Integration of excimer laser micromachining in a biomedical sensor microfabrication process

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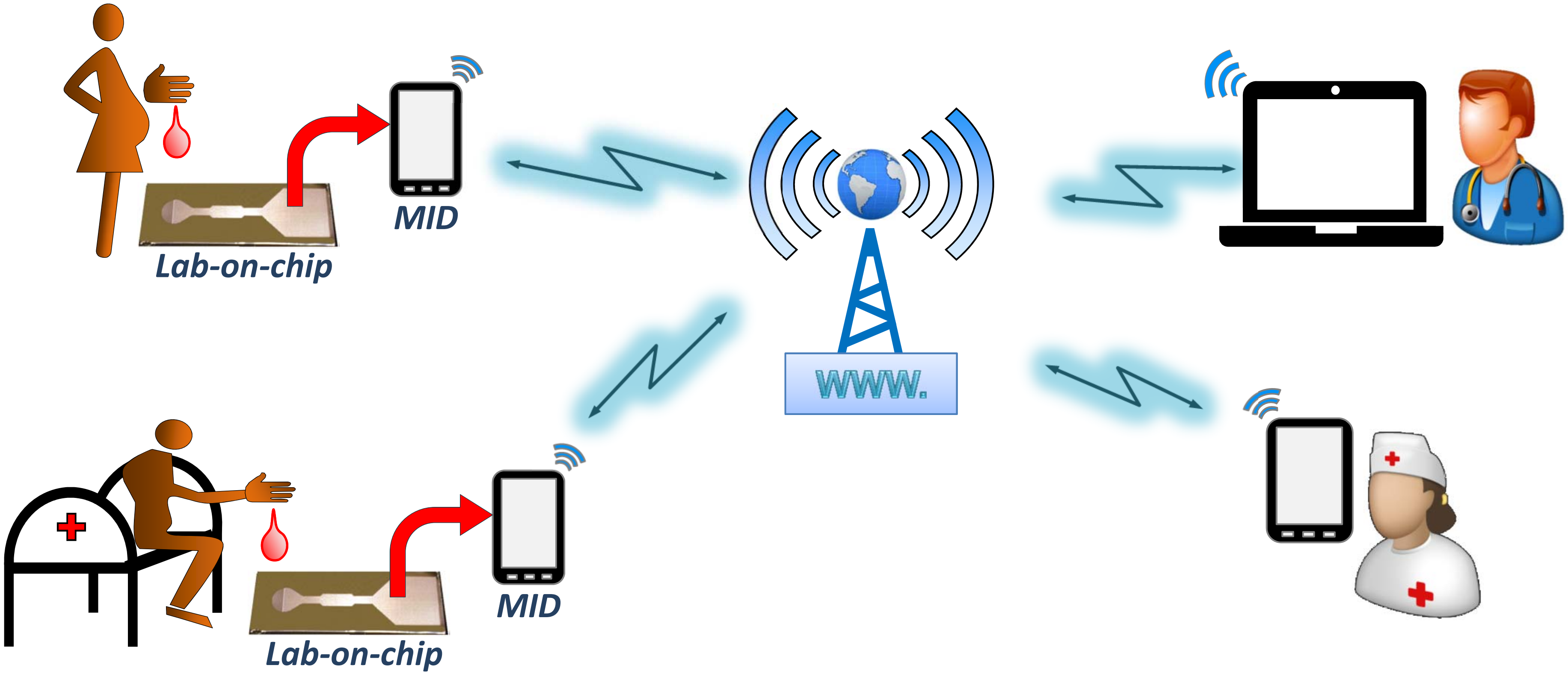
Outline

- Introduction
- Microchip layout
- Measurement principle
- Micromachining of capillary structures by excimer laser
- Microfabrication of the biochip by replication
- Experimental validation
- Conclusions

Introduction

MID-based smart homecare diagnostic network*



Inexpensive compact diagnostic tool for body fluid assays (≈*100€*)

