Localized surface plasmon resonance in laser-deposited gold nanoparticle layers for total internal reflection based optical sensors

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Abstract: the localized surface plasmon resonance (LSPR) of laser-deposited gold nanoparticles layers has been investigated using spectral transmission, total internal reflectometry and total internal reflection ellipsometry (TIRE). The LSPR characteristics depend on the size and density of nanoparticles within the layers which in turn can be adjusted to a certain extent through the laser process parameters and that with the high spatial resolution provided by the laser beam. Moreover it appears that the use of total internal reflection (TIR) as a readout configuration can significantly enhance LSPR-based sensors sensitivity to refraction index variations in probed liquid samples in comparison to the transmission read-out configuration. The laser implementation of LSPR-supporting nanoparticles in a lab-on-a-chip device integrating a TIR-based multiplexed optical read-out system is discussed here in the frame of biopesticides detection.

1. What is our instrumental concept?

- **LSPR detection spots locally synthesized using laser direct writing**
- **LSPR detection in Total Internal Reflectance (TIR) mode**

2. What is the goal of our instrumental approach?

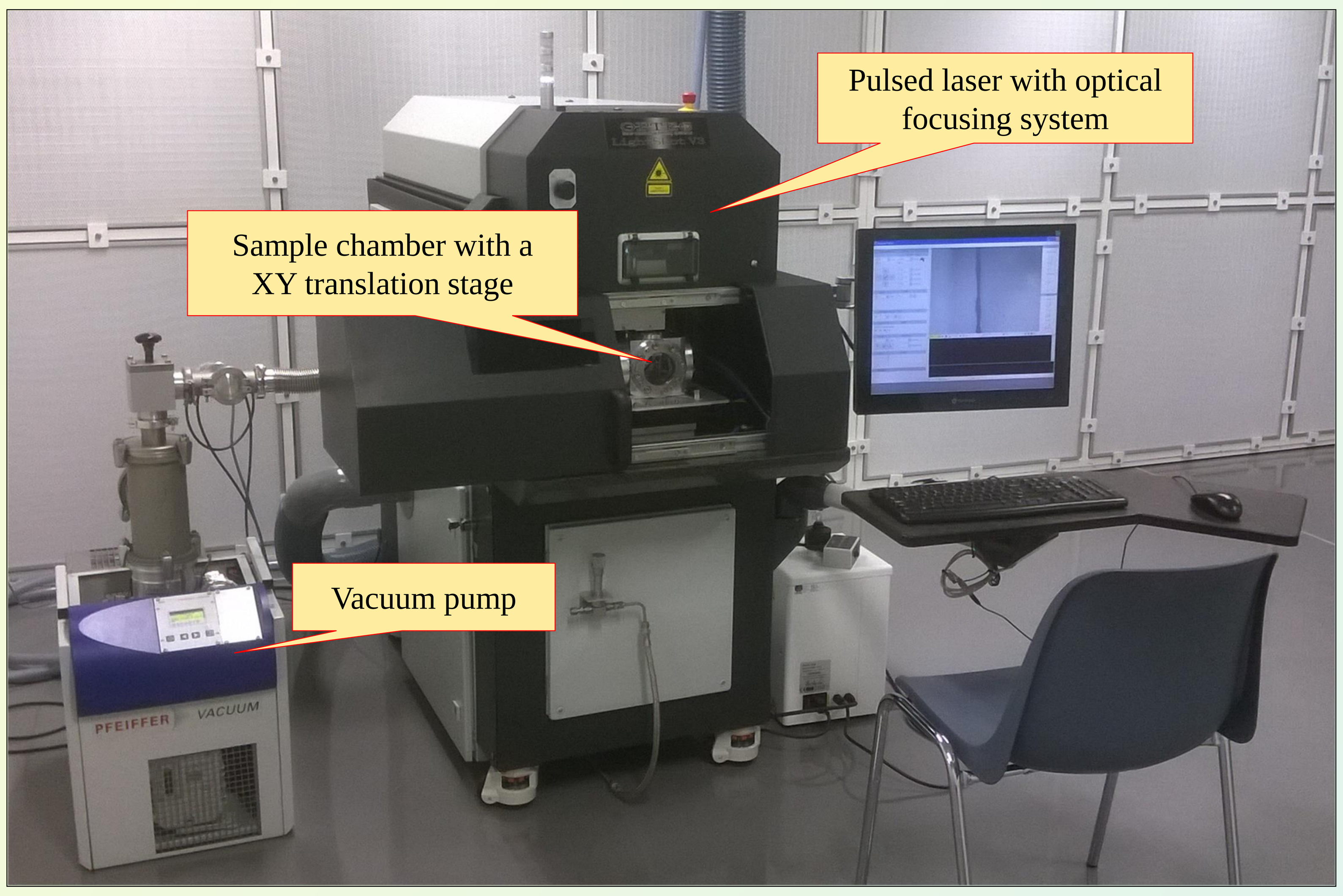
Since two different detection formats (SPR & LSPR) are combined in the same lab-on-chip device

