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Photoacoustic technique for the characterization of plasmonic properties of 2D periodic arrays of gold nanoholes

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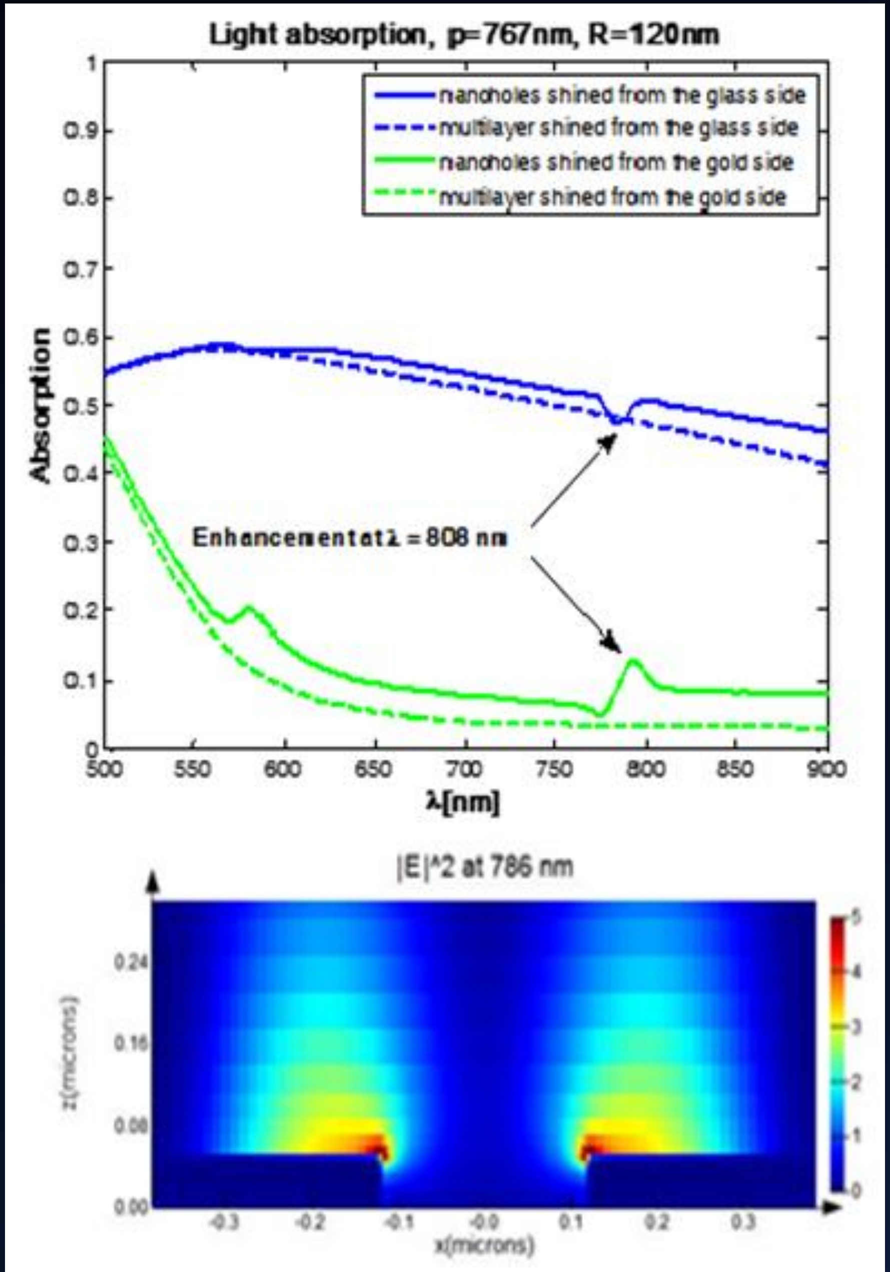
Overview

1. Motivation
2. About the structure
3. Photo-acoustic technique
4. Results
5. Conclusion



1. Motivation

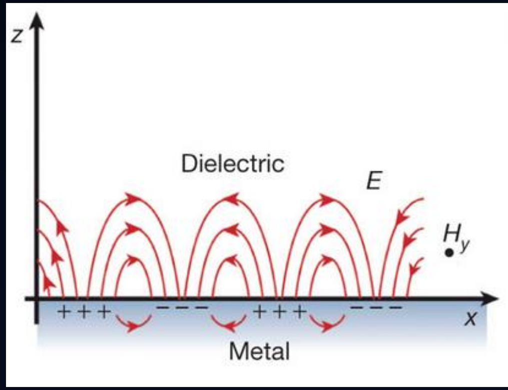
- Surface Plasmon Polaritons (SPPs) = EM surface waves existing at the metal-dielectric interface
- Excitation: an incoming EM field must couple to the oscillation of electron plasma in metal

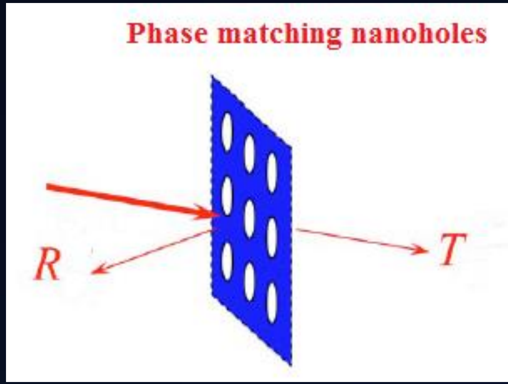
- An appropriate grating matches the wave-vectors
- Bloch Wave SPPs = the coherent superposition of propagating SPPs.

✓ High field localization in subwavelength regions

✓ Transmission enhancement

✓ High performance optical components circuits, biosensors, SERS…





$$\lambda_{SPP} = \frac{p}{\sqrt{n_x^2 + n_y^2}} \sqrt{\frac{\varepsilon_m(\lambda)\varepsilon_d(\lambda)}{\varepsilon_m(\lambda)+\varepsilon_d(\lambda)}}$$

2. About the structure

- Electron Beam Litography Au/Cr 50/10

Au thickness: 50 nm
Cr thickness: 5 nm
Glass substrate

- 2 types:

The *big* one – period ~ 1280 nm, diameter ~ 390 nm
The *small* one – period ~ 770 nm, diameter ~ 240 nm

- Rectangular array:

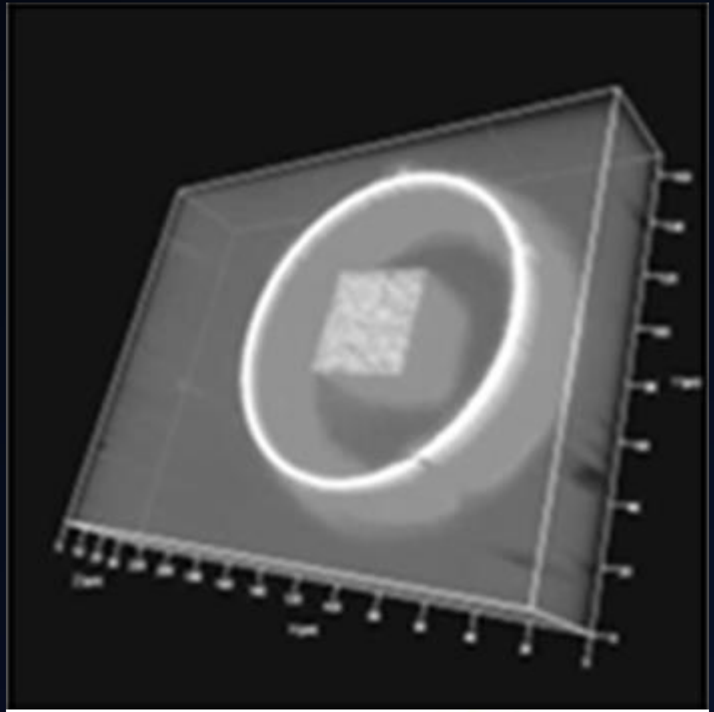
~ 35 µm for the big, ~ 12 µm for the small

