UNIVERSITÀ
DEGLI STUDI
DI PALERMO

ELECTRONICS GROUP ACTIVITIES

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Outline

- Introduction
- Facilities and activities at UNIPA
  - Clean room
  - Resistive switching memory devices
  - Thin film deposition and characterization
  - Photovoltaics
  - Microwave Electronics Lab activities
  - Ultrafast and Terahertz spectroscopy Laboratory (UFL) activities
  - Characterization of Silicon Photomultipliers (SiPM)
  - Characterization of Silicon Carbide UV photodetectors
  - Photoplethysmography system with SiPM
  - LiDAR with SiPM
- Conclusions

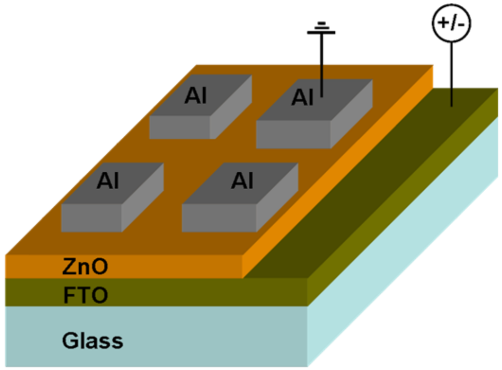
Clean room

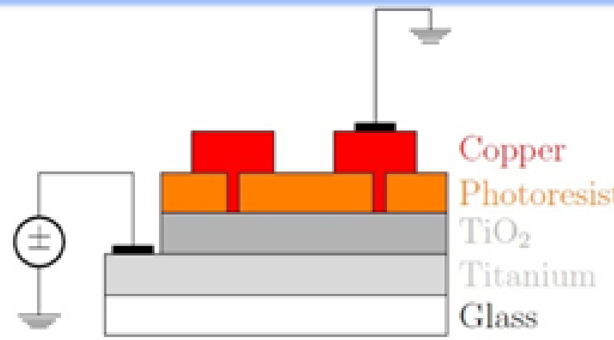
Class 100 clean-room facility includes:

- Electron beam thin film deposition system;
- RF sputtering station;
- Reactive ion etcher;
- Ion beam etcher;
- Dedicated vacuum thermal evaporator with criogenic pump, 5 evaporant sources, 3 crystal thickness monitors for co-evaporation and movable metal shadow mask for molecular organic devices;
- Glove box;
- Quadrupole mass spectrometer;
- Programmable spinner;
- Oven and hot plate;
- Microprobe station;
- Ultra pure water and nitrogen generators.

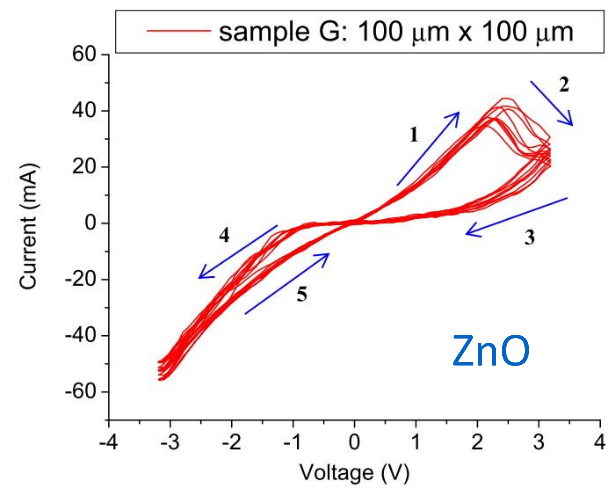
Resistive switching memory devices

Device structure

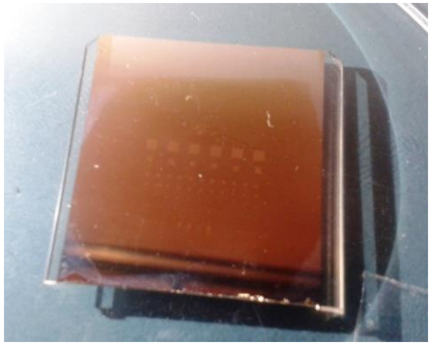




- **Fabrication:**
  - Metal oxide growth by Pulsed Laser Deposition (PLD) and anodizing
  - Laser lithography
    - Device sizes: 1×1 to 300×300 μm^2



- **Material systems:**
  - FTO/ZnO/Al
  - FTO/VO_2/Al
  - Ti/TiO_2/Cu



Ion Plating Plasma Assisted (IPPA) deposition system

IPPA deposition system

- IPPA system for thin film deposition by vacuum Physical Vapor Deposition, able to produce several types of thin film coatings (metallic and dielectric) with the desired chemical, physical and structural properties;
- Multi-crucible Electron Gun and Joule effect thermal evaporation sources that can be used singularly or in co-evaporation for preparation of binary or ternary compounds;
- Reactive and Non-reactive Plasma generation within the chambers
  - Sputter cleaning of substrates;
  - Thin film deposition at low temperature;
- Real time thin film thickness measurement during the growth phase by means of quartz crystal microbalance;
- Vacuum system composed of a rotary pump (oil-free) and a cryogenic pump capable to reach together a high vacuum of about $5x10^{-6}$ torr;
- Thin film thickness range: 10 nm ÷ 2 μm.

Mechanical and Optical characterization

Prism coupling system made by Metricon able to measure thin films refractive index (accuracy ± 2×10^{-4}) and thickness (derived using the Wentzel-Kramers-Brillouin approximation).

Thin film thickness measurements with the surface profiler DekTak 3030.

Specifications:

Minimum vertical resolution: 0.1nm/7.5 µm

Scan length: 50 µm – 50 mm

Stylus Tracking Force: 1-30 mg

Maximum Sample Thickness: 45 mm

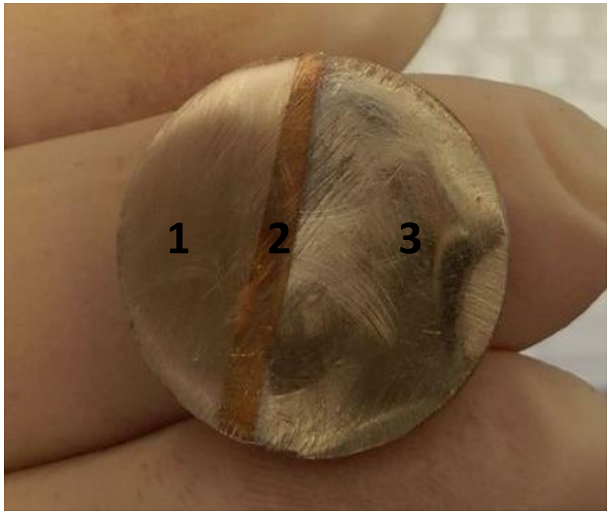
Thin films deposition and characterization

TiO_2 thin films for protection and conservation of cultural heritage

Photo taken inside the chamber during a deposition process of titanium thermally evaporated by means of electron gun, in plasma of Argon, Oxygen and Nitrogen.

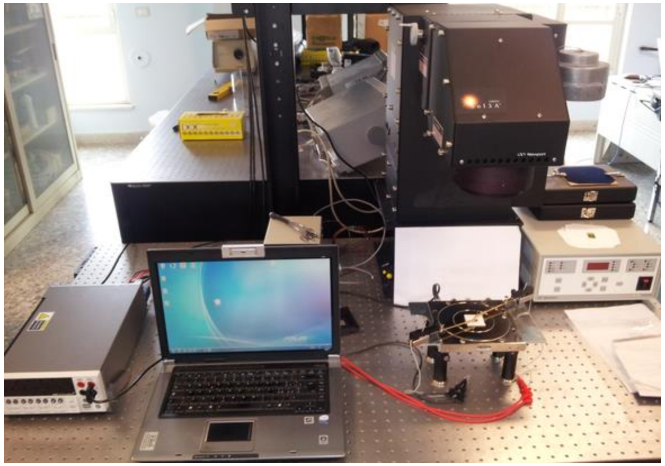
Bronze coin, partially treated with TiO_2 thin film, exposed to air for 30 days :

- part 1 (cleaned shortly before to take the photo) is the real aspect of bronze;
- part 2 is the aspect of oxidized bronze;
- part 3 is the aspect of bronze treated with a 100-nm-thick titanium dioxide thin film that is not changed despite the air exposition.

