Sensitivity-enhanced localized surface plasmon resonance biosensing format dedicated for point-of-care testing (POCT) tools

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Abstract: one of the most advantageous instrumental approaches, offering a very attractive price-performance ratio, consists in the aggregation of different biosensing formats in one single POCT instrument with an arbitrary arrangement of biosensors on the biochip surface. We focus on theoretical and experimental investigations of optional plasmonic-related biosensing formats, easy to be integrated in lab-on-chip devices involving conventional planar SPR biosensing. One of such detection formats involves localized surface plasmon resonance (LSPR) spectroscopy at the frustrated total internal reflection conditions (LSPR_TIR), [1-2]. We report on the numerical and experimental study of the localized surface plasmon resonance (LSPR) spectroscopy of gold nanoparticles (NPs) structures at the frustrated total internal reflection (LSPR_TIR). The investigated NPs μ-structures were manufactured using two different microfabrication methods: the original one, involving the direct pulse laser writing and the nano-sphere lithography (NS_L). The former technology, developed by our research team, provides powerful tools for flexible patterning of the multichannel biochip with array of LSPR probes.

Introduction

What is our instrumental concept?

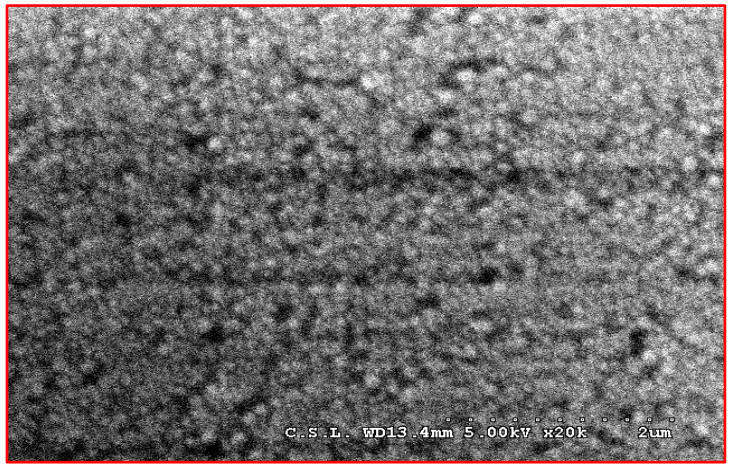
- **Two detection formats on the same lab-on-chip device: SPR & LSPR**
- **LSPR detection spots locally synthesized using laser direct writing**
- **LSPR detection in Total Internal Reflectance (TIR) mode**

What is the goal ?

- ✓ Large amount of information on the liquid sample
- ✓ 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

First proof-of-concept experimental investigations

Gold NPs synthesized by direct pulse laser writing (DPLW) :



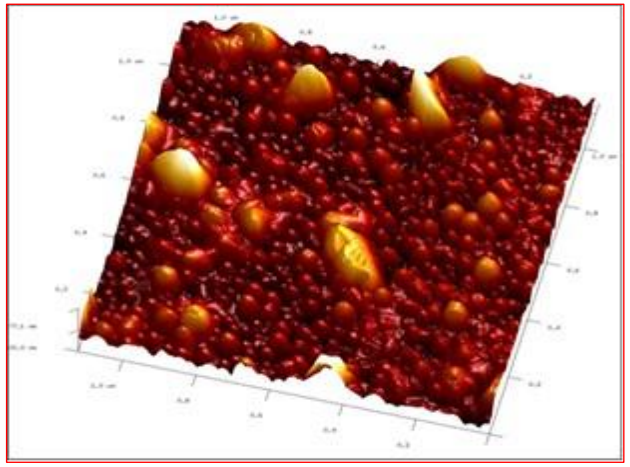


Fig.1. 2D and 3D nano-metrology using scanning electron and atomic force microscopy

Nano-metrology main results:

