CNR-IFN micro and nanofabrication facility: from high resolution electron beam lithography to macroscopic soft litographies

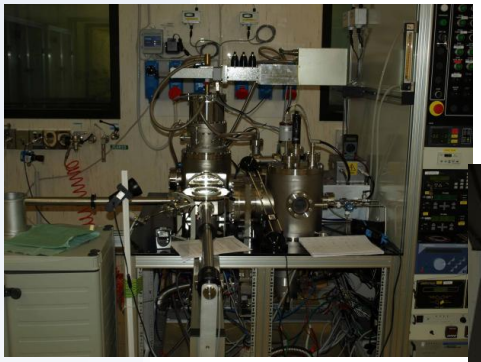
A. Gerardino,
M.G. Castellano
IFN-CNR Roma

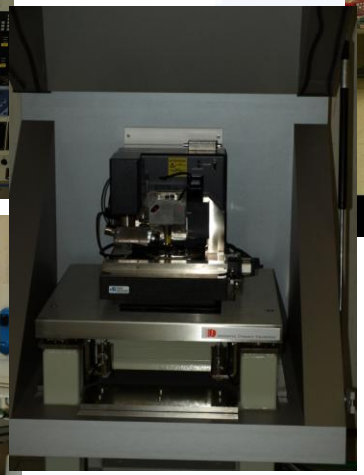
ISTITUTO DI FOTONICA E NANOTECNOLOGIE (CNR-IFN)

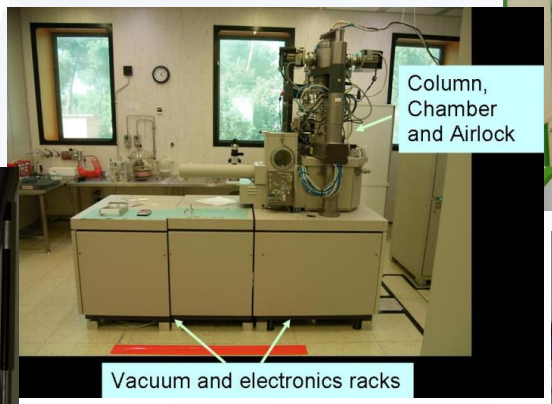
IFN-Rome 14 permanent scientists 10 PhD/postdocs

- Lithography (Electron Beam Lith., Photolith, Imprinting)
- Thin-film technology (sputtering, evaporators)
- Dry etching (RIE)
- MEMS (deep reactive ion etching, wet etching)

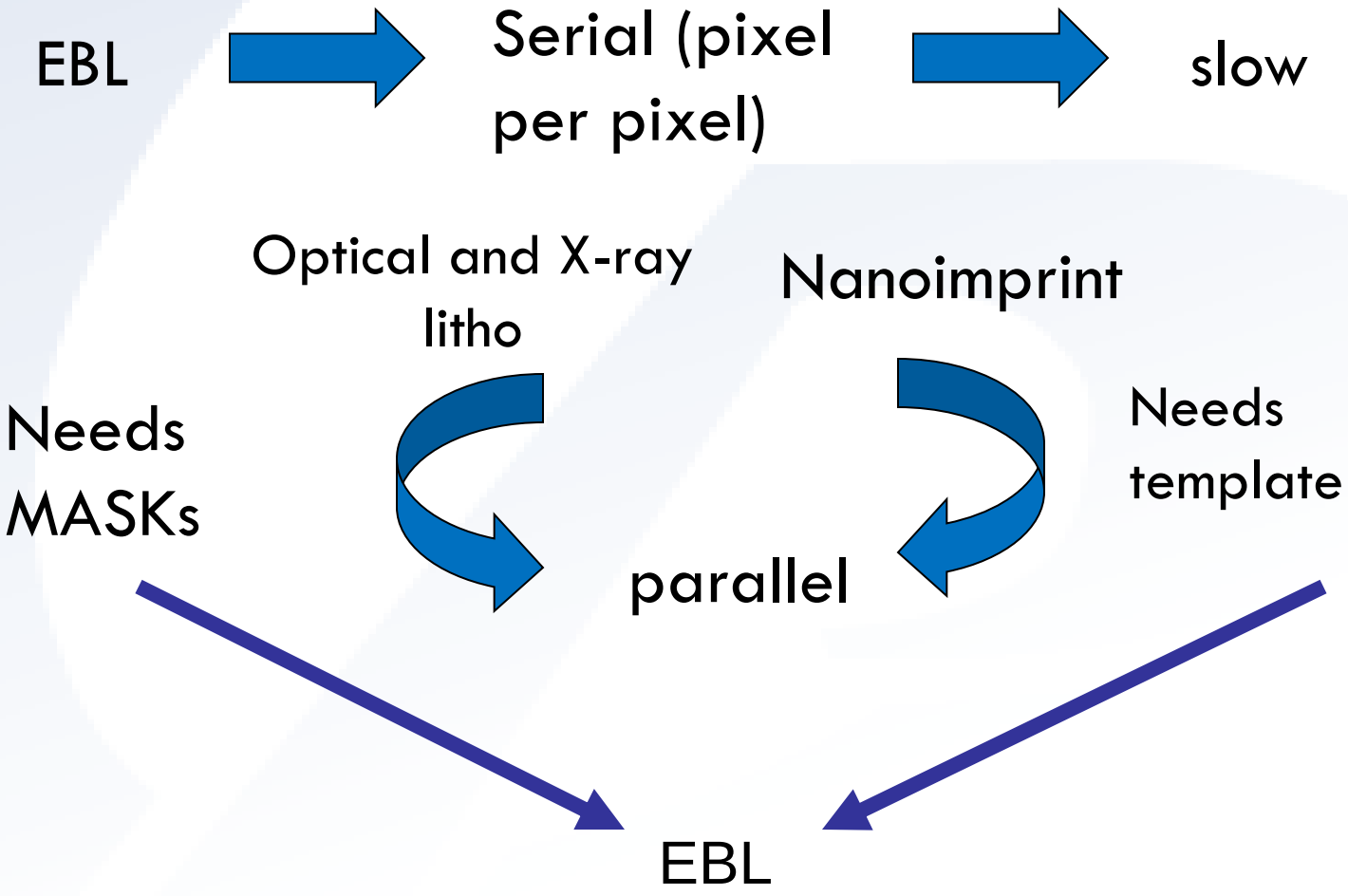
- 250mq clean room







A comparison…



How does EBL work?

http://www.cnf.cornell.edu/cnf_spie1.html#2.1.3

Electron Source

Electron Optics

Vacuum System

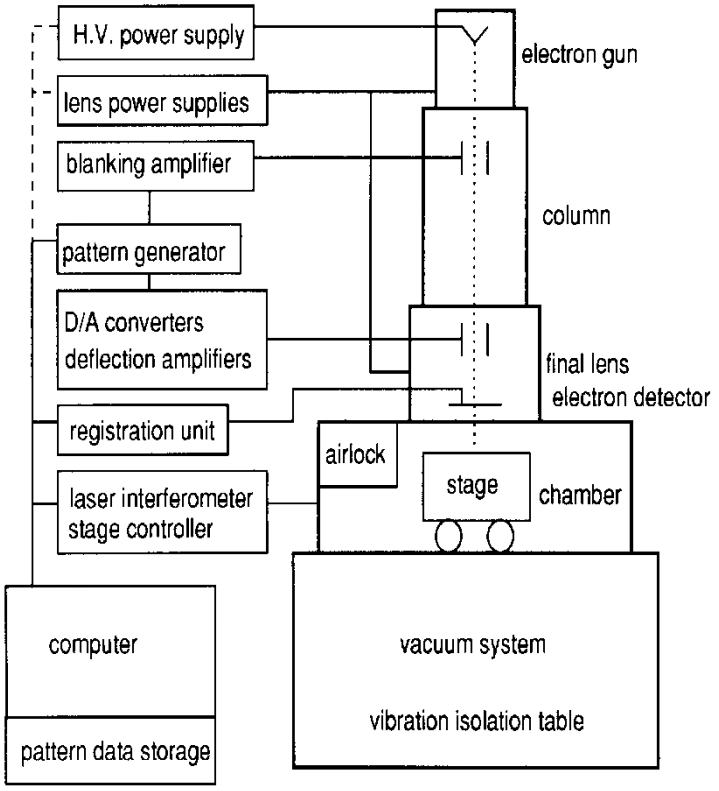
Pattern Generator

Stage system

Substrate Handler

Control Electronics

Correction Systems

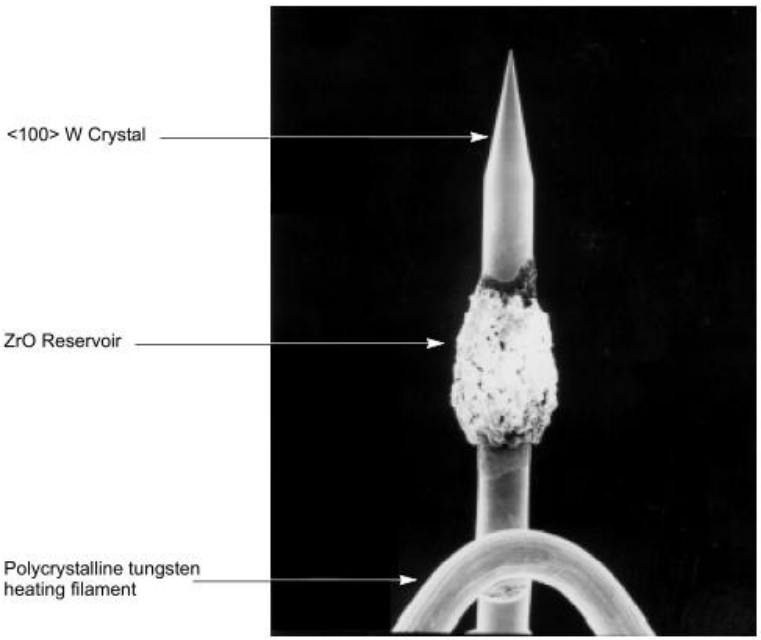


Electron Sources: Field Effect

A Schottky emitter tip is shown in *Figure 2-3*. It is composed of the following elements:

- A piece of single crystal tungsten (W) wire oriented along the <100> crystal plane
- A zirconium oxide (ZrO) reservoir
- A polycrystalline tungsten heating filament

Figure 2-3 Schottky Emitter Tip



lying an electric field sufficiently
g, electrons can be extracted by
l effect.

ron sources are usually made of a
tungsten or LaB6

e sources are coated with a
rial with lower work function: when
d the second material is adsorbed
e first one lowering its work function
ttky emitters)

EBPG 5HR, Vistec (now Raith nanofabrication)