- Large amount of information on the liquid sample
- High degree of miniaturization for the plasmonic multichannel sensor
- Relative simplicity of fabrication in large bi-dimensional array of LSPR sensors adapted to microfluidic system architecture
- The light do not pass through the solution to analyze

The wavelength spectrum is not perturbed by light reflection/refraction at the inner walls of the microfluidic channel and in the liquid sample

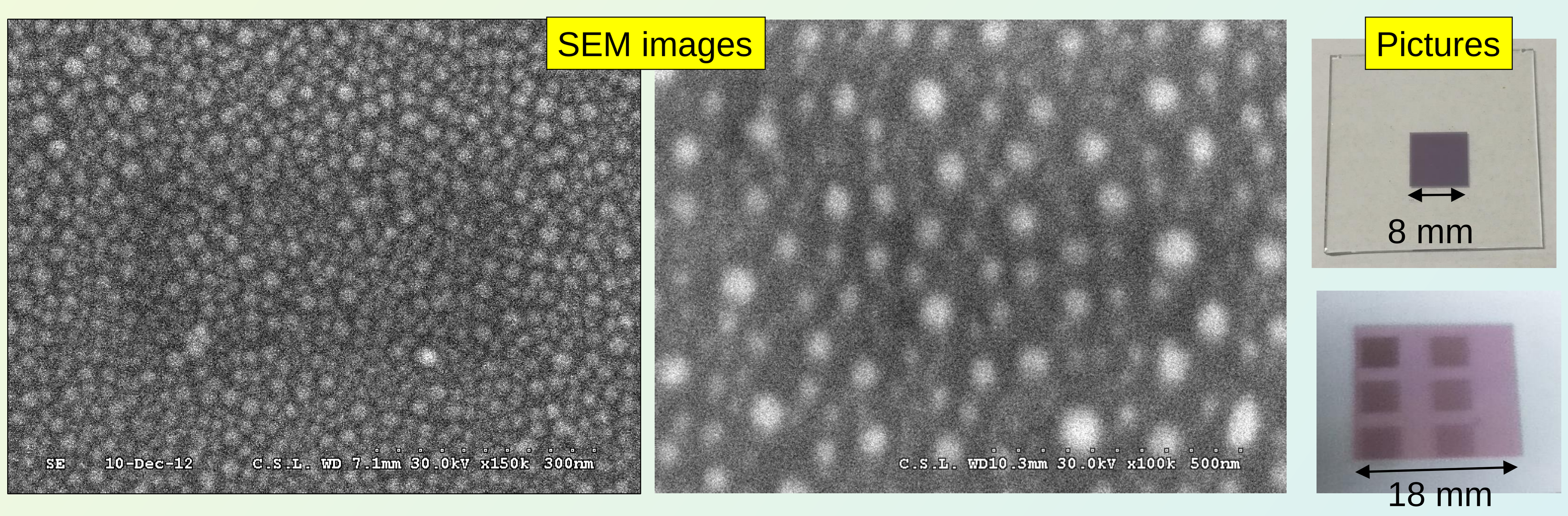
3. First proof-of-concept experimental investigations

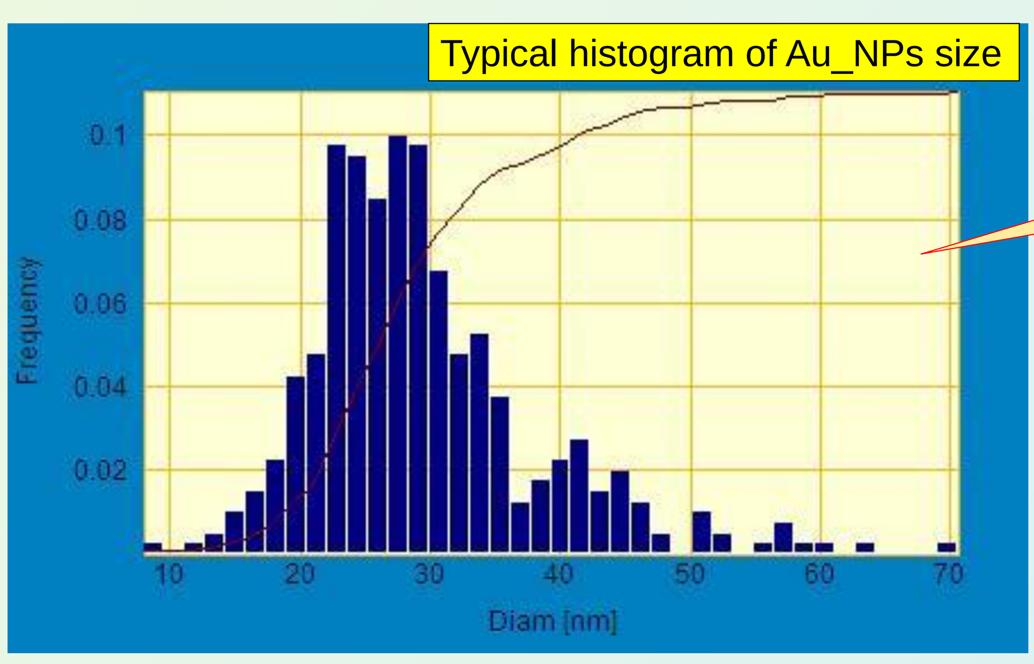
3.1. Experimental set-up for Au_NPs local deposition



