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FONDAZIONE BRUNO KESSLER
CENTER FOR SENSORS AND DEVICES

Optimization of Focused Ion Beam patterning parameters for direct integration of plasmonic nanostructures on Silicon photodiode

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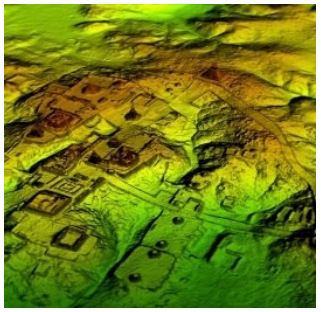

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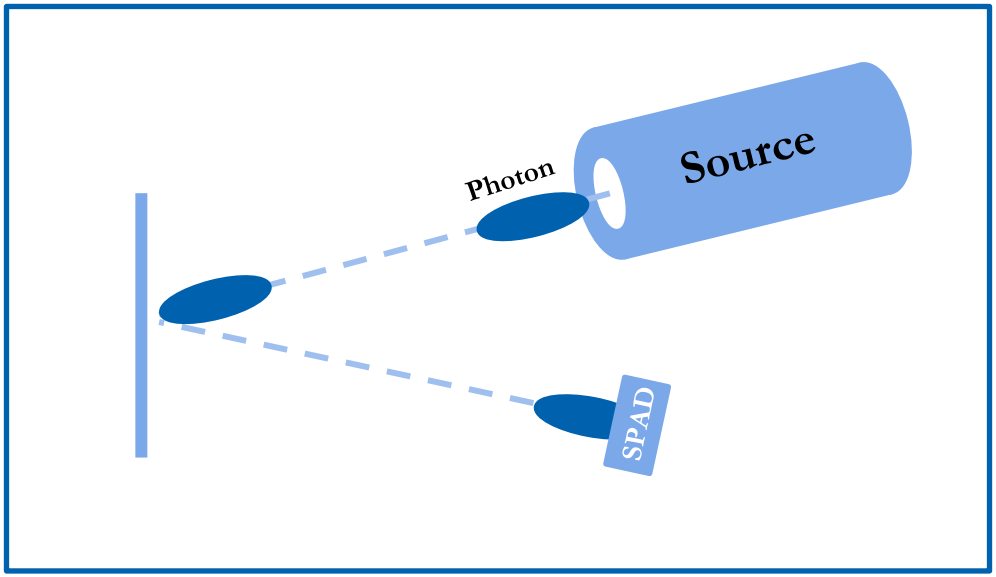
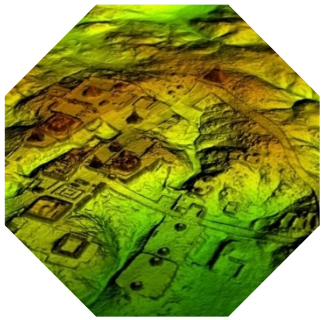
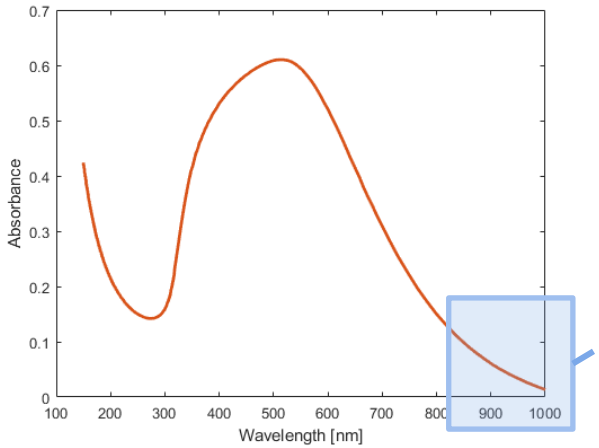
Problem statement