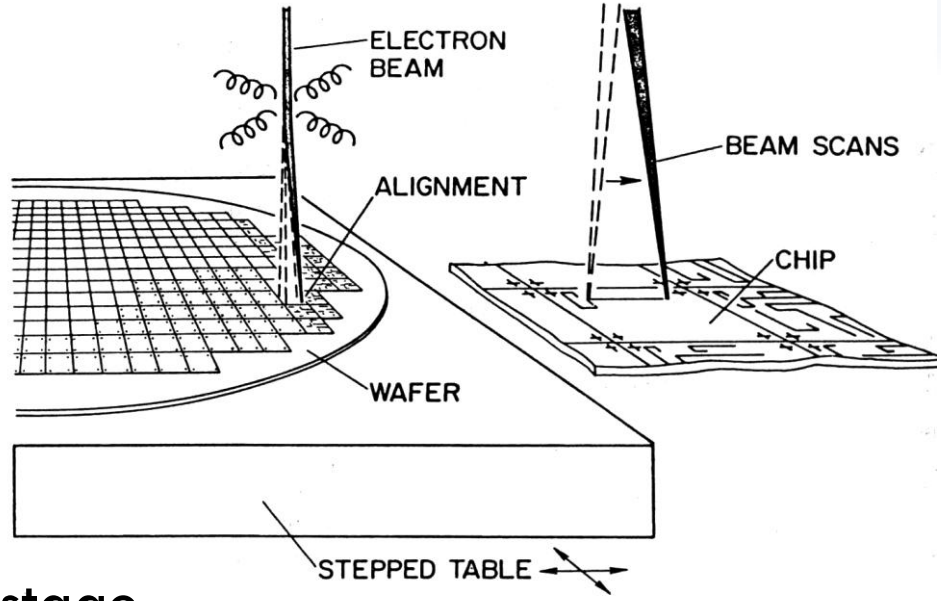
Column, Chamber and Airlock

Vacuum and electronics racks

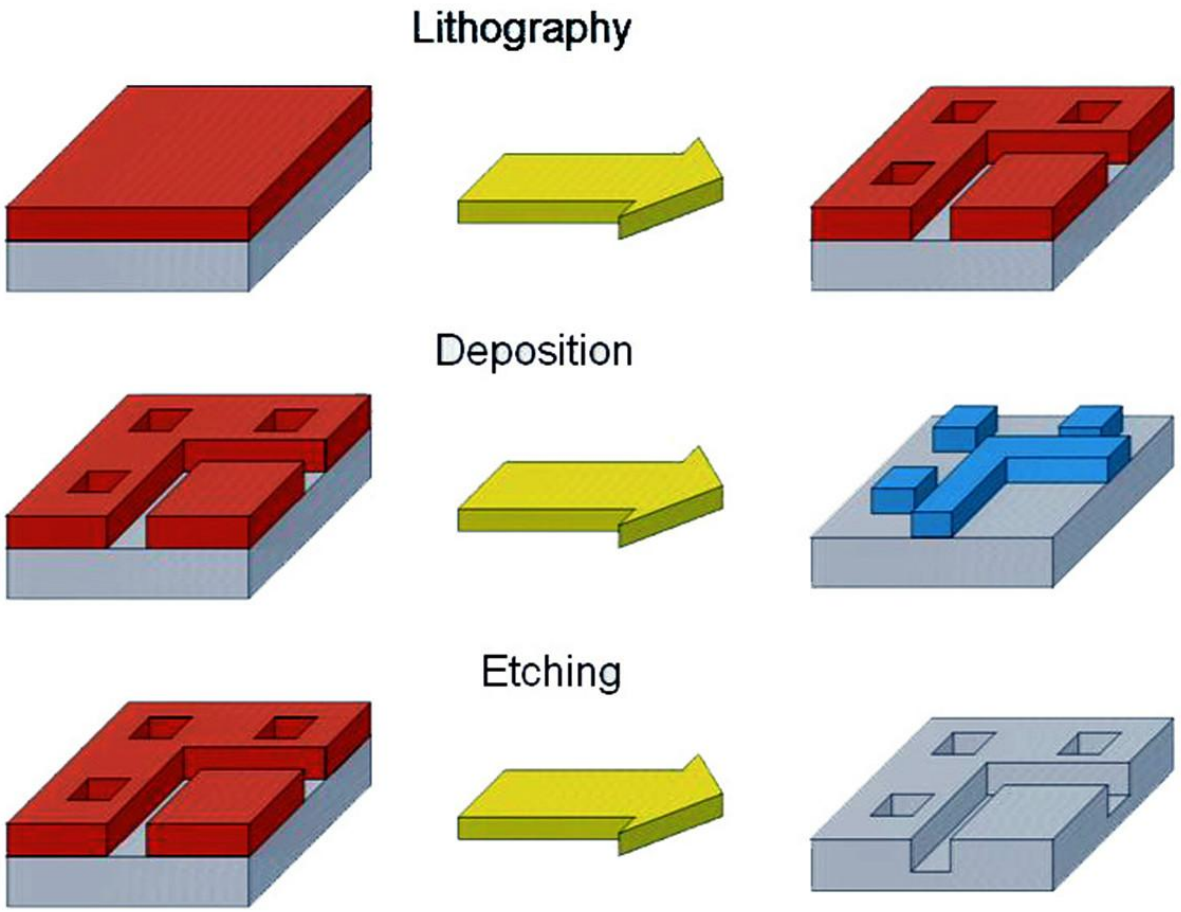
- 100kV FEG
- Step frequency max. 10 MHz
- beam spot: 8 nm
- Laser interferometer ($\lambda/120 \sim 5nm$)
- x & y stage movement 127mm
- Mask fabrication (up to 4")
- direct writing (up to 4")

How does it work?

- The e-beam is directed onto a substrate coated with an electronic resist
- The e-beam is deflected to direct write the chosen pattern
- The main deflection is linked to the acceleration voltage and defines writing field of fixed area
  - To write on bigger areas, the stage moves; this movement is controlled by laser interferometer (resolution some nms)

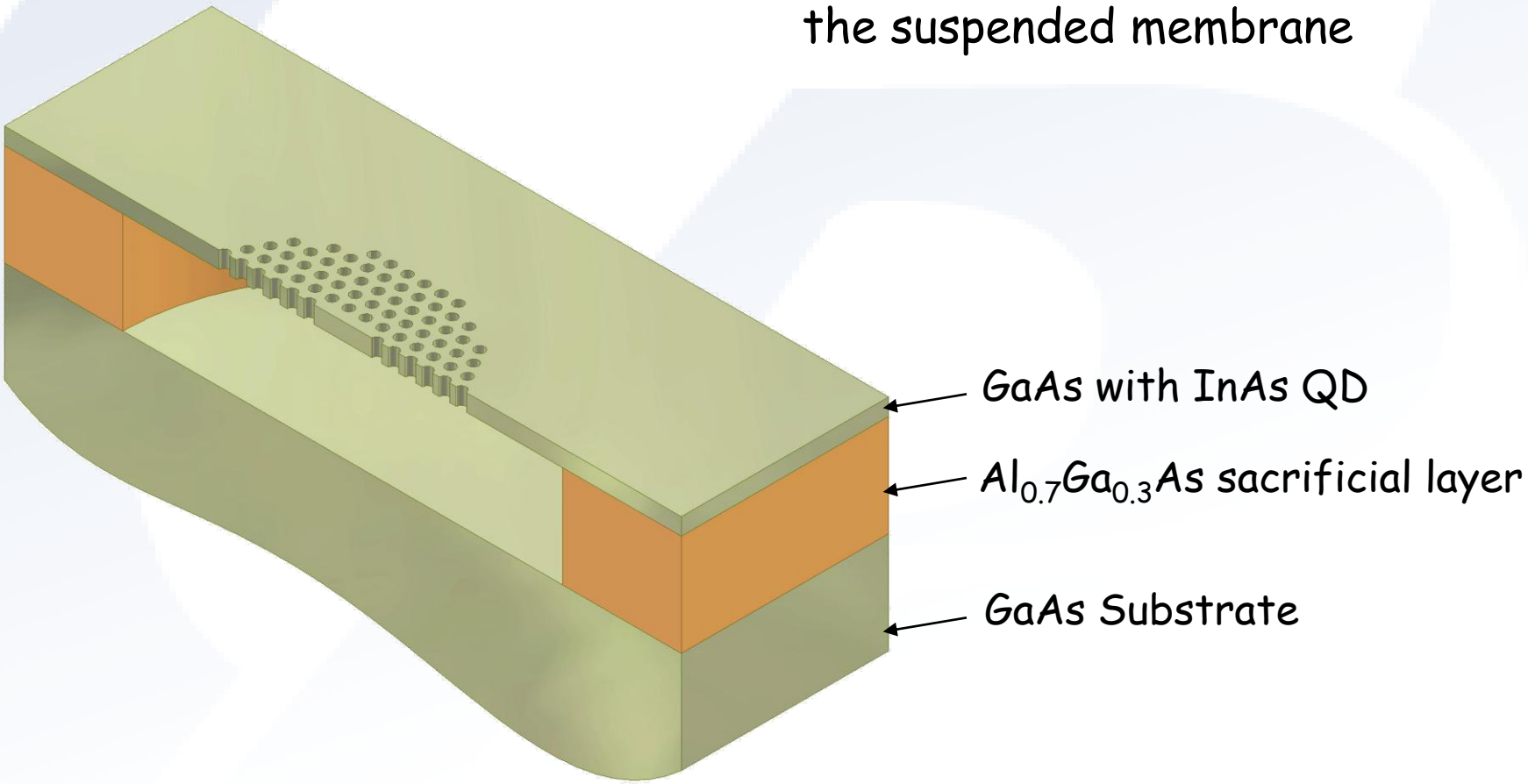


Why EBL? High resolution pattern transfer

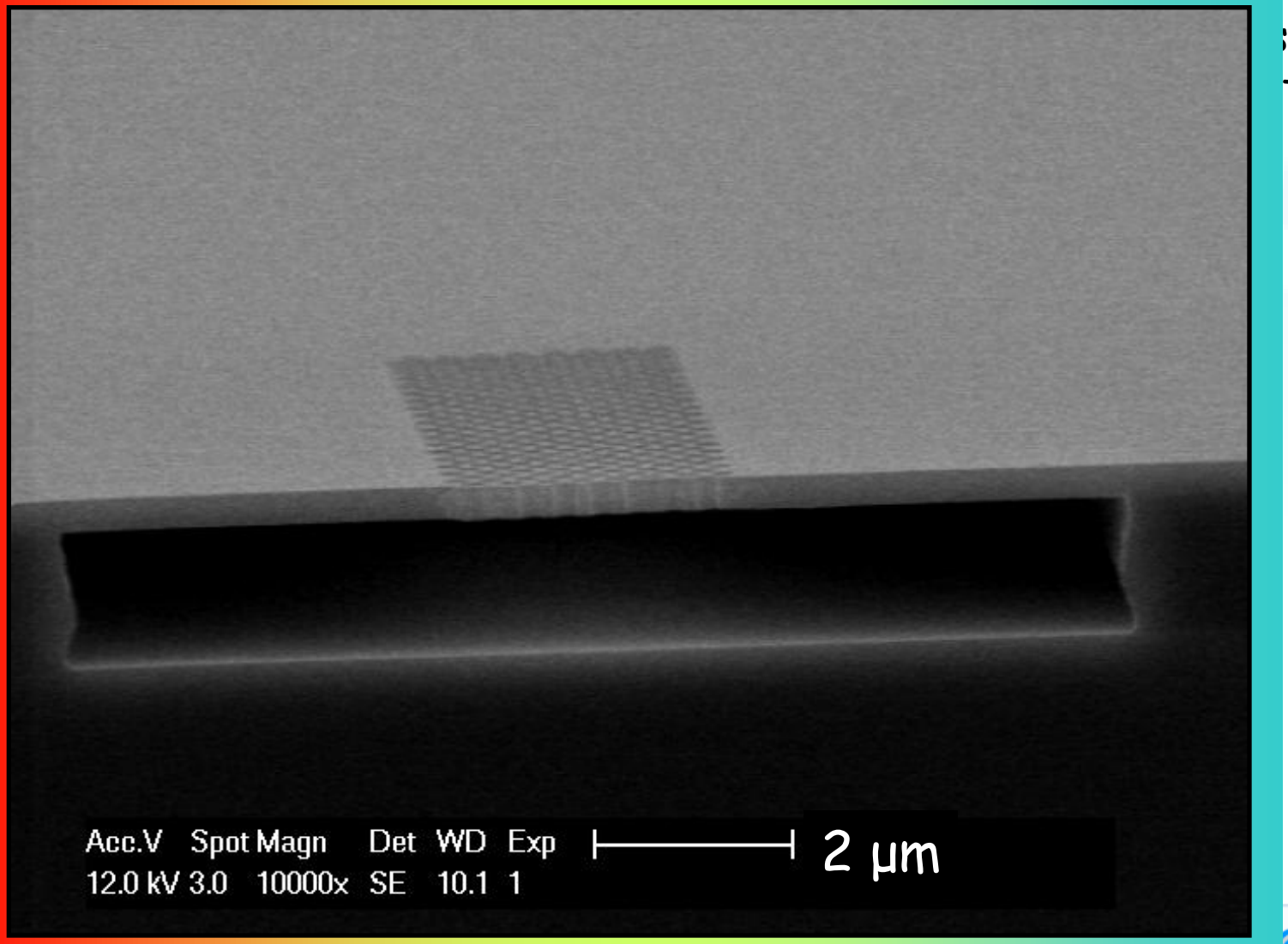


Sample fabrication

HF wet etch of the $Al_{0.7}Ga_{0.3}As$ sacrificial layer – formation of the suspended membrane