First experimental results:

Laser-deposited Au_NPs :





PSD (Particle size distribution) is sensitive to the selected laser deposition conditions

Deposition conditions, as well as post-treatment optimization is under progress

Nano-metrology (SEM & AFM) reveals:

- High reproducibility of the NPs shape & density
- AuNPs typical size ~30 nm, max range : 10-70 nm

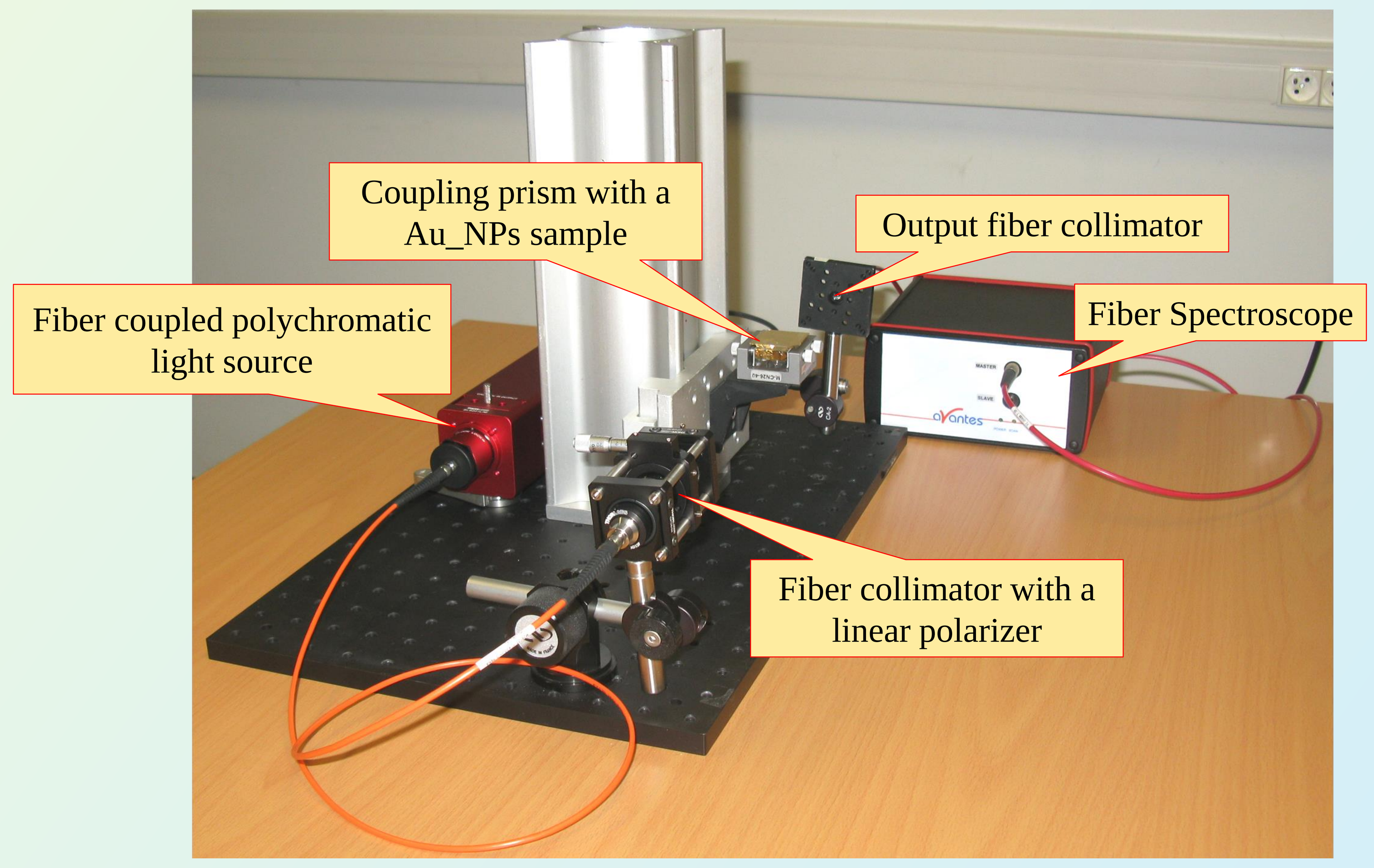
Extinction cross section ≈ Absorption cross section

