Surface Plasmon Resonance

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Outline

- Introduction
- Surface Wave
- SP wave
- Excitation of SP wave
- Experimental Setup
- Results

History

- A Otto
- E Kretschmann
- Biacore

Theoretical Background

Plasmons

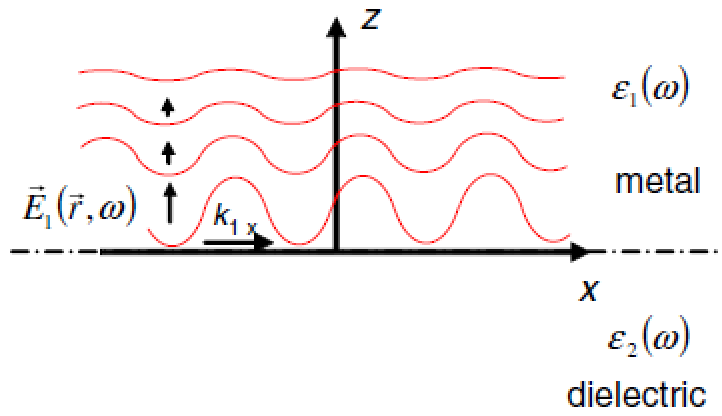
Plasmons are quasi particles of plasma oscillations
Usually excited by the applied electric field.

Surface Plasmons

Surface plasmons are coherent electron oscillations which occur at the interface of a metallic and a dielectric medium.
Energy of SP's is lower than that of plasmons.

Structure of a surface wave

SP wave is a surface wave
Typical confinement thickness is of the order of 30nm



$$\vec{E}_1(\vec{r},\omega) = \vec{E}_0 e^{i(\vec{k}.\vec{r}-\omega t)}$$

$$\nabla^2 \vec{E}_1(\vec{r},\omega) + \varepsilon_1(\omega)\frac{\omega^2}{c^2}\vec{E}_1(\vec{r},\omega) = 0$$

$$-k_1^2 + \varepsilon_1(\omega)\frac{\omega^2}{c^2} = 0$$

$$\vec{k}_1 = k_{1x}\vec{u}_x + k_{1z}\vec{u}_z$$

$$k_{1x}^2 + k_{1z}^2 = \varepsilon_1(\omega)\frac{\omega^2}{c^2}$$

Lets assume wave vectors are

$$k_{1x} = k_{1x}^{'}$$

$$k_{1z} = ik_{1z}^{''}$$

Then resulting wave is

$$\vec{E}_1(\vec{r},\omega) = \vec{E}_0 e^{-k_{1z}^{''}z} e^{i(k_{1x}^{'}x - \omega t)}$$

The SP wave

The SP wave is generated by the coupling of an optical wave and an electromagnetic wave on the interface of two media which have different refractive indices.
Medium 1 is isotropic, homogeneous and metallic with dielectric constant $\varepsilon(\omega)$
Medium 2 is homogeneous and isotropic dielectric.

Dielectric constant of gold can be calculated through Drude-Sommefeld free electron model.
So

$$\varepsilon_{1Drude} = 1 - \frac{\omega_p^2}{\omega^2} \qquad \omega_p^2 = \frac{ne^2}{\varepsilon_0 m}$$

Dispersion relation of the SP wave;

