



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

Lecture 11: Plasmons- II

Surface Plasmon: Excitation of, Penetration depth, propagation length

Sachin Kumar Srivastava

Department of Physics



Propagation Length

Wave-vector of a surface plasmon wave

$$k_x = k_o \sqrt{\frac{\epsilon_s \epsilon_m}{\epsilon_s + \epsilon_m}}$$

Please note:

$$\epsilon_m = \epsilon_{m1} + i\epsilon_{m2} \Rightarrow k_x = k'_x + ik''_x$$

$$k'_x = k_o \sqrt{\frac{\epsilon_s \epsilon_{m1}}{\epsilon_s + \epsilon_{m1}}}$$

$$k''_x = k_o \sqrt[3]{\frac{\epsilon_s \epsilon_{m1}}{\epsilon_s + \epsilon_{m1}}} \left(\frac{\epsilon_{m2}}{2\epsilon_{m1}^2} \right)$$

Propagation Length

$$L_{sp} = (2k''_x)^{-1}$$

	$\lambda = 543 \text{ nm}$	$\lambda = 633 \text{ nm}$
Gold-Air (μm)	10.17	15.34
Silver-Air (μm)	29.82	43.67

Miniaturized sensors!!

Penetration Depth

Assuming

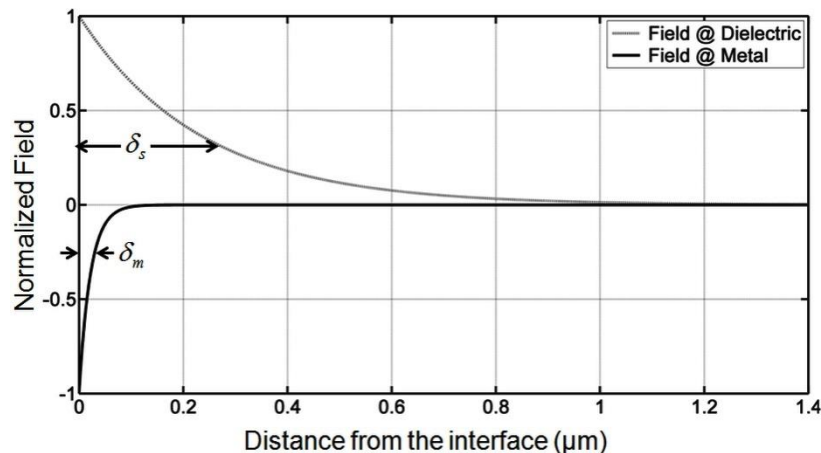
$$|\epsilon_{m1}| \gg |\epsilon_{m2}|$$

Penetration depth into dielectric medium

$$\delta_s = \frac{\lambda_0}{2\pi} \left[\frac{\epsilon_{m1} + \epsilon_s}{\epsilon_s^2} \right]^{\frac{1}{2}}$$

