

Automatized setup for plasmonic measurements based on prism coupling technique

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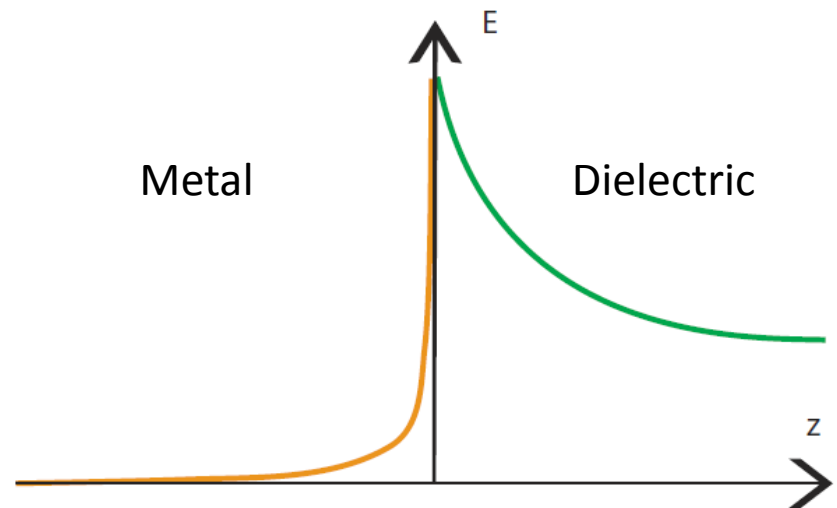
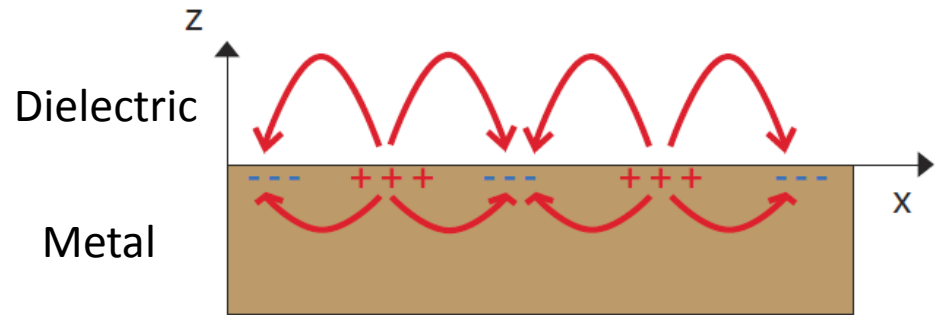
Estonia

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Introduction: Surface plasmons

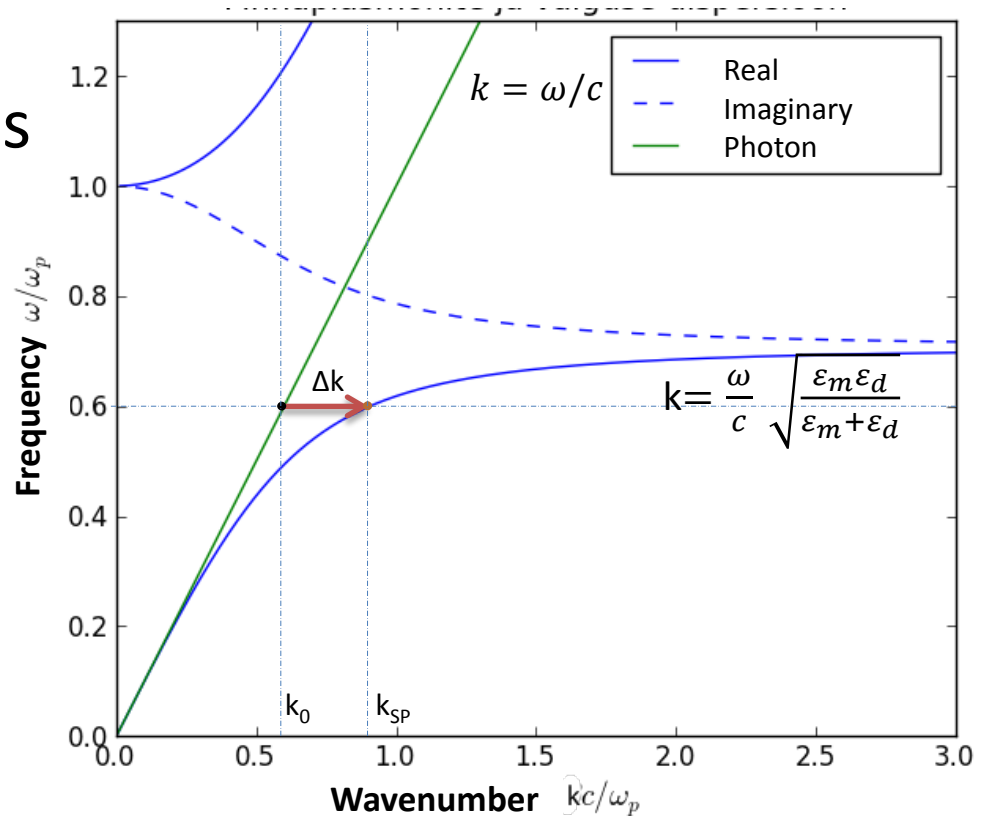
- Electromagnetic wave confined to metal-dielectric interface
- Caused by oscillation of free charges
- Exponential decay to the both medium