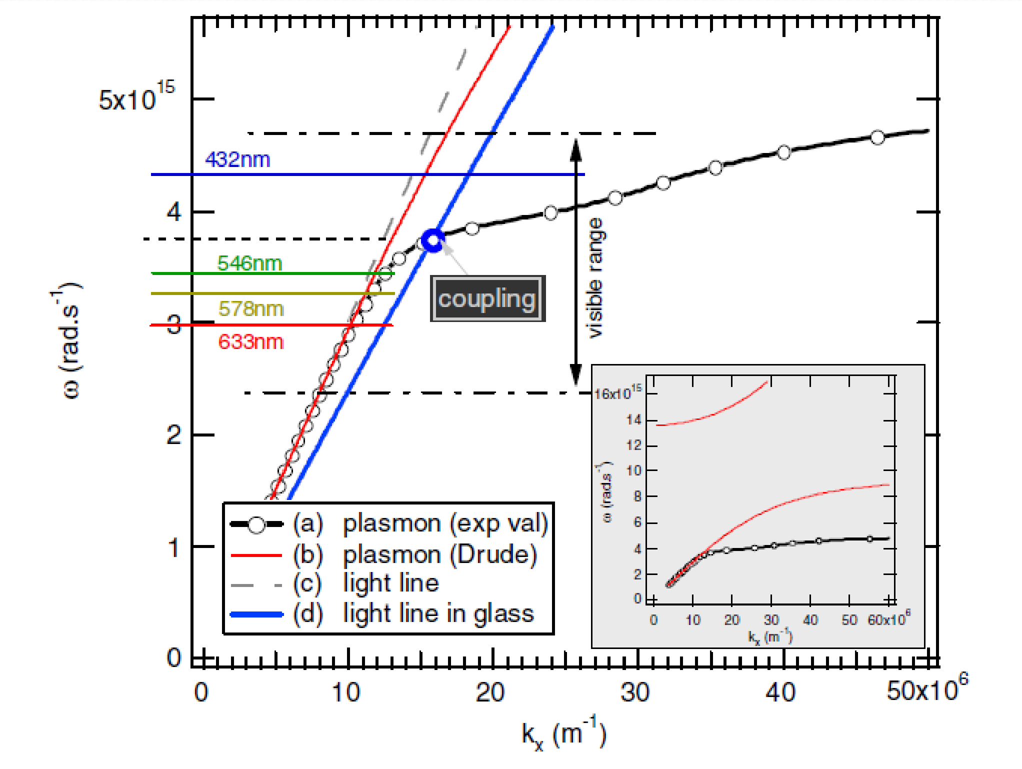
$$k_x^2 = \frac{\omega^2}{c^2} \cdot \frac{\varepsilon_1(\omega).\varepsilon_2(\omega)}{\varepsilon_1(\omega) + \varepsilon_2(\omega)}$$

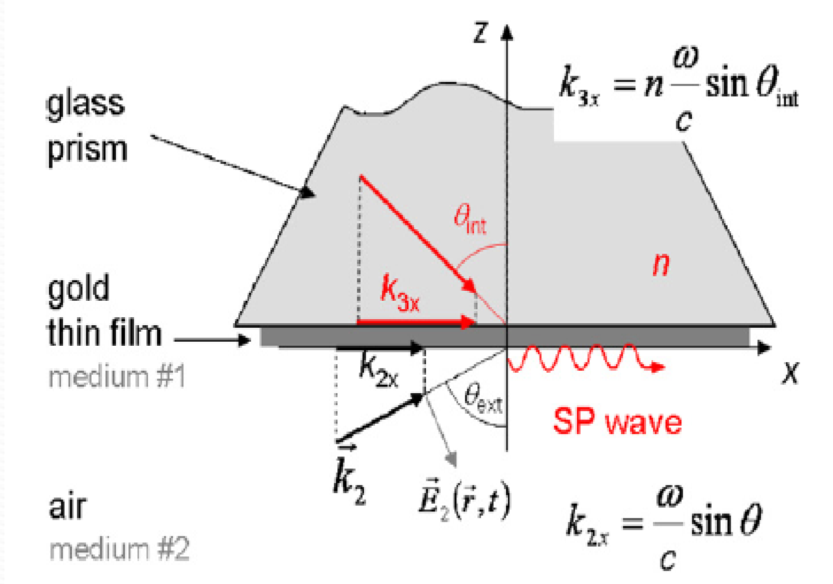
$$k_{1z}^2 = \frac{\omega^2}{c^2} \cdot \frac{\varepsilon_1^2(\omega)}{\varepsilon_1(\omega) + \varepsilon_2(\omega)}$$

$$k_{2z}^2 = \frac{\omega^2}{c^2} \cdot \frac{\varepsilon_2^2(\omega)}{\varepsilon_1(\omega) + \varepsilon_2(\omega)}$$

Excitation of SP wave

The SP wave is excited by coupling of an optical beam.
Energy **ħω** and Momentum **ħk** should be conserved.