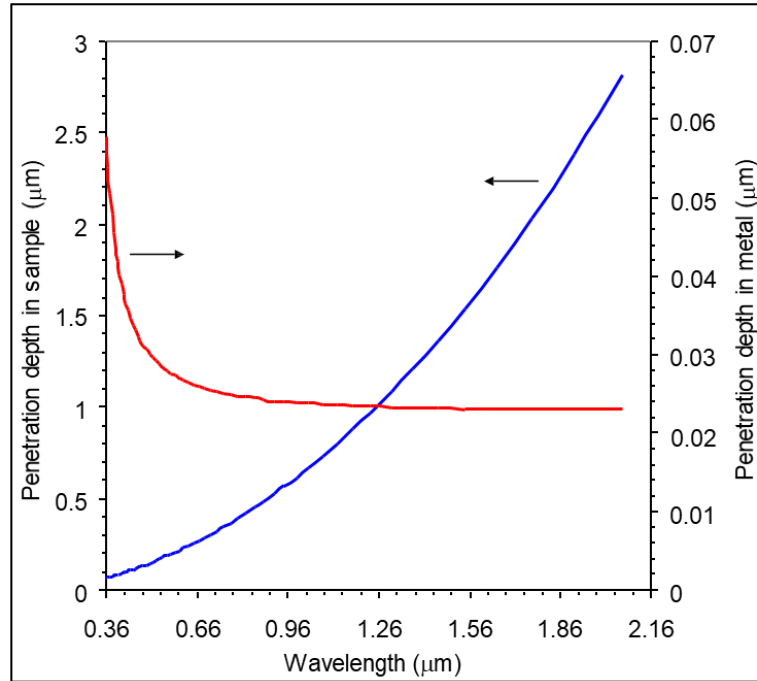
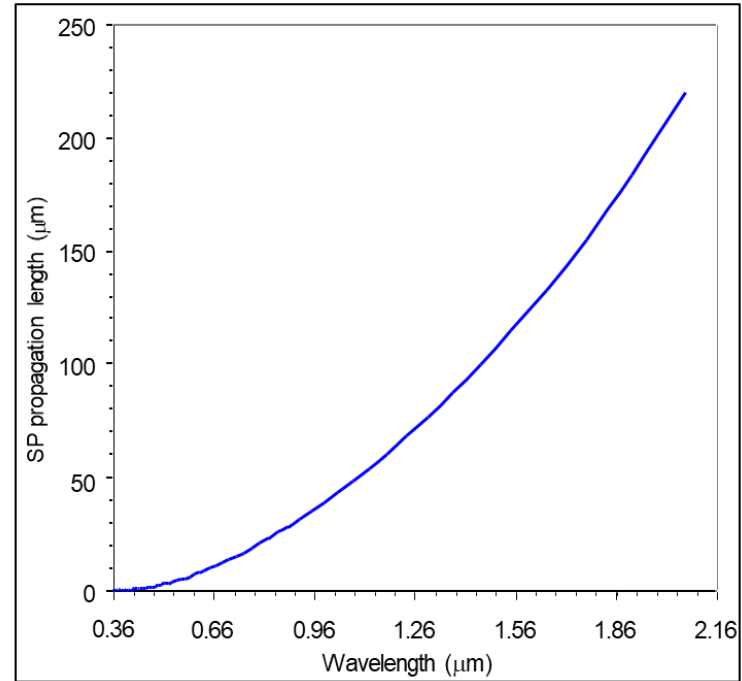
Penetration depth into metal

$$\delta_m = \frac{\lambda_0}{2\pi} \left[\frac{\epsilon_{m1} + \epsilon_s}{\epsilon_{m1}^2} \right]^{\frac{1}{2}}$$



Penetration Depth (nm)				
	$\lambda = 543 \text{ nm}$		$\lambda = 633 \text{ nm}$	
	Metal	Dielectric	Metal	Dielectric
Gold	26.67	250.12	26.76	350.18
Silver	23.08	298.52	23.12	414.48