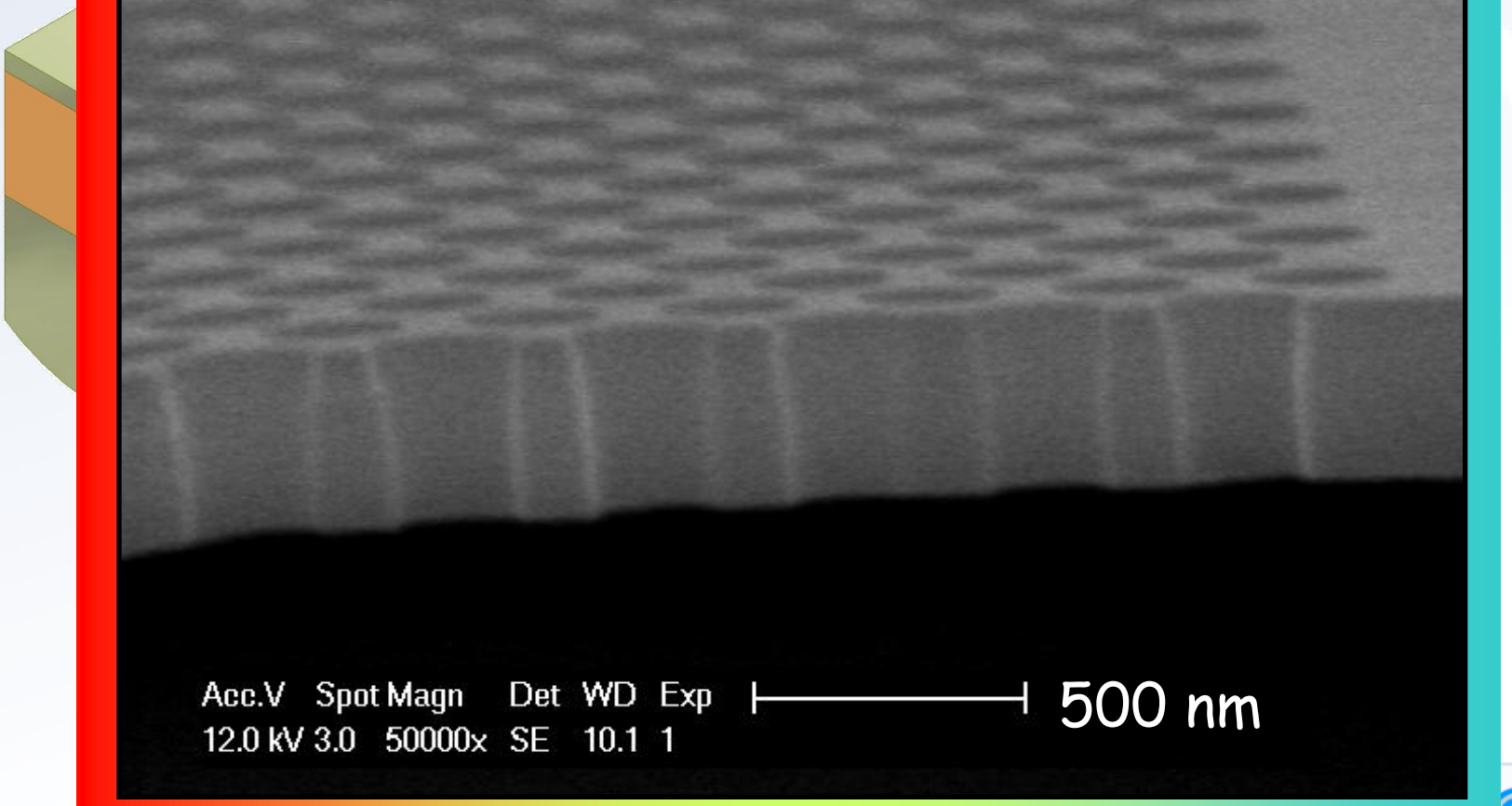
Sample fabrication



the

layer

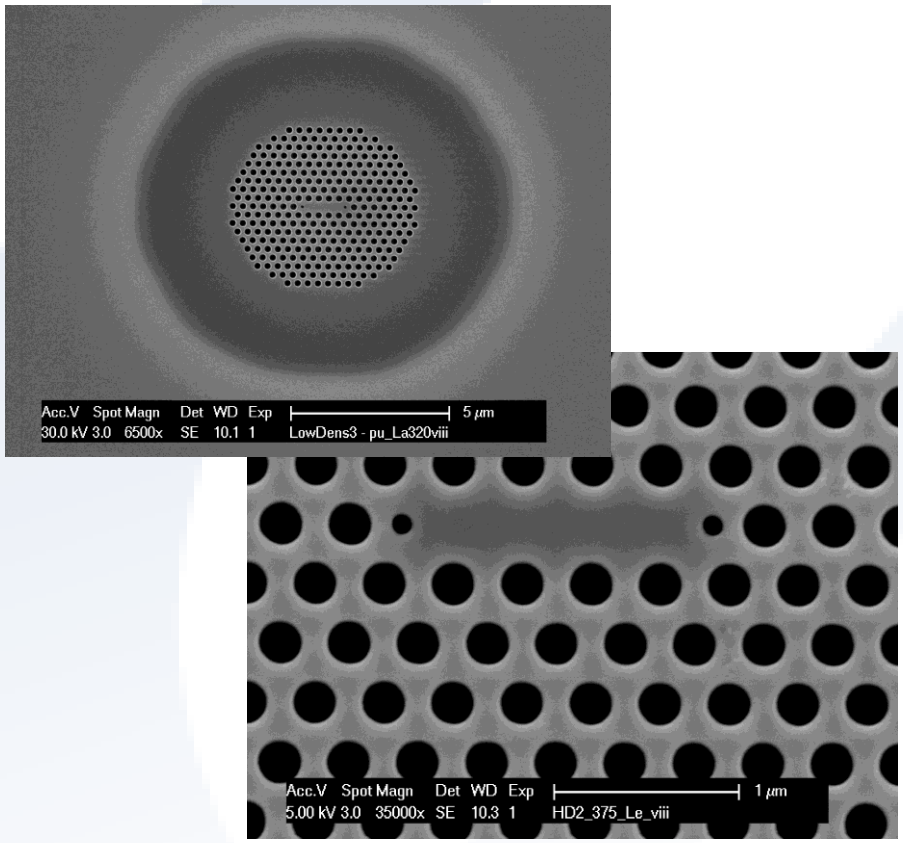
Sample fabrication



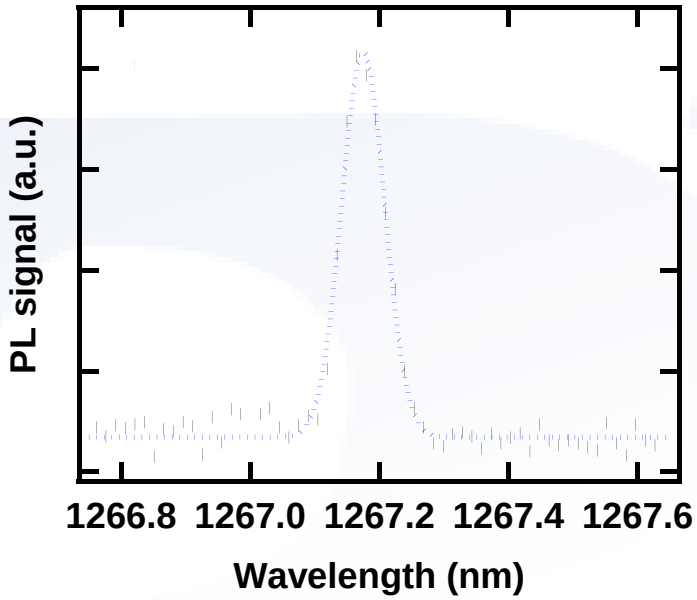
the

layer

Photonic Crystal nanocavity



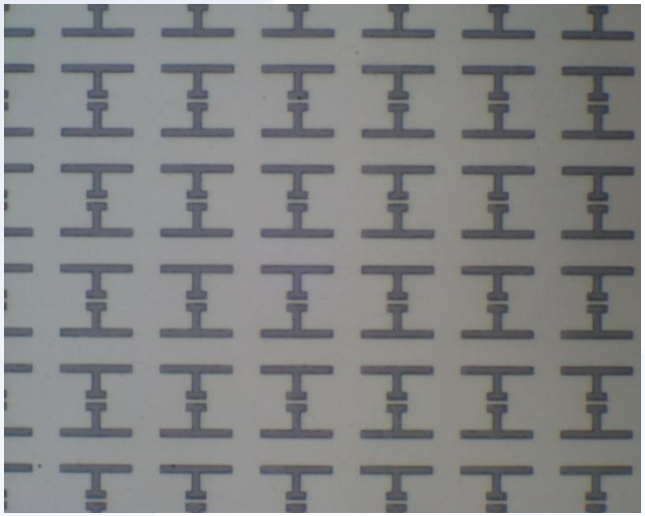
SEM images of a L3 line defect cavity with modified first hole configuration



cavity mode with FWHM $\Delta\lambda$=0.077 nm and Q=16 500 under strong optical pumping