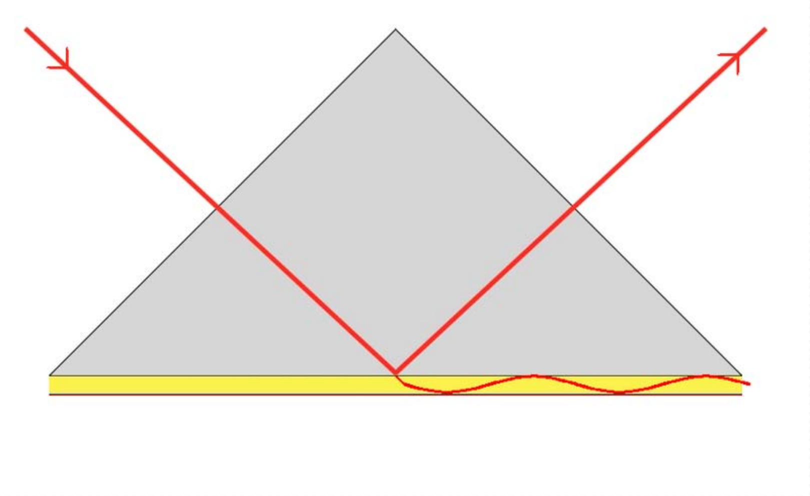


Thickness of the thin film is critical.
It should be optimized so momentum will be transferred by maximum.

Condition for coupling the excitation wave with the SP wave

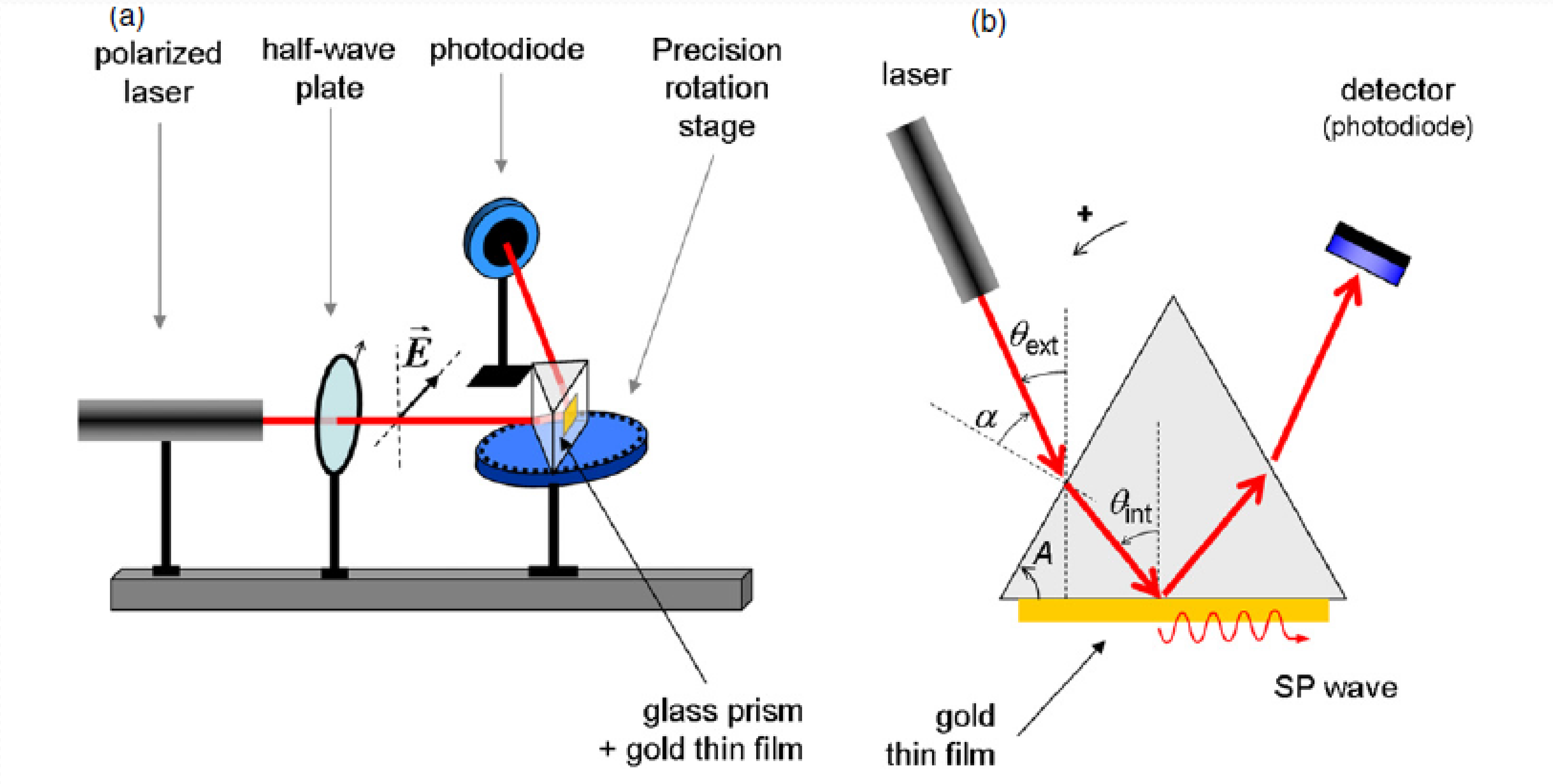
$$(n \sin \theta_{\text{int}})^2 = \frac{\varepsilon_1(\omega).\varepsilon_2(\omega)}{\varepsilon_1(\omega) + \varepsilon_2(\omega)}$$