Penetration depth of SPs vs. wavelength

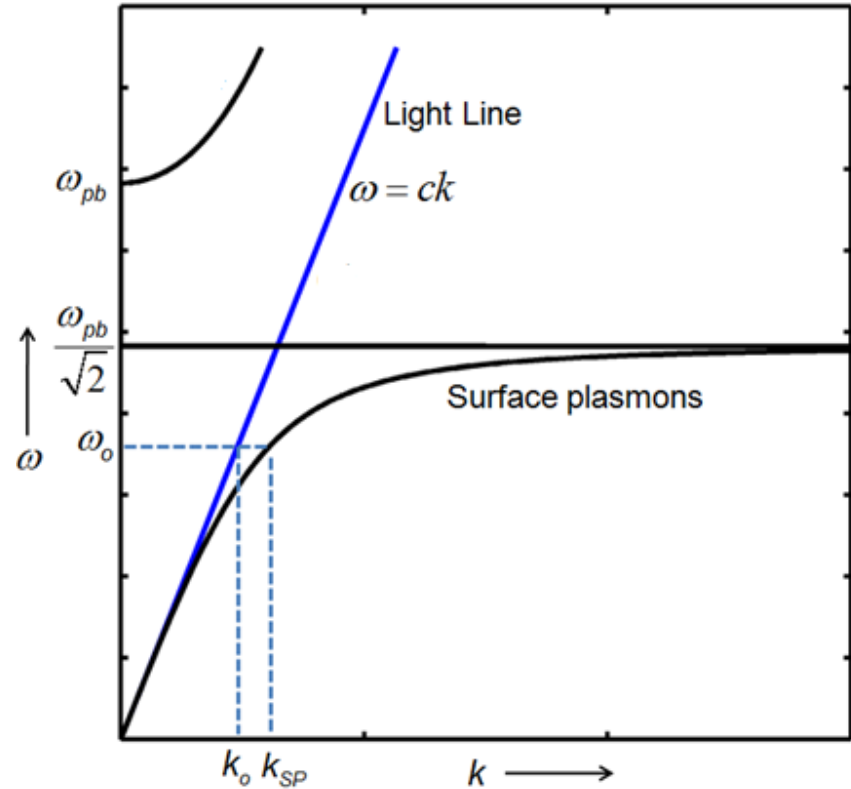


In the infrared the penetration inside the sample increases with the wavelength: Important for detecting large biological entities!

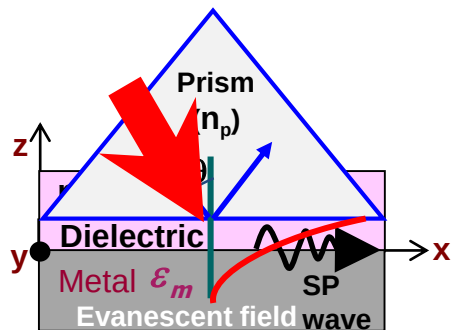
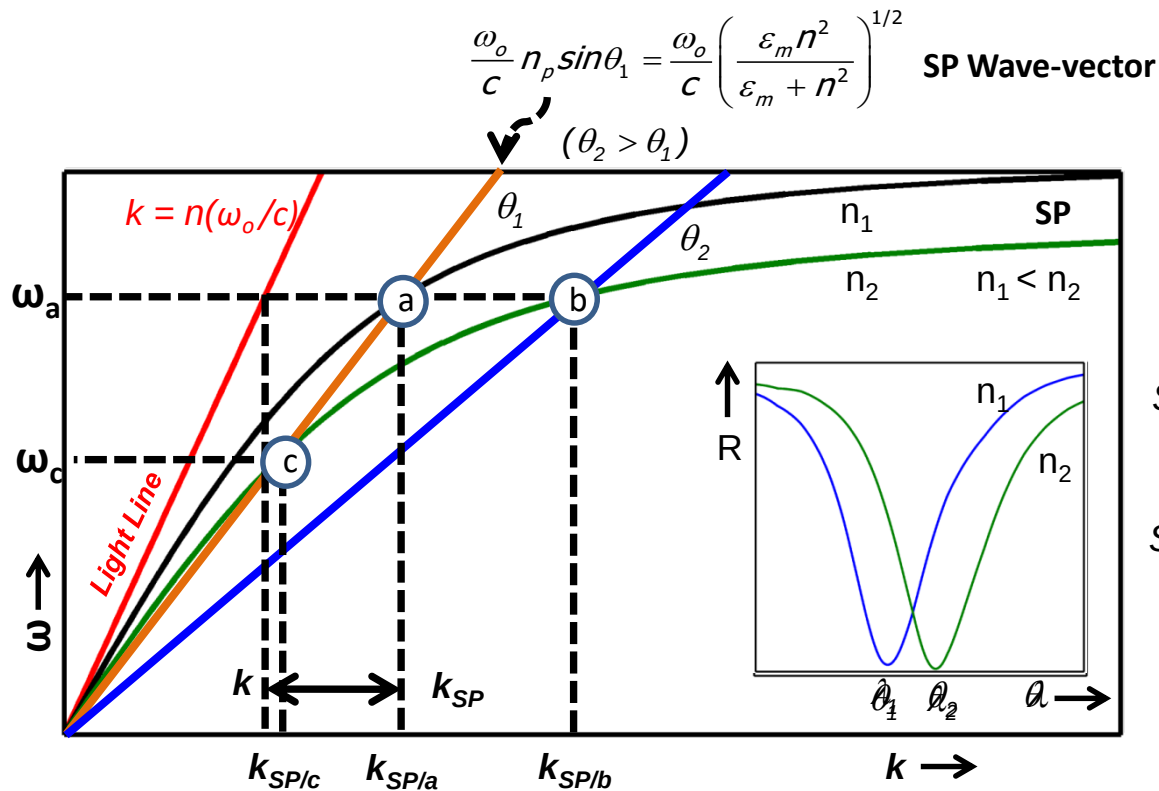
SPR Dispersion Curve