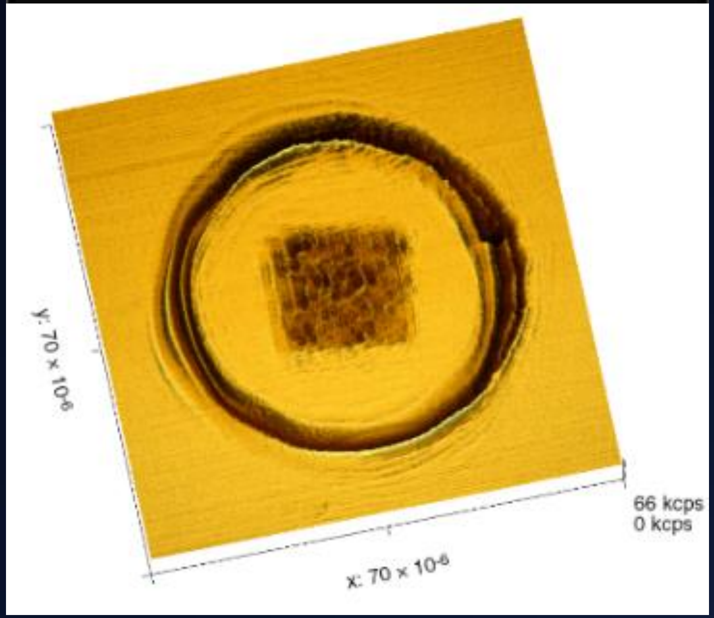
- Scattering ring:

~ 24 µm for the big, ~ 50 µm for the small

- Characterization:

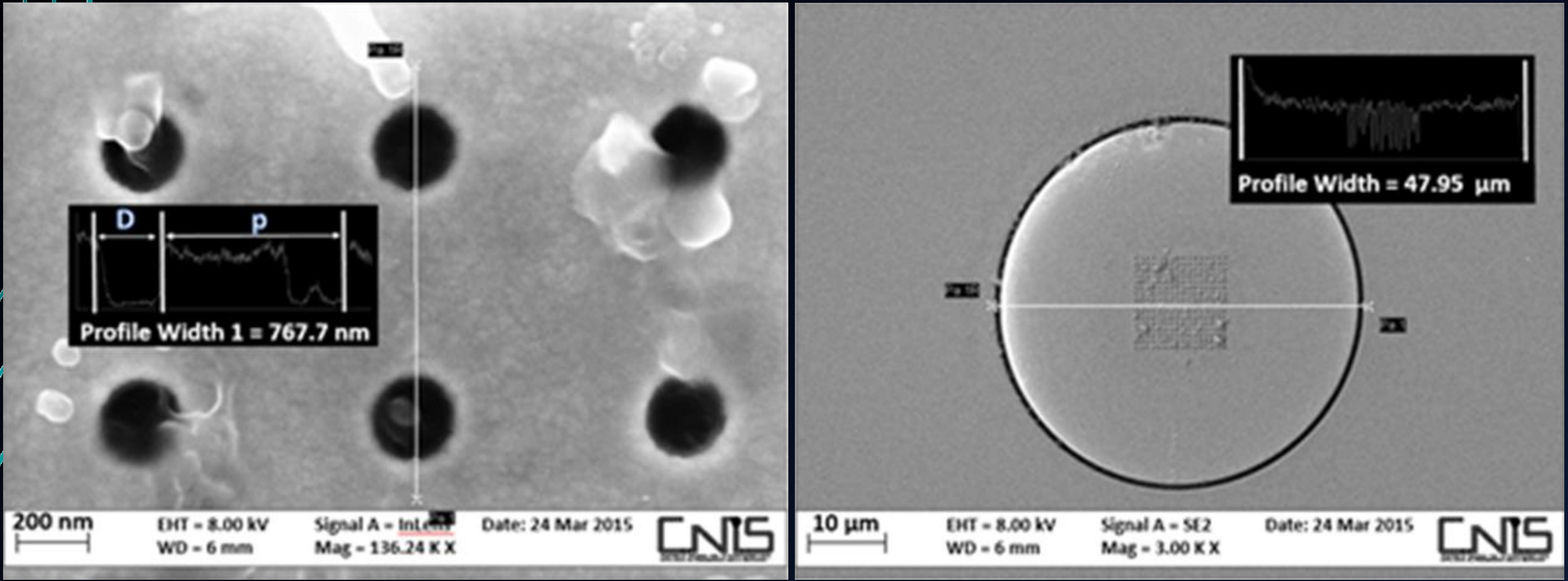
AFM microscopy, SEM microscopy,
Energy dispersive X-ray microscopy





2. About the structure

The small



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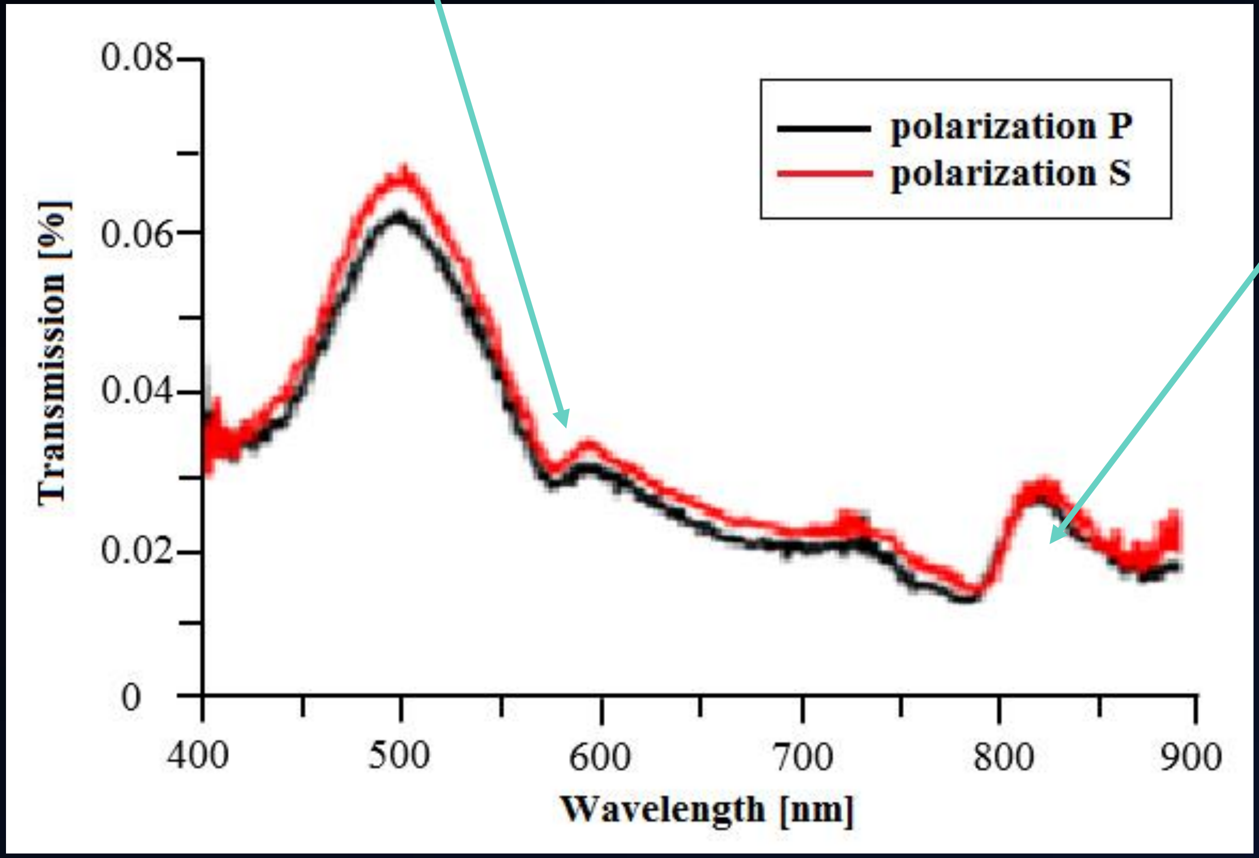
2. About the structure

Fano-like resonance shapes

BWSPP air-Au (1,1)

BWSPP air-Au (1,0)



$$\lambda_{SPP} = \frac{p}{\sqrt{n_x^2 + n_y^2}} \sqrt{\frac{\varepsilon_m(\lambda)\varepsilon_d(\lambda)}{\varepsilon_m(\lambda)+\varepsilon_d(\lambda)}}$$

