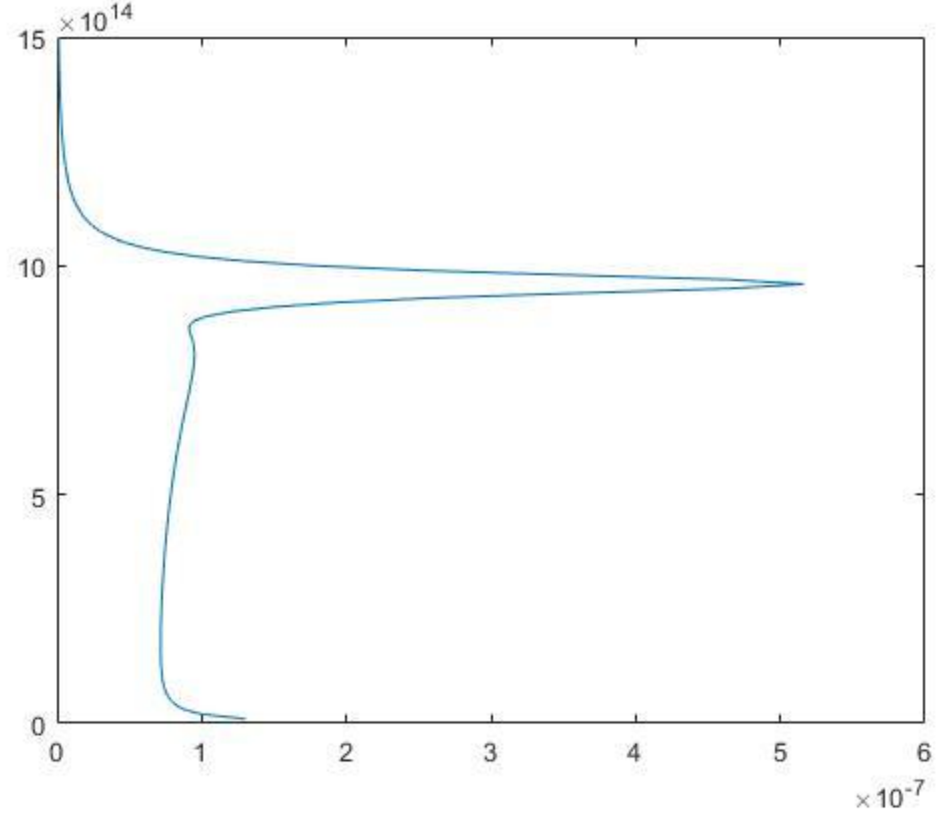
SPP dispersion Air/Ag (ω[Hz] vs k[1/m])