Surface Plasmon Wave Vector

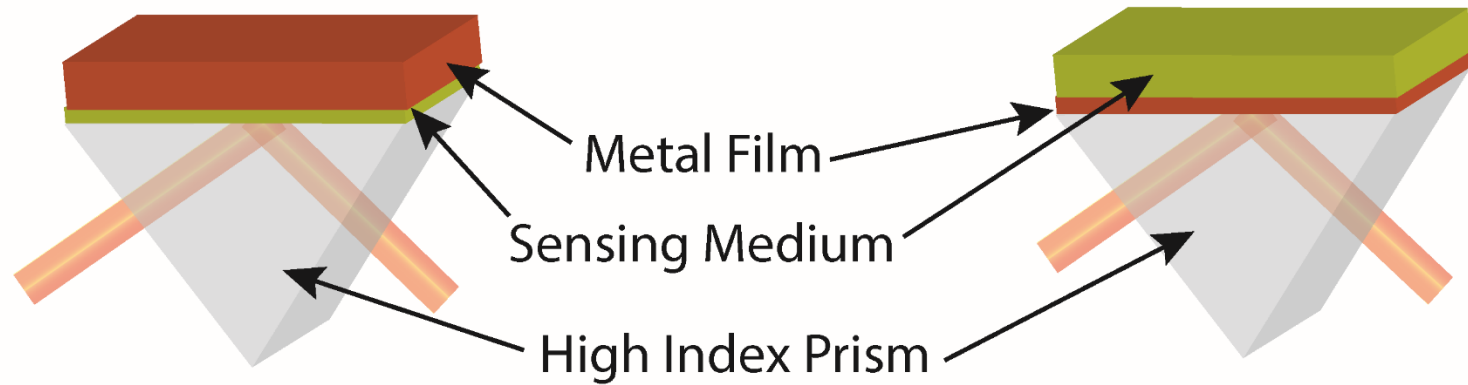
$$\Rightarrow k_{sp} = \frac{\omega}{c} \sqrt{\frac{\epsilon_s \epsilon_m}{(\epsilon_s + \epsilon_m)}}$$