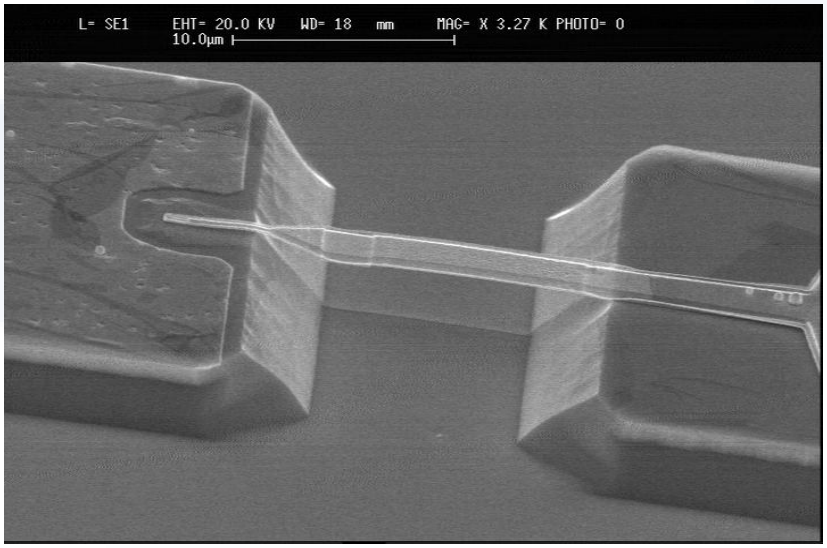
Sensing & Security

Metamaterial filters for the 1÷5 THz range



- 200 nm Au on Si
- gap 0.6 μm (5 THz filter)
- 20000 elements on (5 x 5)mm^2 area
- electron-beam lithography

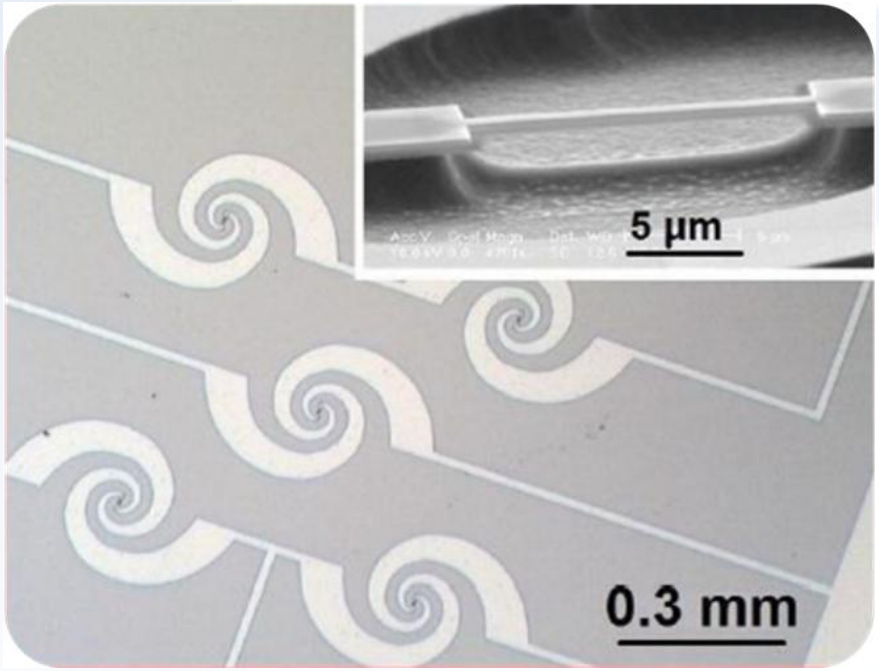
Schottky diode for electronic and photonic applications in the THz range

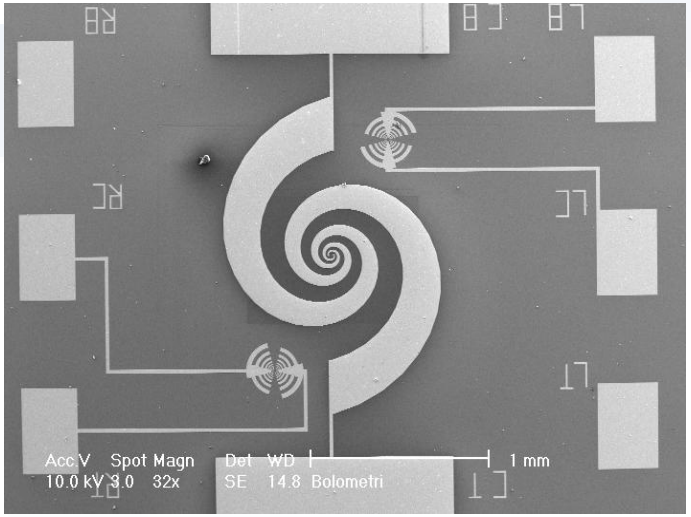


Nanometer size Au anodes on epitaxial GaAs. The bridge suspension of the metal contact between mesas allows better isolation and elimination of the parasitic capacitive effects.

Sensing & Security

SHAB (Superconducting Hotspot Air-Bridge) detector for THz applications



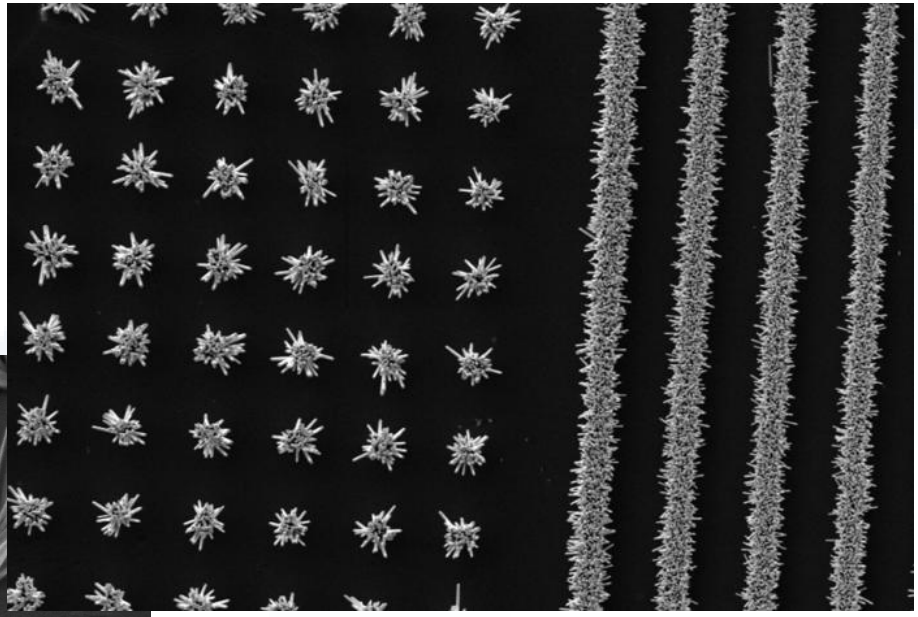


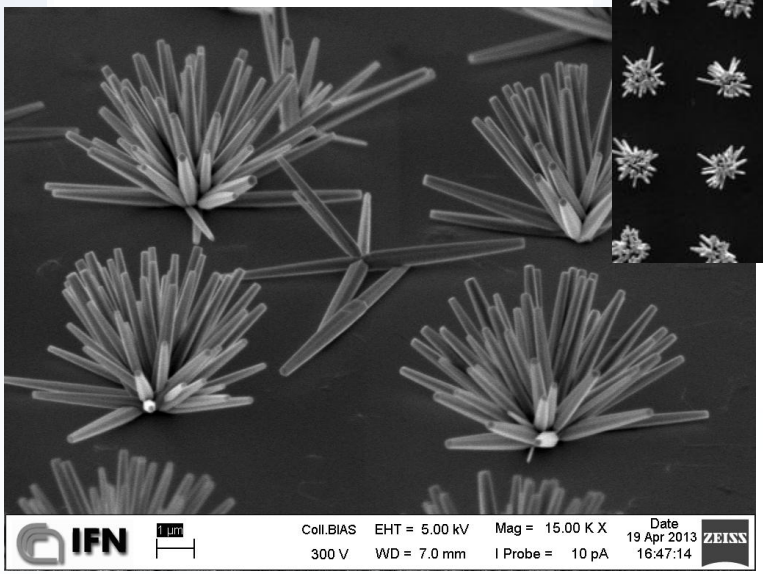
A suspended metal (Nb) bridge acts as a radiation detector up to THz frequencies.

Enabling technologies: sputtering, DRIE, electron-beam lithography.