Introduction: How to excite?

Problems:

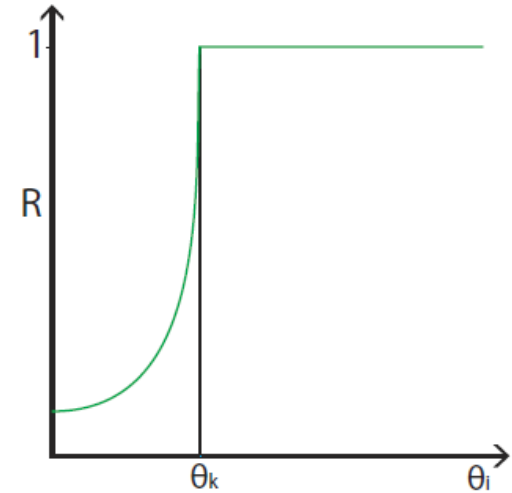
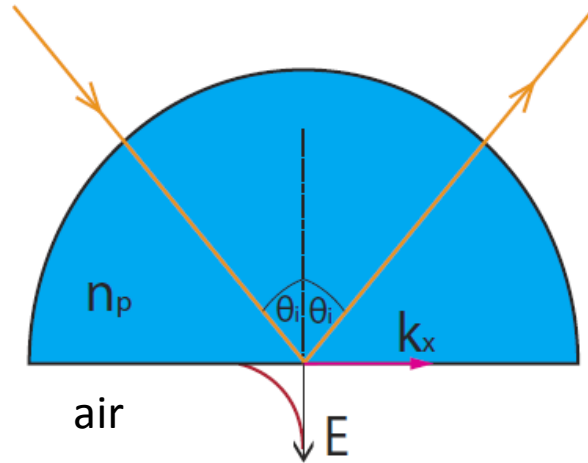
- Photon momentum is smaller than surface plasmons at the same energy



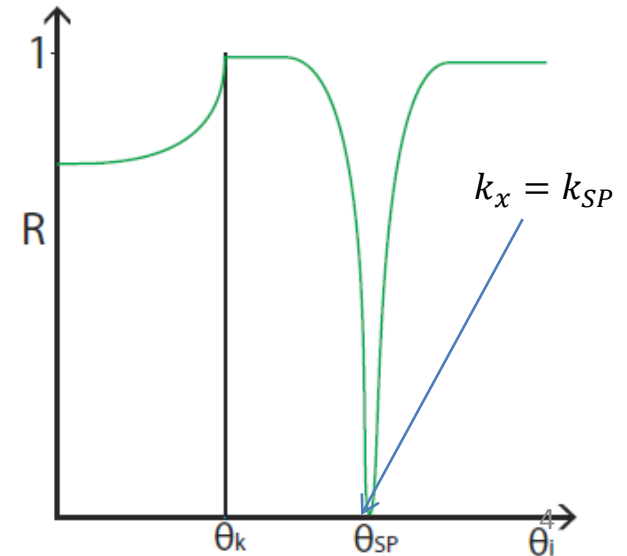
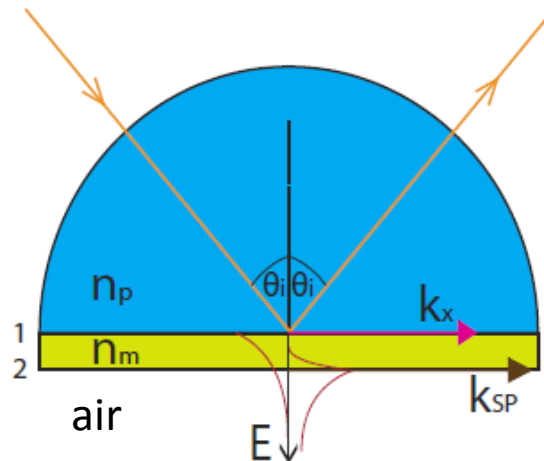
Introduction: Kretschmann scheme