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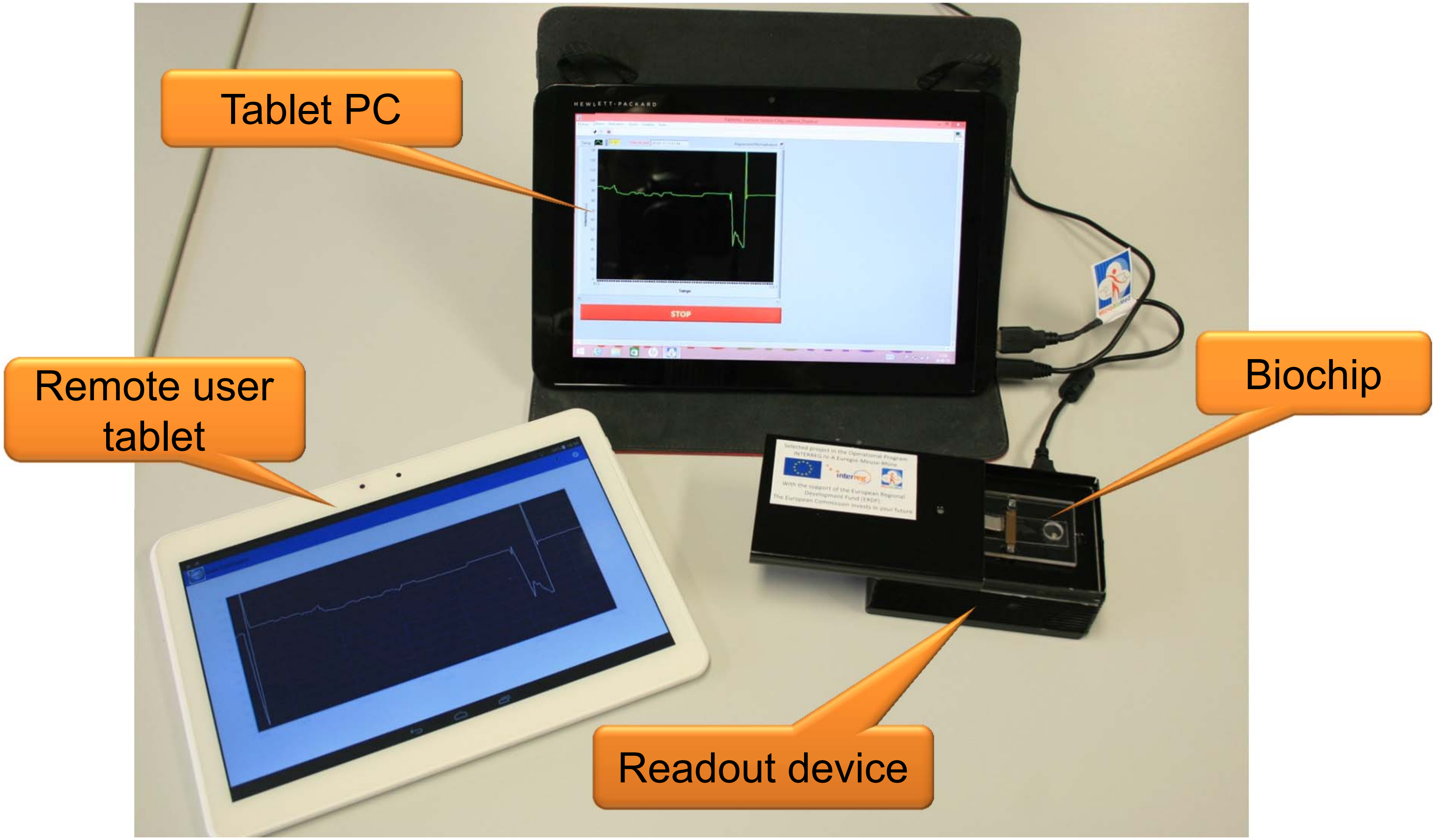
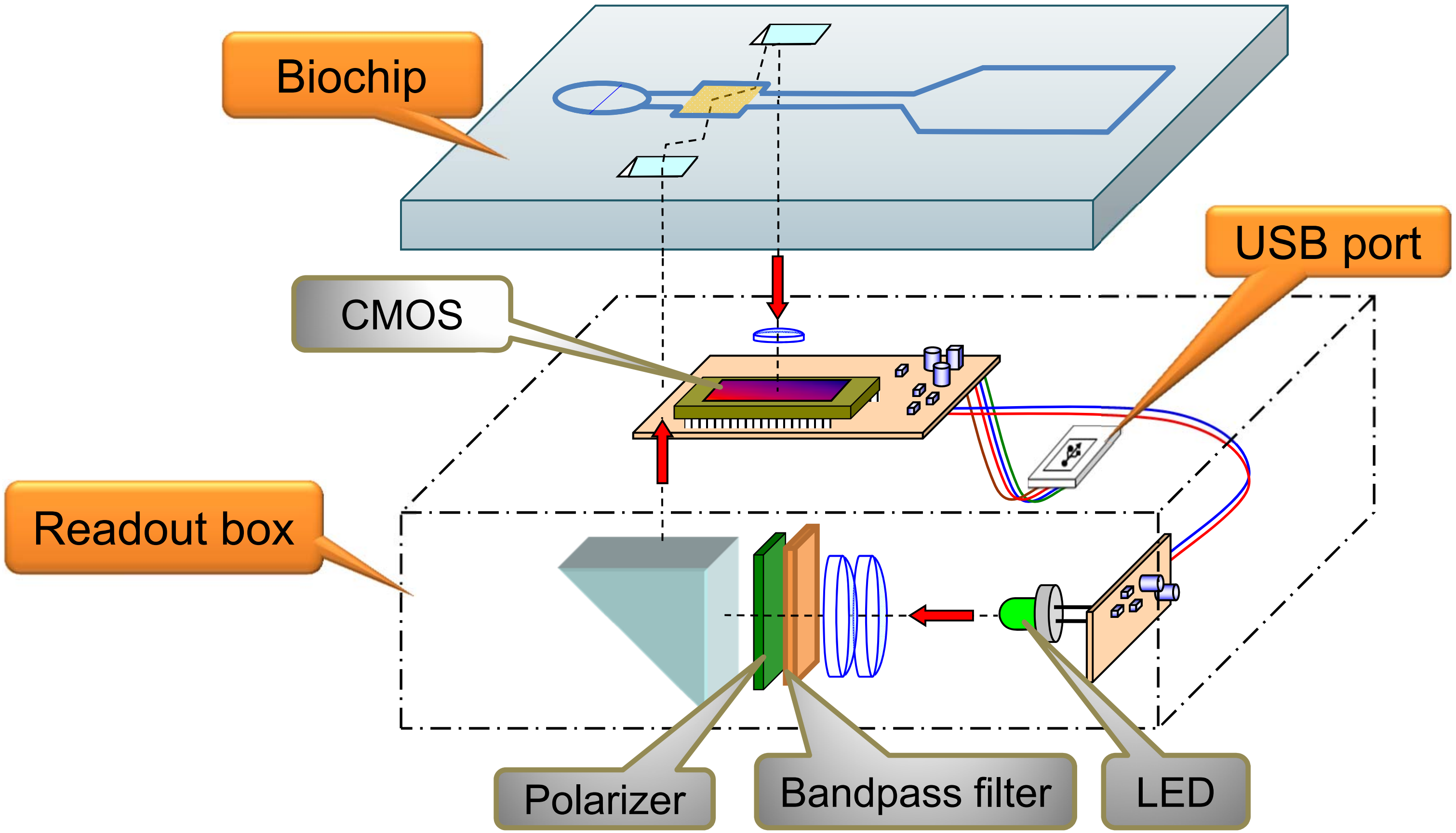
* *MID → "Mobile Internet Devices" (PC tablets, smart-phone, …)*

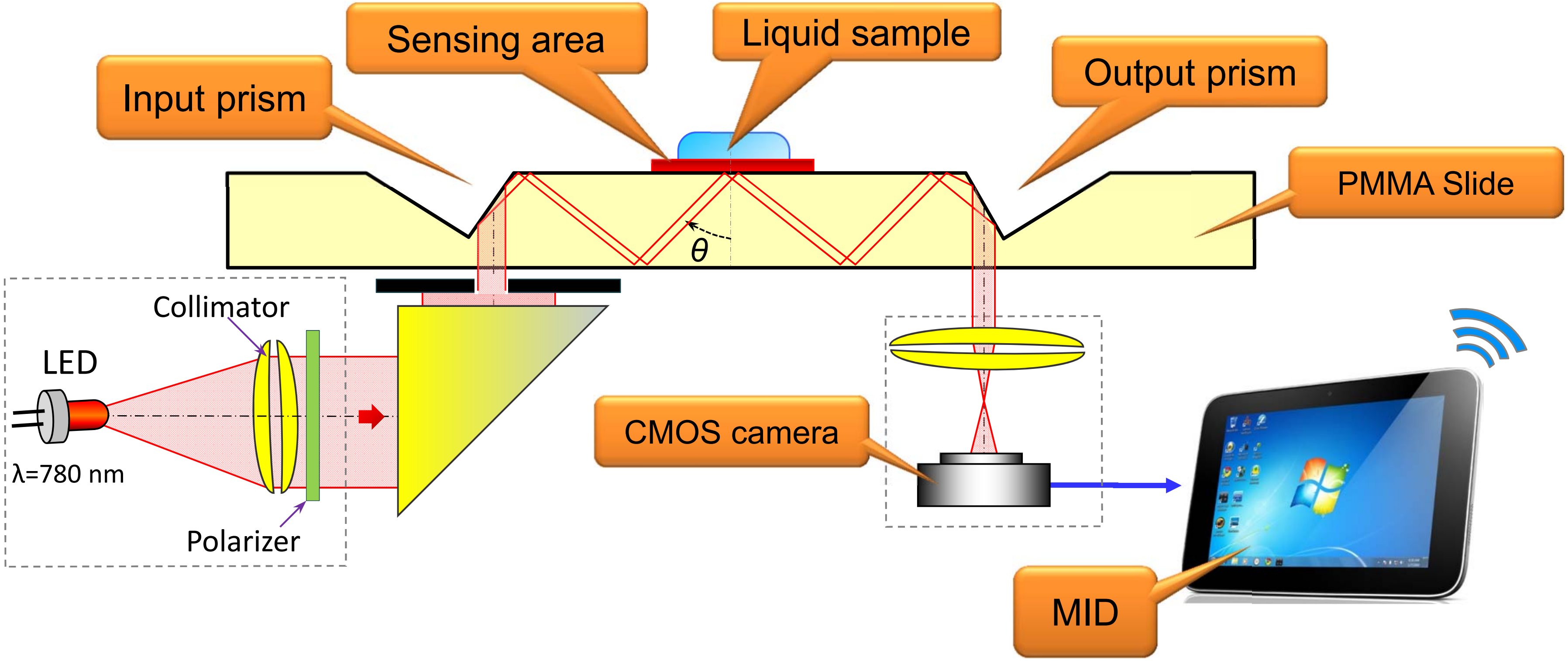
Low-cost homecare diagnostic tool
First proof-of-concept prototype