LSPP



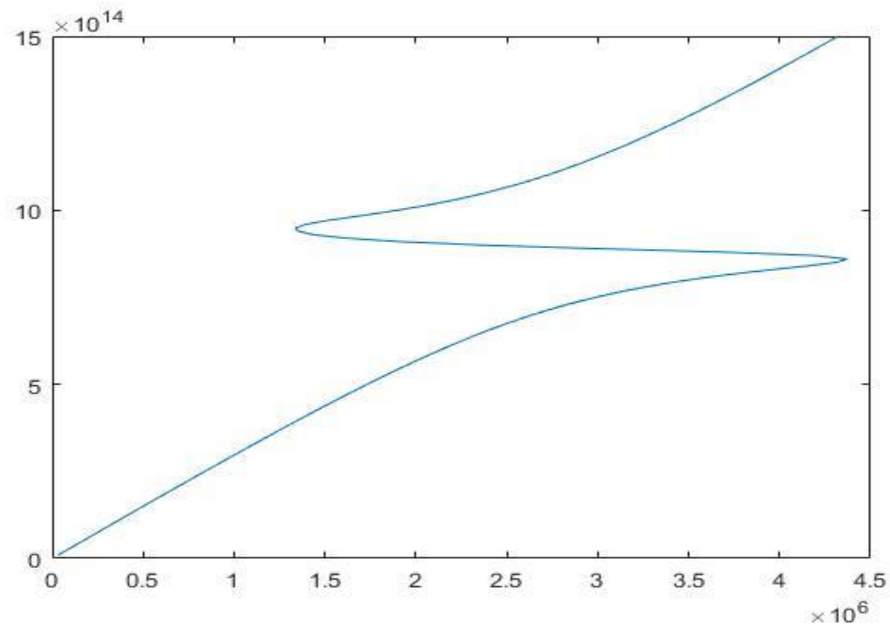
ω vs lc



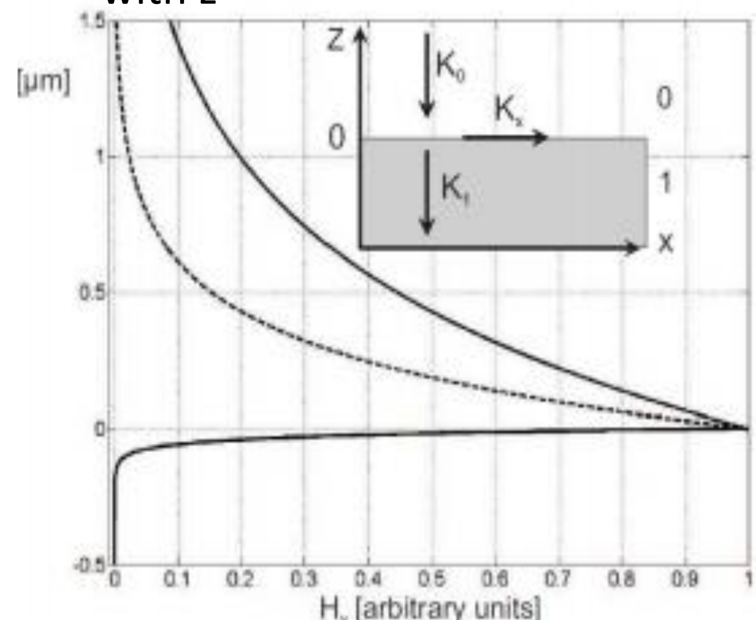
Surface Plasmons on Thin films

- Limit Large thickness (D << SPP penetration length in the metal [i. e., D & 70 nm for gold or silver in the visible domain])
- Two uncoupled single interfaces
- Bound, quasi bound and radiative mode

SPP dispersion (ω[Hz] vs k[1/m])



Magnetic Field
with z



Problem: find when Ohmic loss condition for exponential decay is satisfied

$$k_x(\omega) = k'_x + ik''_x$$

$$k'_x . k''_x > 0$$

Two Coupled Interface

- Fresnel Reflectivity solving numerical equation implicitly

$$R^p_{0,1} = \frac{(k_0/\epsilon_0 - k_1/\epsilon_1)}{(k_1/\epsilon_1 + k_0/\epsilon_0)}$$

$$R^p_{0,1} + R^p_{1,2} e^{2ik_1 D} = 0,$$

Or transcendenal Equation from continuity at boundary

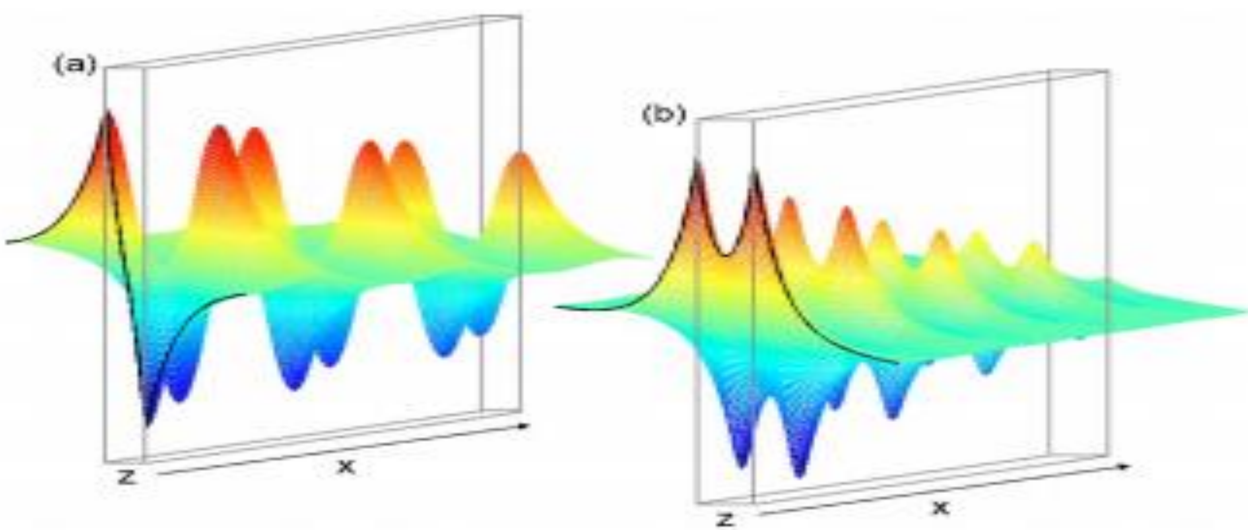
$$\tanh(S_2 h)(\epsilon_1 \epsilon_3 S_2^2 + \epsilon_m^2 S_1 S_3) + [S_2(\epsilon_1 S_3 + \epsilon_3 S_1)\epsilon_m] = 0$$