Configurations for exciting SP wave



Kretschmann configuration

Experimental Setup

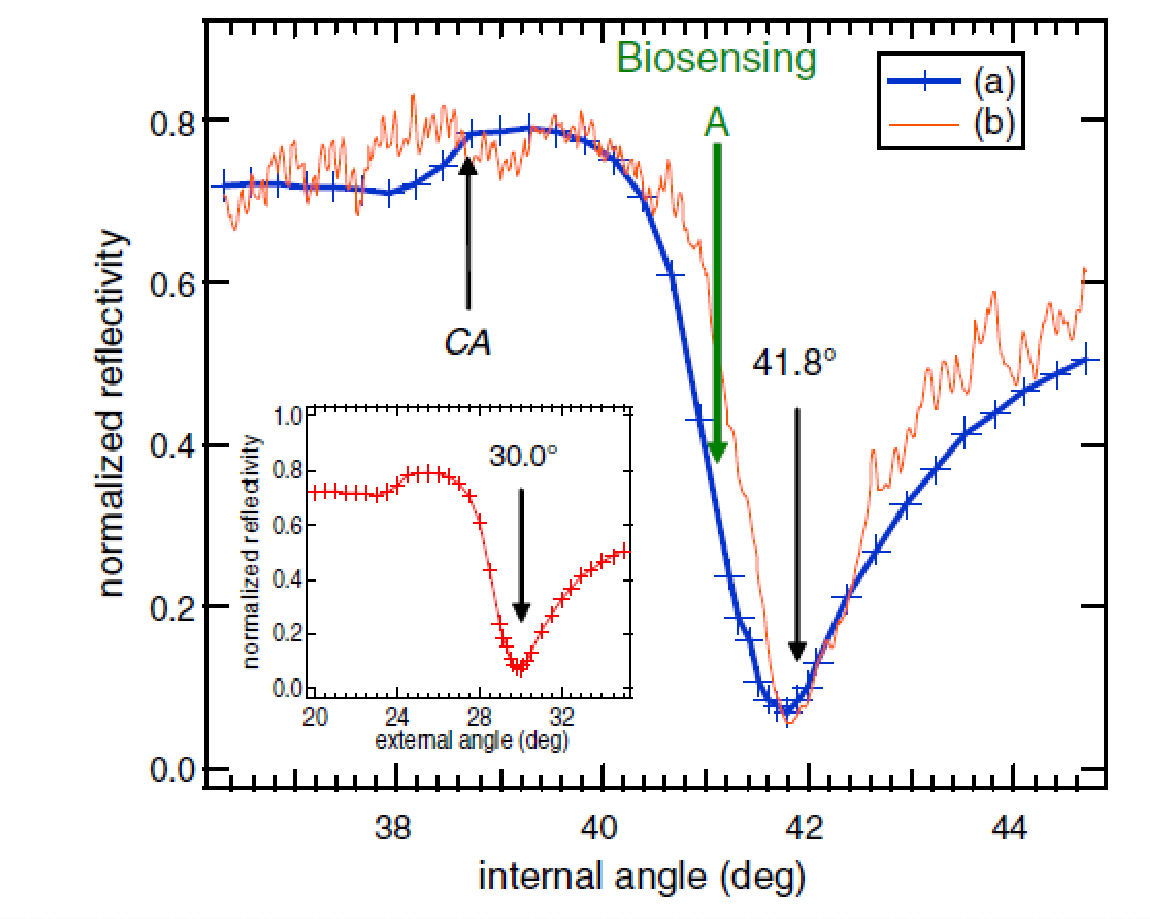


$$\theta_{\text{int}} = \arcsin \frac{\sin(\theta_{ext} - A)}{n} + A$$

Required Elements

- Light Source
- The Prism
- Thin Film
- Rotation Stage
- Detector

Reference Results



References

- Olivier Pluchery, Romain Vayron and Kha-Man Van, 'Laboratory experiment for exploring the surface plasmon resonance' , Eur. J. Phys. **32** (2011).
- Mark Fox, 'Optical Properties of Solids'.

Thanks