Sensing & Energy Harvesting

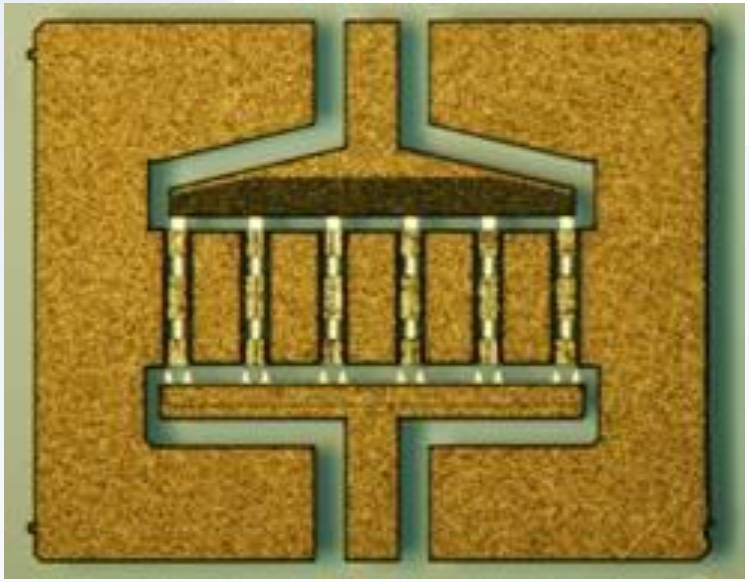
Controlled growth of ZnO nanowires

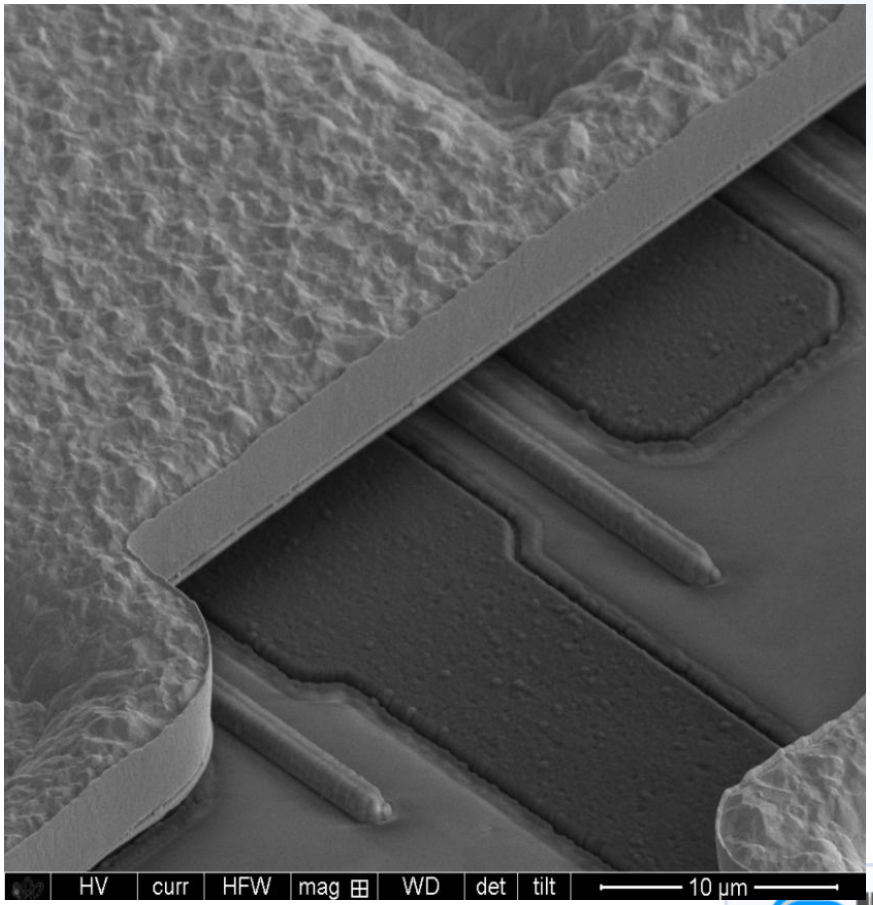




Fast Electronics

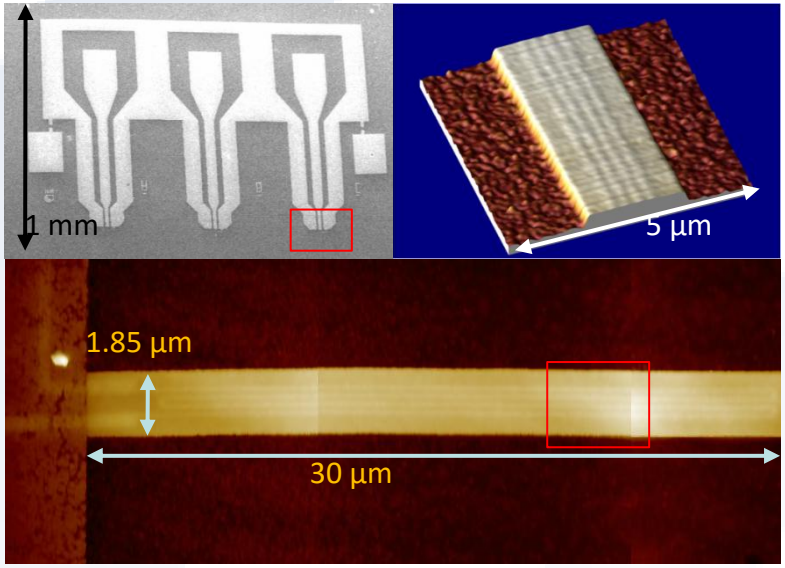
GaAs High Power Amplifier (HEMT) with T-shaped gate (Lg=150nm) collaboration with Selex ES





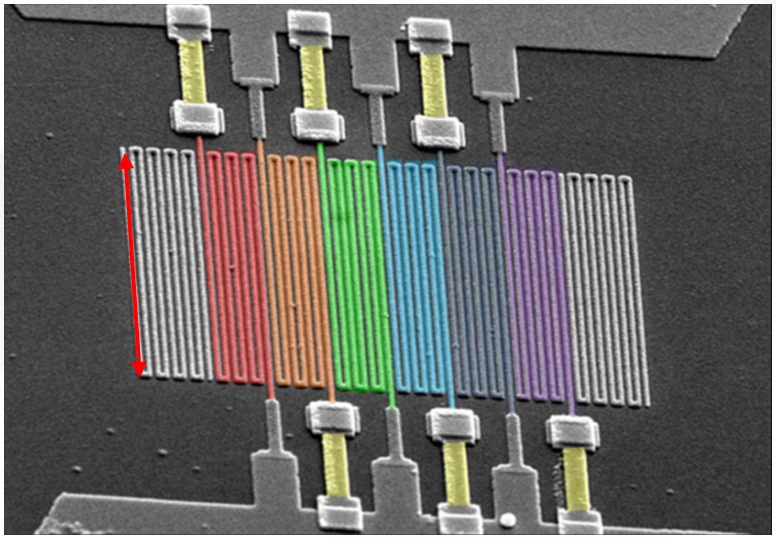
Detectors

SSPD (Superconducting Single Photon Detector):



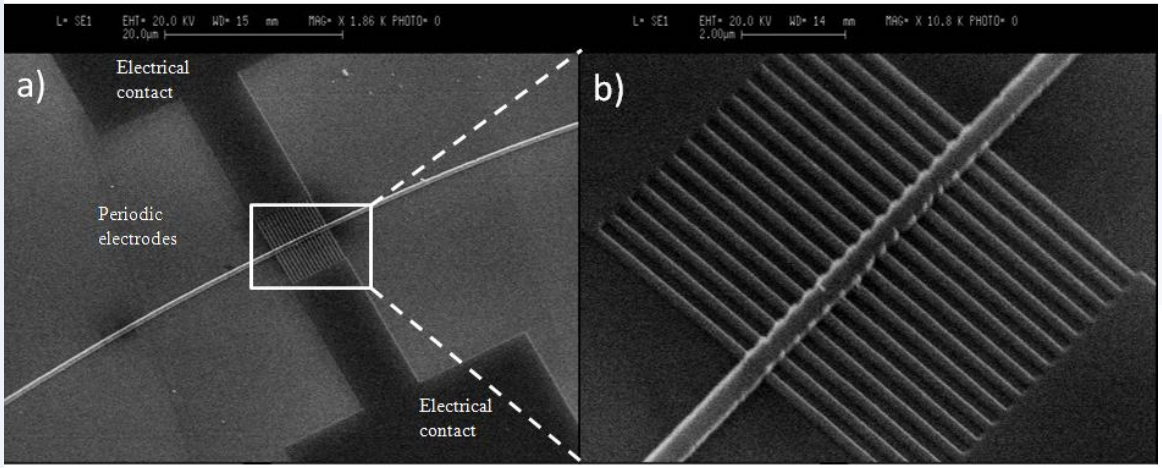
Nanowire superconducting single photon detector integrated on a GaAs/AlGaAs ridge waveguide for integrated quantum photonics applications.

Photon number resolving detector



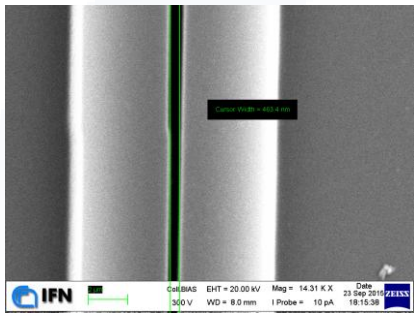
Photon number-resolving detector at telecommunication wavelengths, based on meanders of superconducting nanowire in the nm scale.