Surface plasmons excitation



Two important configurations: Otto vs Kretschmann

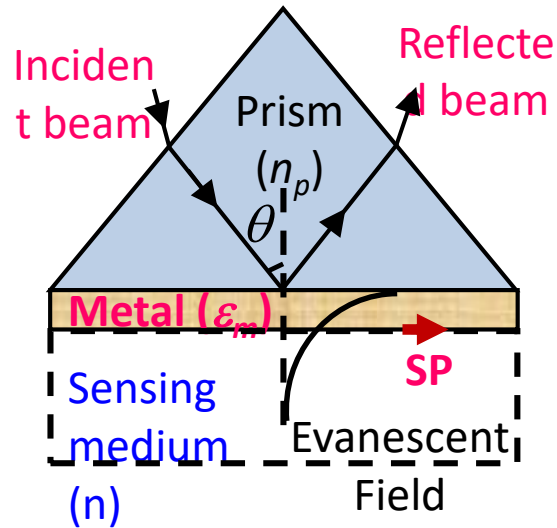


Otto

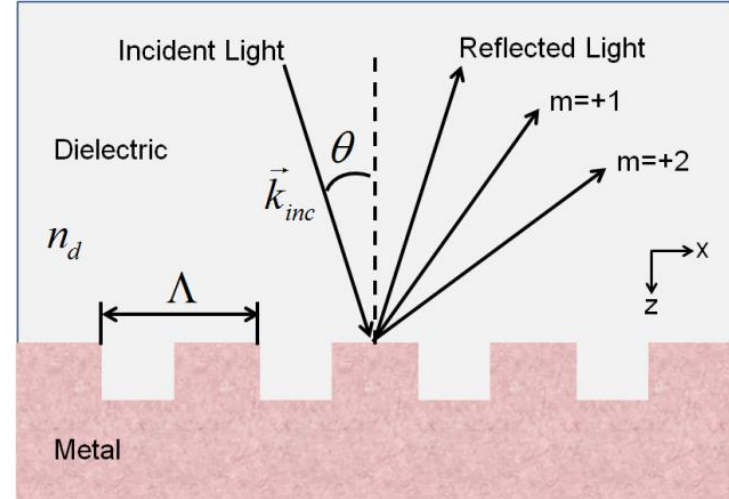
Kretschmann

Other methods of SPR realization

Kretschmann Configuration



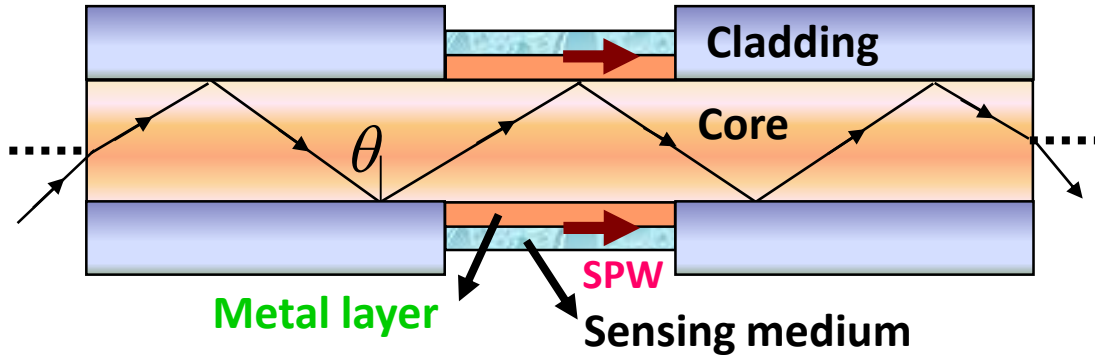
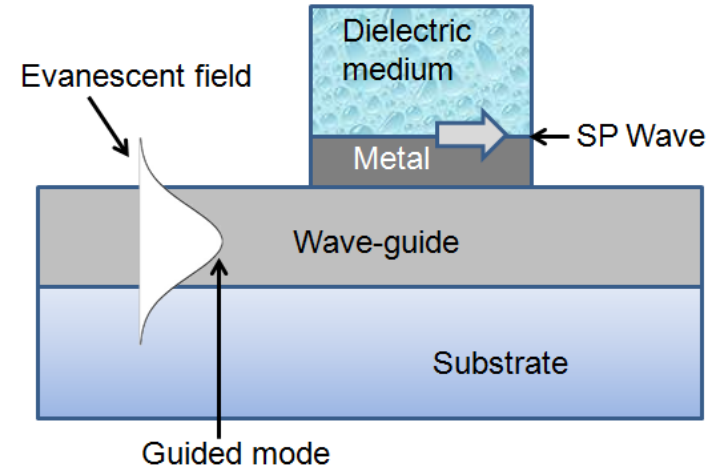
Gratings based coupling



$$\frac{2\pi}{\lambda} n \sin \theta \pm m \left(\frac{2\pi}{\Lambda} \right) = k_{SP}$$