Diagnostic tool layout



1. Biochip optical readout principle



Sensing area structure based on SPR (**Surface Plasmon Resonance**)

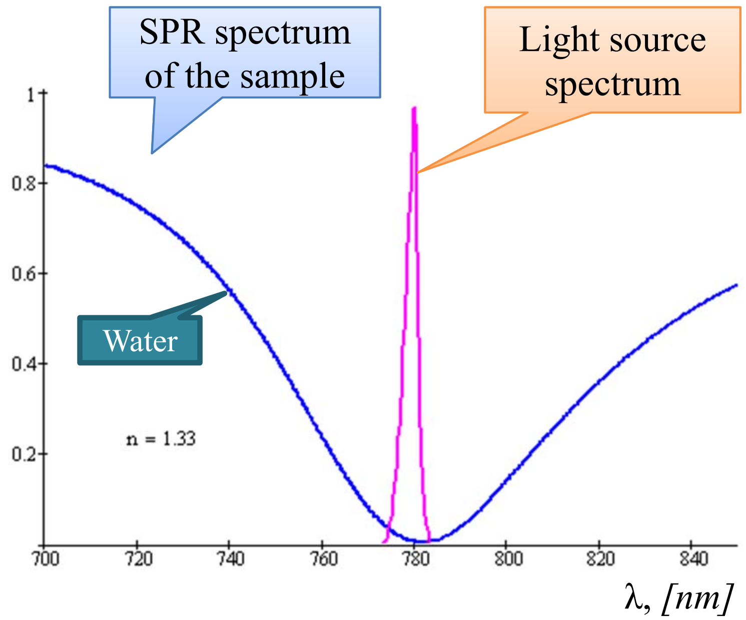
SPR detection format → Functionalized gold layer

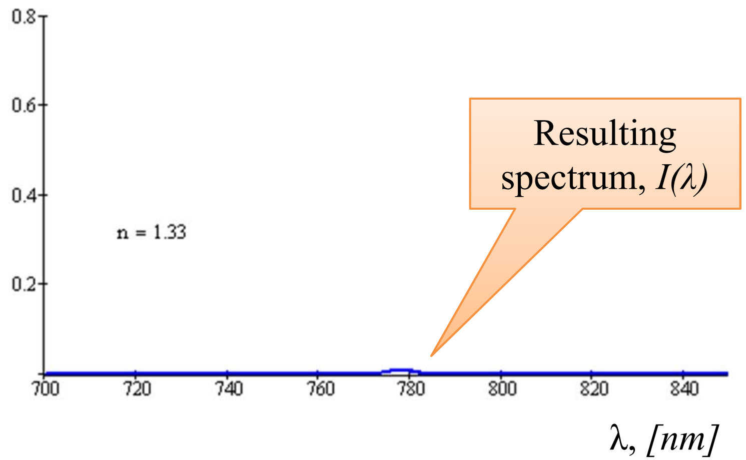
LSPR detection format → Functionalized gold nanoparticles

2. Biochip optical readout principle

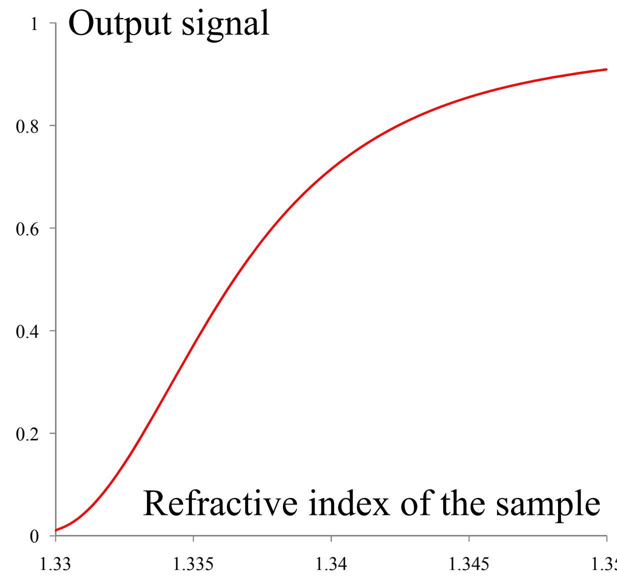
SPR = Surface Plasmon Resonance

Change of the refractive index of the liquid or analyte surface binding events shift the resonance dip in the reflectivity spectrum