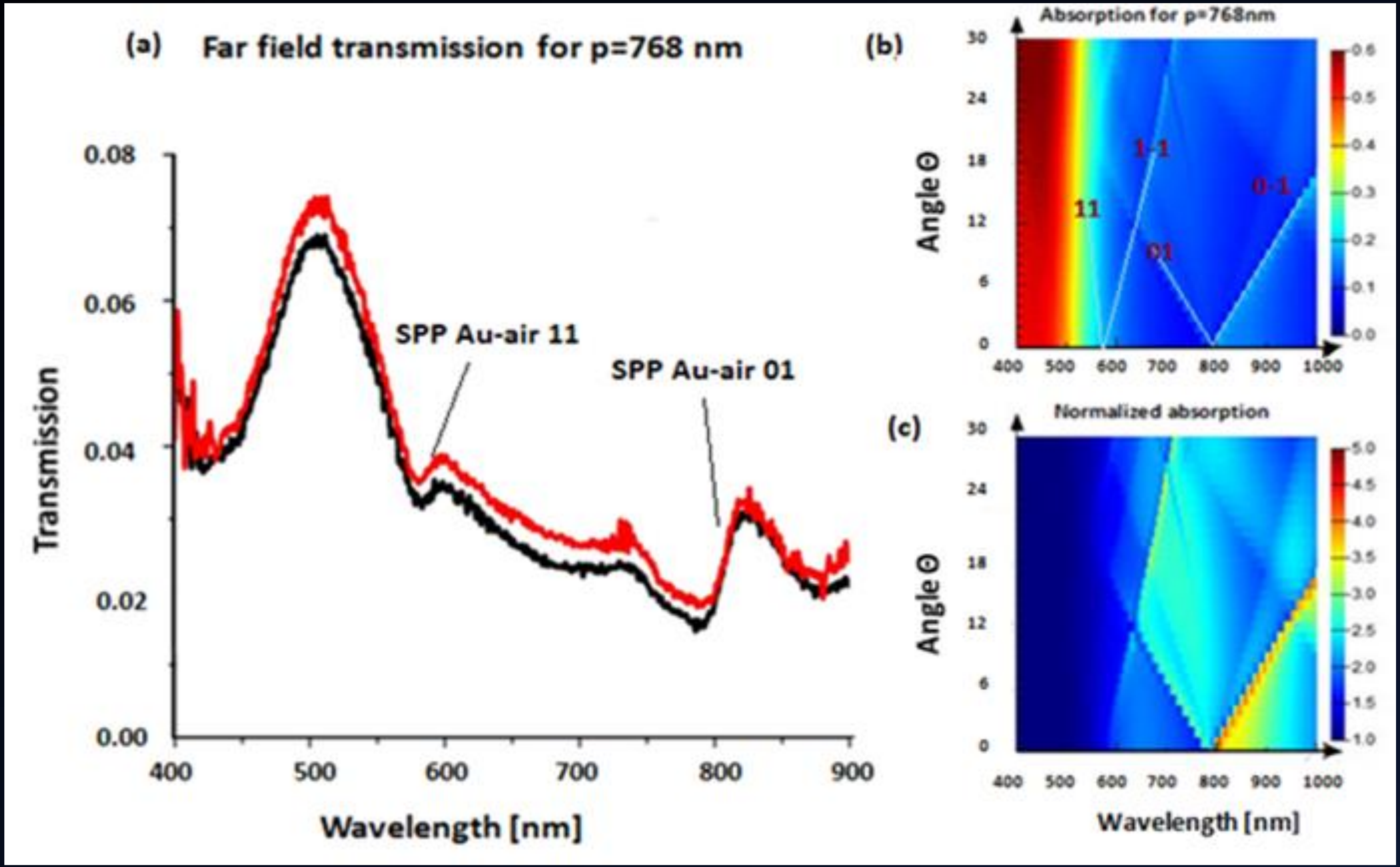
$$\lambda_{air\_Au(1,0)} \approx 786\ nm$$

- Red shifts of 4%

additional radiation damping (2 Hamiltonian approach)

- No polarization dependence

2. About the structure



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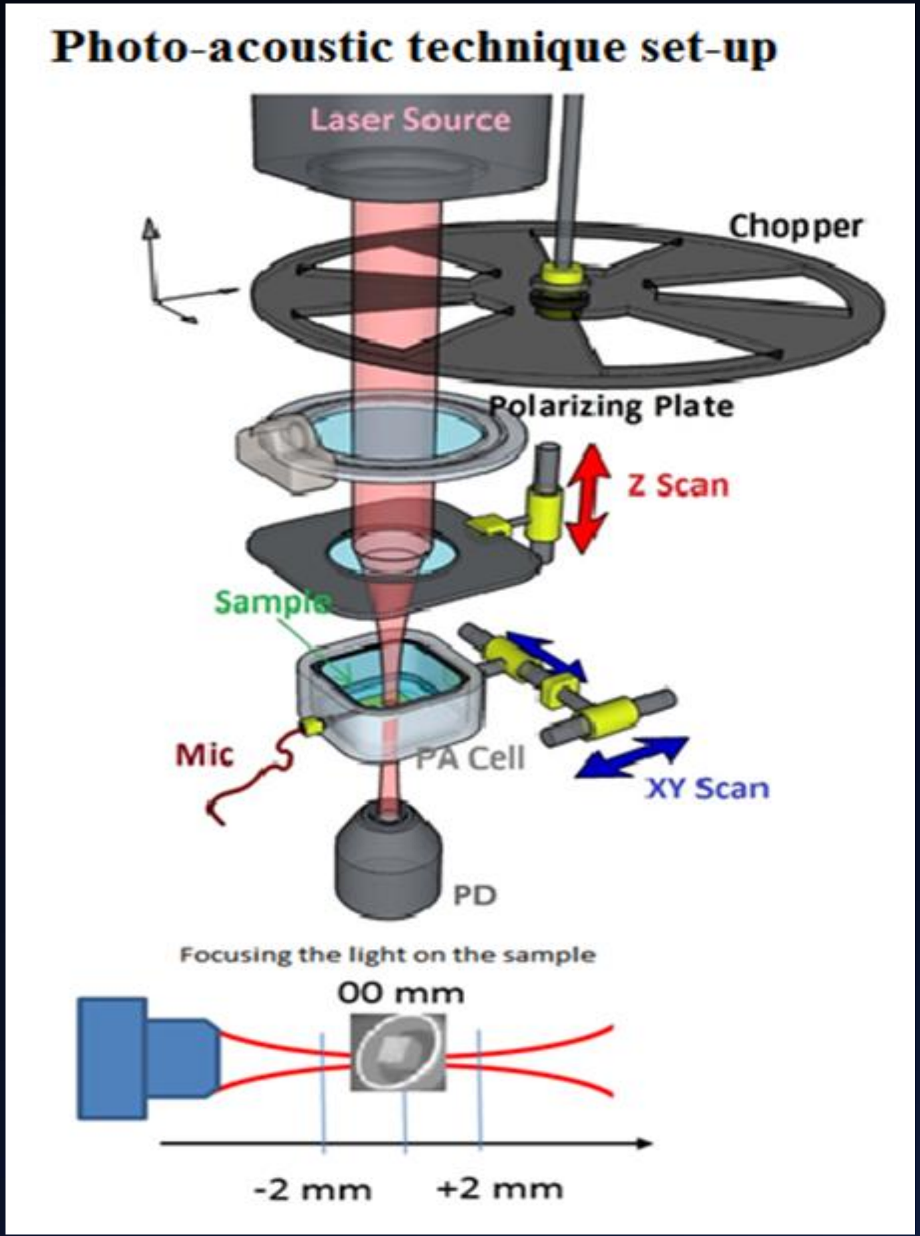
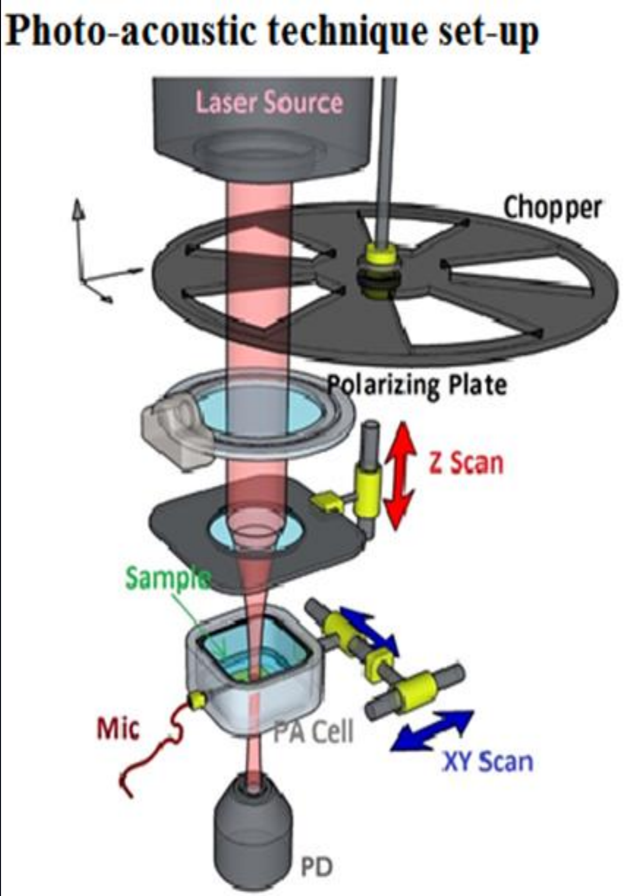
3. Photo-Acoustic technique