Other methods of SPR realization

Fiber optic SPR sensor

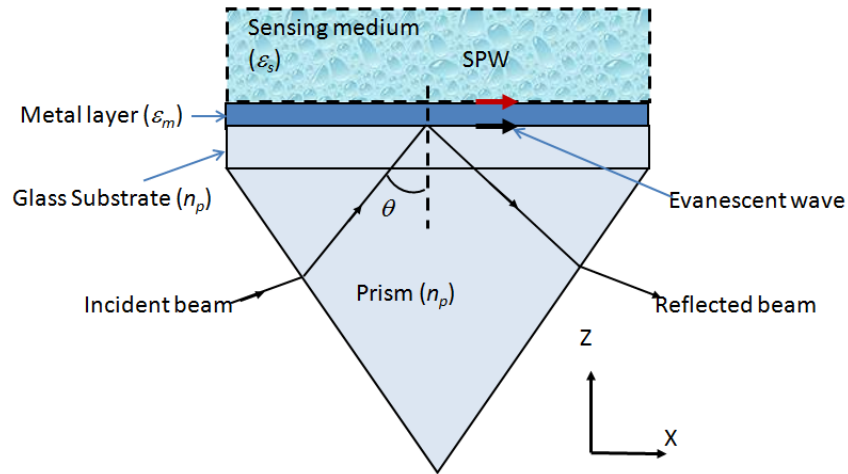
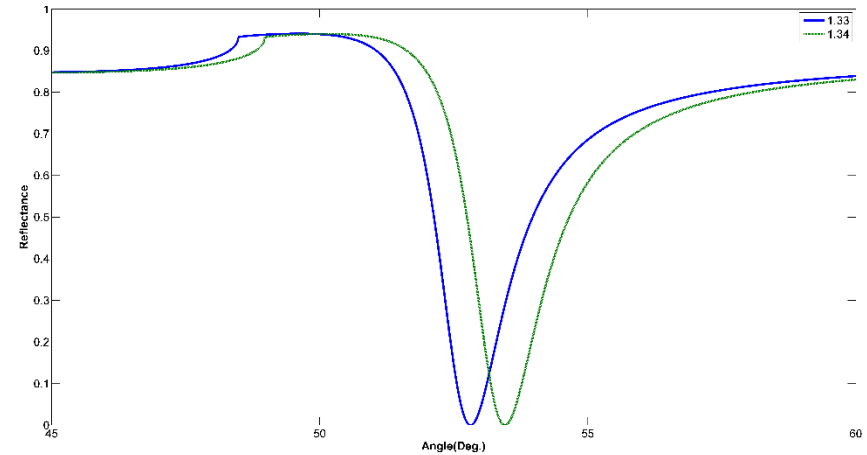


Waveguide SPR sensor

Sensing with SPR

Monochromatic light

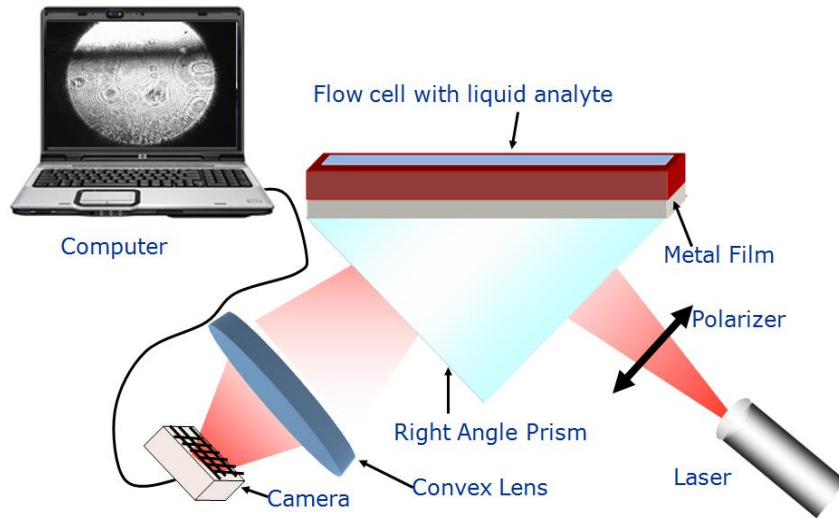
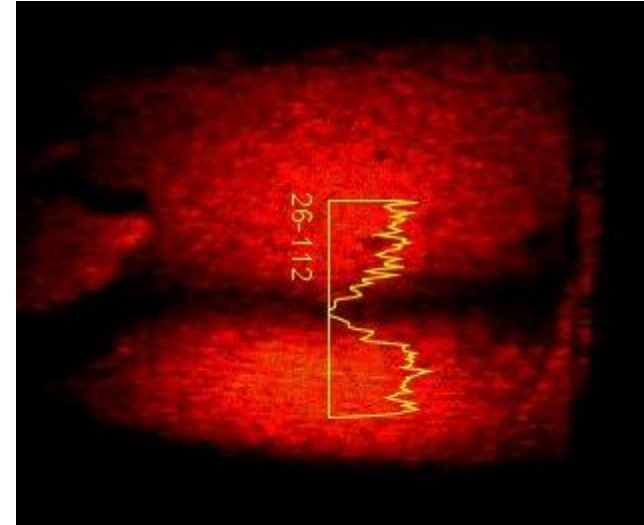
Angular interrogation