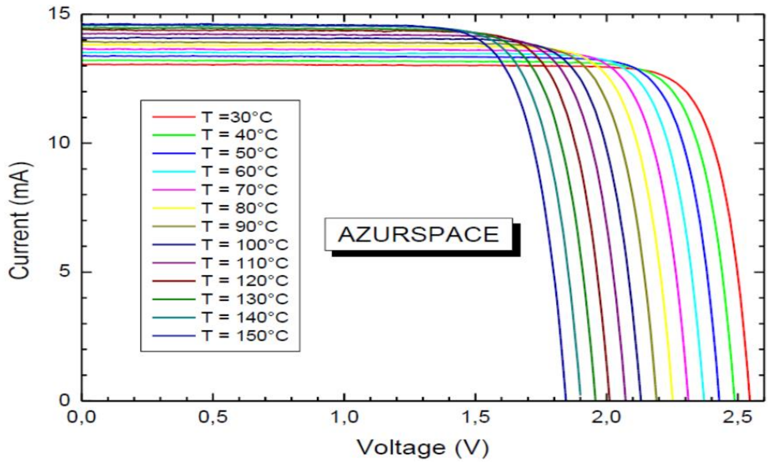


Electrical characterization of photovoltaic cells

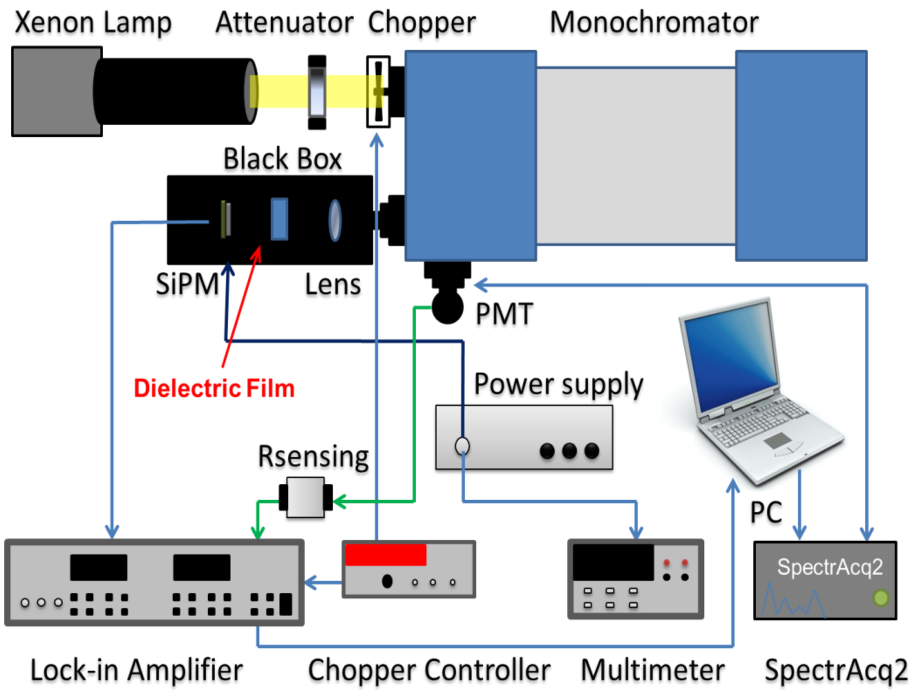
International standard ASTM E948-09: *Standard Test Method for Electrical Performance of Photovoltaic cells using reference cells under simulated sunlight*



Experimental setup at LOOX

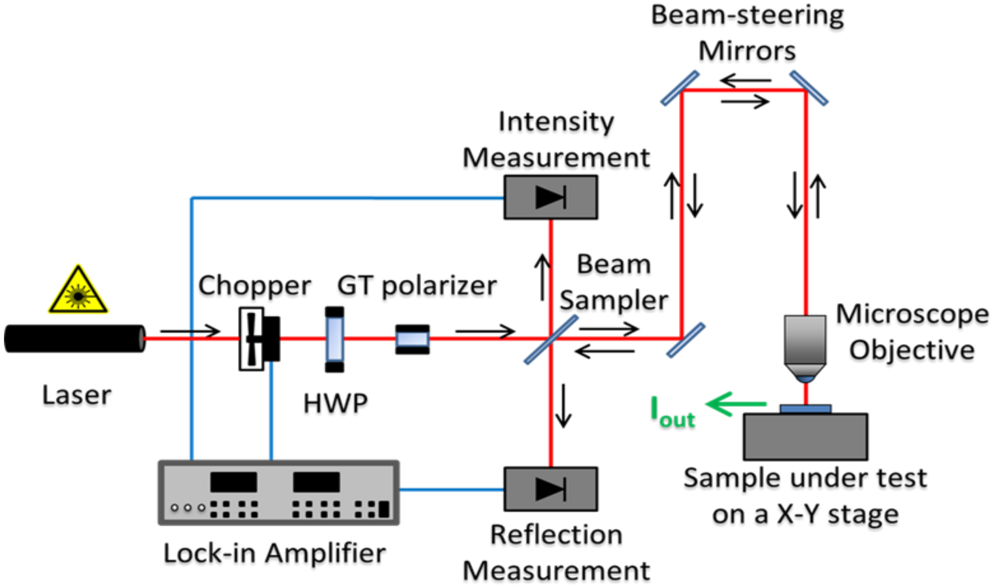


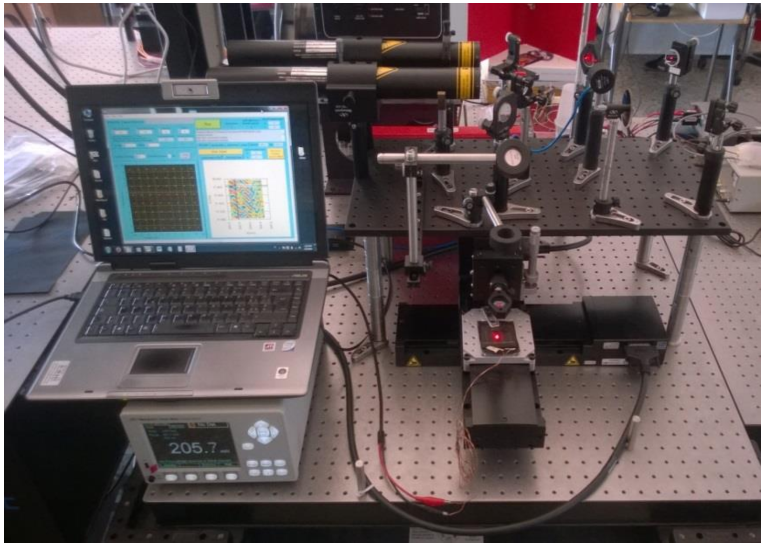
Optical characterization of photovoltaic materials



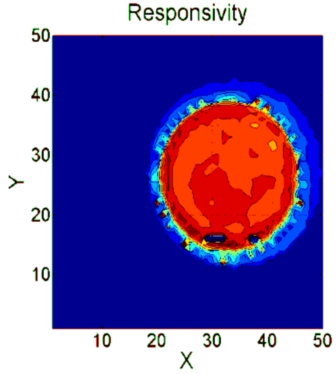
I-V measurements of a multi-junction solar cell carried out by using **a Oriel® Class AAA solar simulator at 1 sun concentration** and at varying temperatures.