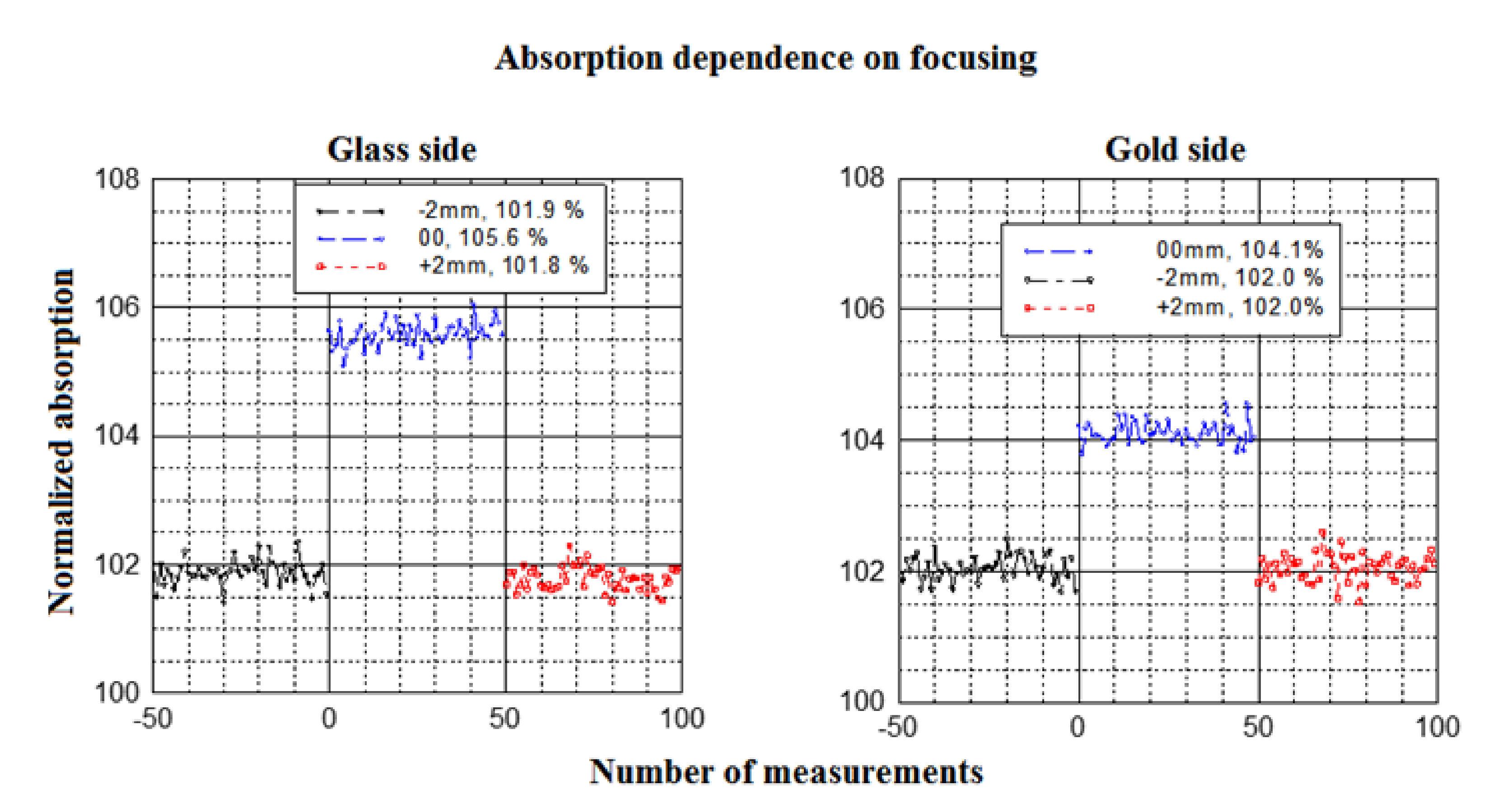
- Absorption measurement:
- Absorption → heat
- Heat → acoustic signal
- Acoustic signal → pressure change
- Pressure variations → electrical signal (close and sensitive microphone)
- Input light: a diode laser at 808 nm
- Shining of sample from both sides
- Focusing on a different spatial positions: ±2mm and 0mm
- Mechanical chopper at 25 Hz

✓ Different focusing points change the periodical part contribution to the overall absorption
✓ Normalized to the multilayer without holes



3. Photo-Acoustic technique





- ✓ 808 nm is close to BWSPP air-Au
- ✓ The absorption at focus is 4-10% higher than out of focus
- ✓ A great agreement with the simulation results!

✓ Very stable and sensitive method independent on scattering

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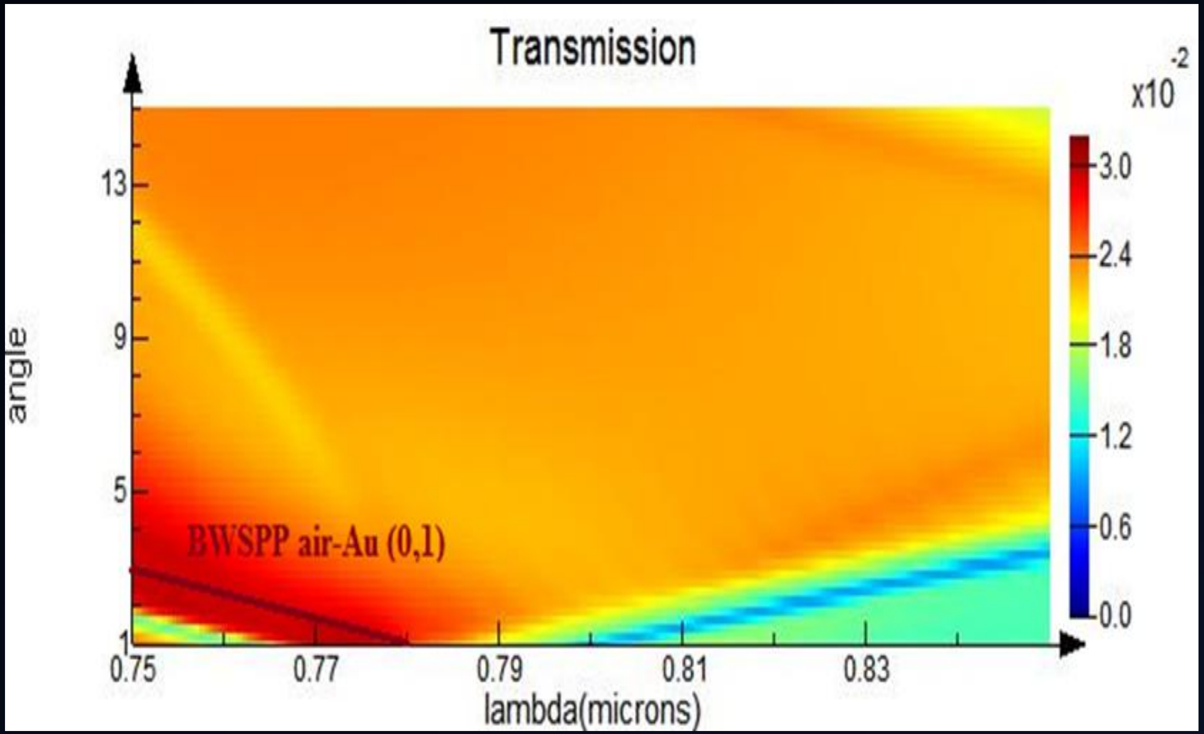
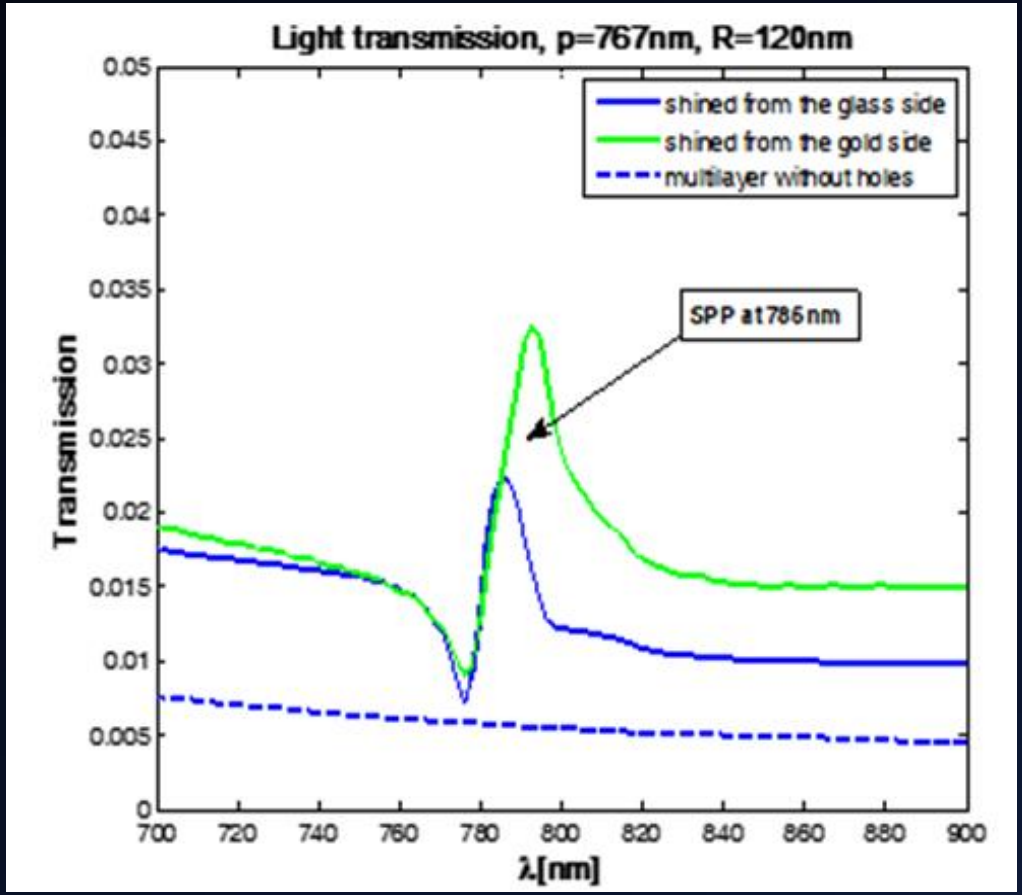
3. Photo-Acoustic technique