Sensing with SPR

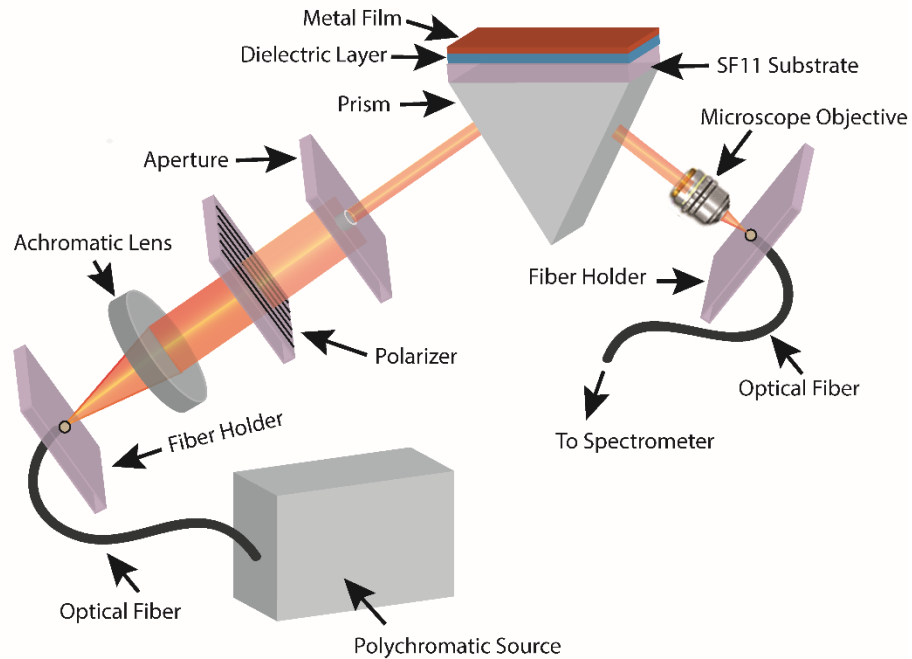
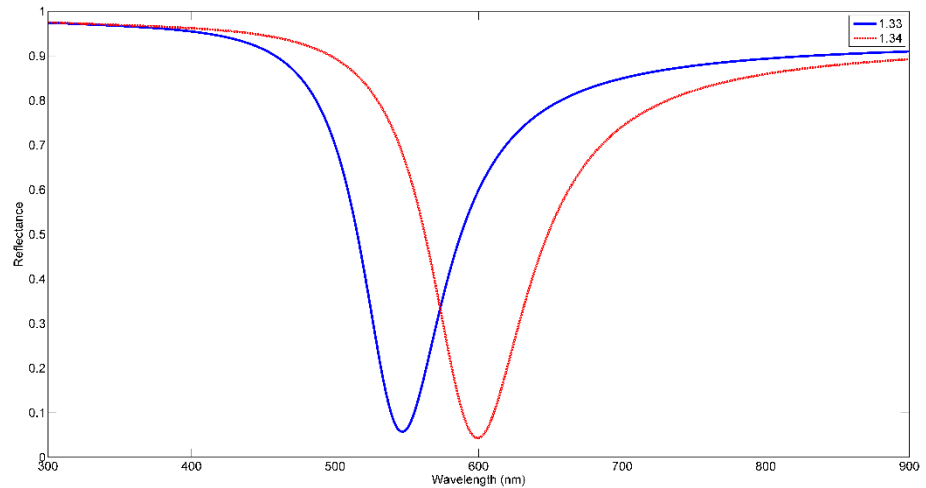
Monochromatic light

SPR Imaging



Spectral Interrogation

Polychromatic light



Summary

1. Expression for propagation length and penetration depth were obtained and discussed
2. Dispersion curve of SPs was studied and the issues with excitation of SPs were discussed.
3. Methods to overcome such issues and excite SPs were presented and the use of SPs for sensing in various modes of operation was discussed.

Thank You