Code for Dispersion relation

```
w=10^13*[1:150];
D=70*10^-9;
kx=10^5*[1:150];
c=3*10^8;
E=5;
W=(8.9*(1.6*10^(-19) ))/(6.626*10^(-34));
ep=1;
eps=E-((W)^2)./(w.^2+i*w.*(10^15)/17);
epss=2.25;
k0=-(((w.^2./c^2).*ep-(kx).^2).^0.5);
k1=(((w.^2./c^2).*eps-(kx).^2).^0.5);
k2=-(((w.^2./c^2).*epss-(kx).^2).^0.5);
f=@(kx,w)((k0./ep)+(k1./eps)).*((k2./epss)-(k1./eps)).*exp(i*k1.*D)+(-
(k0./ep)+(k1./eps)).*((k2./epss)+(k1./eps)).*exp(-i*k1.*D);
fimplicit(f,[10^5 10^7 10^13 10^15] )
```

Symmetry

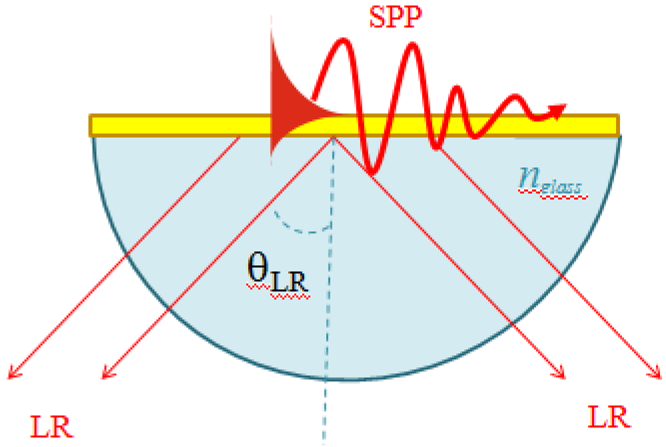
- Four significant solutions.
- Two are nonradiative (Fano modes)
- Other two are both leaky in nature correspond to a surface plasmon guided by one or the other dielectric-metal interface.
- Decay exponentially across the metal film and they couple to a broad spectrum of radiation fields in one of the dielectric.
- All four solutions are also found for dissimilar bounding media.