N E A R - I N F R A R E D



Applications of single photon counting optical sensors

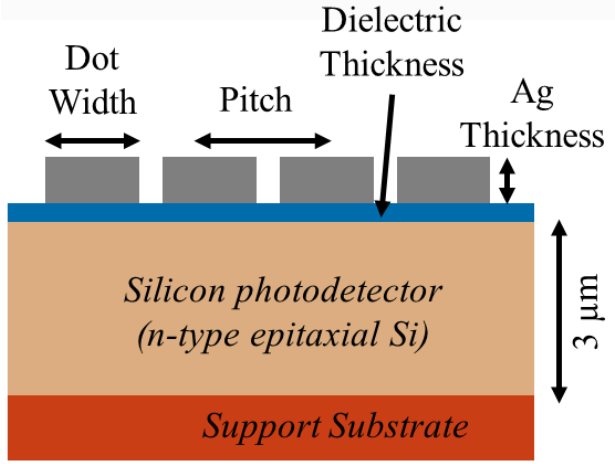


QE hindered by Silicon

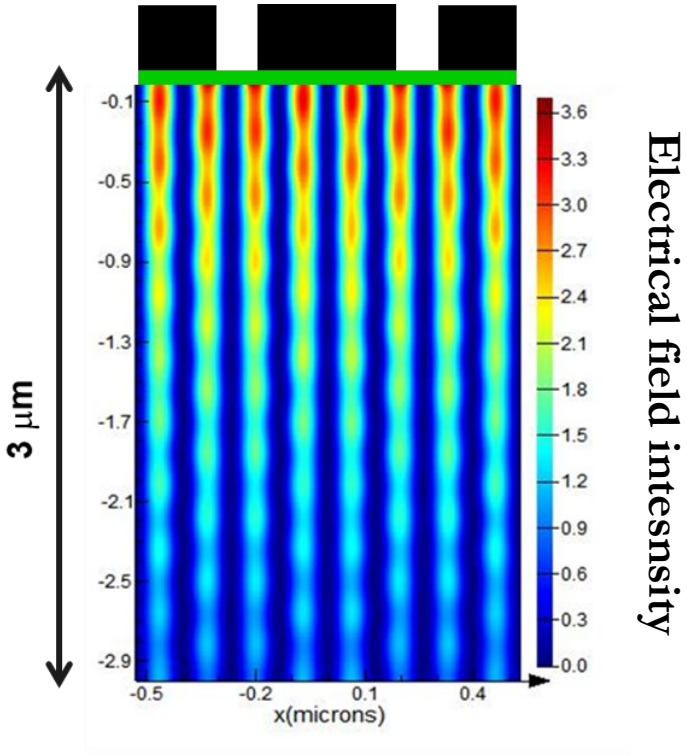
low absorbtion coefficient

Proposed Approach

Plasmonic nanograting supporting surface plasmon polaritons

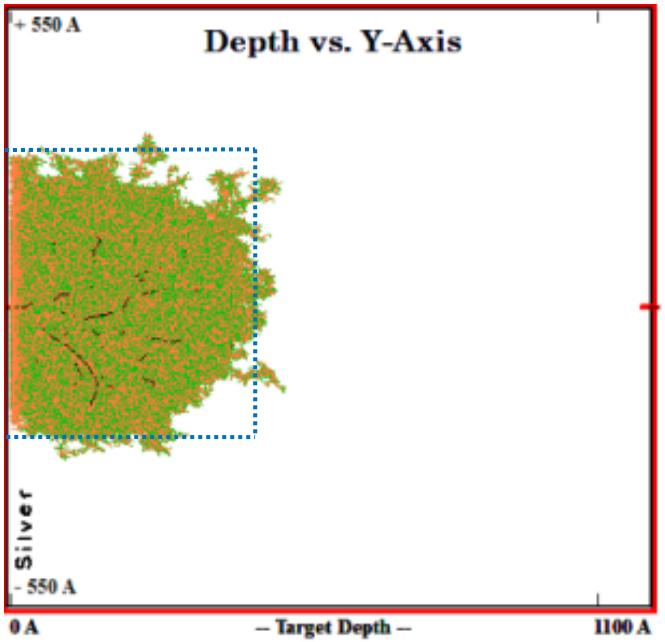


- Easy integration
- Easy plasmonic properties tunable



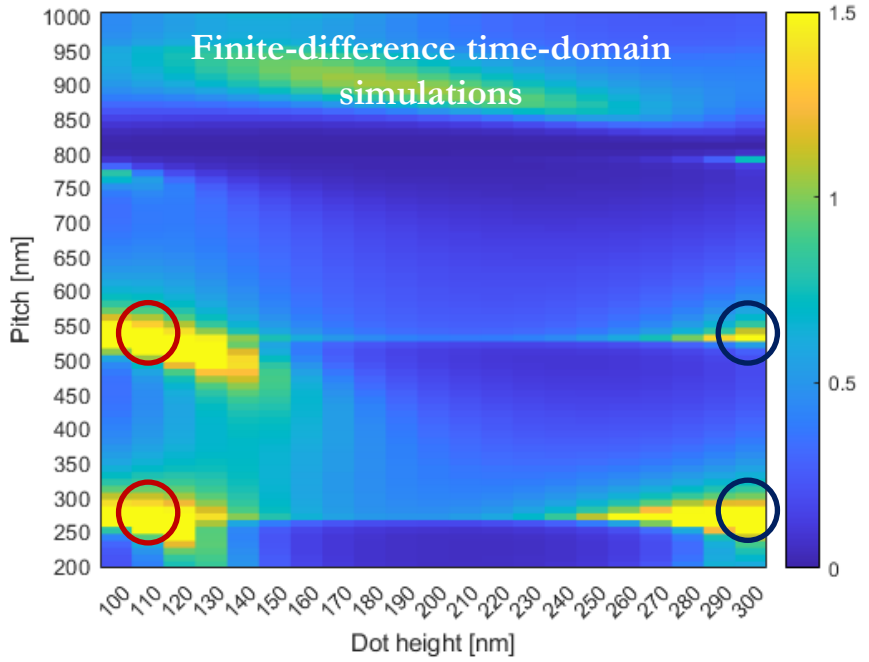
Simulation results

Theoretical collision cascade of Au gold ions in silver layer from Montecarlo simulation



Theoretical collision cascade of gold double charged ions at 35 keV in silver layer exhibiting a box shape (blue dotted line) close to the ideal configuration, with a sputter yield of 15.6 silver atoms per incident ion.

Absorption normalized to Si with Perfect AntiReflective Coating (PARC) at wavelength 950 nm (NIR)