Total internal reflection:

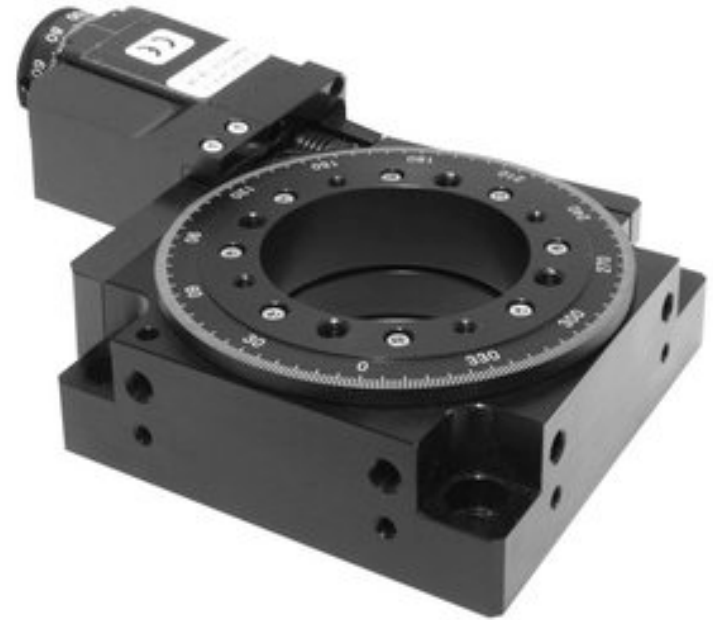
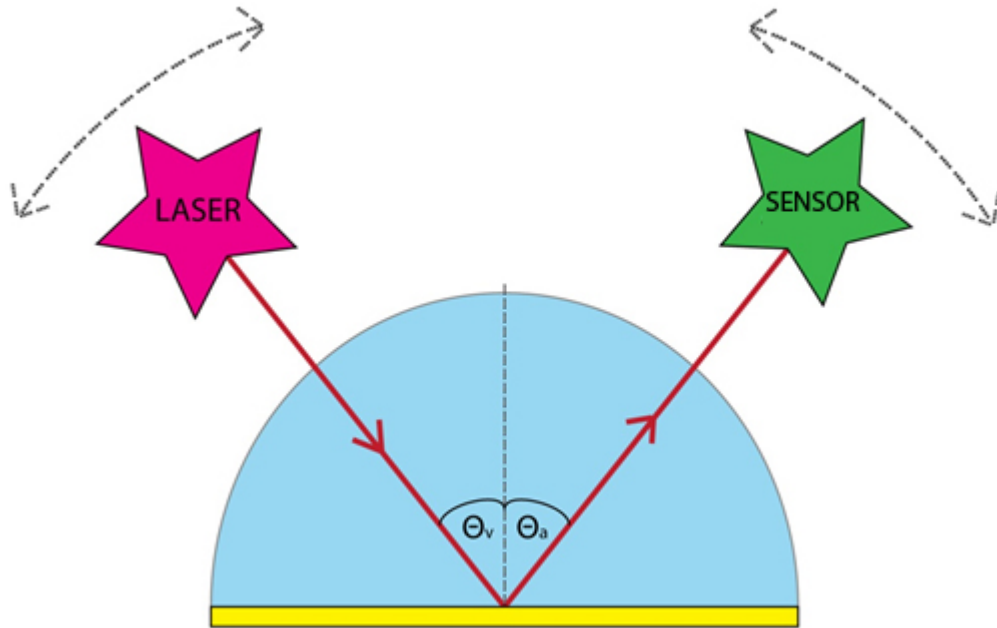
$$k_x = n_p k_0 \sin(\theta_i)$$



Exciting surface plasmons with Kretschmann scheme:



Built machine: 2-axis motorized goniometer



- Based on two motorized rotational stages (STANDA)
- Angle resolution: 0.00125°

Built machine

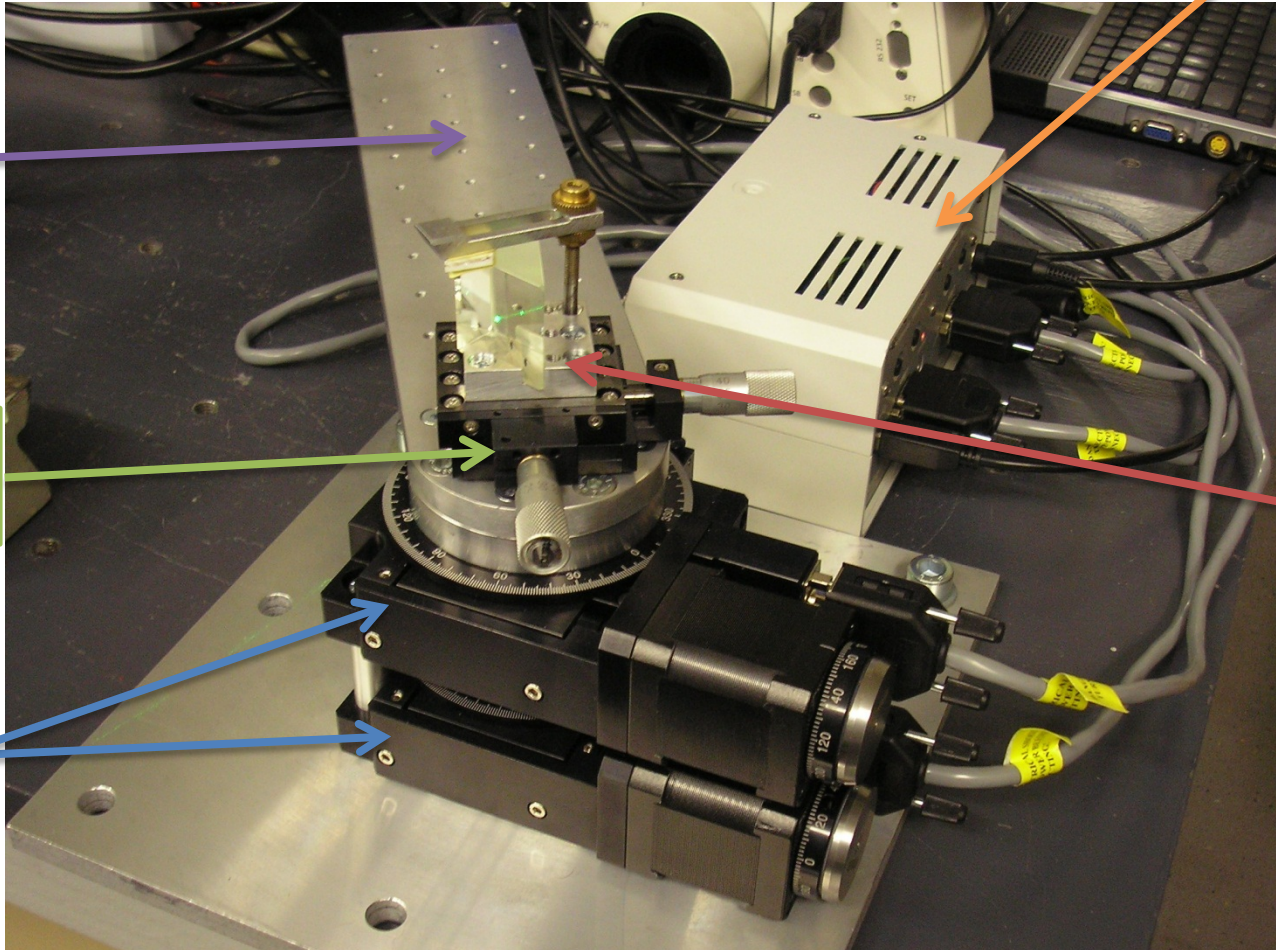
2 axes stepper motor controller

Mounts for sensors

XY translation stage

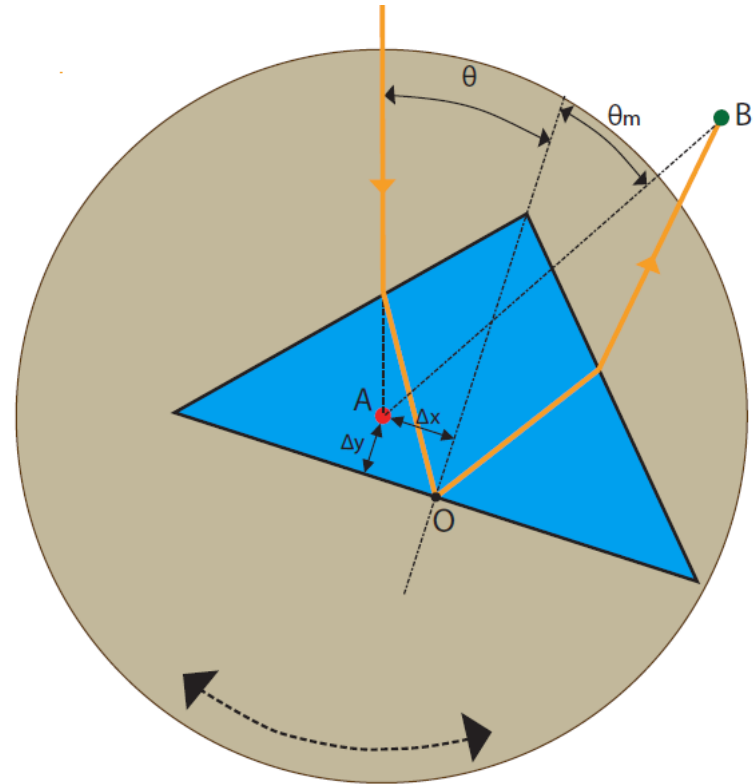
2 rotational stages

right angle prism holder



Built machine: Control logic

- Python (numpy, scipy, matplotlib etc) and C++ (boost)
- More than 8000 lines of code (object oriented)
- Graphic user interface (Qt)
- Calibration algorithms
 - Prism position
 - Sensor position
 - Ray center finder
- Measurement setups
- Sensors:
 - Labjack
 - Light power meters
 - Spectrometers



Built machine: graphical user interface