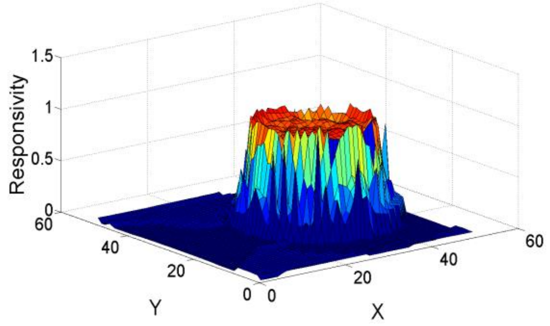
Laser Beam Induced Current (LBIC) measurements of solar cells





Sketch and photograph of the experimental setup for LBIC measurements at LOOX



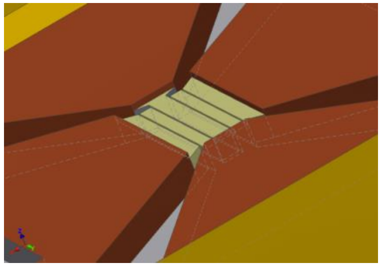


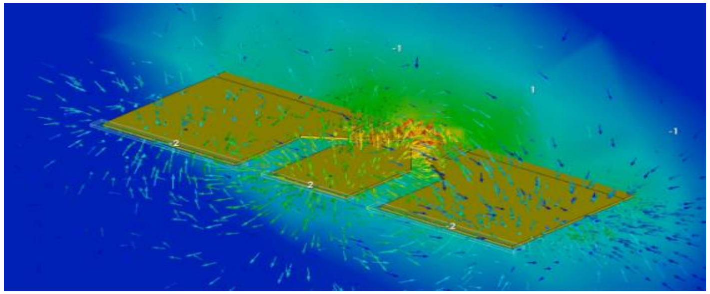
Photoresponse scan of an experimental dye sensitized solar cell via LBIC measurements

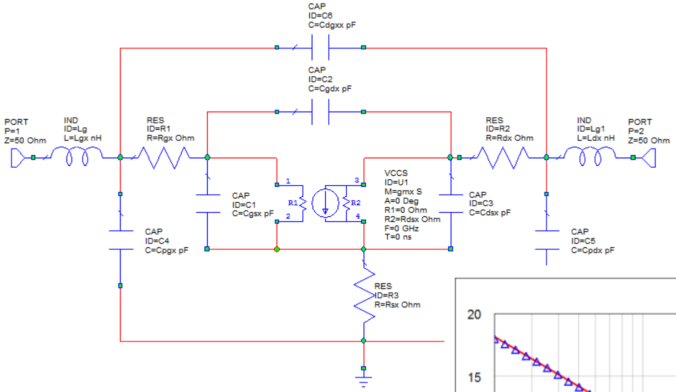
Microwave Electronics Lab (LEM)

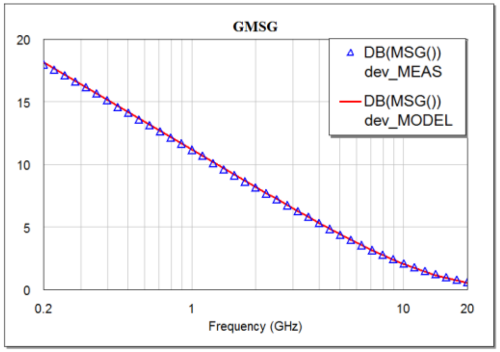
Competences:

- Linear and Nonlinear characterization of microwave devices;
- Linear and Nonlinear circuit and behavioral modeling of microwave devices;
- Noise characterization and modeling of microwave devices;
- Algorithms and methods for analog microwave circuit/EM simulation;







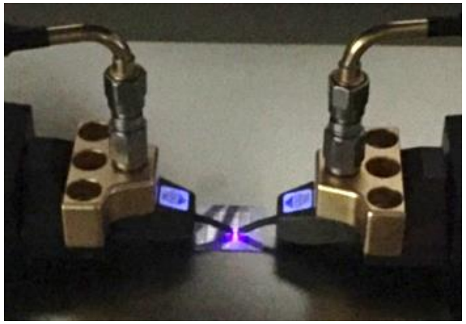


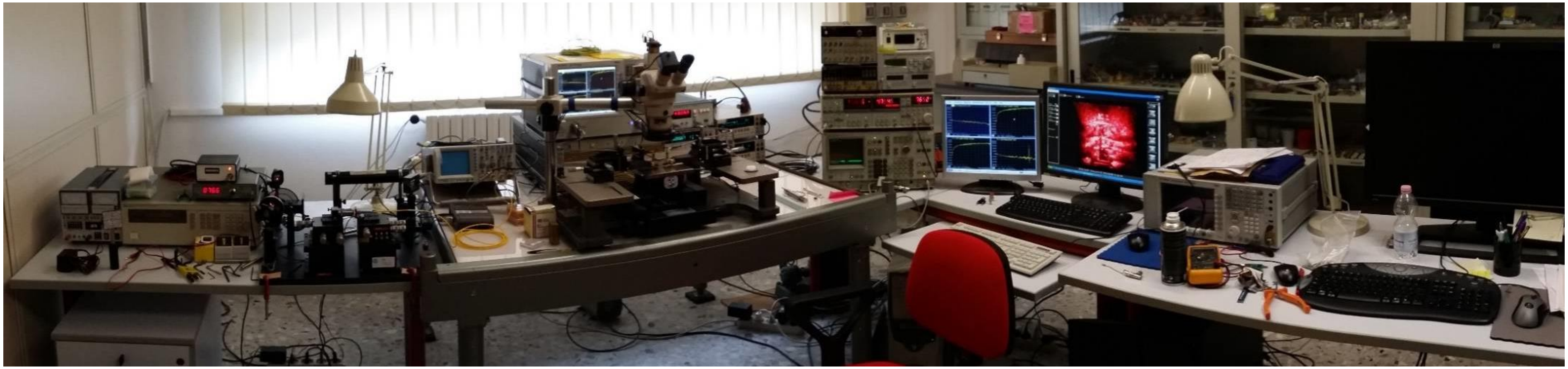
- Computer-assisted design of microwave circuits and systems;
- Custom, high-efficiency, simulation and design techniques for high-stability free-running and injection-locked oscillators (ILO) development;
- Design and realization of passive and active HMIC;
- Development of custom, automated, RF/uW test-benches.

Microwave Electronics Lab (LEM)

Equipment for Microwave measurements

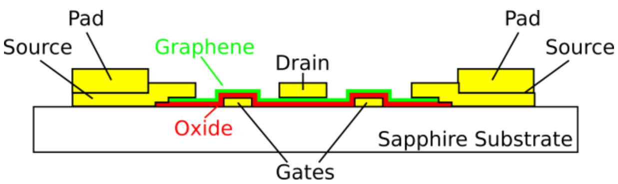
- Vector Network Analyzers (LF, RF and Microwave to 50GHz);
- System for noise figure/parameters measurements (to 26.5GHz);
- Wafer-probe station (with probes to 50GHz);
- Coaxial and microstrip Transistor Test-Fixtures (to 26.5GHz);
- Synthesized signal generators, Spectrum analyzers, Power meters, etc.;
- Source-Measure Units (SMU) and precision DMMs for device biasing/characterization (DC/PULSE);
- Coaxial and waveguide active/passive components;
- Components for optical benches development.