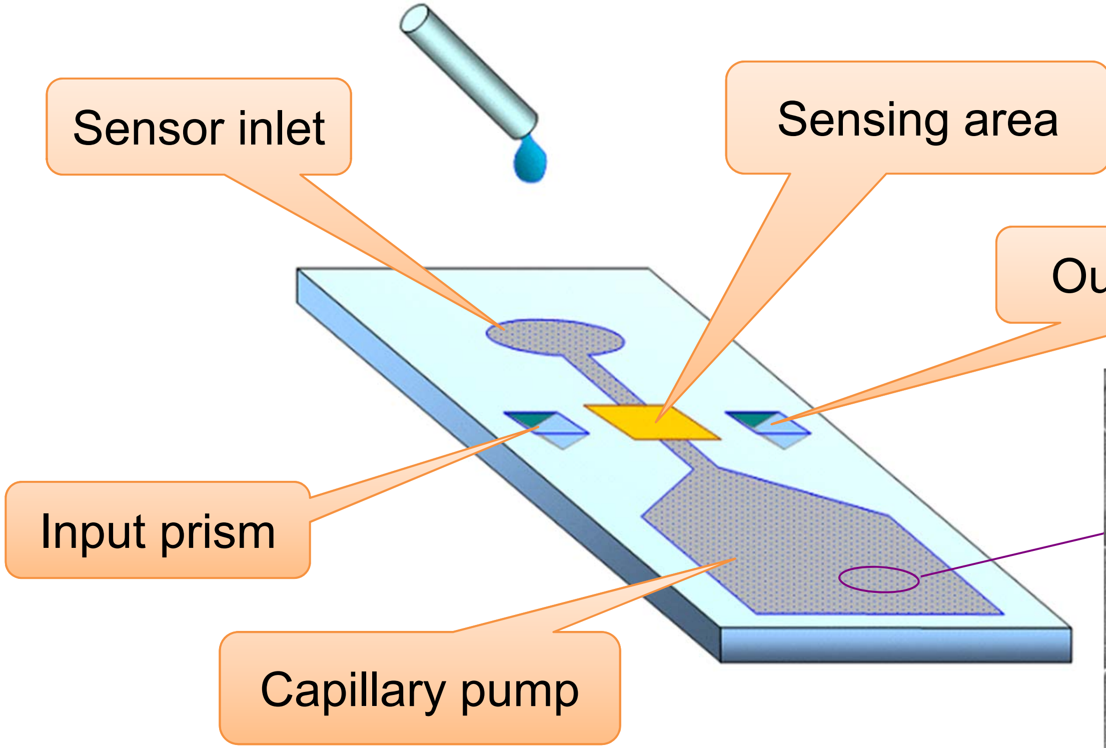


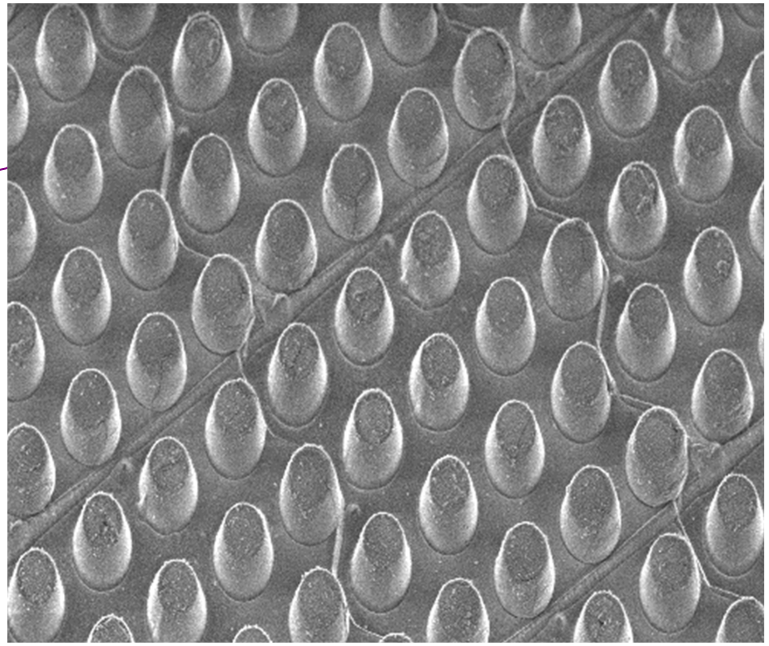


$$\int_{\lambda 1}^{\lambda 2} I(\lambda)\, d\lambda$$



Biochip design

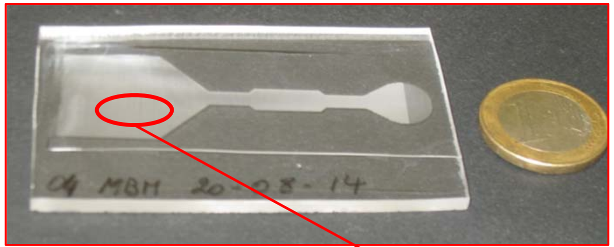


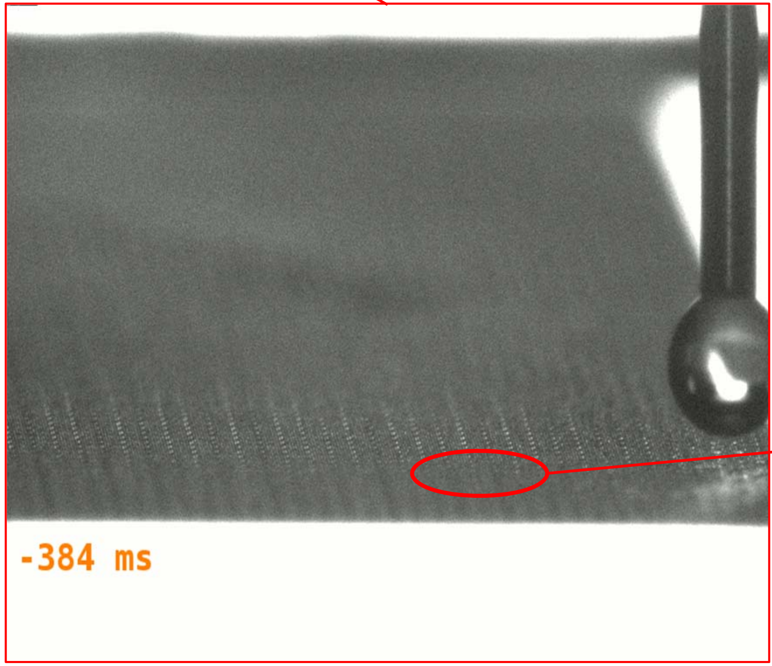


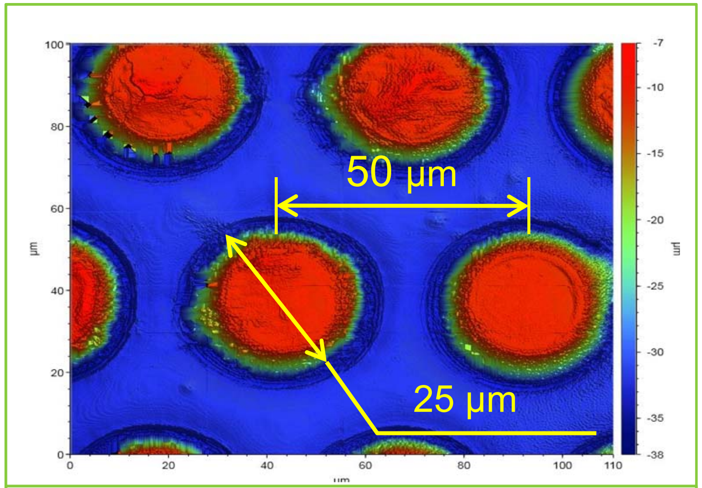
µ-pillars structure machined by excimer laser