The screenshot displays the Goniometry software interface. The main window features a menu bar (File, View, Calibration, Scan, Options, Help) and a toolbar with icons for various functions, some labeled with red numbers 6 through 11. The interface is divided into several panels:

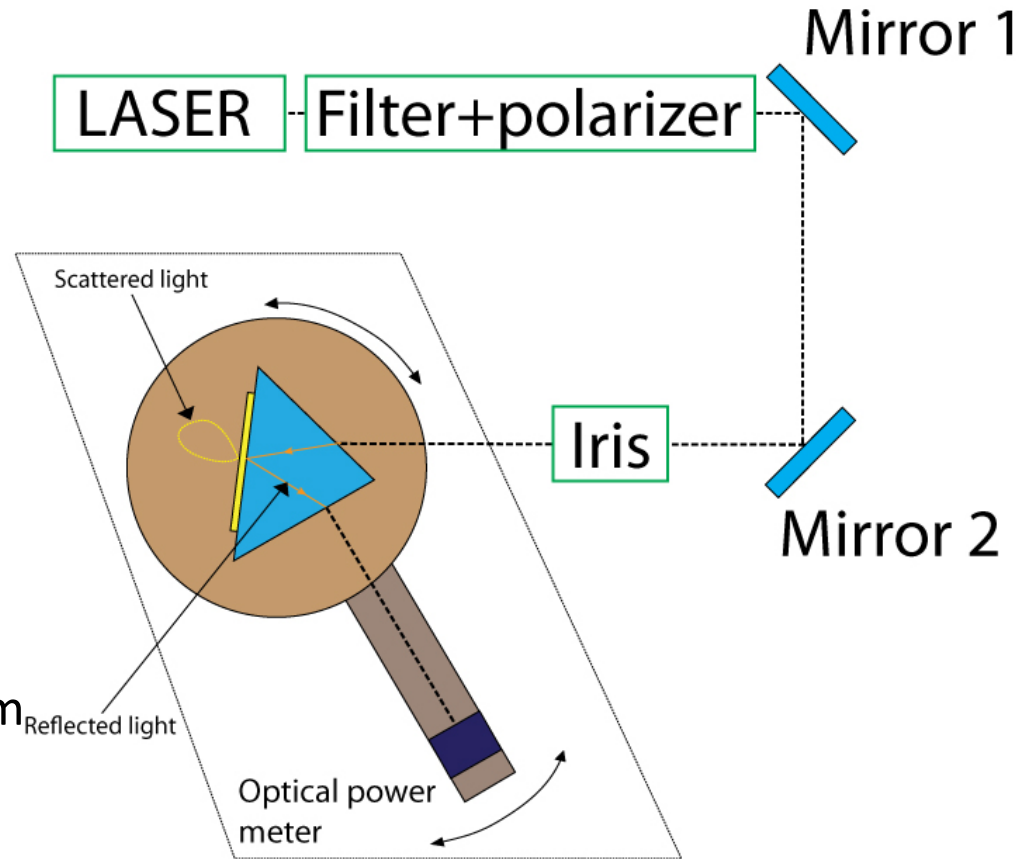
- Configuration (1):** Shows settings for Geometry (Plate Transmit) and Sensor (LabJack), with Connect and Disconnect buttons.
- Manual Control (2):** Includes input fields for Prism and Sensor (both set to 0.000), and buttons for Go to offset, Focus on the ray, and Stop.
- Plotters (4):** A tree view showing the active plot: Interferents klaasplaadilt (2D line plotter).
- Property Editor (5):** A table of properties for the selected plot.