Laser synthesized μ-structures

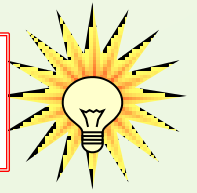
The most appropriate format for LSPR sensor read-out:

Proposed sensing concept

Oblate spheroid NPs of 50-70 nm in size, deposited with a relatively high surface density

Specular light intensity monitoring

NPs TIR excitation via **evanescent** wave (**LSPR_TIR reflectometry**)



Preliminary numerical study of the proposed concept

1. Normal incidence vs. oblique incidence in TIR conditions

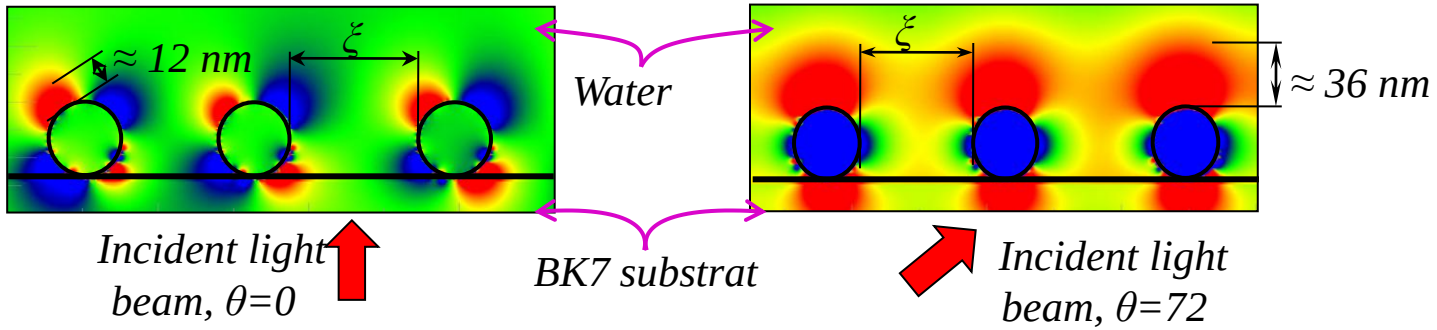


Fig.2. Poynting vector field calculated for gold NPs of 50 nm deposited on BK7/Water interface with ξ=100 nm

2. Effect of the NPs density on the LSPR evanescent optical field

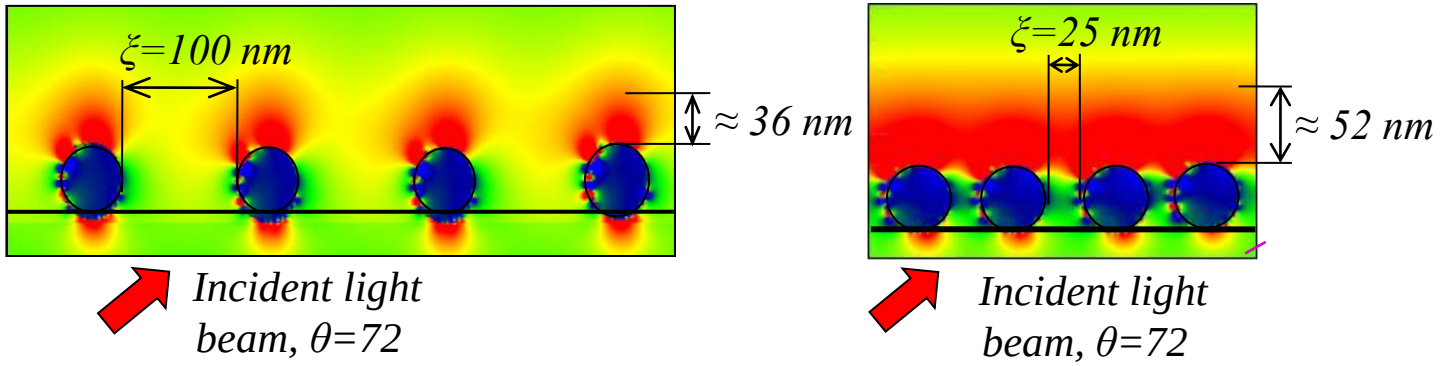


Fig.3. Poynting vector field calculated for gold NPs of 50 nm deposited on BK7/Water interface with ξ =100 nm and ξ =25 nm