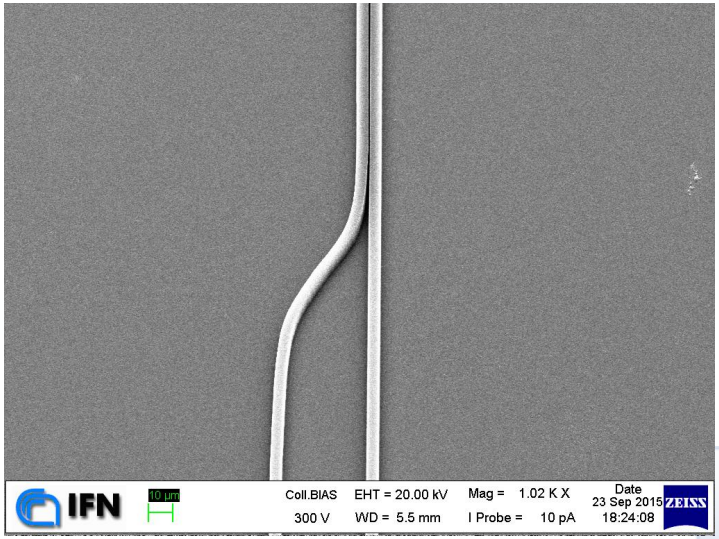
Guided Optics



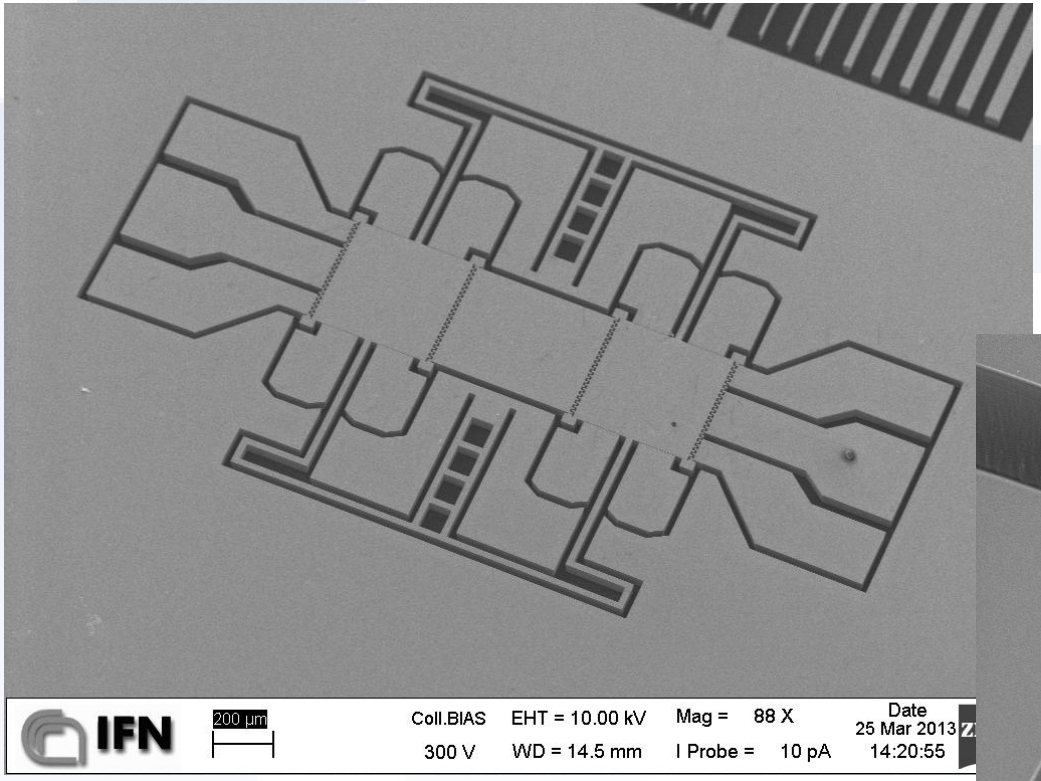
Bragg Optical modulator

waveguides

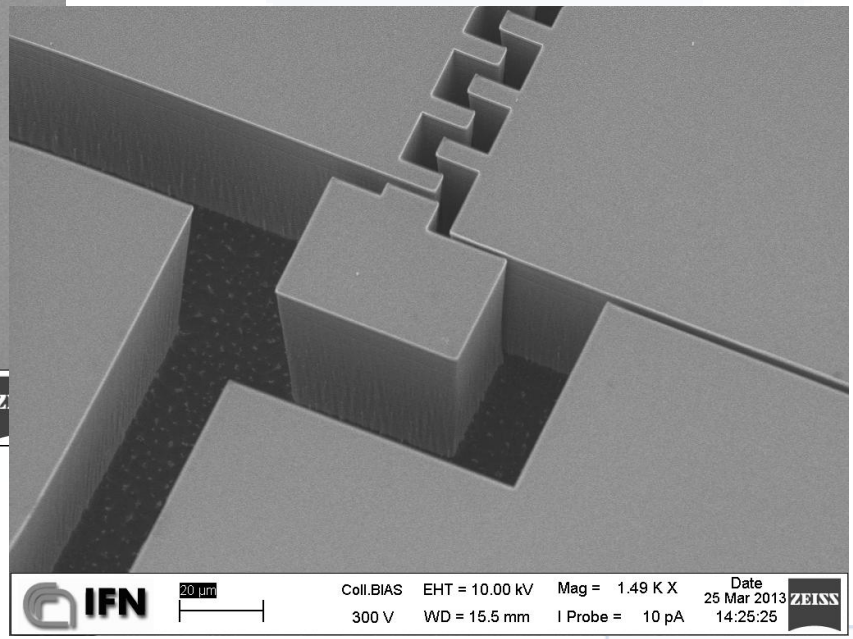




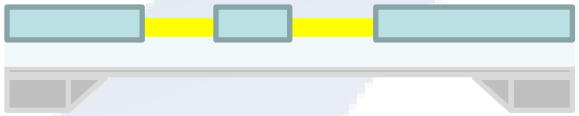
Gyroscope



In collaboration with Thales Alenia Space

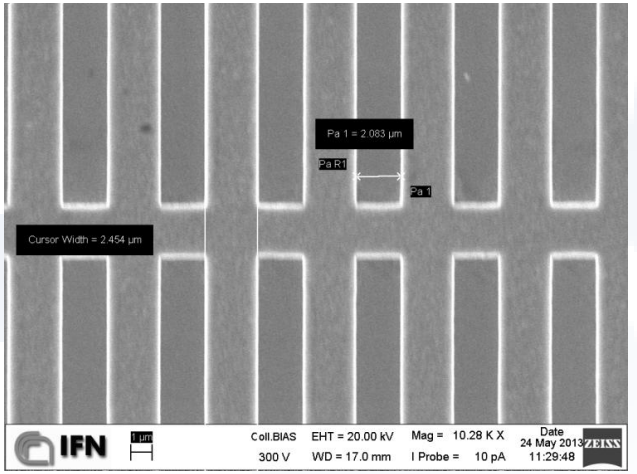


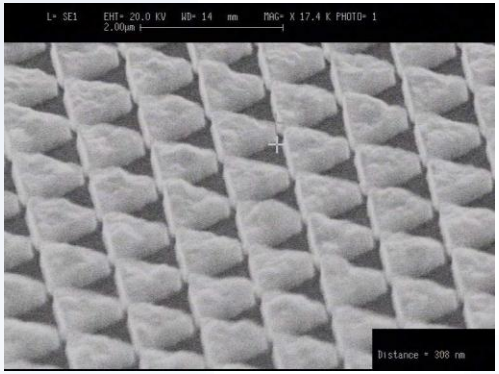
Soft & X-rays masks

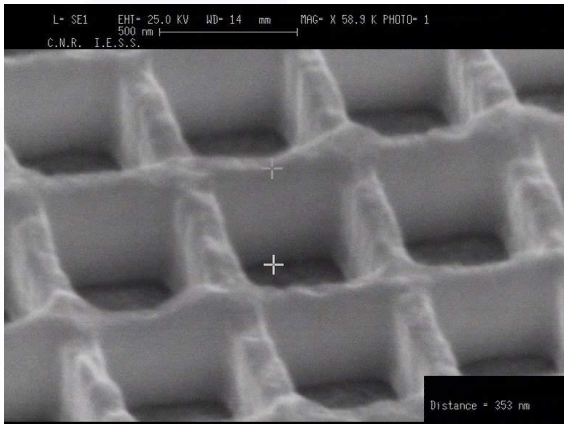


CRESCITA
GALVANICA ORO

RIMOZIONE
RESIST



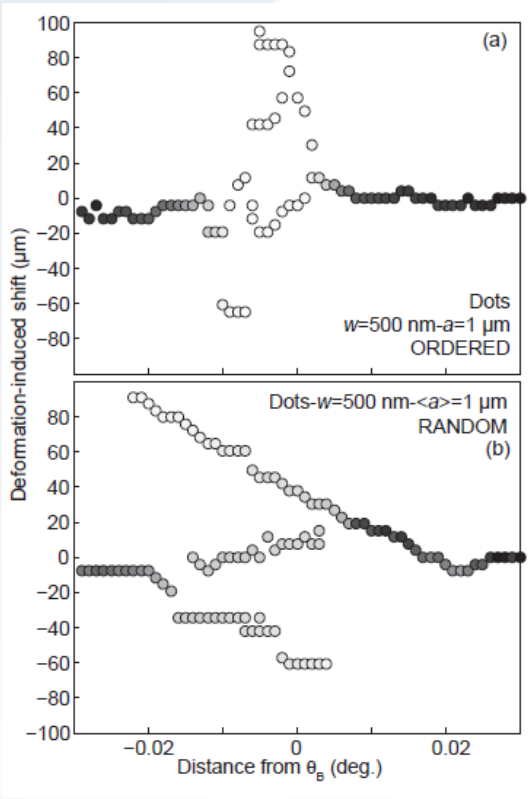


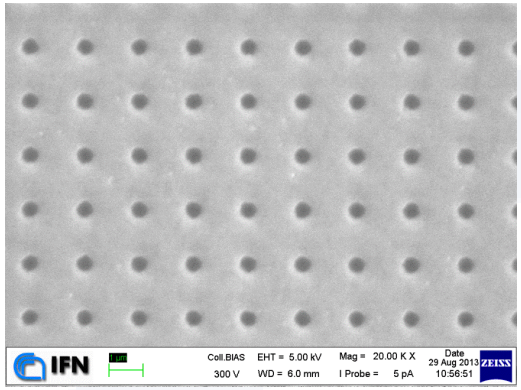


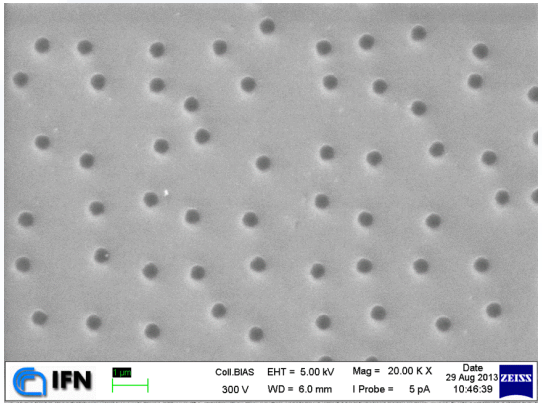
Progetti FIRB e CARIPLO
in collaborazione con
EUV/Soft X-ray (EGERIA & DPP)

X-ray optics based on Berry-phase effect

Hydrogen in Diluited Nitrides: X-ray optics based on Berry-phase effect



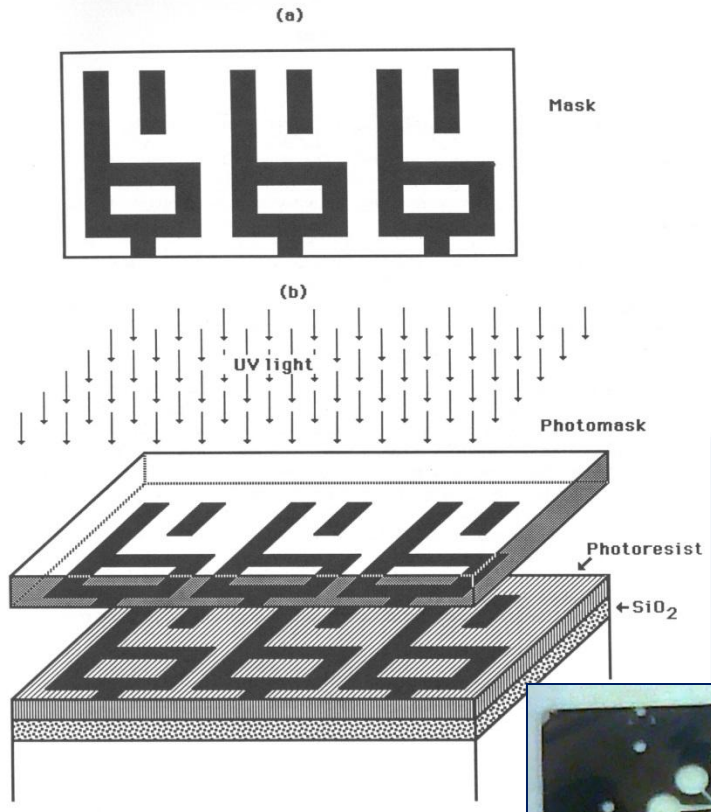




Measurements at

ESFR Grenoble Synchrotron

Optical lithography

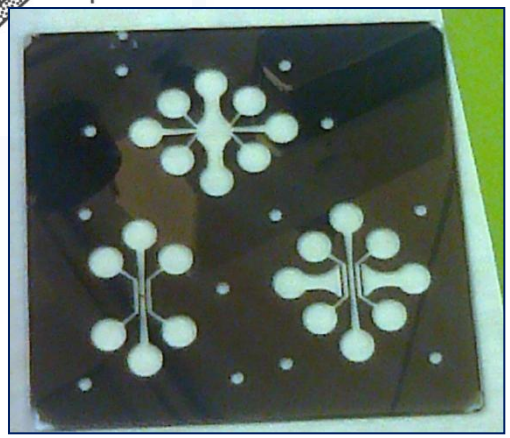


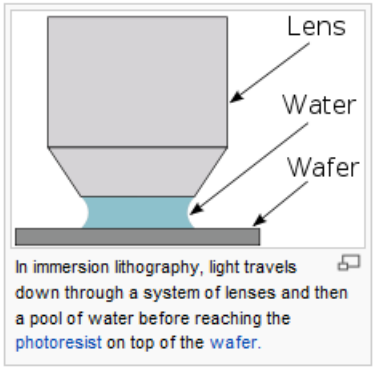
Need a mask!

PARALLEL PROCESS

- resist: sensitive to UV light (thickness: 100 nm- mms)
- mask: quartz and Cr film
- exposure: UV
- development

IMMERSION LITHOGRAPHY



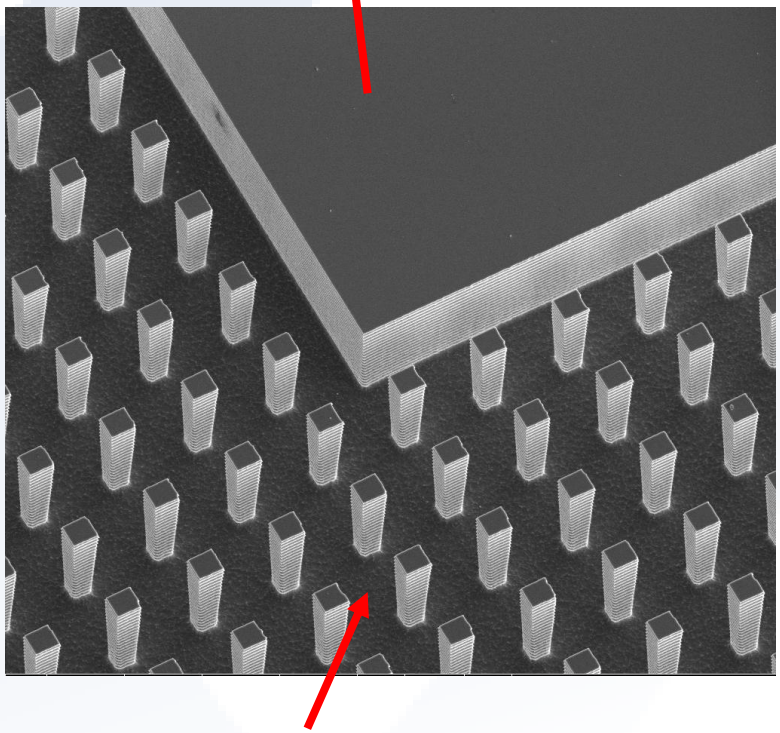


In immersion lithography, light travels down through a system of lenses and then a pool of water before reaching the photoresist on top of the wafer.