The most appropriate format for LSPR sensor read-out:

Specular light intensity monitoring

Classical detection method	**Proposed** sensing concept
NPs free space excitation via **propagating** wave (Transmission mode)	NPs TIR excitation via **evanescent** wave (**LSPR_TIR reflectometry**)
Experimentally obtained refractive index sensitivity of LSPR sensor ~ 90 nm/RIU	Sensing concept under experimental investigation by our team
In good agreement with theory (Mie)	

3.2. Experimental set-up for LSPR_TIR reflectometry

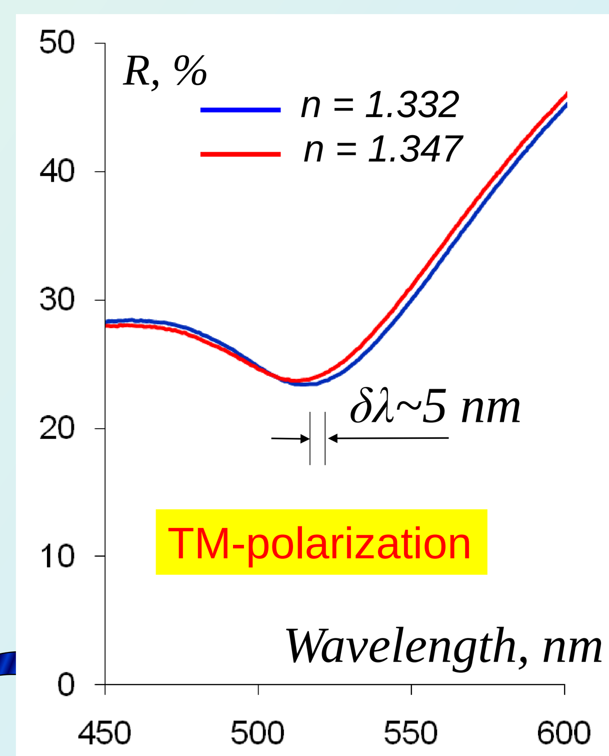


Broken symmetry of the "NP/substrate" system

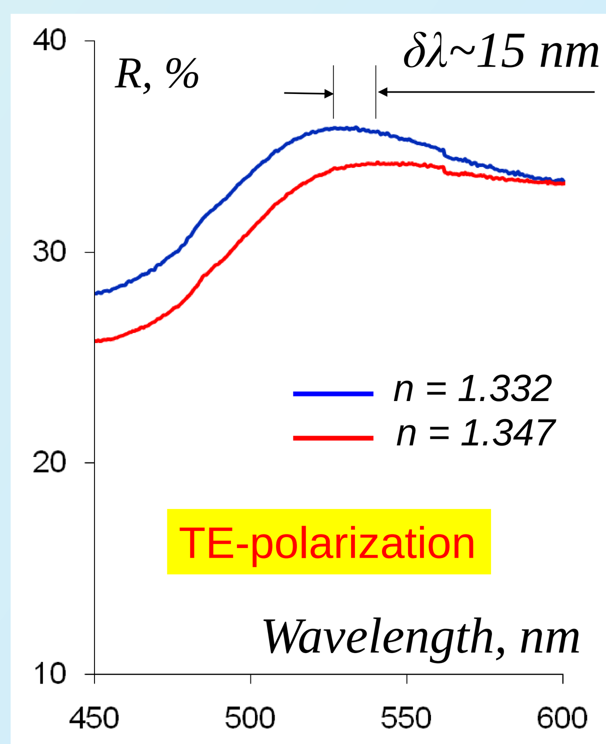
Multipolar excitation of NPs → The optical signature of the system depends on the light wave polarization

First experimental results

LSPR-TIR reflectometry at a fixed incidence angle (*73°*) for different liquid samples



Refractive index sensitivity ~ 300 nm/RIU



Refractive index sensitivity ~ 900 nm/RIU

Conclusion:

- Bio-sensing involving *LSPR_TIR* detection format and an associated nanoparticles deposition method involving laser direct writing are proposed and experimentally investigated
- A relatively high sensitivity of *LSPR* sensors in the TIR interrogation mode is experimentally demonstrated
- Au_NPs laser deposition technology is under optimization

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