The central plot, titled "Interferents klaasplaadilt", shows Normaliseeritud intsnsiivsus (Normalized intensity) on the y-axis (ranging from 0.70 to 1.10) versus Nurk (kraad) (Angle in degrees) on the x-axis (ranging from 0 to 10). Two data series are plotted: p-polarisatsioon (blue line with dots) and s-polarisatsioon (green line with dots). Both series exhibit oscillatory behavior, with the s-polarization series generally having a higher amplitude. A red number 3 is placed near the plot area.

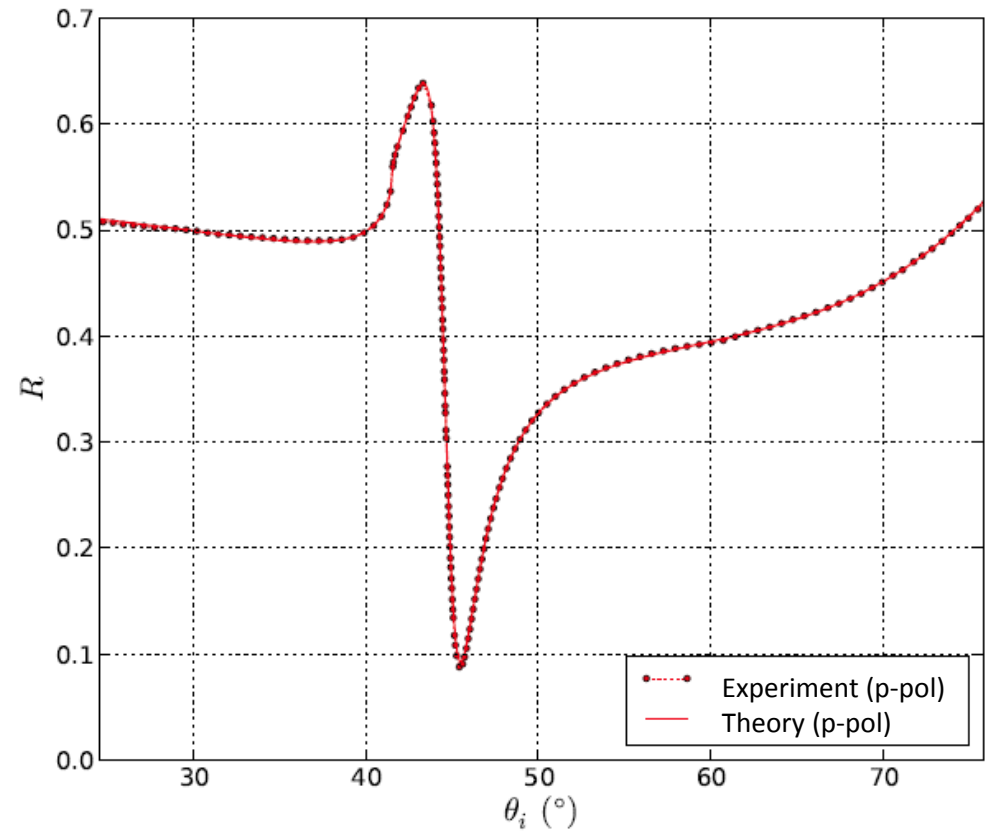
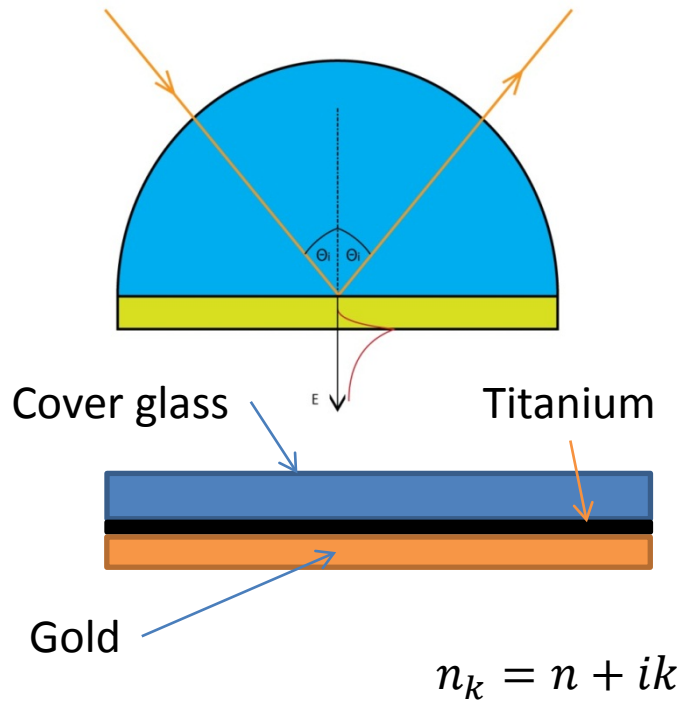
Property	Value
Titles:	
X-title:	Nurk (kraad)
Y-title:	Normeeritud intsnsiivsus
Title:	Interferents klaasplaadilt
Limits:	
X-axis range:	(None, None)
Y-axis range:	(0.7, 1.1)
Normalize:	
Normalize:	<input type="checkbox"/>
Normalize to:	1.00
Reference:	-1
Options:	
Grid:	<input checked="" type="checkbox"/>
Legend:	<input checked="" type="checkbox"/>
Visible:	<input checked="" type="checkbox"/>
SubPlot:	111