DOWN TO 35 NM

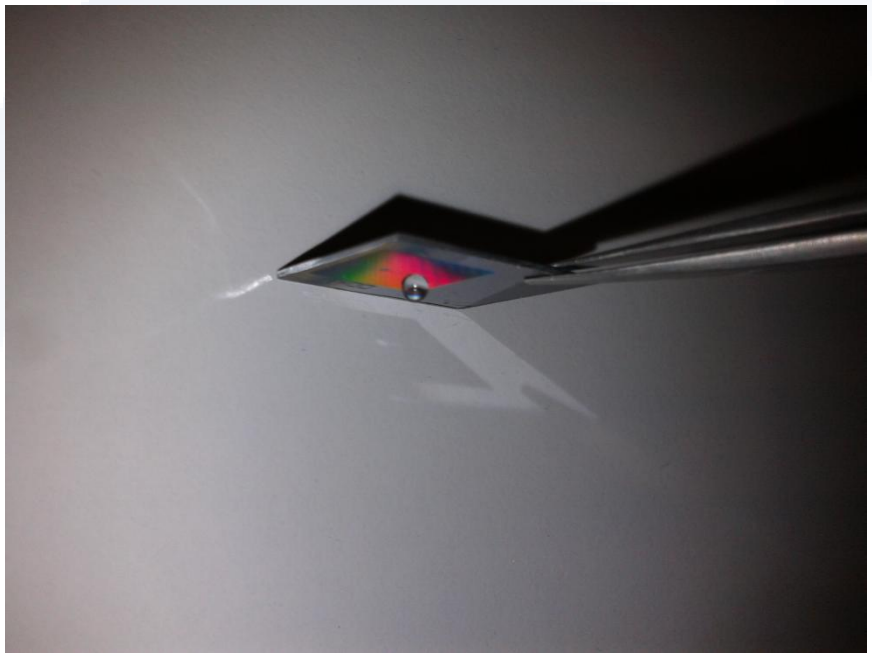
Superhydrophobic liquid sample holder

HYDROPHILIC AREA (anchor point)



SUPERHYDROPHOBIC
(θ>150°; roll off angle <4°)

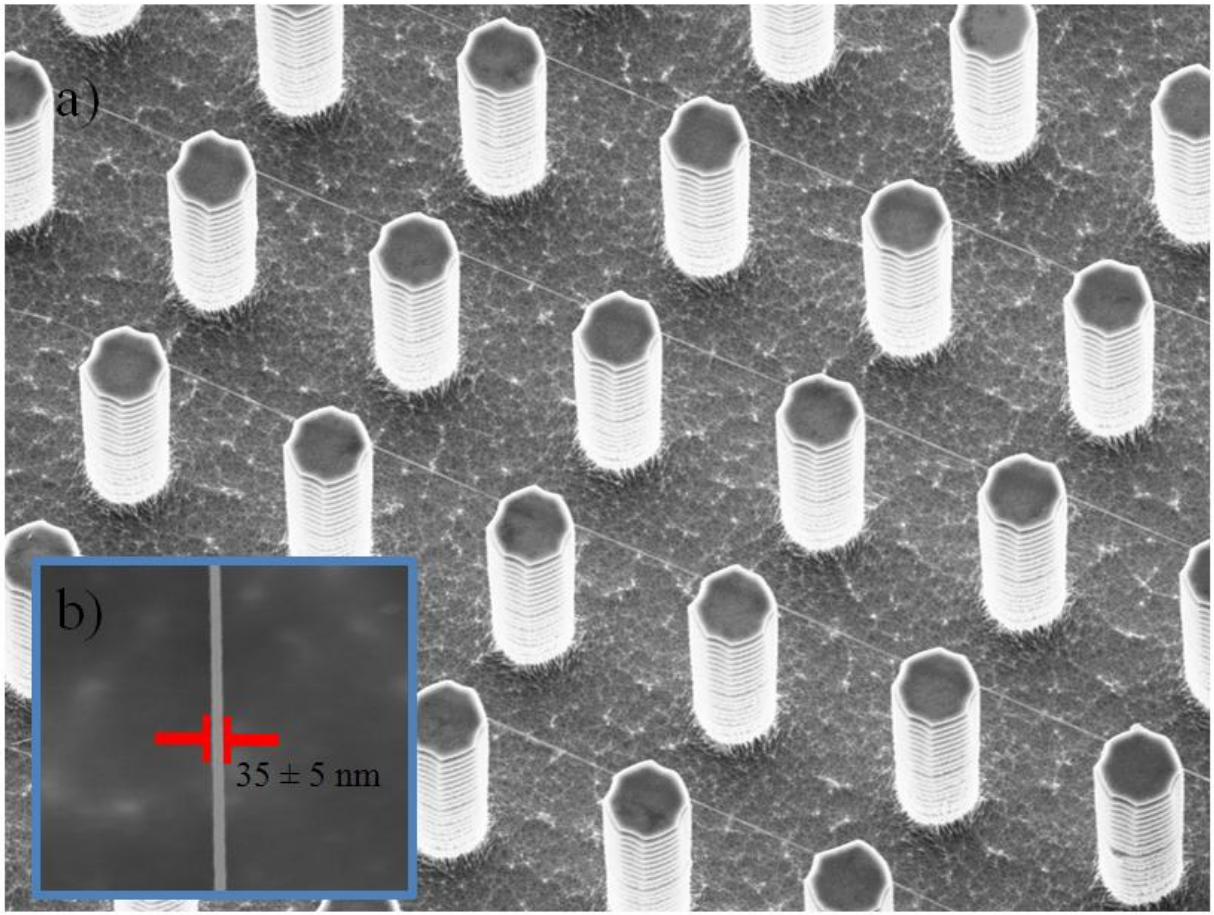
Pillars side: 5μm; pitch: 14μm



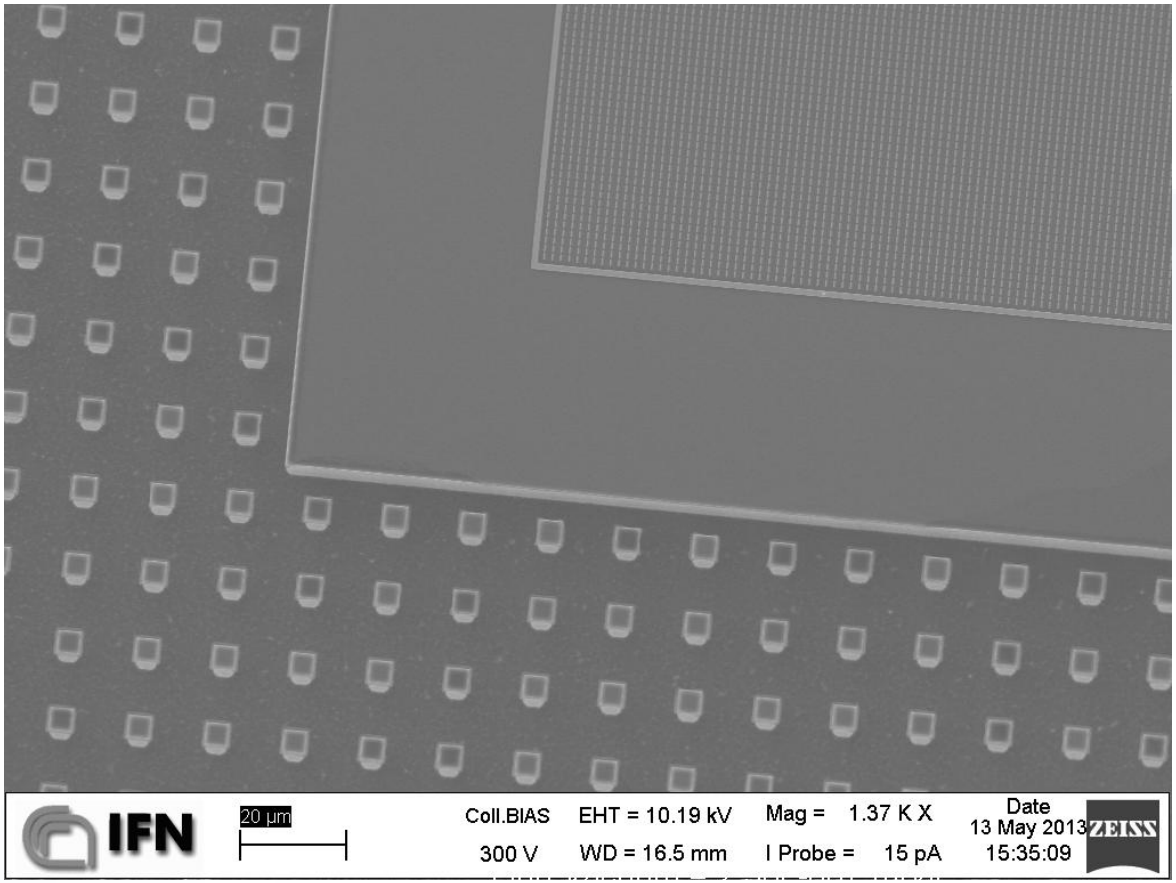
Upside down drop!