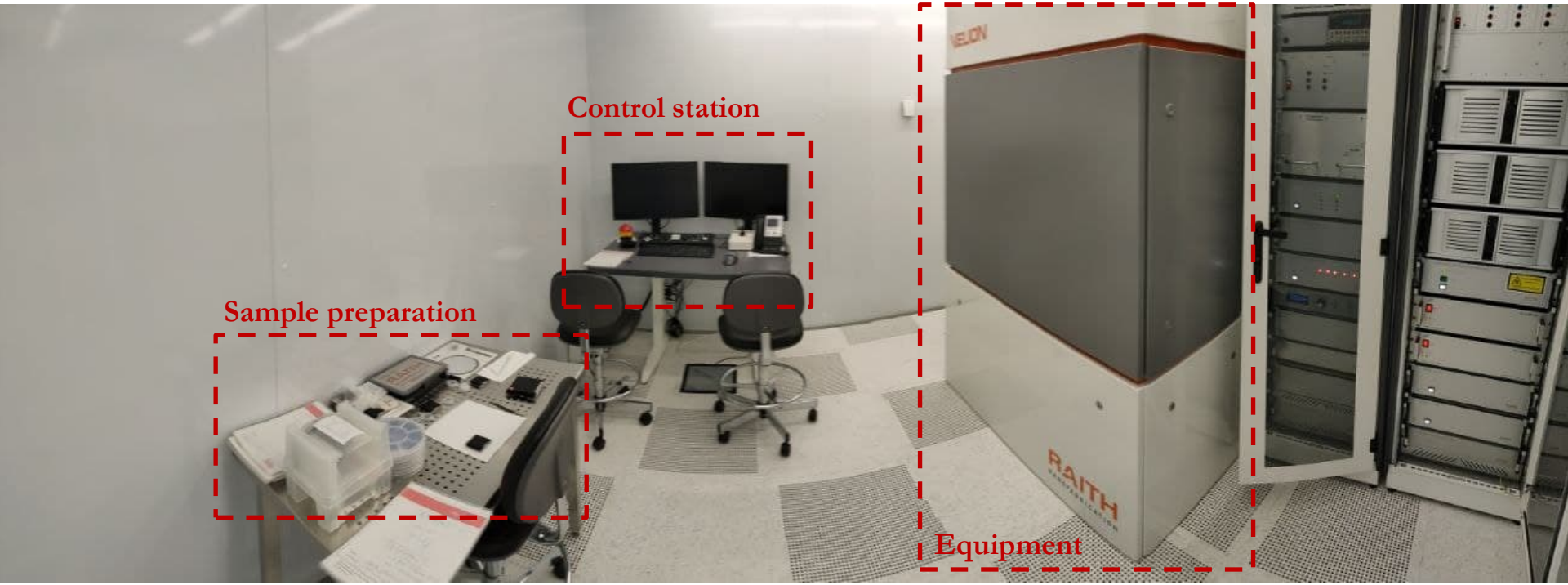
Pitch = 530nm
Metal thickness = 110 nm

Pitch = 260nm
Metal thickness = 110 nm

Pitch = 530nm
Metal thickness = 290 nm

Pitch = 260nm
Metal thickness = 290 nm

Focused Ion Beam equipment in FBK's facilities



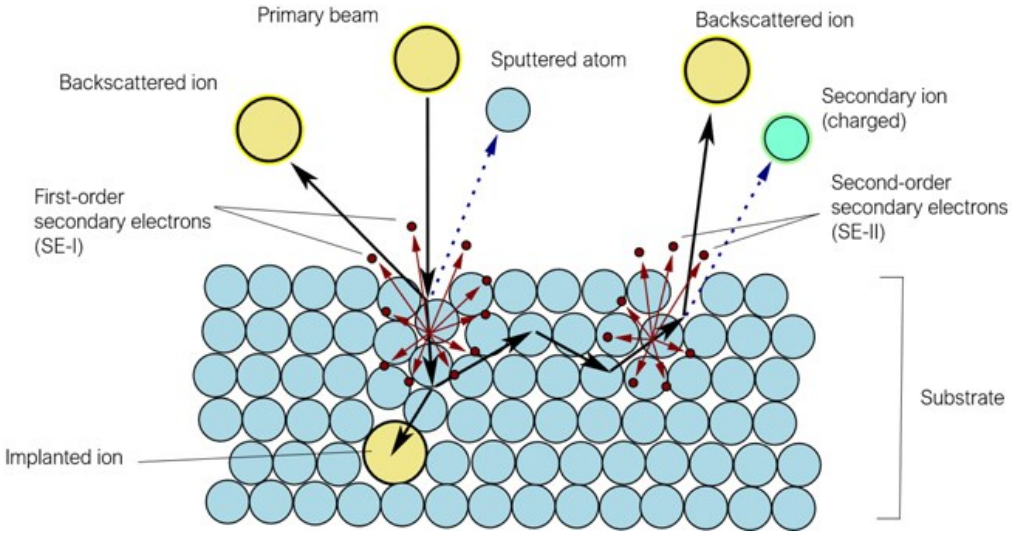
Focused ion beam - eutettic liquid alloy Au/Si/Ge source

Electron beam

Optical microscope

Focused Ion Beam working principles

Au (+, ++)
Ge (+, ++)
Si (++)



Sputtering yield:

$$Y = \frac{number\ of\ incident\ ions}{nuumber\ of\ sputtered\ atoms}$$

Y depends on:

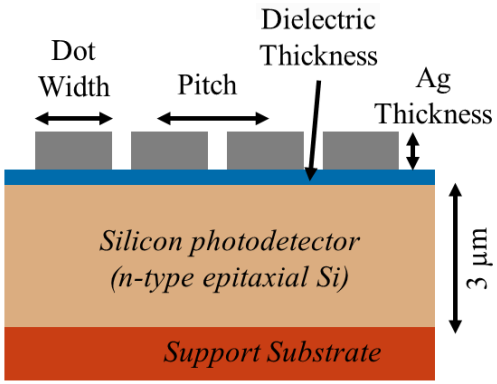
- Ion's mass and charge
- Sample material

Quantity of removed materials depends on:

- **Dose**: superficial density of charge [uC/cm2]
- **Dwell time**: time spent on a single spot [ms]
- **Current Beam**: the value of the current of the beam [pA]
- **Loops**: numer of loops in which the Dose is divided in
- **Scan direction**