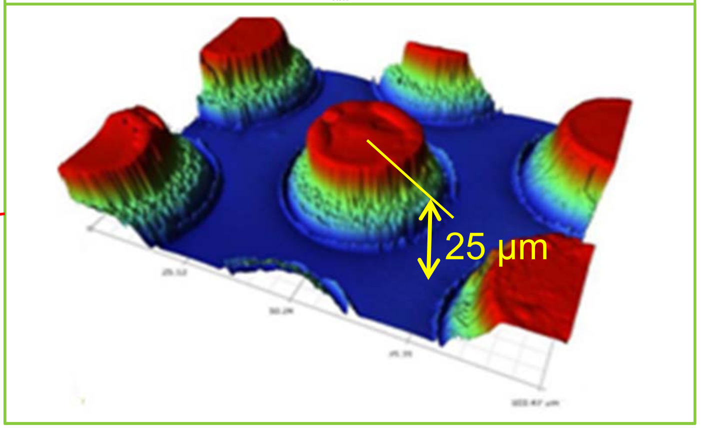
Microfluidic capillary structure

Machined by excimer laser





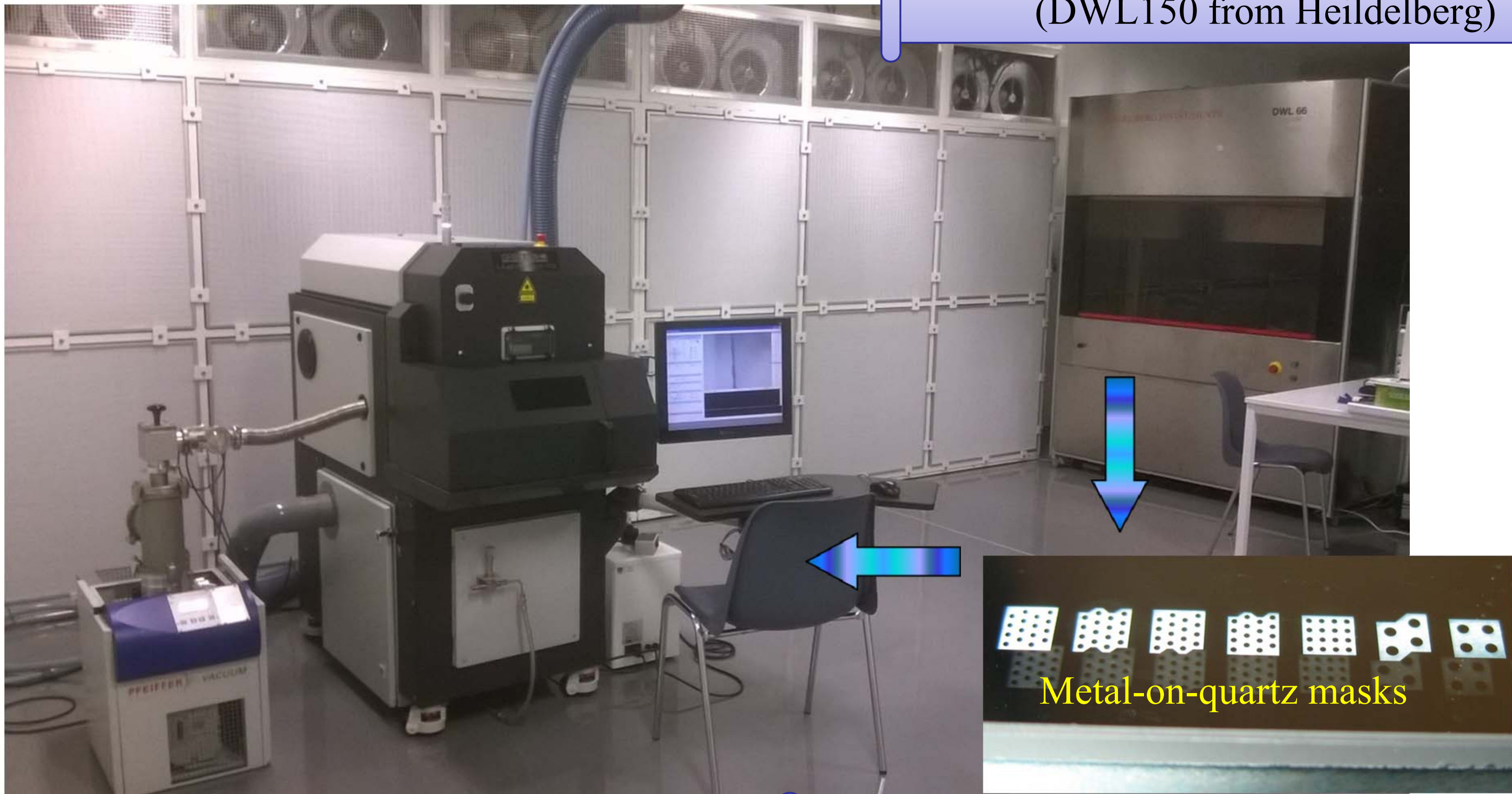




Measured by interferometric profilometry

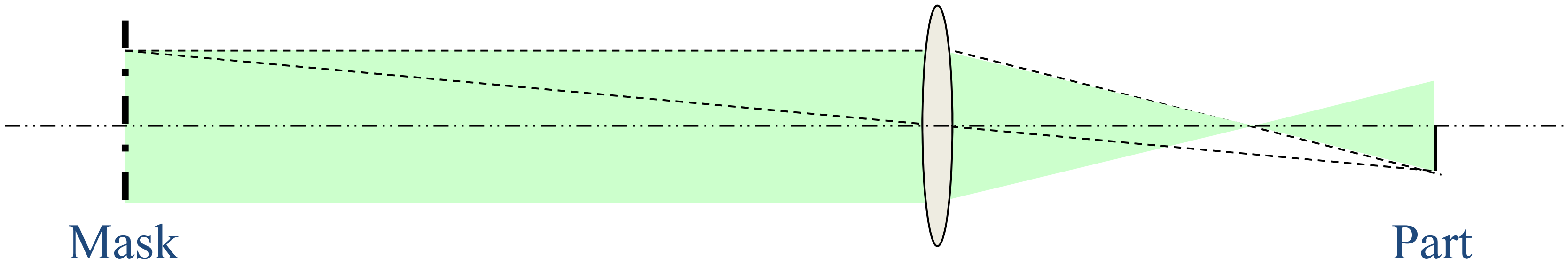
Implementation of the microfluidic capillary structure.

1. Direct laser writing of the mask
(DWL150 from Heildelberg)



2. Excimer laser micromachining system
Mask projection technique
(Optec, B)

Excimer laser micromachining system used at CSL:
mask projection technique

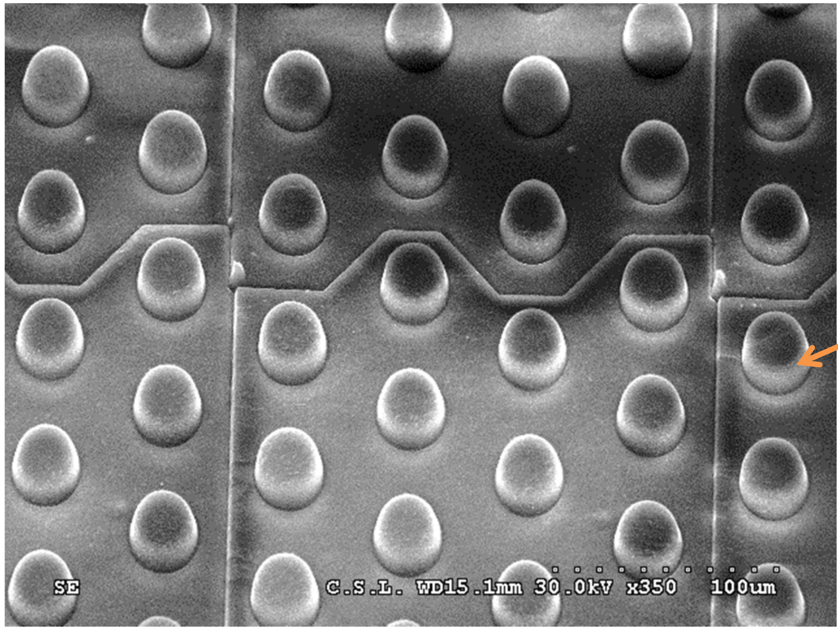


Demagnification : X10 or X16 (ratio between size on mask and on part)
Wavelength : 193 nm (ArF), pulse duration : 5 ns
Laser energy : 16 mJ/pulse, repetition rate: 1 - 300 Hz
Optical resolution : 1.5 µm
Beam size: 2.5x2.5 mm2 on mask
Masks: structured metallic sheet or metal on quartz
Materials: polymer, ceramic, glass, …

Implementation of the microfluidic capillary structure.