Experiment: Setup

- Laser: 532, 593 nm
- Triangular prism
- Optical power meter:
 - Thorlabs PM100
 - Silicon Sensor PM130
- Aim
 - Test setup by
 - Characterize thin gold film using surface plasmons
 - Study surface roughness influence



Experiment: Exciting surface plasmons



Theory calculated with Transfer Matrix Method (Python module)

$$\delta_m = 31 \text{ nm}$$

$$\delta_d = 242 \text{ nm}$$

$$L = 4,3 \text{ } \mu\text{m}$$

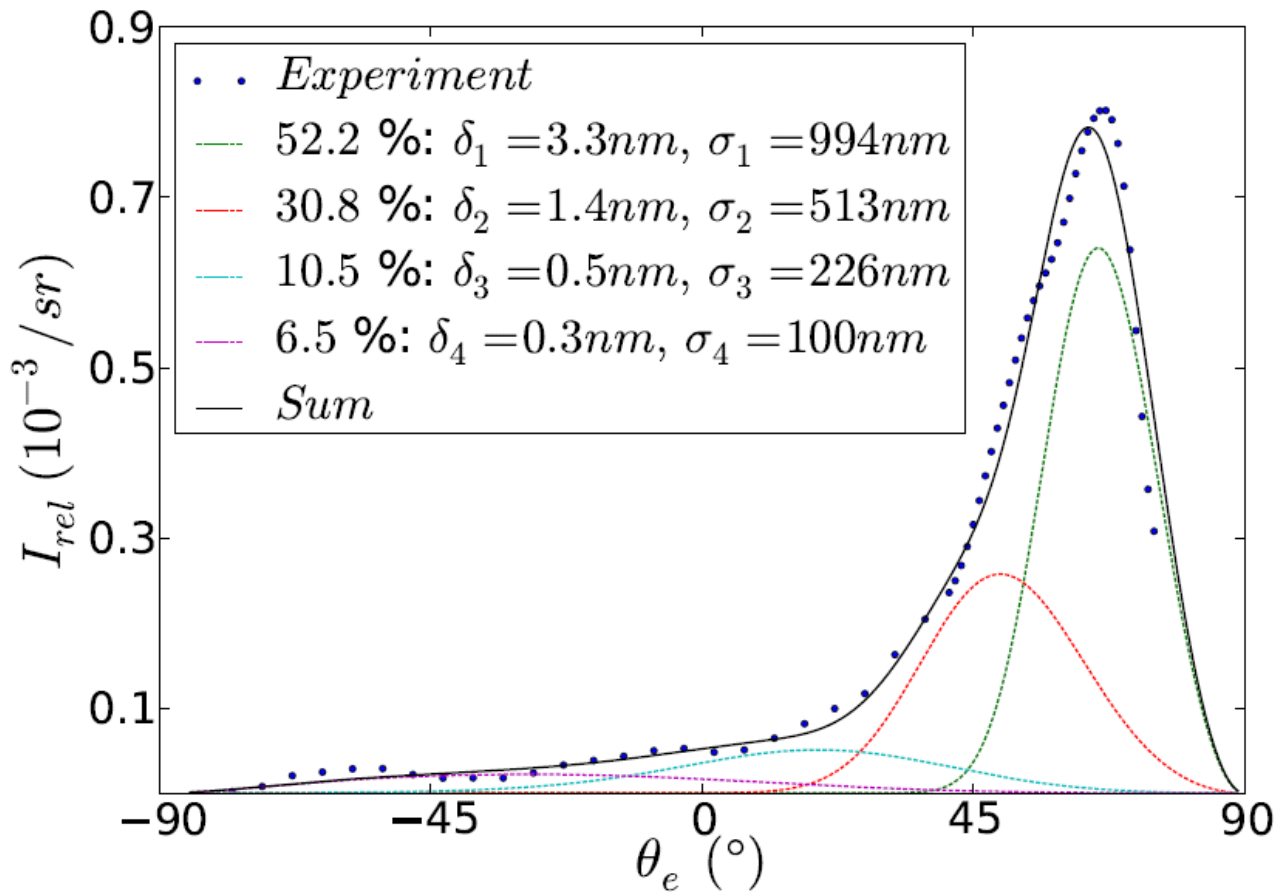
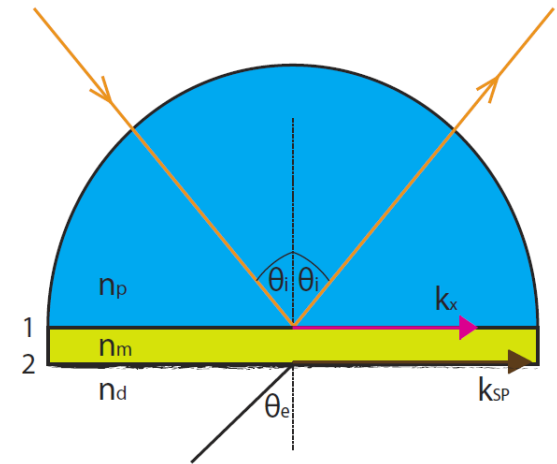
Medium	Intial guess (Palik)			Fitted parameters		
	h (nm)	n	k	h (nm)	n	k
Cover glass	∞	1,51		∞	1,51	
Titanium	5,0	2,02	2,78	5,78	2,11	3,72
Gold	50,0	0,26	2,97	48,75	0,28	2,86
Air	∞	1,0		∞	1,0	