Nanofabrication

Compatibility of the proposed structures with Focused Ion Beam technique



Pitch = 530nm
Metal thickness = 110 nm

Pitch = 260nm
Metal thickness = 110 nm

Most reliable structure configuration

High aspect ratio and the low beam spot size required

Pitch = 530nm
Metal thickness = 290 nm

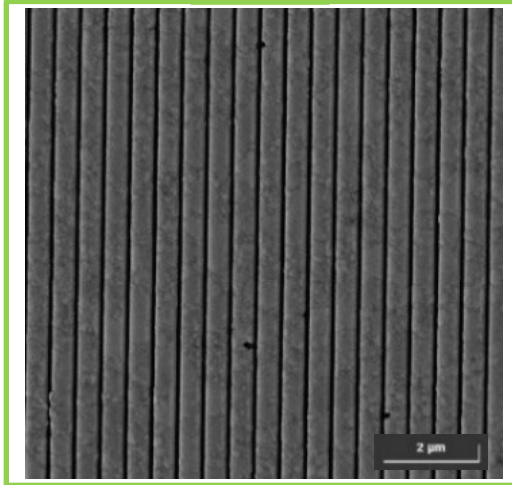
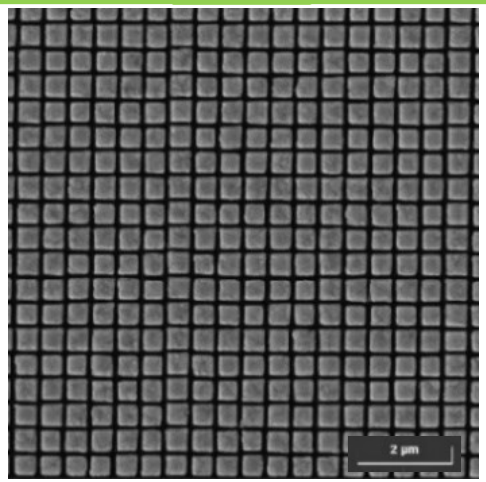
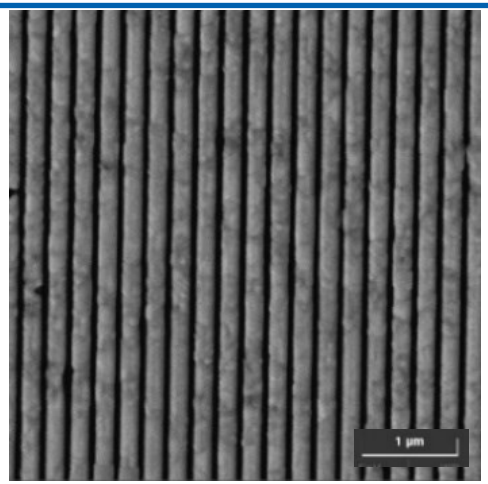
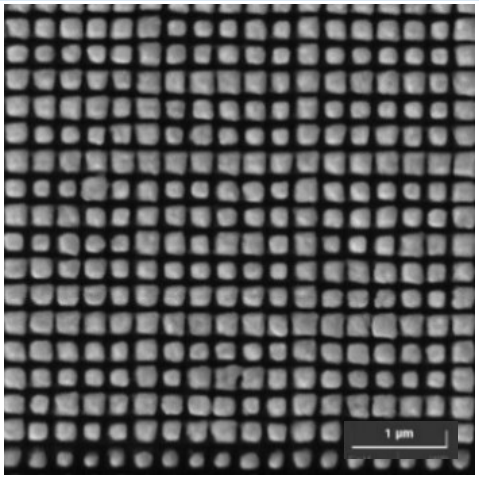
Pitch = 260nm
Metal thickness = 290 nm

Long dwell time leading to

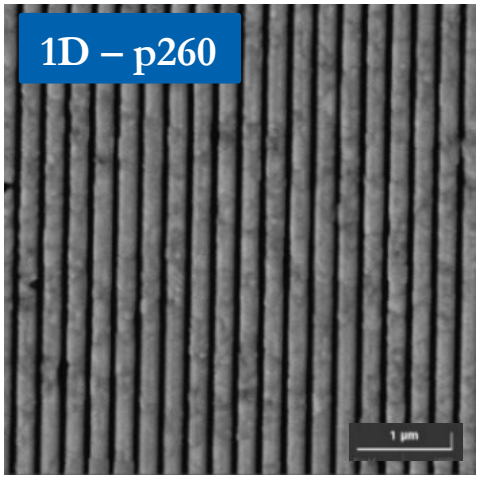
i) Low lateral definition of the structures;

ii) too long patterning time;