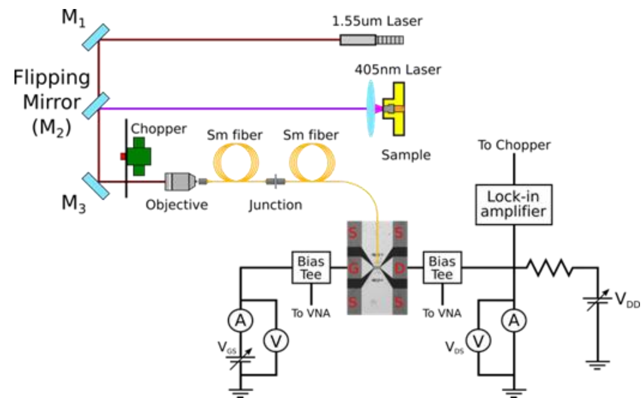


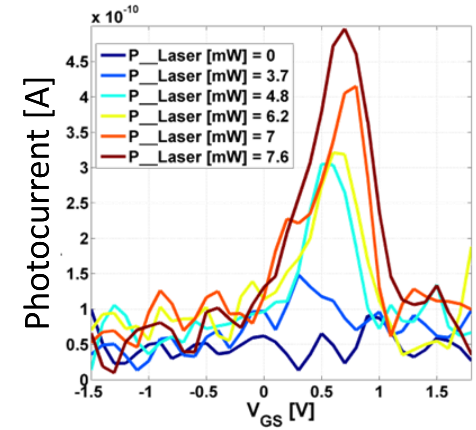


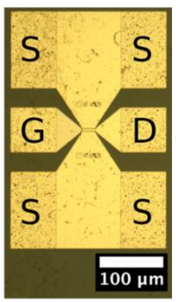
Main activities underway

- Design and electro/optical characterization of Graphene Field Effect Transistors (GFETs)



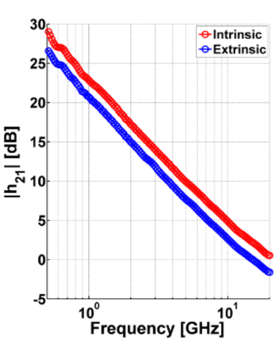


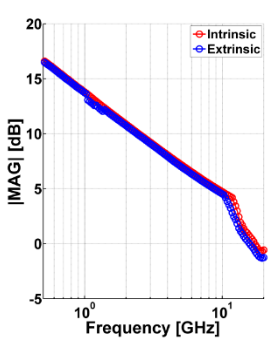




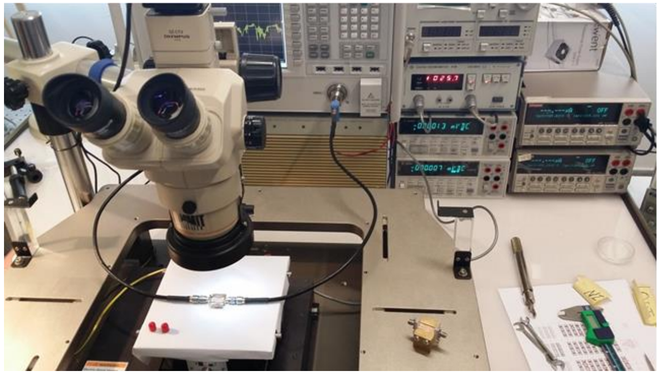
Optical characterization

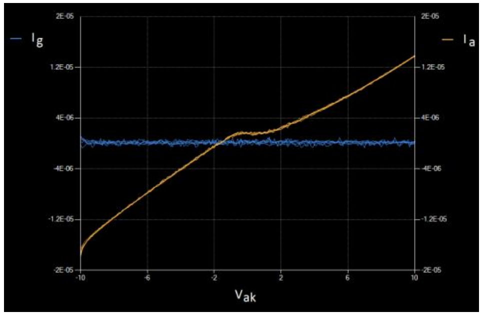
RF measurements

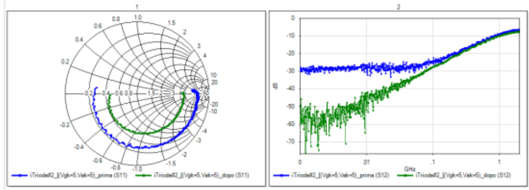




- RF/Microwave characterization and modeling of iTRIODES (in cooperation with STM)







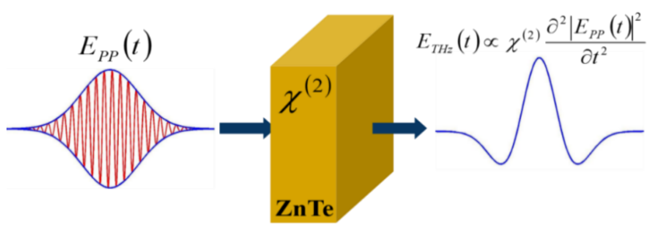
Ultrafast and Terahertz spectroscopy Laboratory (UFL)

Mediterranean Center for Human Health Advanced Biotechnologies (CHAB)

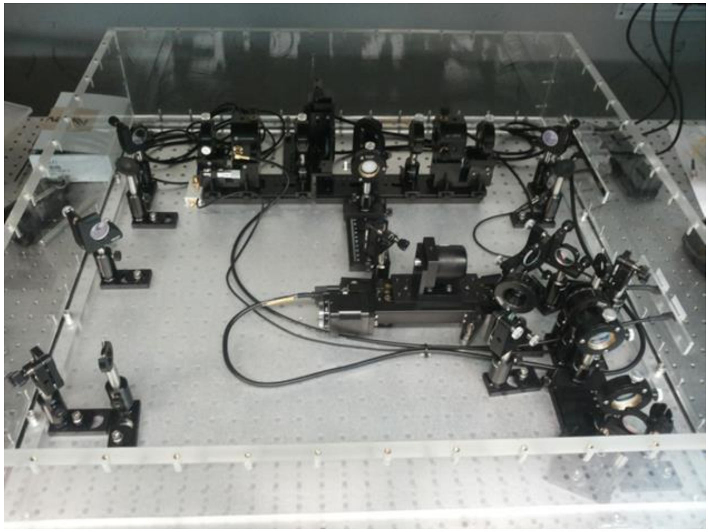
CHAB

Equipment

- fs Ti:Sapphire Laser: Spectra-Physics SOLSTICE with MAI-TAI SP oscillator
- THz-TDS setup based on photoconductive antennas and/or ZnTe nonlinear crystals



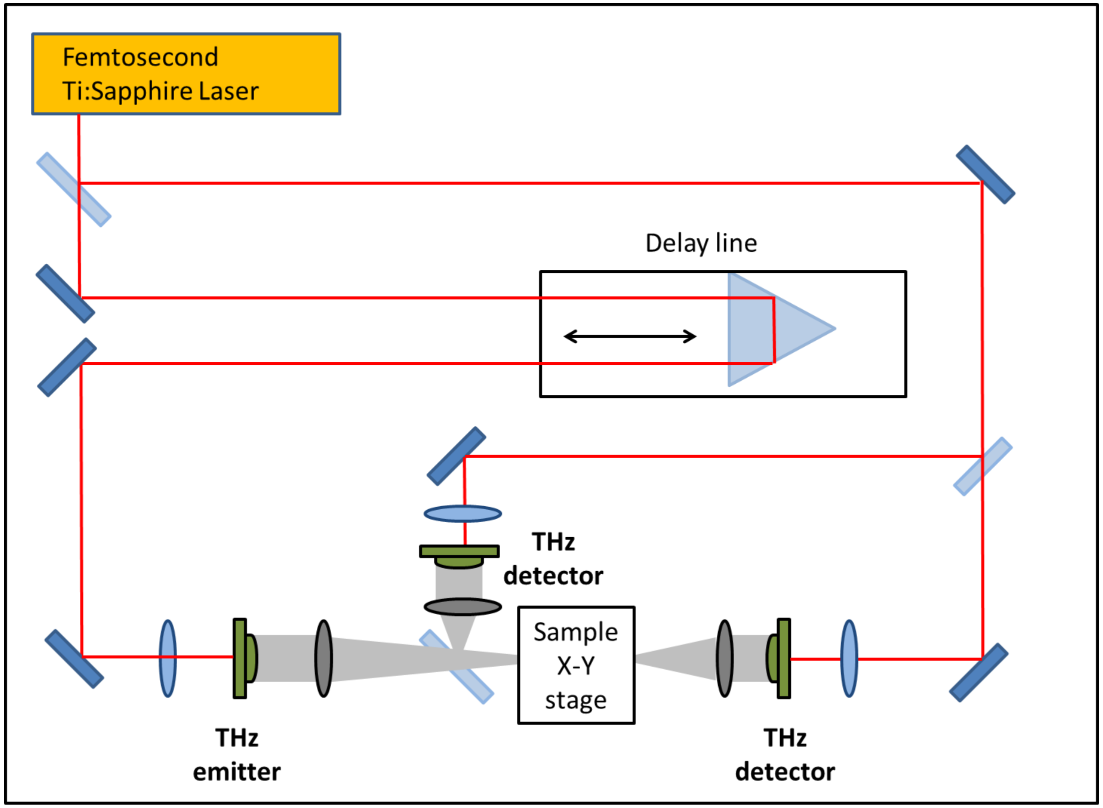
	Solstice-50F	Solstice-100F
Pulse Width[2]	<50 fs	100 fs
Repetition Rate[3]	1 kHz, 5 kHz, 10 kHz	
Average Power	>3.5 W	
Pulse Energy	>3.5 mJ, >0.7 mJ, >0.35 mJ	
Wavelength[4]	795–805 nm	780–820 nm
Operating Temperature Range	±5°C	
Pre-Pulse Contrast Ratio[5]	1000:1	
Post-Pulse Contrast Ratio[6]	100:1	
Stability[7]	<0.5% rms over 8 hours	
Transform Limit[8]	<1.5 x transform limit	
Spatial Mode	TEM_{00}	
Beam Diameter (1/e²)	7 mm (nominal)	
Polarization	Linear Horizontal	