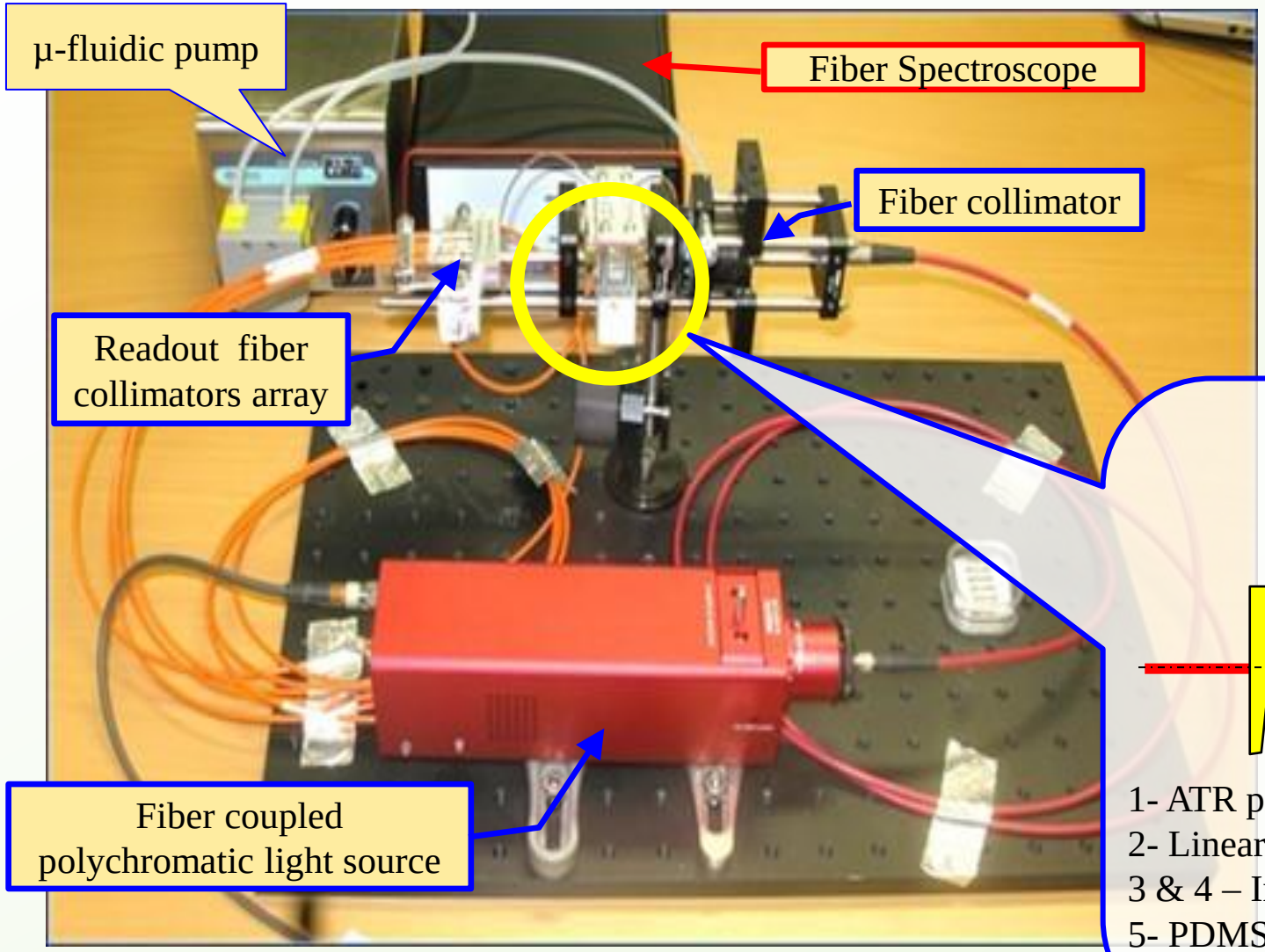
Numerical study results

An increase in the density of NPs leads to:

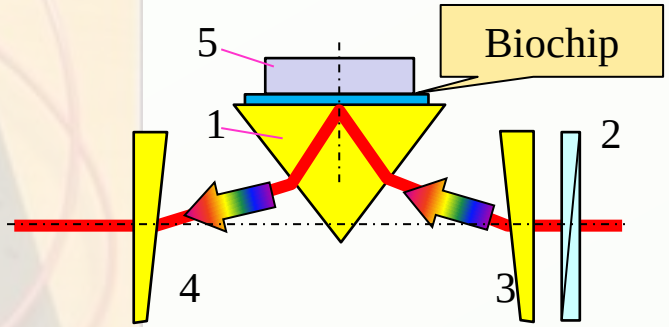
- A significant enlargement of the confinement region of the evanescent field generated by metal NPs
- The penetration depth of LSPR field into the sample strongly depends on the NPs density on biosensing area

The effect of these phenomena on the LSPR biosensor performance should be investigated experimentally

Experimental set-up



Coupling optical system

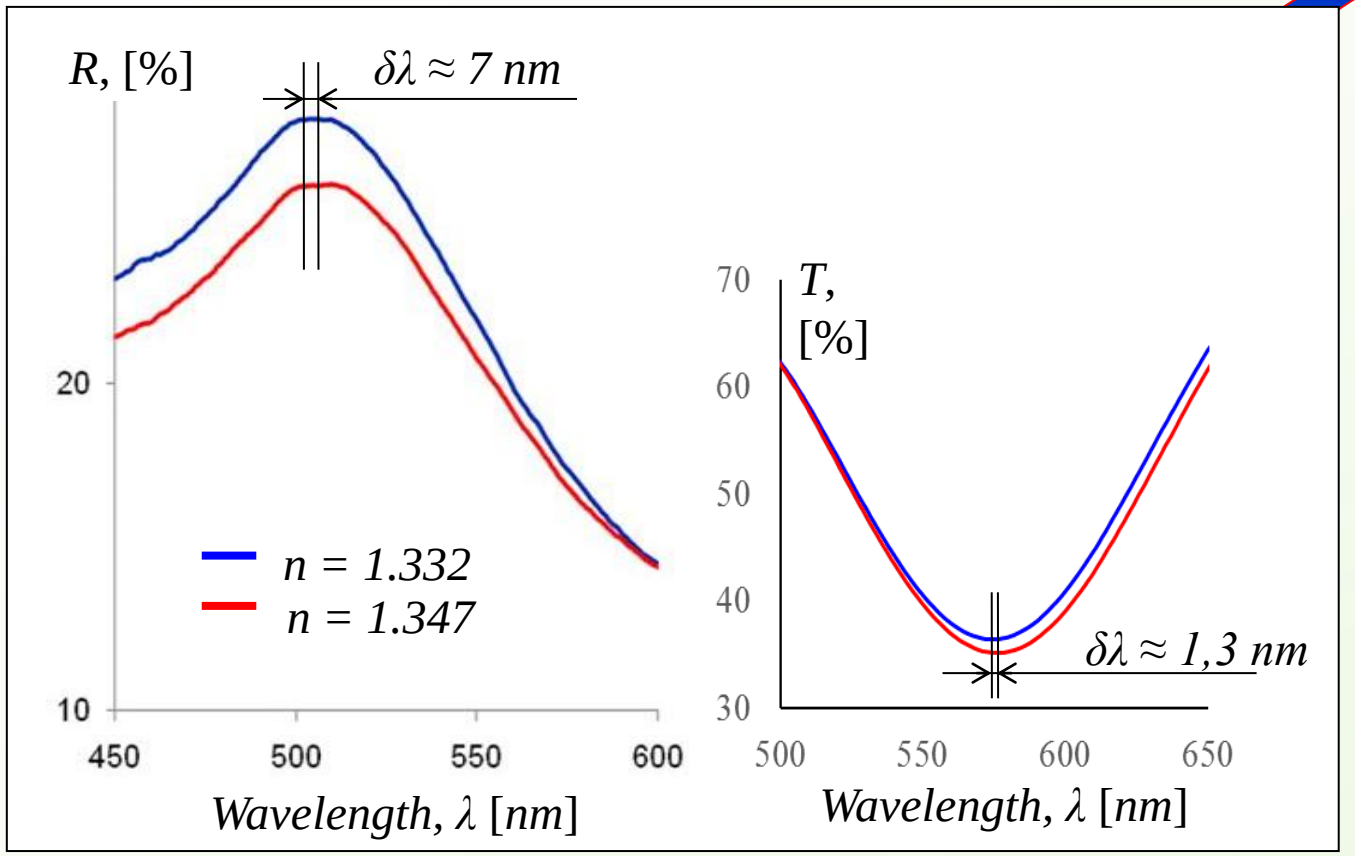


1- ATR prism coupler