SEM characterization

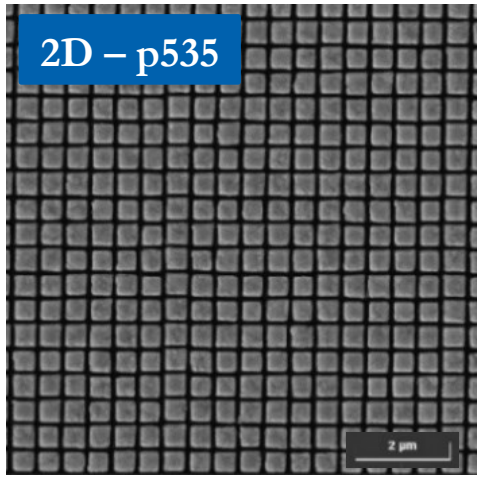
1D	2D	
		High reliability High dimensional conformaty
		Low reliability Low dimensional conformaty

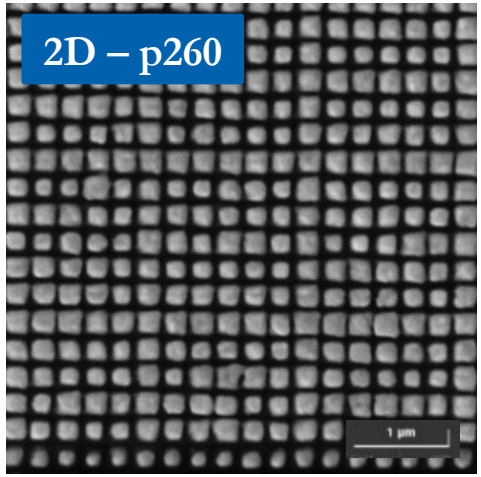
Dark current values



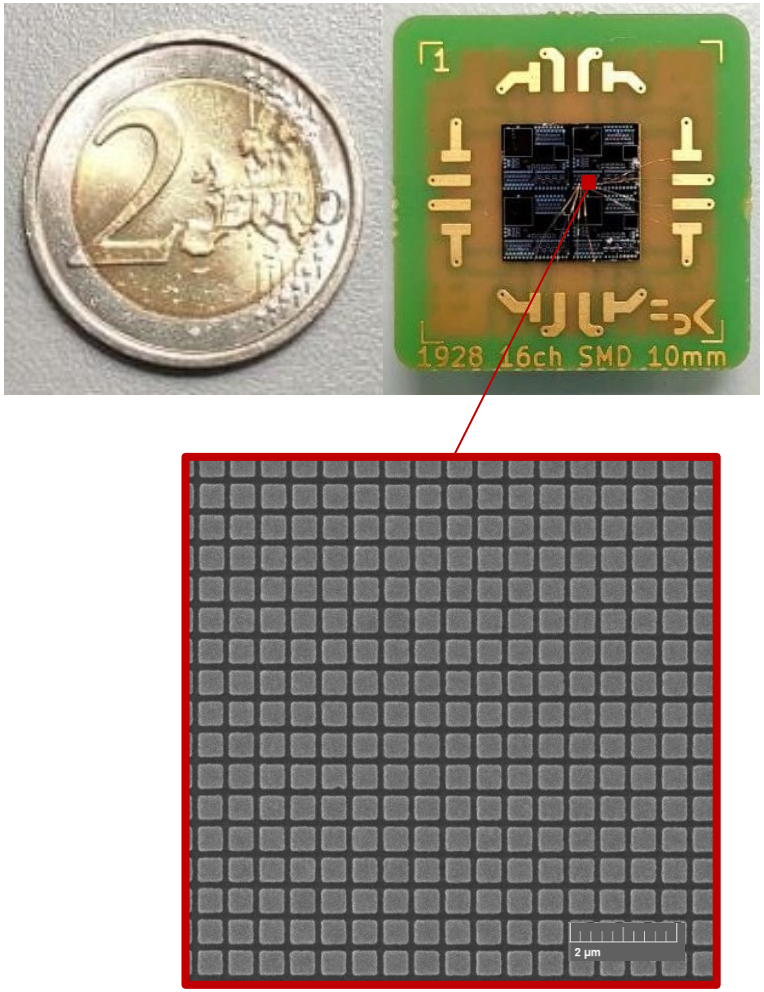
Reference
21 pA

FIB 1D	FIB 2D
p-535,h-110	**p-535,h-110**
41 pA	25 pA
p-260,h-110	**p-260,h-110**
10 pA	37 pA





Conclusion



Successfull integration of metallic plasmonic nanostructures on active device without inducing any irreversible damage in the active region of the device.

This result paves the way to further applications given by the integration of plasmonic nanostructures with photodetectors, such as **plasmonic biosensors all-in-one**

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CONTACT

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