Ultrafast and Terahertz spectroscopy Laboratory (UFL)

THz Time-Domain Spectroscopy (TDS) system by **EKSPLA** (http://www.ekspla.com) employs **photoconductive antennas** based on low-temperature grown (LTG) GaAs.

- Single-cycle pulses (<3 ps) of THz radiation are detected after propagation through a sample and an identical length of a free space.
- By comparing the Fourier transforms of such temporal pulses, it is possible to recover the **absorption spectra (the so-called "fingerprint")** of the sample under investigation.
- **THz imaging**, both in **transmission** and **reflection** configurations, can be achieved by transversally moving the sample under test.

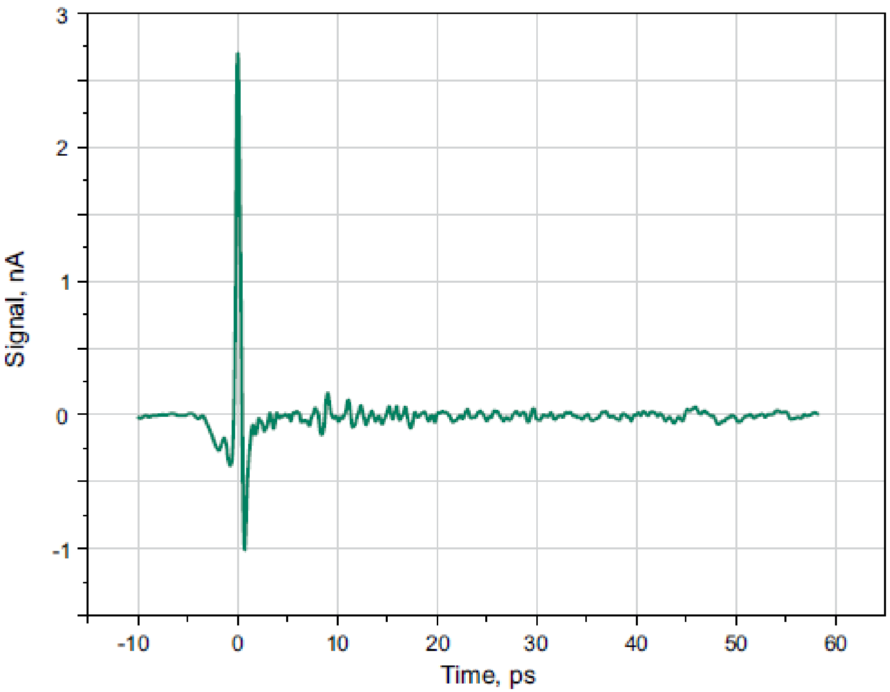


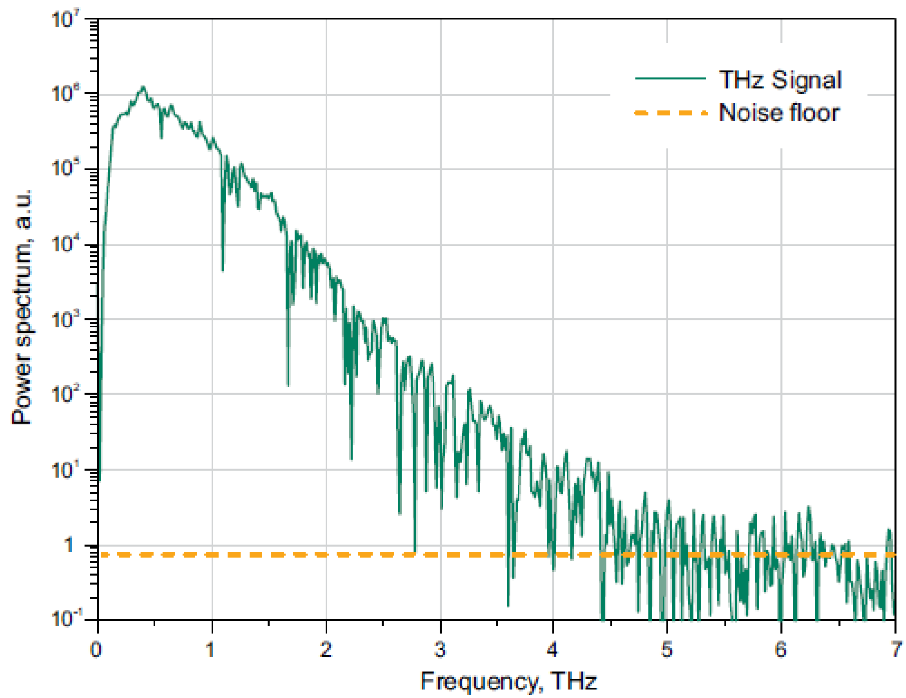
EKSPLA

The setup is enclosed within a **nitrogen purged box** as to decrease THz absorption and distortion due to the ambient humidity.

Specifications

- Useable spectral range 0.2 – 3.5 THz (6-100 cm^{-1})
- Typical spectral resolution < 25 GHz
- Power S/N ratio more than to 10^6:1 @0.4 THz
- Spatial resolution for THz imaging < 300 μm

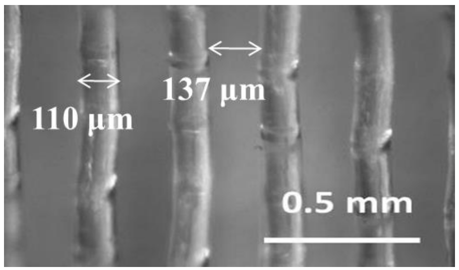


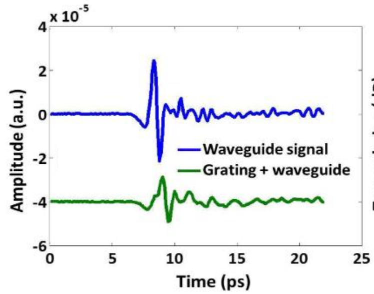


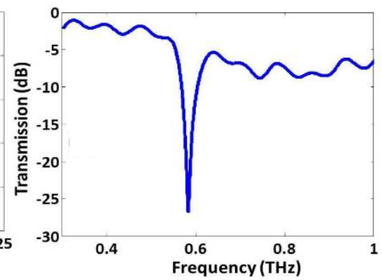
Typical THz pulse waveform and Fourier-transform spectrum

Main activities underway

- Characterization of THz devices for next-generation systems based on Two-Wire waveguide Transmitter (TWT)