Excimer laser machining

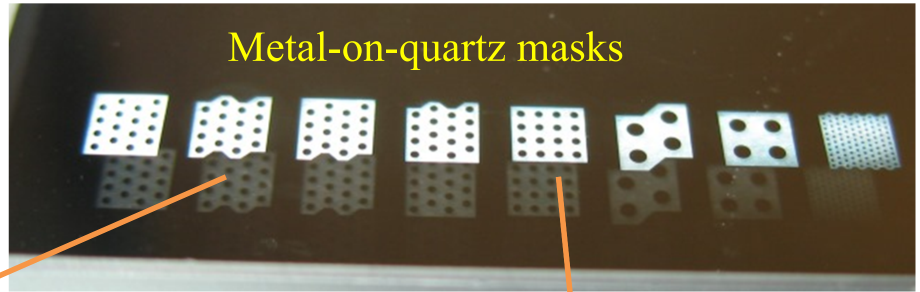
200 µm

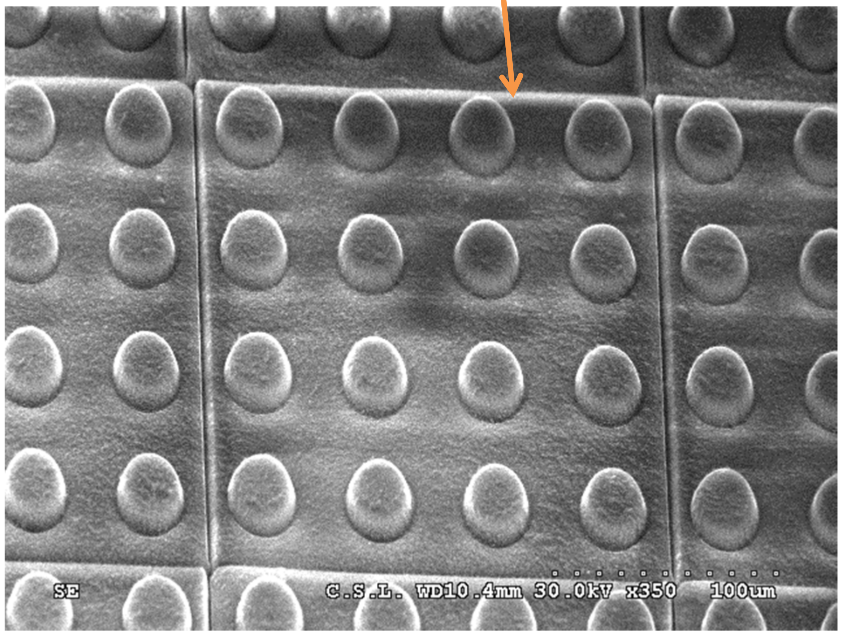


ϕ_{pillars} = 25 µm

Pillars machined in PMMA

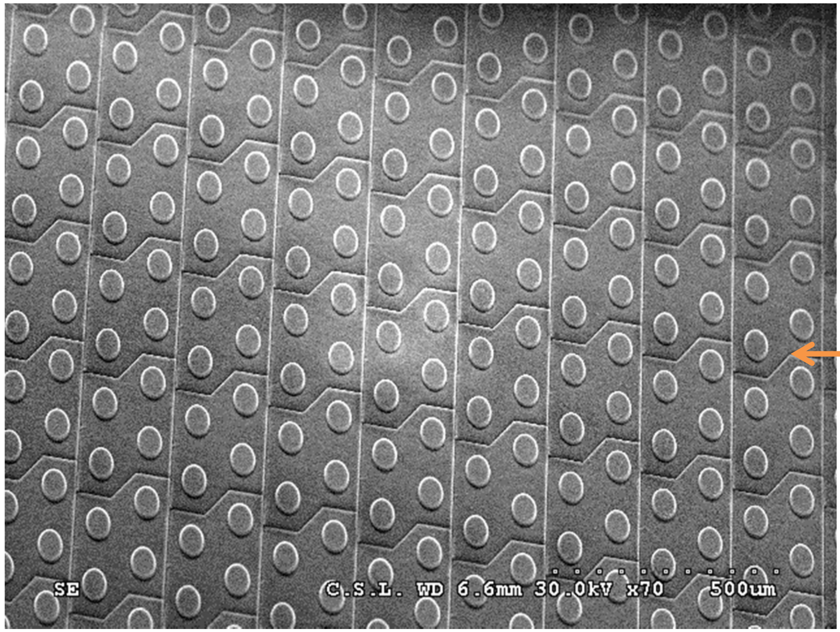
STEP & REPEAT PROCESS FROM BASIC PATTERN ON MASK
(~ 0.25 s for 1 pattern with 25 µm depth)

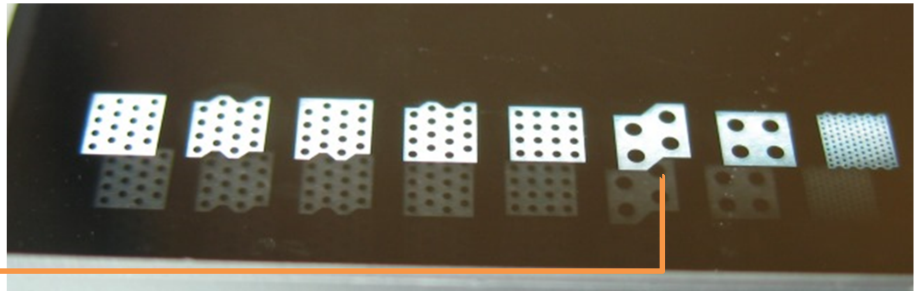




Implementation of the microfluidic capillary structure.