- FDTD Lumerical
- 400-1000 nm for the small
- 700-1500 nm for the big

Simulations

The small - transmission





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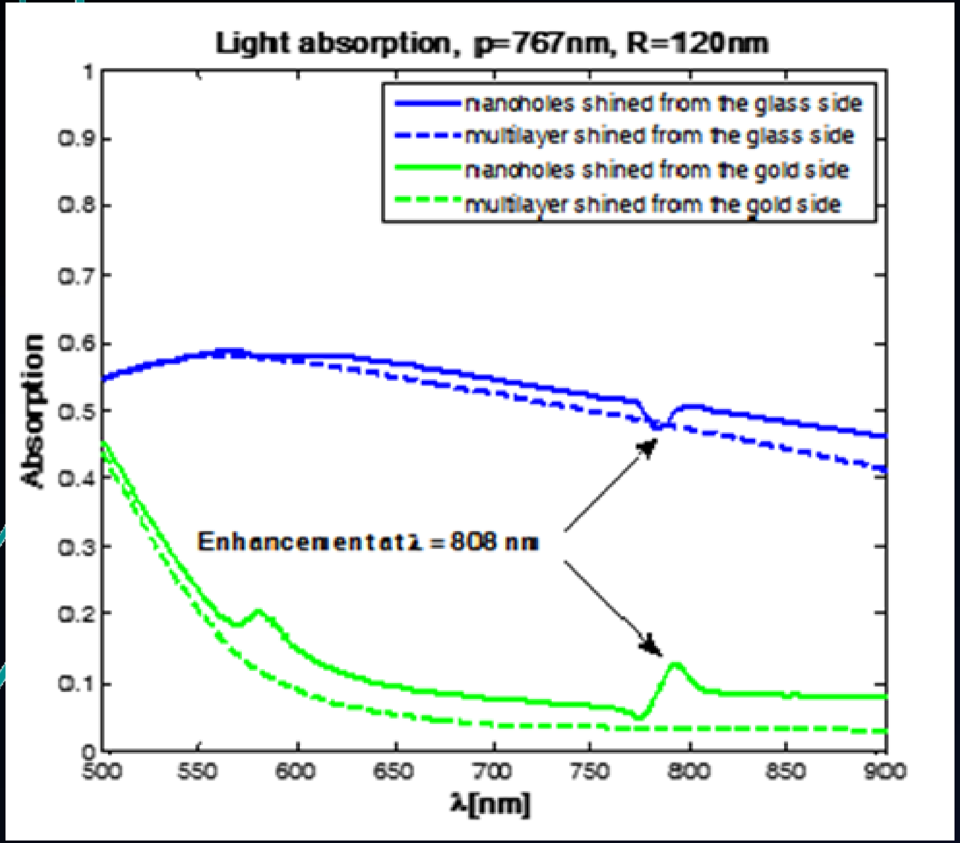
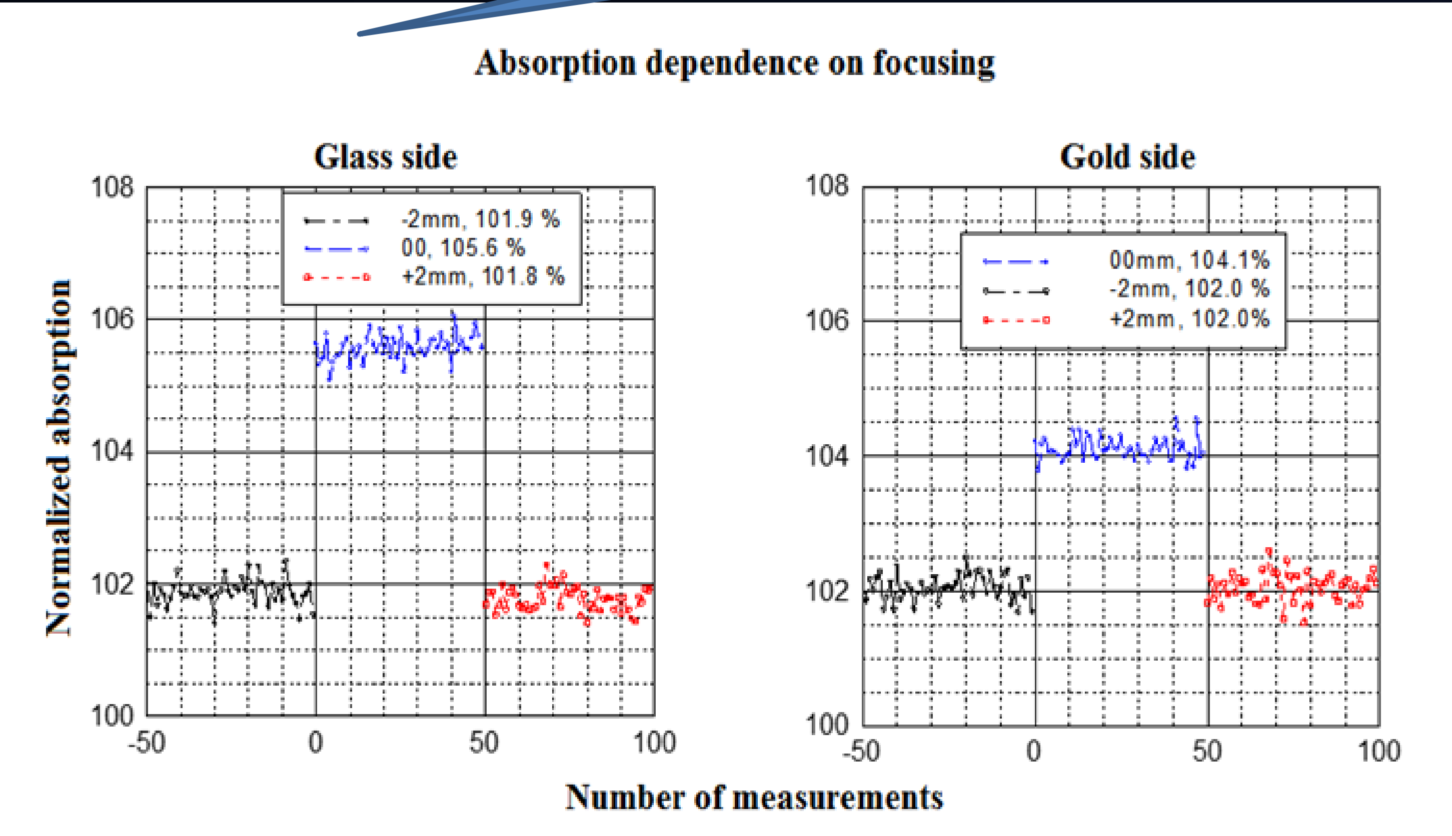
3. Photo-Acoustic technique