Superhydrophobic liquid sample holder

Collaborazione con Dip. Fisica del Policlinico A. Gemelli



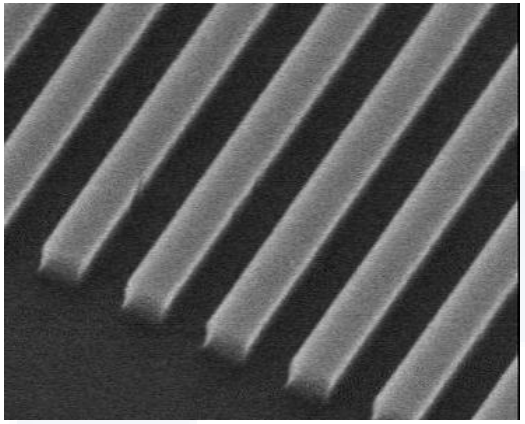
Plasmonic midinfrared biosensors

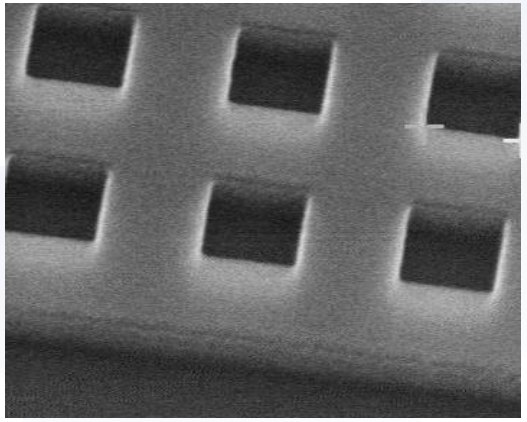


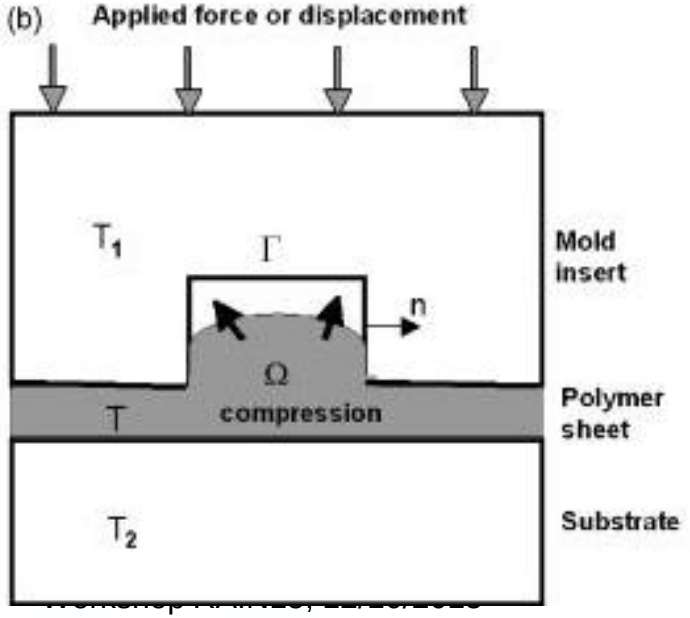
Nanoimprinting

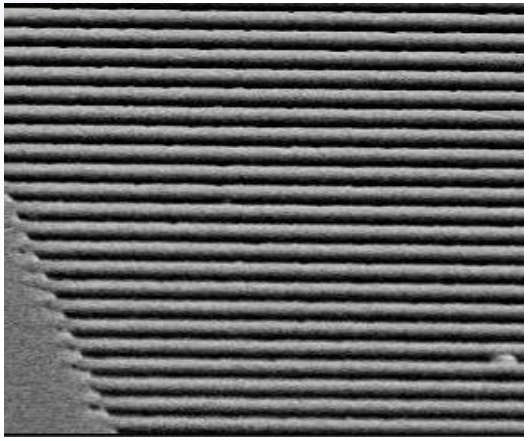
T_g: 90-200°C P: 50-130 bar

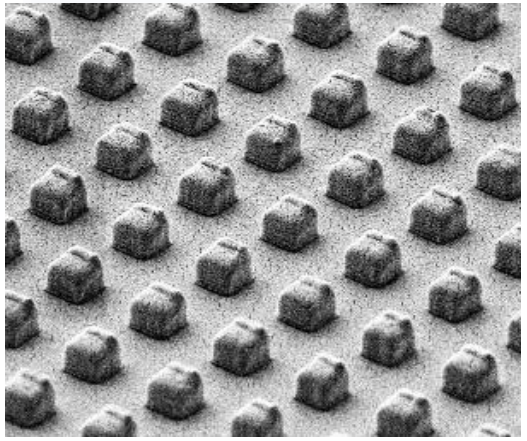
Si etched master







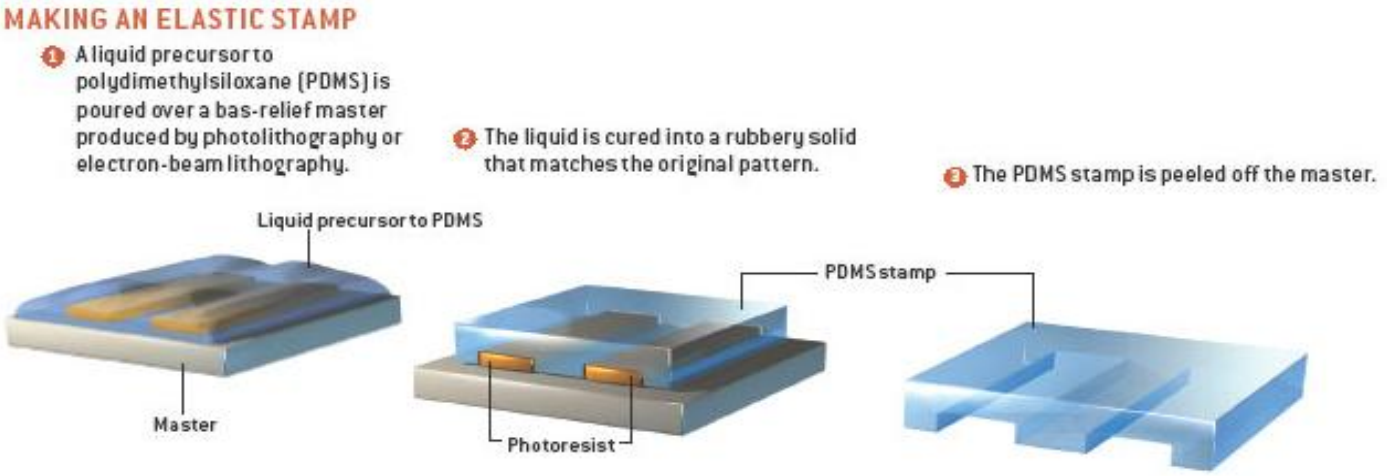


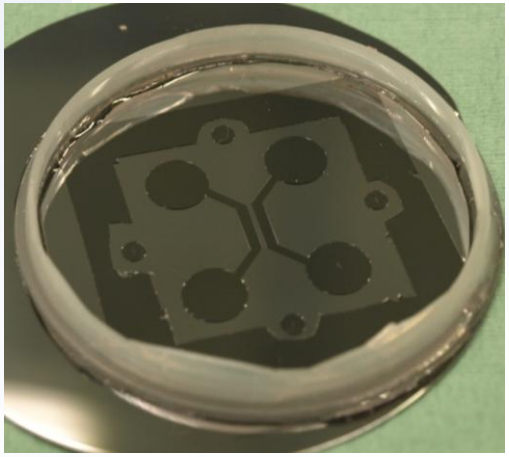


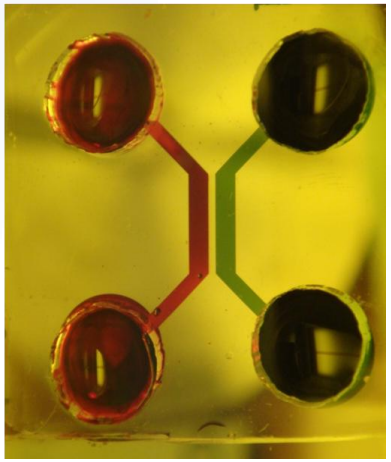
PS nanoimprinted petri

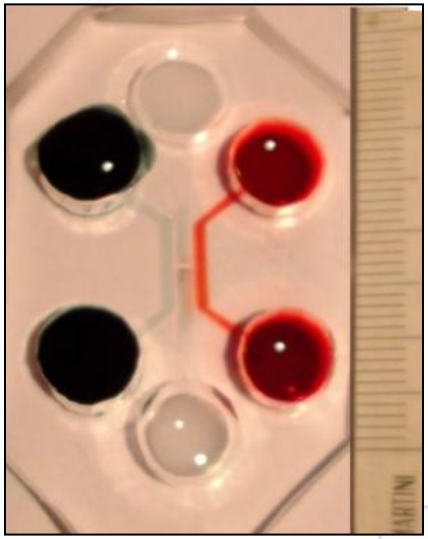
PE nanoimprinted coverslip

Soft Lithography

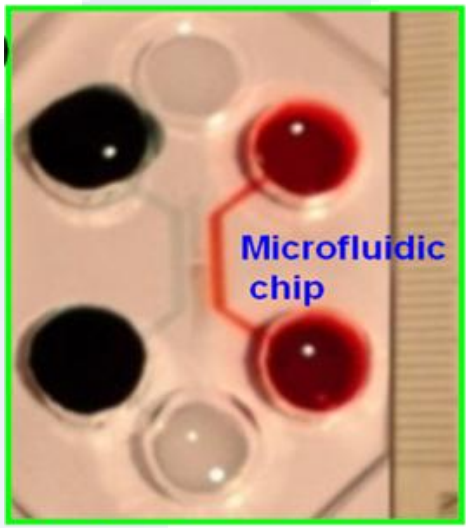


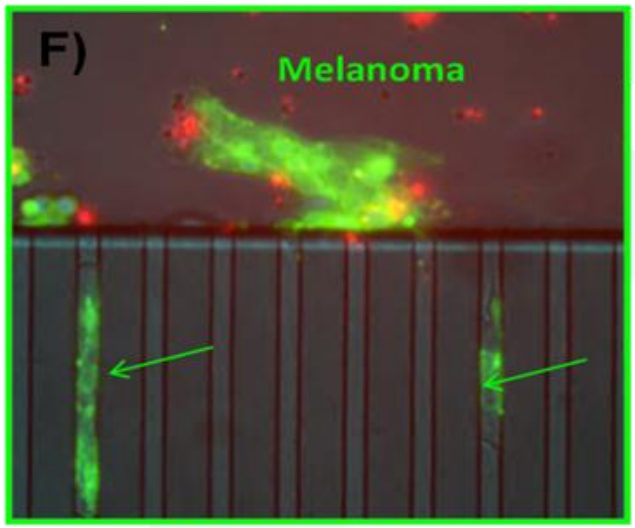


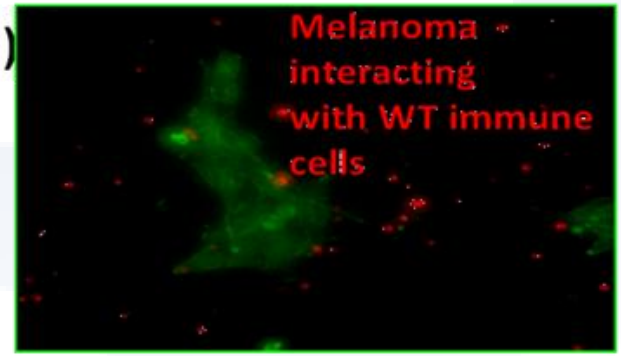


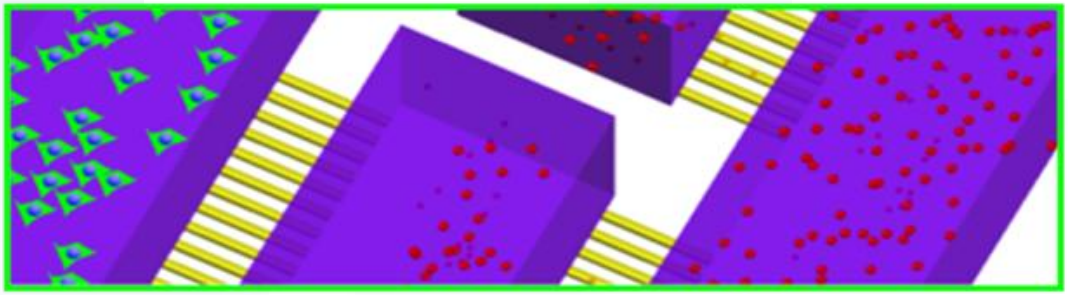


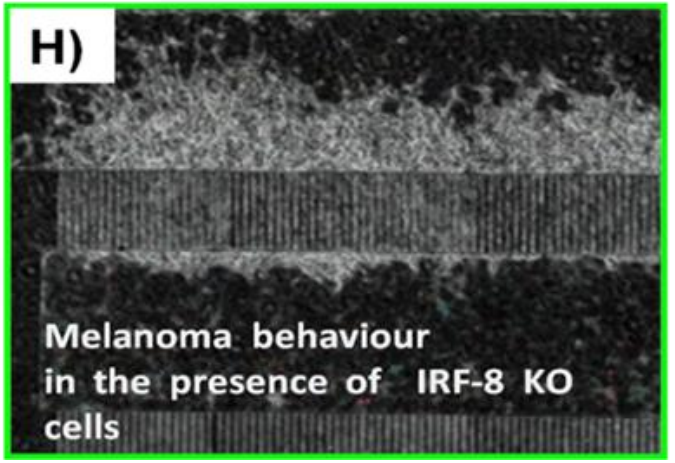
microfluidic co-culture chip











GRAZIE PER L'ATTENZIONE!

annamaria.gerardino@cnr.it