Excimer laser machining

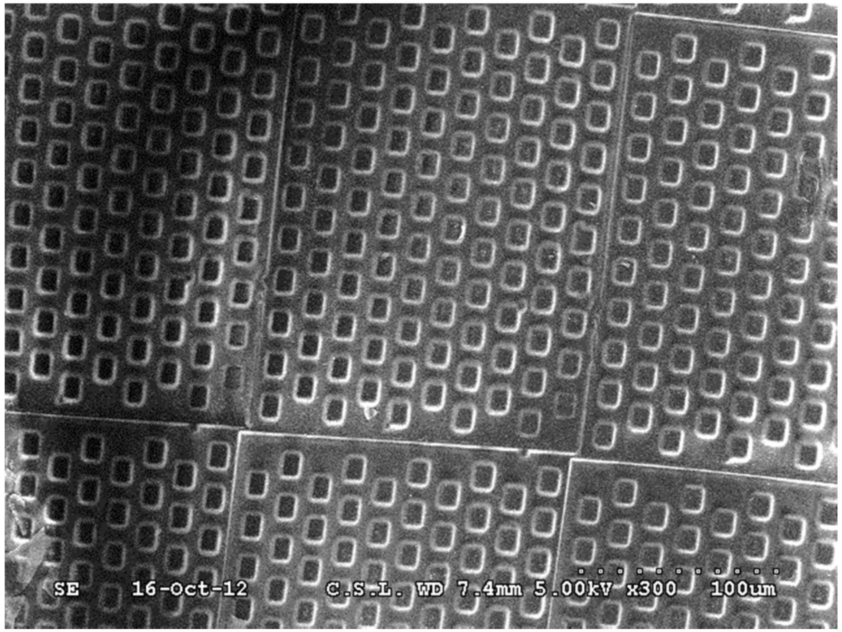




$\phi_{pillars} = 50\ \mu m$

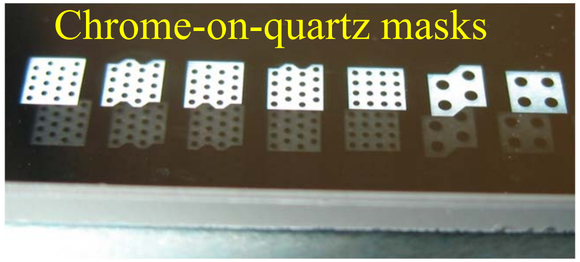
STEP & REPEAT PROCESS FROM BASIC PATTERN ON MASK

10 µm square pillars

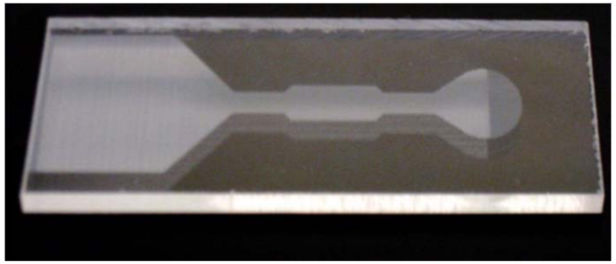


Implementation of the microfluidic capillary structure.

1. Direct laser writing of the mask for μ-pillars

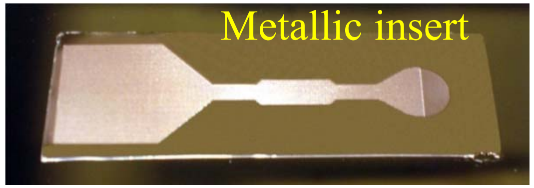


2. Excimer laser machining

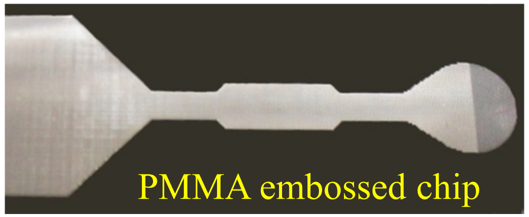


Original chip in PMMA

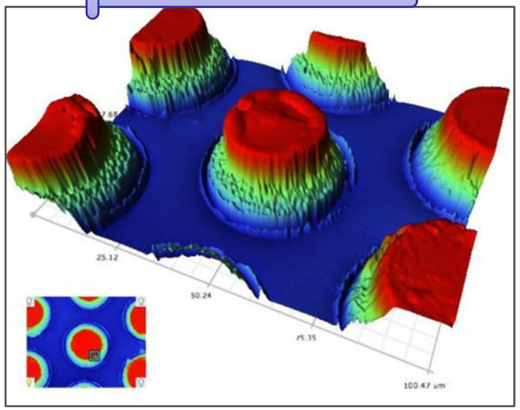
3. Replication Master generation



4.Hot embossing

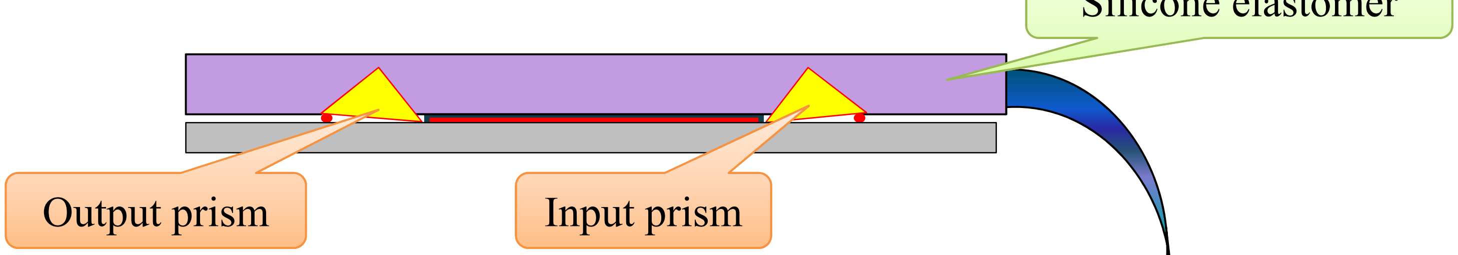


5. Metrology

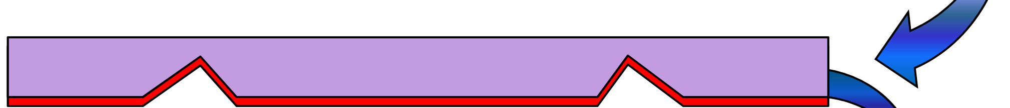


Step1: Nickel-mould template fabrication

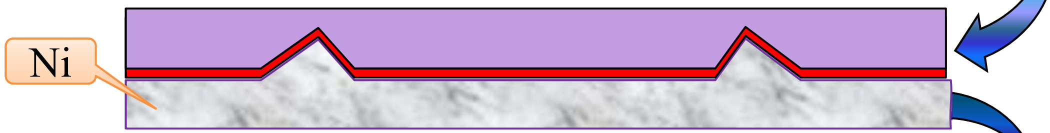
- Transfer of the commercial prisms into an imprint