The small - absorption

Simulations



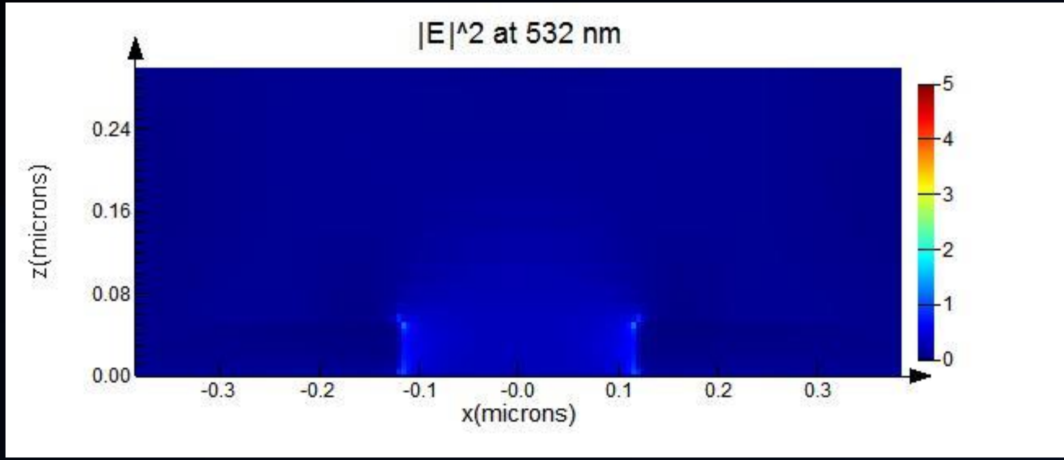


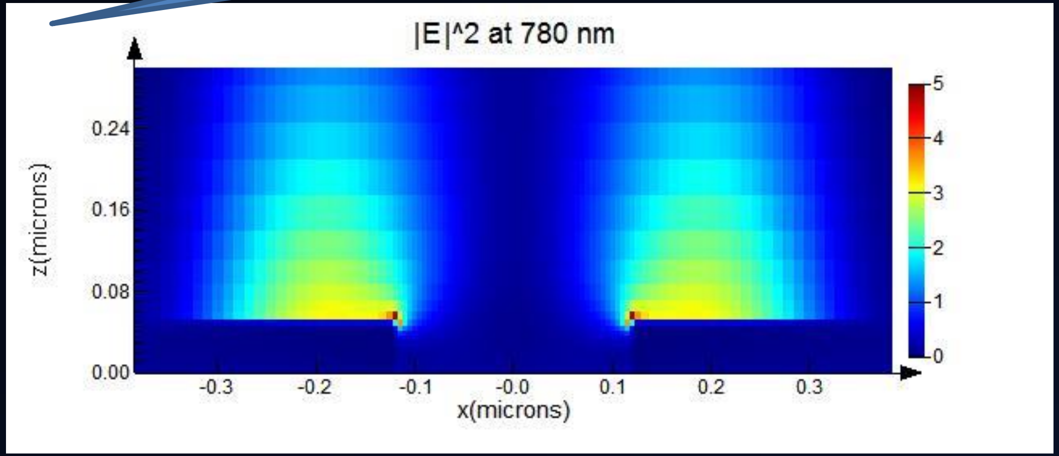
- ✓ The absorption at BW-SPP wavelength is 4-10% higher normalized to the structure without holes

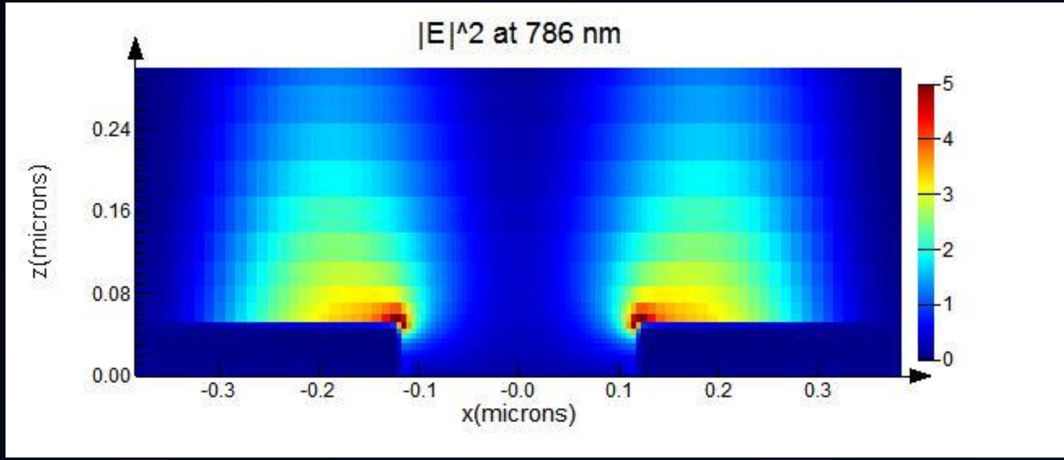
3. Photo-Acoustic technique

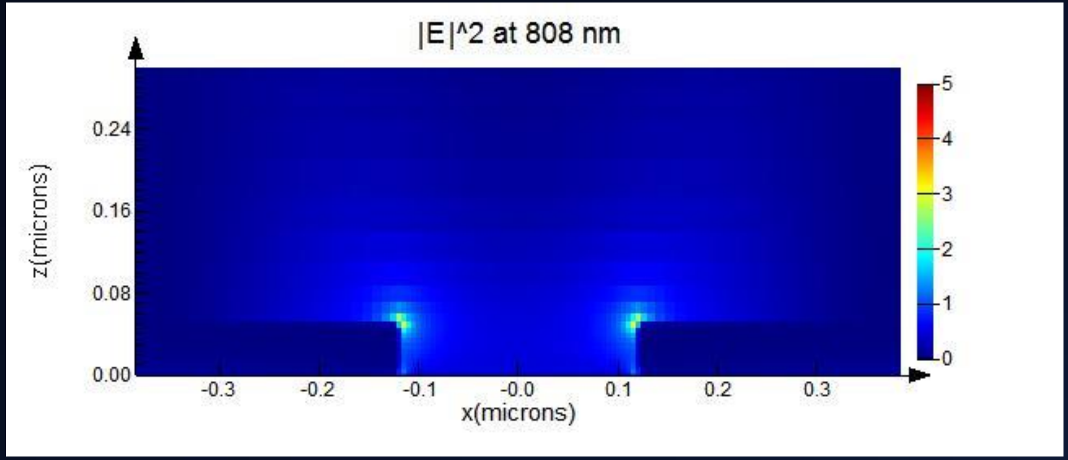
The small – electrical field enhancement