2- Linear polarizer
3 & 4 – Input & Output Round Wedge Prisms
5- PDMS slab with a µ-fluidic channel system

Proposed LSPR_TIR detection format vs. conventional LSPR one

LSPR_TIR detection

LSPR detection



First experimental results

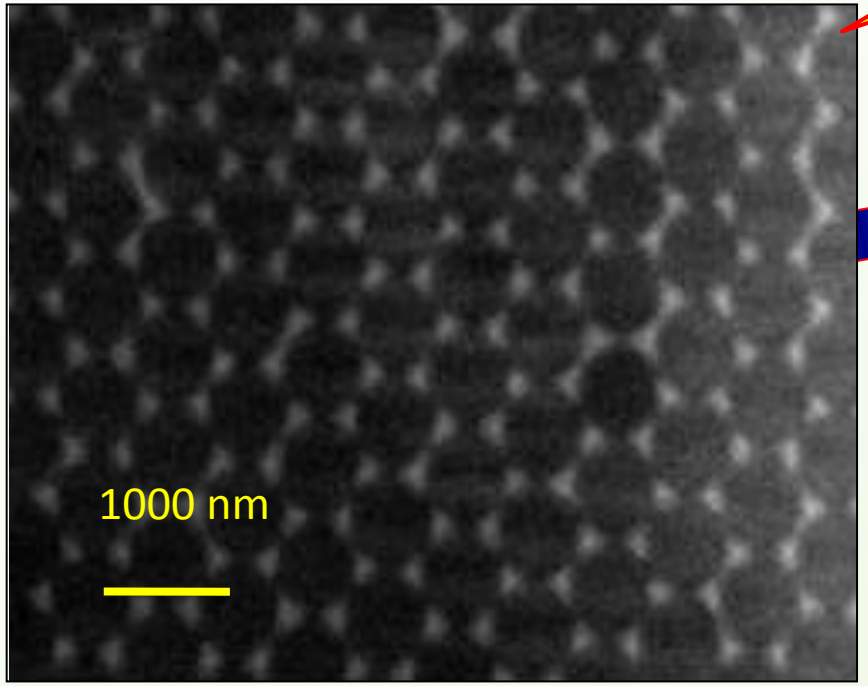
Detection format	Bulk sensitivity
Conventional LSPR	90 [nm/RIU]
Proposed LSPR_TIR	480 [nm/RIU]

A bulk sensitivity improvement of 500% compared to conventional LSPR format is achieved