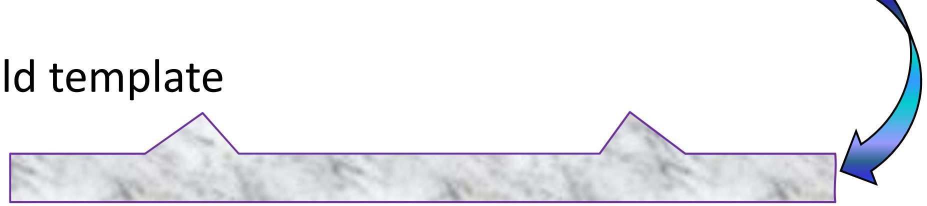
- Metal layer vacuum deposition



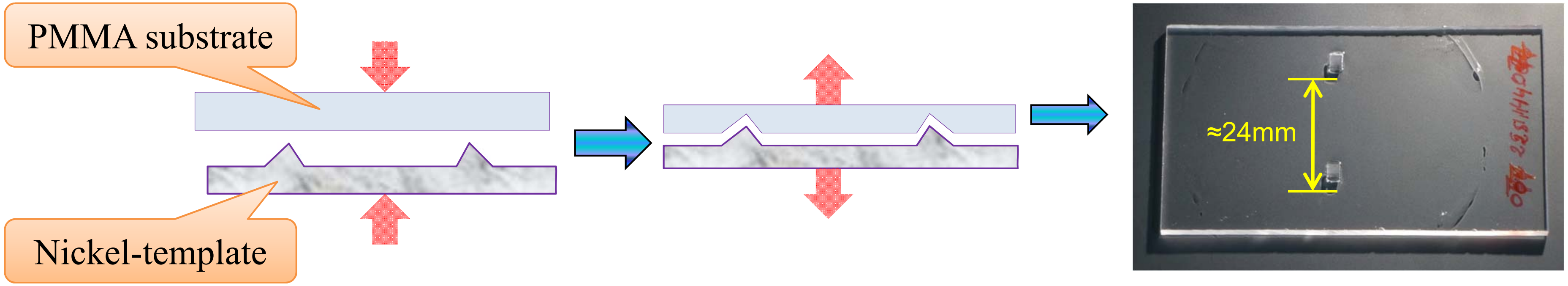
- Electroplating of Nickel



- Nickel-mould template

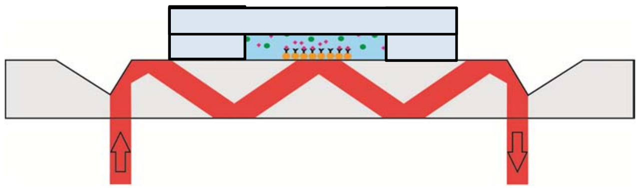


Step 2: Replication of the prism coupler by hot embossing

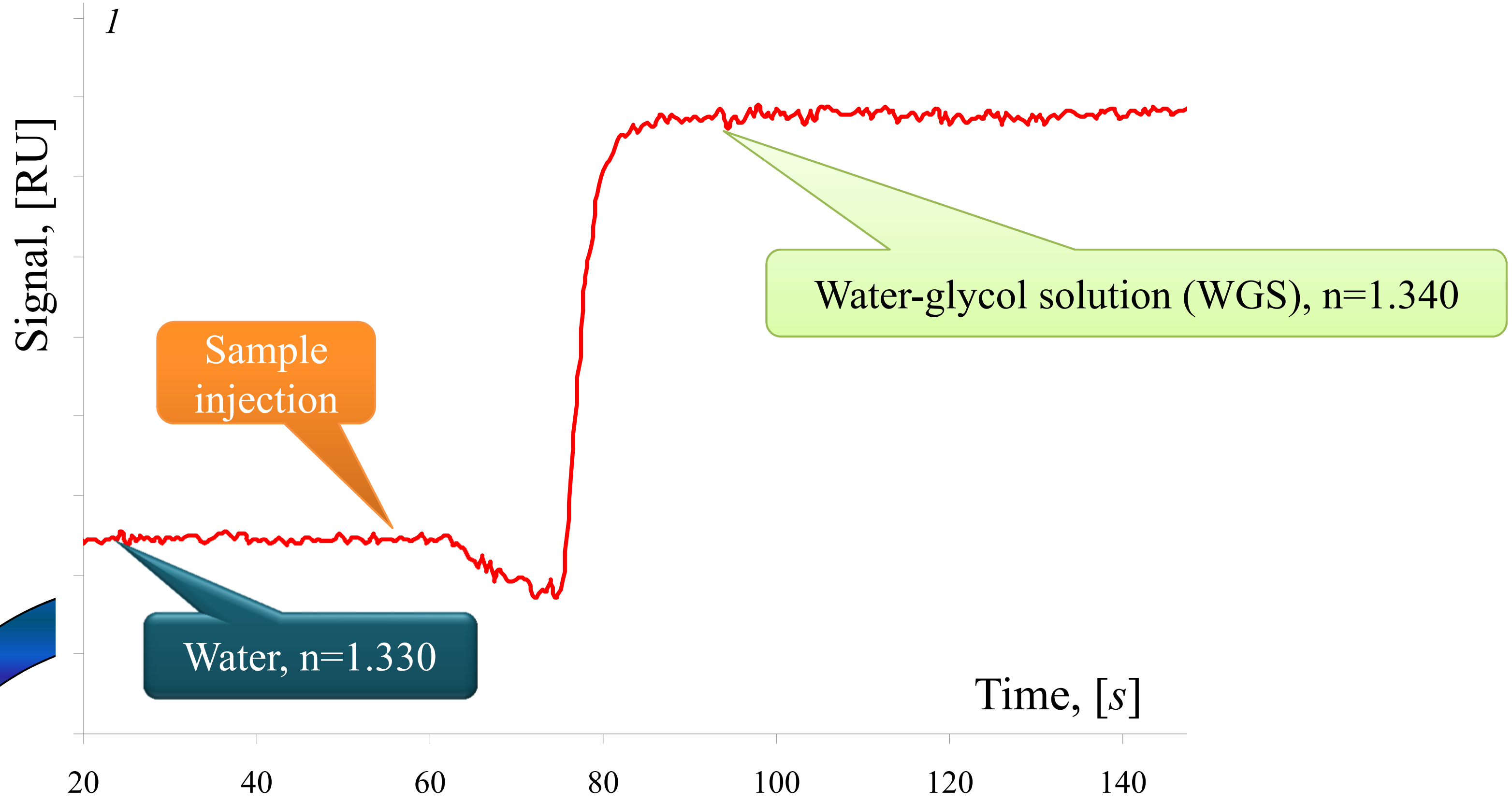


Step 3: Sensing area coating (Gold, 50nm) and functionalization

Step 4: Association of the biochip with a 0.5-mm thick PMMA cover slab



Experimental validation: SPR sensogram



Refractive index resolution, $\delta n \approx 1.0 \cdot 10^{-4}$ [RIU]

Concept goals and key features

Biochip concept

- ✓ **Integrated architecture**
- ✓ **Low cost (*fabrication by replication*)**
- ✓ **Easy use** → Optical coupling without matching liquid; Passive capillary pumping (without an external pump)

Laser micro-machining of capillary structures

- ✓ **Excimer mask projection technique is efficient for 10 – 50 µm pillars structures**
- ✓ **Flexible technique (different design can be quickly performed and tested) , but requires a dedicated mask**

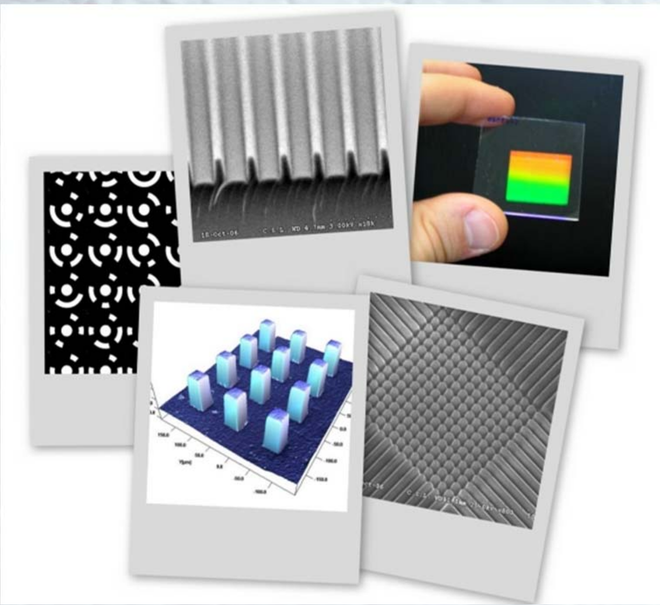
Outlook for CSL

- ✓ **Design and prototypage of microchip integrating optics, SPR and microfluidics**

ACKNOWLEDGEMENTS

"MICROBIOMED" project from the INTERREG IV-A Euregio Meuse-Rhine program
with the financial support of the European Union and the Walloon region

http://www.microbiomed.ulg.ac.be



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