Simulations









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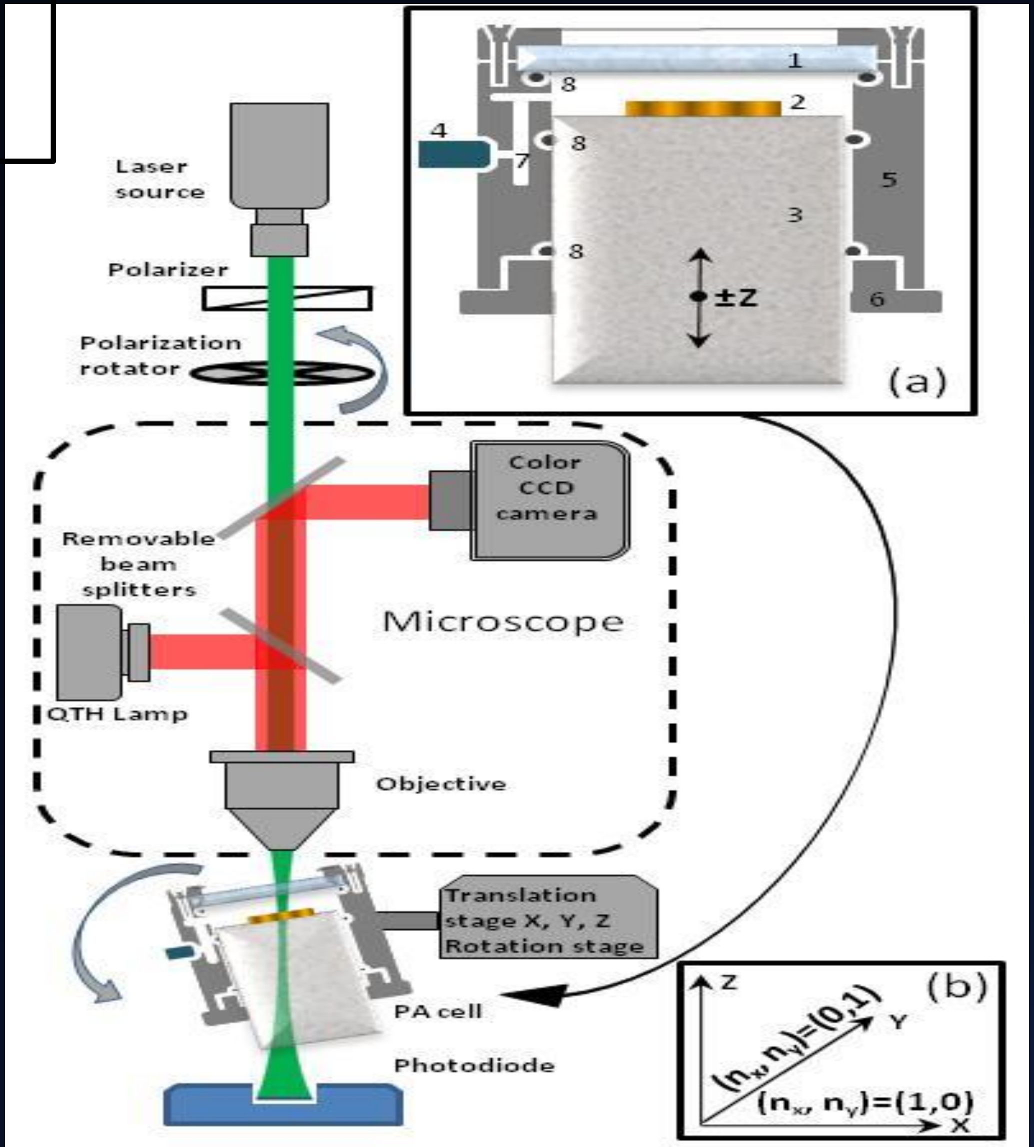
4. Results

✓ Improvements: angle and polarization spatial scan

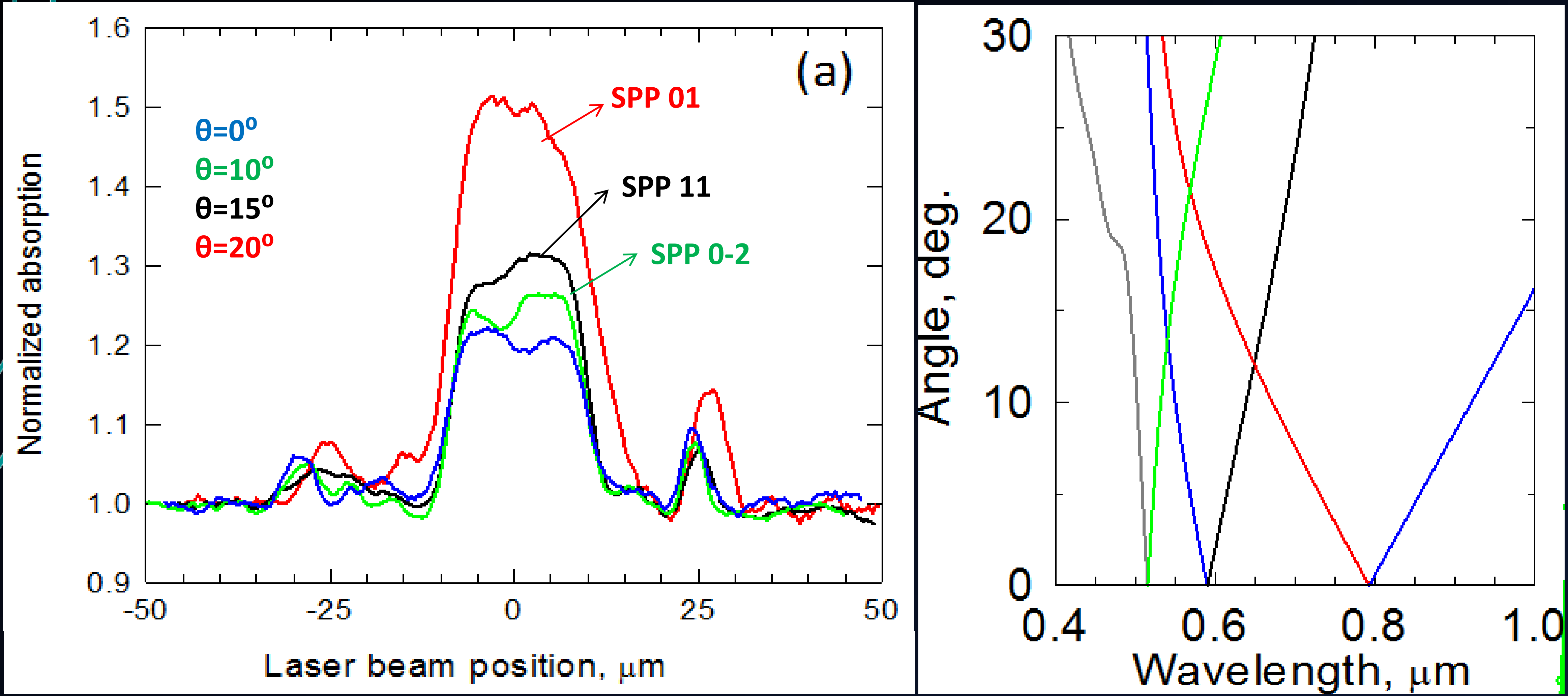
$$\frac{2\pi}{\lambda}\sqrt{\frac{\varepsilon_m(\lambda)\varepsilon_d(\lambda)}{\varepsilon_m(\lambda)+\varepsilon_d(\lambda)}} = \frac{2\pi n}{\lambda} sin\Theta(u_x + u_y) \pm n_x \frac{2\pi}{p}(u_x) \pm n_y \frac{2\pi}{p}(u_y)$$

1-window(CaF_2)
2-sample
3-quartz cylinder 50 mm DIA
4-microphone
5-inox cell body
6-threaded flange
7-sound labyrinth
8-O-ring.