Fair testing

Reference NPs μ-structure used in comparative study

Triangular NPs synthesized by NS_L

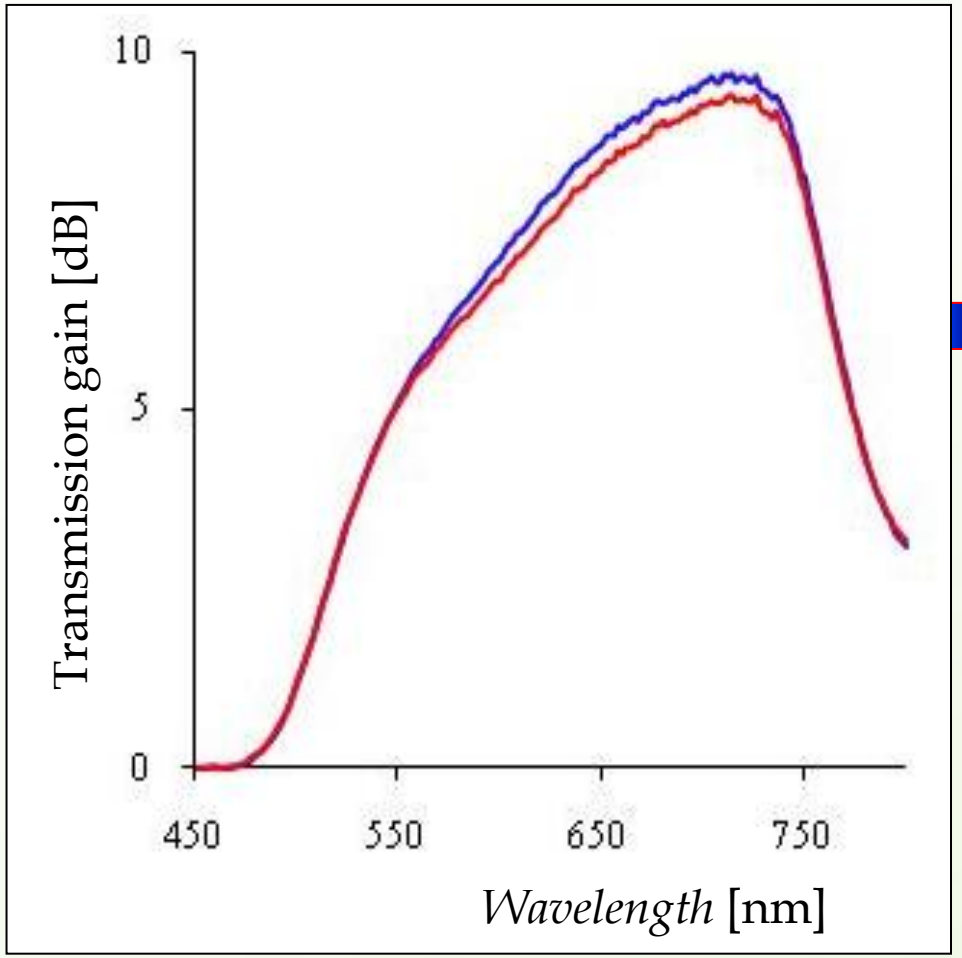


Detection format	Bulk sensitivity
Conventional LSPR	≤ 200 [nm/RIU]
Proposed LSPR_TIR	~700 [nm/RIU]

A bulk sensitivity improvement of 350% compared to conventional LSPR format

Light polarization conversion effect

TE to TM conversion



A novel biosensing format

?

Currently under investigation

Conclusion:

- *LSPR_TIR* biosensing format and an associated NPs synthesis method involving laser direct writing are proposed and experimentally investigated
- A significant improvement in the bulk sensitivity of *LSPR* sensors in the TIR interrogation mode is experimentally demonstrated
- A relatively high efficiency of the light polarization conversion is experimentally demonstrated

Thanks!

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