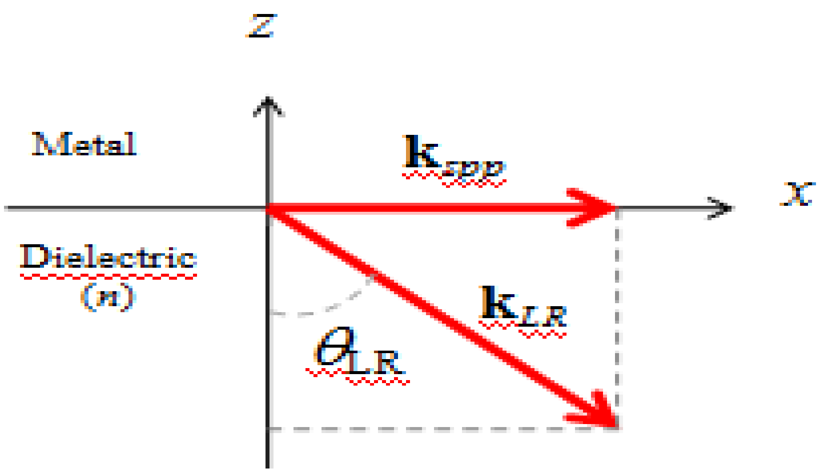


Leakage Radiation Microscopy

- Conserve momentum

$$\mathrm{Re}\left(k_{SPP}\right) = nk_0 \sin\left(\theta_{LR}\right)$$





$$\theta_{LR} = \sin^{-1}\left(\frac{\mathrm{Re}(\beta)}{nk_0}\right)$$

Calculation for Air Silver Glass

$$\varepsilon_d = 1$$

$$\lambda = 700\ nm$$

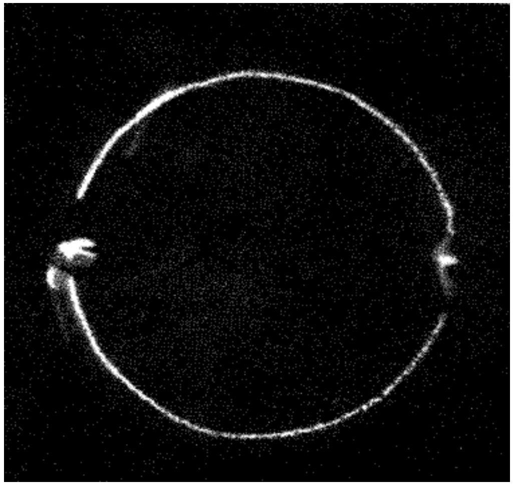
$$k_0 = \frac{2\pi}{\lambda}$$

$$\varepsilon_m(\lambda) = -16 + 1.5i$$

$$n = 1.5$$

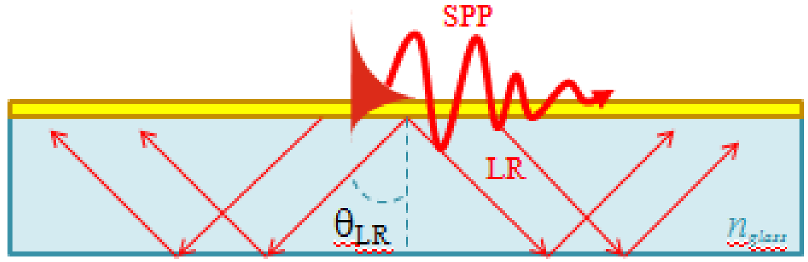
$$\beta = (9.2\times10^6) + i(2.6\times10^4)$$

$$\theta_{LR} = 43.4°$$



Leakage radiation cone

Total Internal Reflection

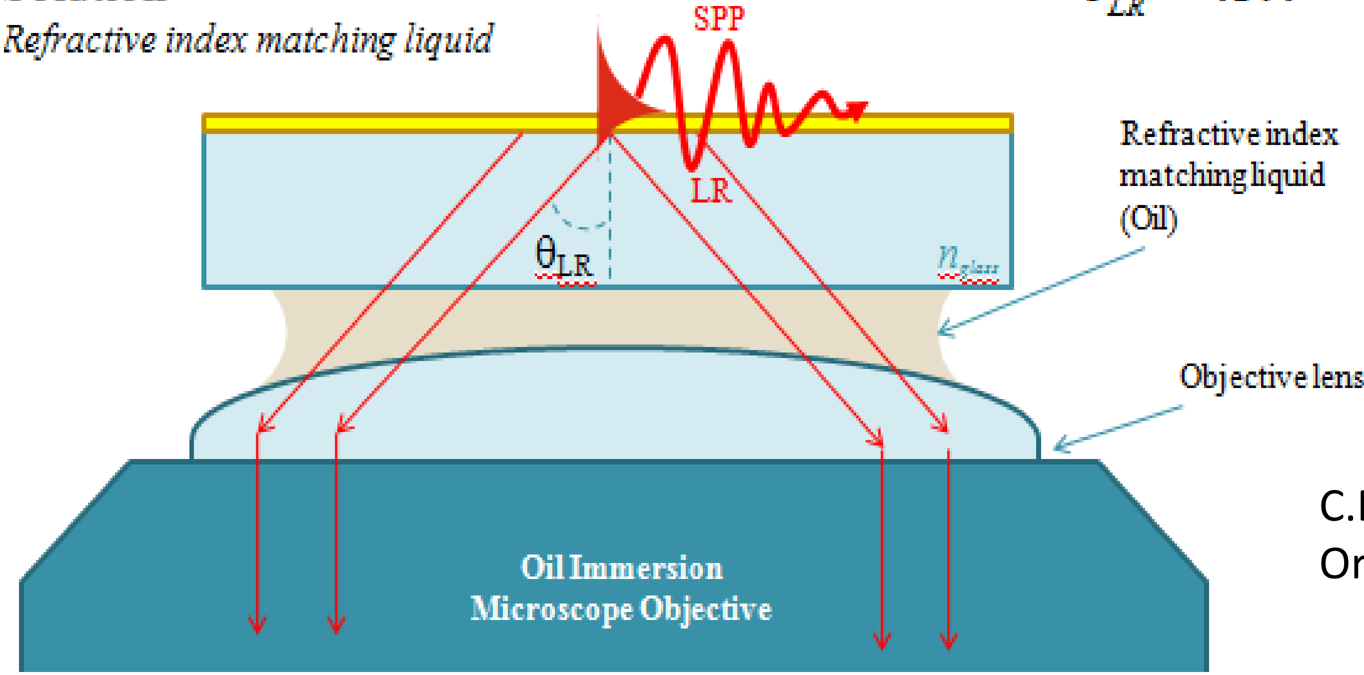


$$\theta_c = \sin^{-1}\left(\frac{n_{air}}{n_{glass}}\right) = 41.8°$$

Solution

Refractive index matching liquid

$$\theta_{LR} = 43.4°$$



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