Experiment: Surface roughness

Theory:

A. Hoffmann, Z. Lenkefi, Z. Szentirmay (1998)

E. Kröger, E. Kretschmann (1970)



δ – root mean square
 σ – correlation length

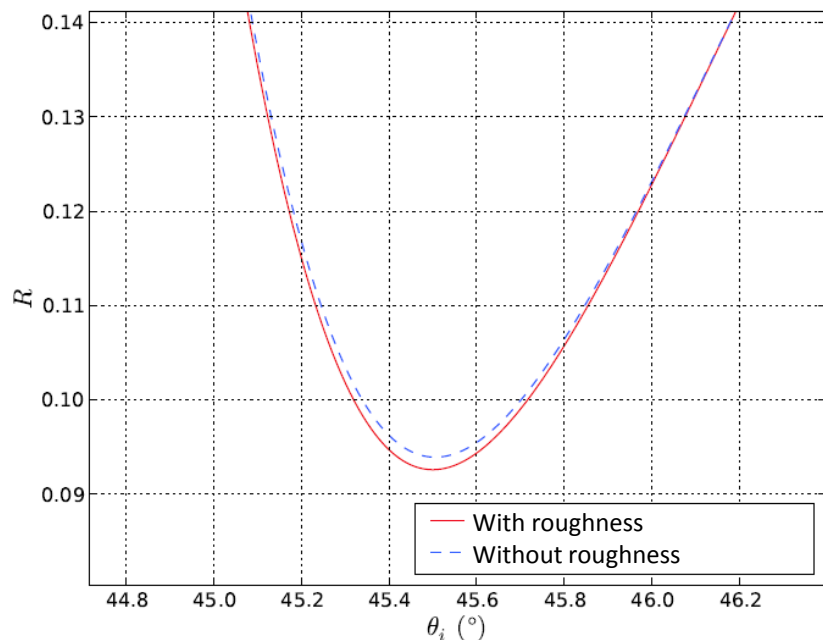
AFM measurements:

$\delta = 3.5 \text{ nm}$

Experiments: Surface roughness effect on gold parameters

Transfer Matrix method doesn't include surface parameters.

Surface roughness influences dispersion relation -> reflectivity curve changes -> previously obtained gold parameters might be inaccurate



Surface Plasmons propagation constant:

$$\beta_{measured} = \beta_{smooth\ surface} + \Delta k_r$$

Surface roughness influence on dispersion relation (calculated by E. Fontana & R. H. Pantell (1988) formulas)

Propagation constant	Real part (m ⁻¹)	Imaginary part (m ⁻¹)
Measured wavenumber ($\beta_{measured}$)	11365564	115543
Roughness influence (Δk_r)	29	1574
Without roughness ($\beta_{smooth\ surface}$)	11365535	113969

Conclusions

- Built setup is essential to study any angular dependency
- Device can be used to characterise thin metal films

Thank you for listening!
Questions?