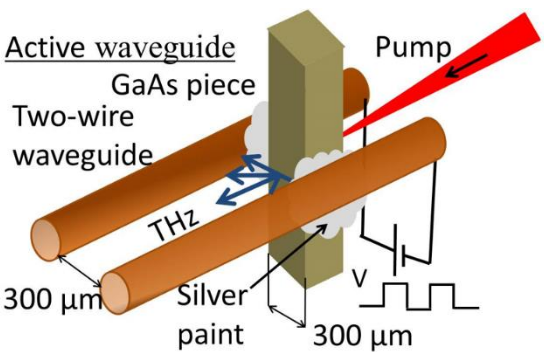






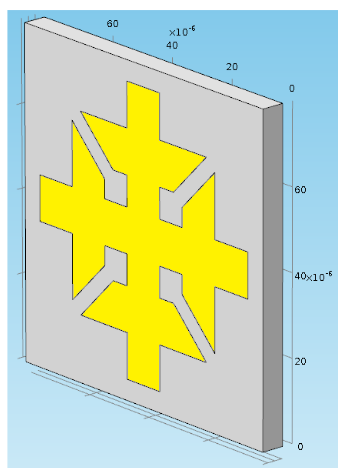
Notch filtering realized via plastic mesh (Bragg grating)

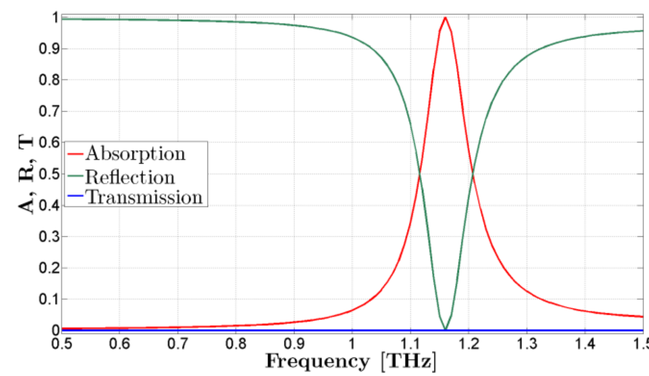
in cooperation with INRS (Canada)



M. K. Mridha et al.
Optics Express 22, 22340 (2014)

- Notch filtering in the THz range via narrow-band metamaterial absorbers

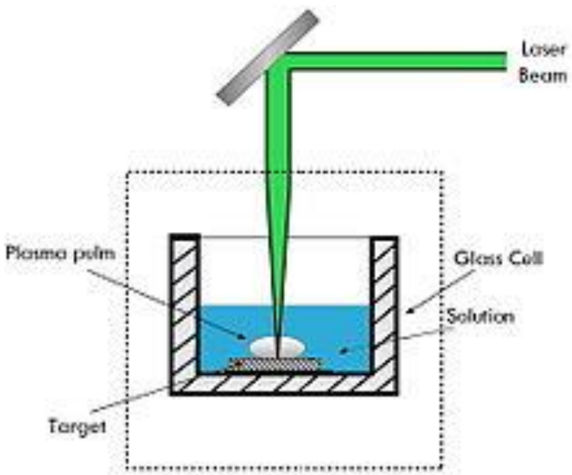


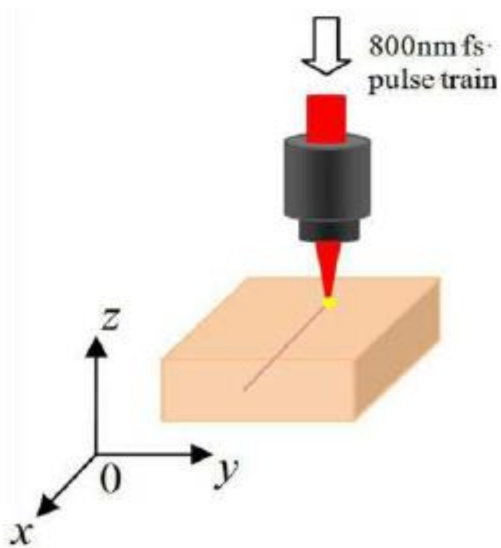


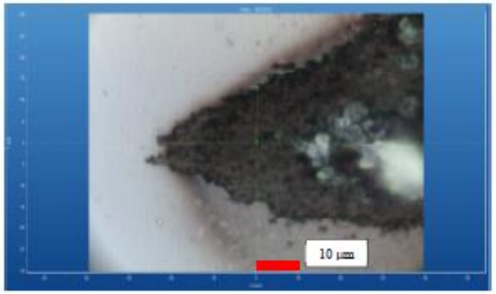
in cooperation with the University «La Sapienza» of Rome

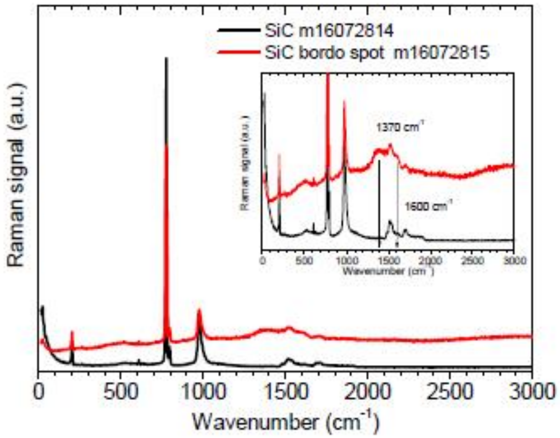
Main activities underway

- Laser ablation
- Laser direct writing
- Laser-induced growth of epitaxial graphene on SiC





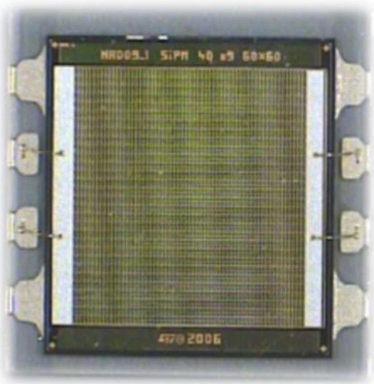


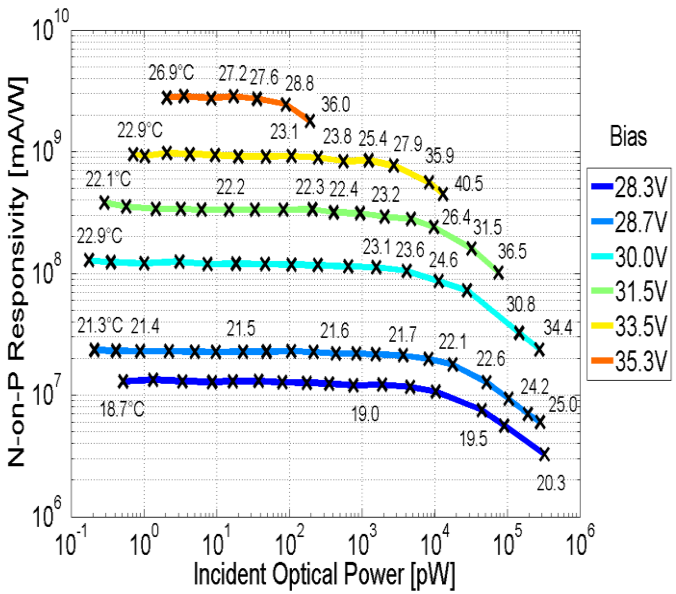


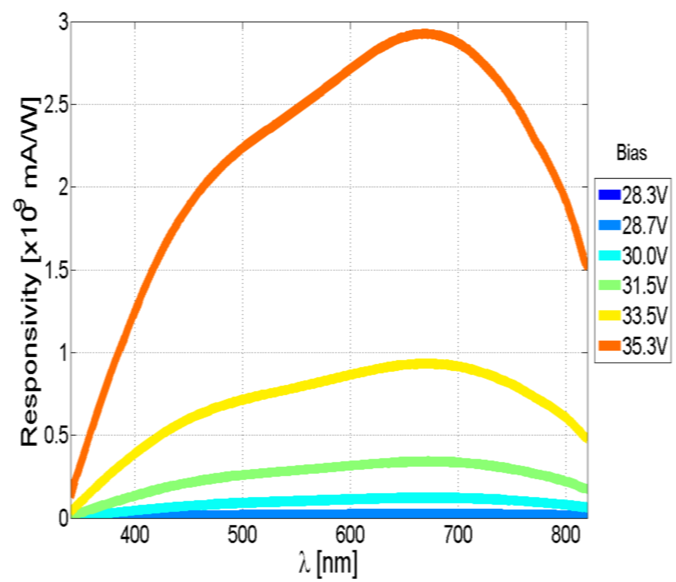
Characterization of Silicon Photomultipliers (SiPM)

LOOX performs a complete electrical and optical characterization, in continuous wave regime, of N-on-P and P-on-N classes of silicon photomultipliers (SiPMs).