4. Results

The small – PA technique



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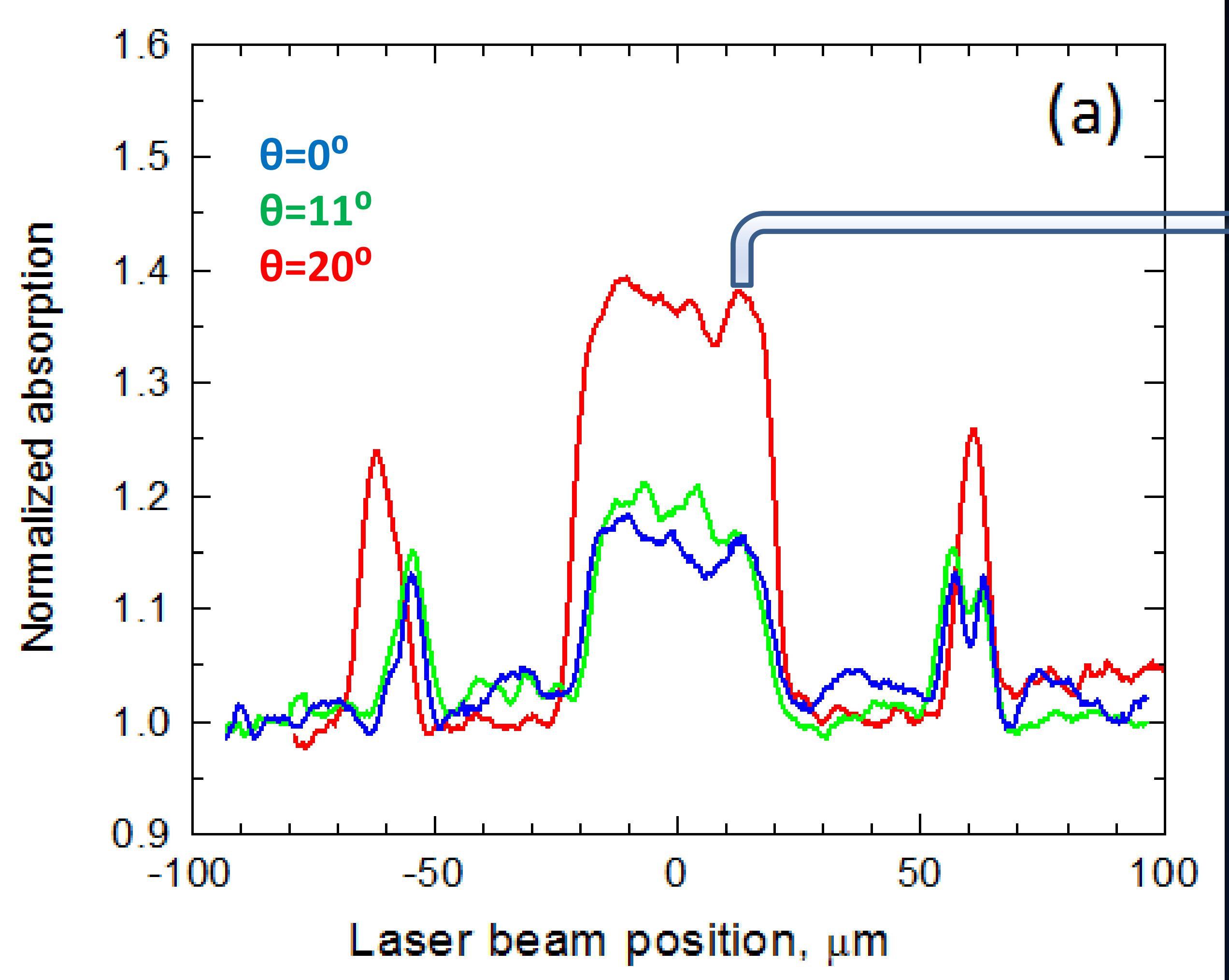
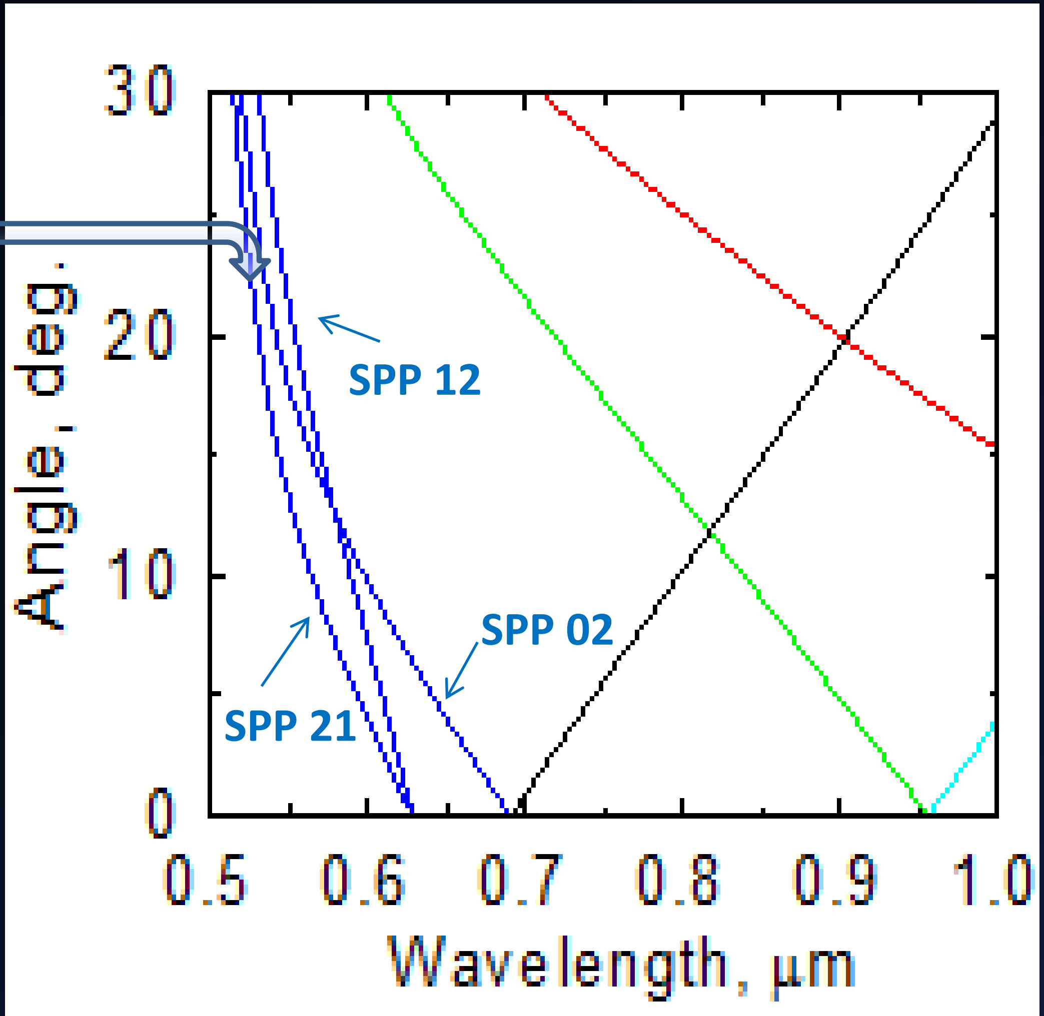
4. Results

The big – PA technique





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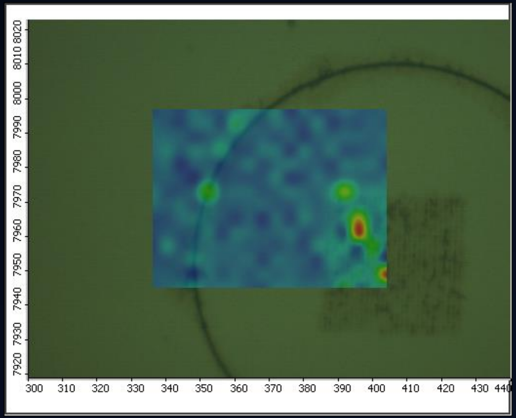
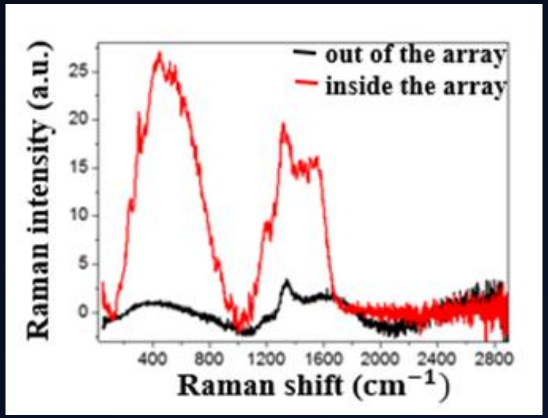
5. Conclusion

- ✓ Optical coupling and SPP forming in the nanostructured 2D array of holes
- ✓ Materials: Au/Cr 50/5 upon glass substrate
- ✓ Photo-acoustic technique for the observation of the SPPs without scattering problems
- ✓ Simulated absorption and field localization in a good agreement with the experiment

* Collaboration with *Institute for Complex Systems ISC-CNR*: Raman spectroscopy for further understanding of the structure field enhancement for SERS substrates





- ✓ Tailoring the properties by changing the diameter or periodicity or hole depth
- ✓ Possibility of choosing the SPP path
- ✓ Simple and reliable technique of observing SPP
- ✓ Fabrication repeatability towards high performance optical components

Thank you for your attention!