Responsivity measurements, performed with an incident optical power down to tenths of pW, at different reverse bias voltages, on a broad (340-820 nm) spectrum and monitoring the device temperature, were carried out. The obtained results demonstrate that such novel silicon photomultipliers are suitable as sensitive power meters for low photon fluxes.





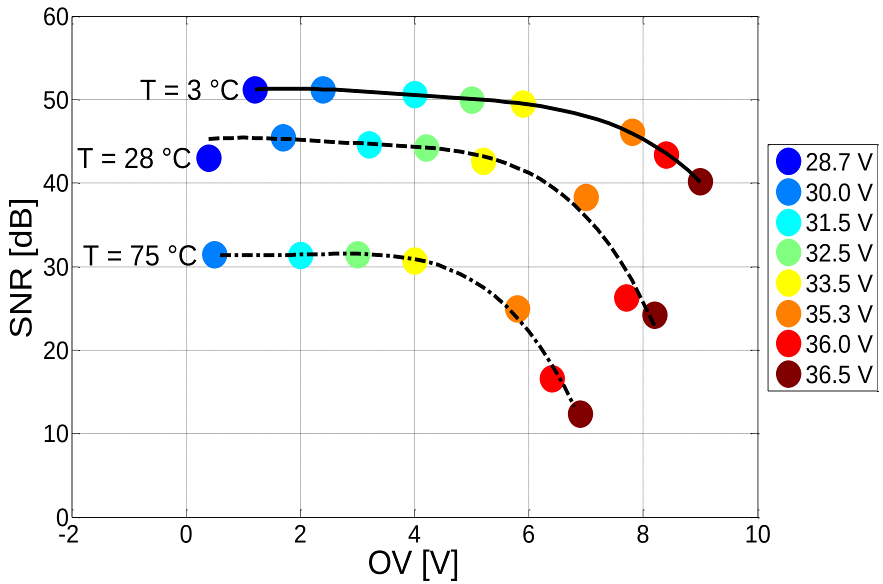


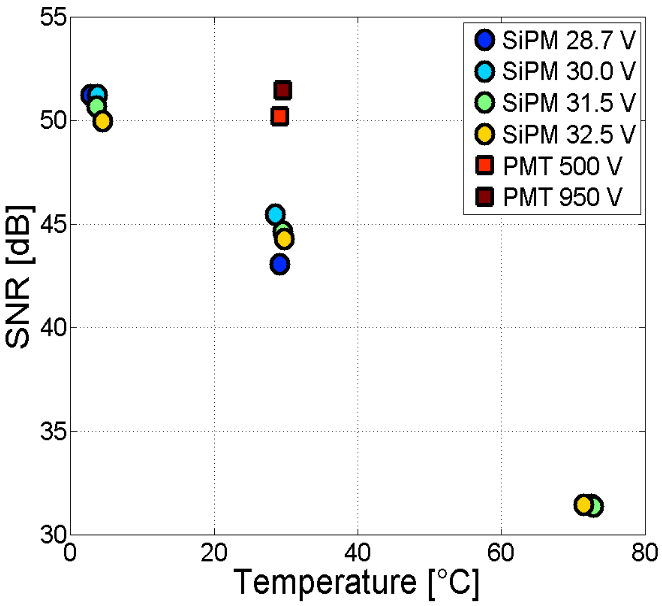
For this activity, LOOX cooperates with the R&D IMS, STMicroelectronics, Catania, Italy.

Characterization of Silicon Photomultipliers (SiPM)

LOOX also performs Signal-to-Noise Ratio (SNR) measurements, in the continuous wave regime, at different bias voltages, frequencies and temperatures and Excess Noise Factor measurements on SiPMs.

A comparison between the SiPM and the photomultiplier tube in terms of SNR, as a function of the temperature of the SiPM package and at different bias voltages has been carried out. Our results show the outstanding performance of this novel class of SiPMs even without the need of any cooling system.





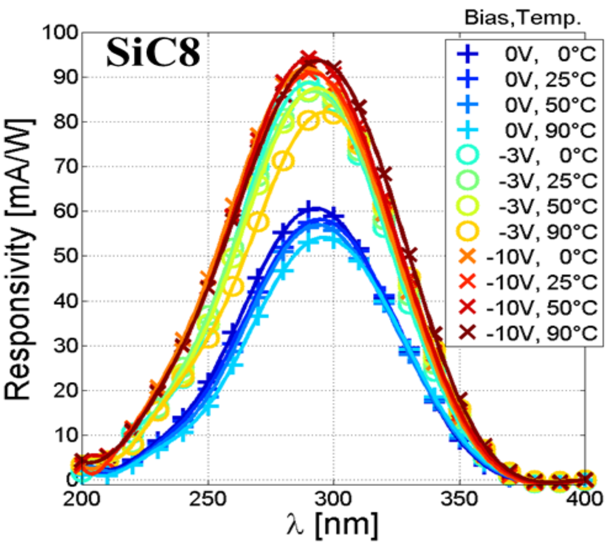
Characterization of Silicon Carbide UV photodetectors

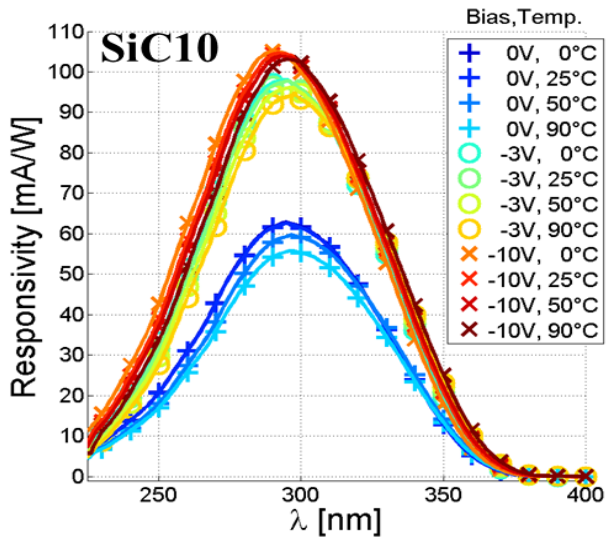
LOOX carried out the characterization of 4H-SiC vertical Schottky UV detectors.

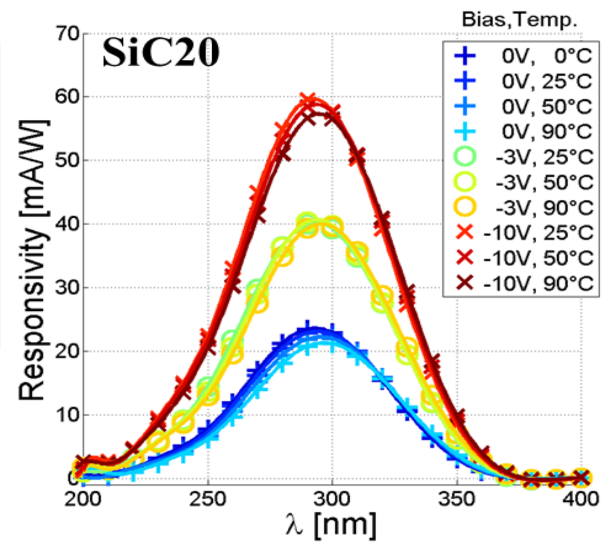
I-V and C-V characteristics, as functions of temperature, were measured in dark conditions.

In addition, responsivity measurements, for wavelengths ranging from 200 to 400 nm, at varying package temperature and applied reverse bias were performed.

A comparison among devices having different strip pitch sizes (SiC8, SiC10, SiC20) has been realized, thus finding the class that exhibits the top performances.







Photoplethysmography measurements

- ***Pulse Transit Time* (PTT):**

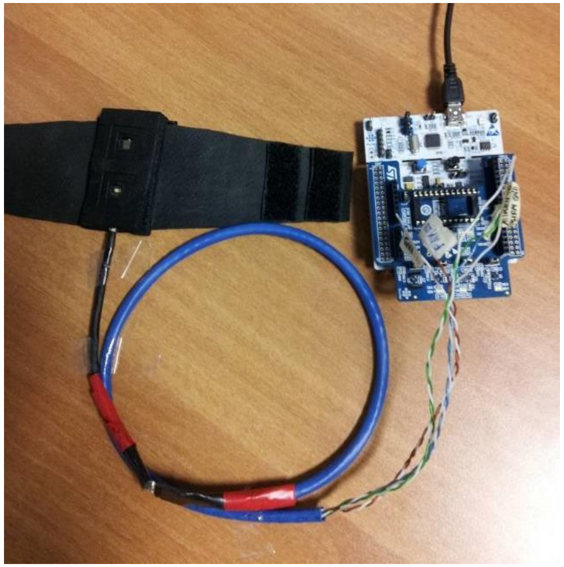
  time it takes the Pulse Pressure waveform to propagate through a length of the arterial tree.

- ***Pulse wave velocity (PWV) and Arterial stiffness*:**

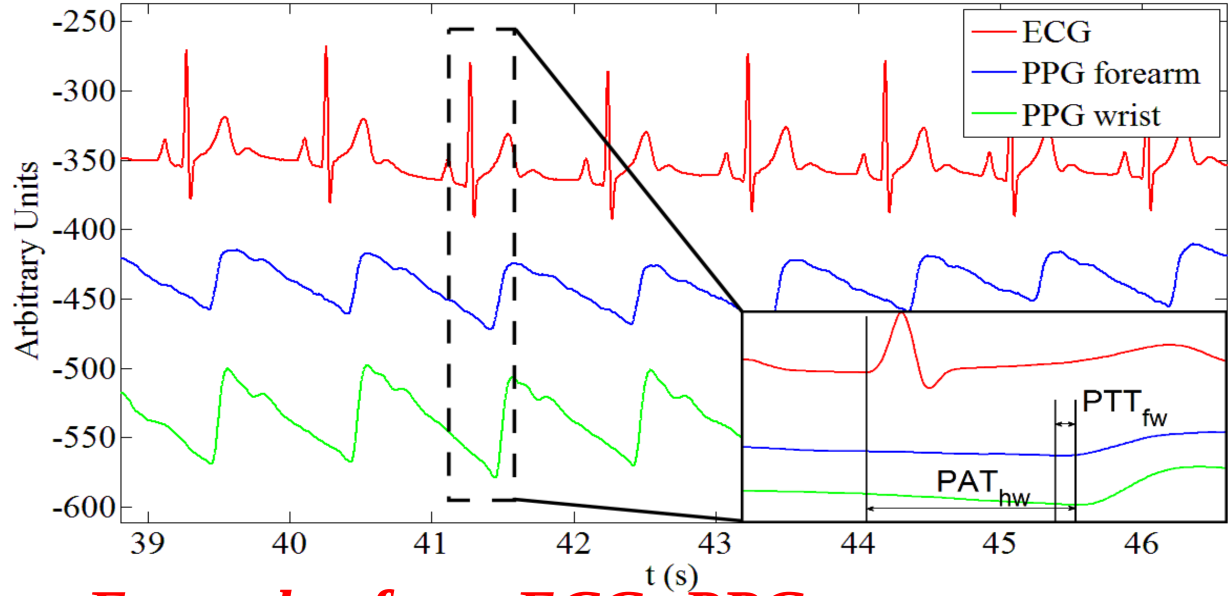
  velocity of the pulse wave through the arterial tree. PWV is used clinically as a measure of arterial stiffness.

- ***Pulse Arrival Time (PAT):***

  time it takes between ventricular contraction occurs and pulse pressure waveform arrive to the observation point.

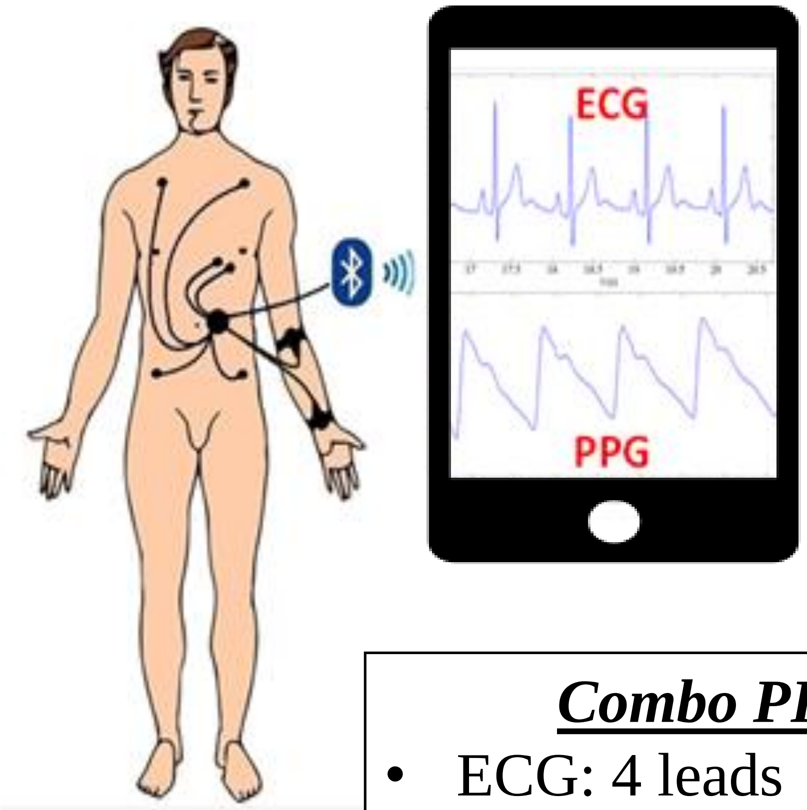


PPG probe



Example of our ECG+PPG measurements

ECG+PPG combo system specifications



PPG – Probes

- ***LED*** : *Wavelength = 940 nm*
- ***SiPM : STMicroelectronics***
  p/n technology, 4871 cells
  $V_{bias} = 30\ V$
- *RC low-pass filter (25 Hz)*
- *Visible-blocking optical filter*

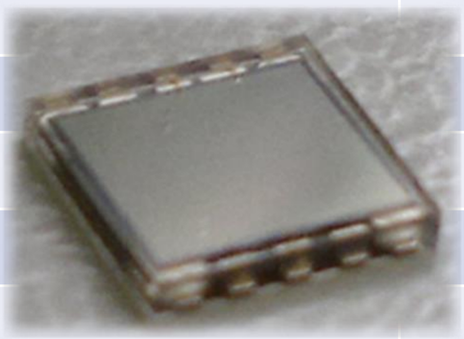
***Combo PPG+ECG* measurement system**

- ECG: 4 leads
- **ADC**: 16-bit Texas Instruments ADS1198
- ARM Cortex M4 **MCU**
- Sampling frequency: 2 kHz
- Data transferred via **Bluetooth**

SiPM vs APD for LiDAR

Si-APD Laser Components SAR500H4	
Breakdown voltage – Operating Bias	175 V – 164 V
Power Consumption	< 150 mW
Package diameter	5.31 mm
Active area diameter	500 µm
Peak responsivity	0.4 MV/W at 905 nm
Bandwidth	20 kHz – 470 MHz
Price	290 €

SiPM STMicroelectronics SPM42H5-60N	
Breakdown voltage – Operating Bias	28 V – 30 V
Power Consumption	< 30 mW
Package dimensions	5 x 5.5 mm^2
Active area dimensions	3.96 x 4.44 mm^2
Number of cells	4871
Fill factor	67.4%
Price (cost of production)	0.50 €



LiDAR with SiPM

2 glass lenses for emission (collimator), beam full divergence = 0.4°

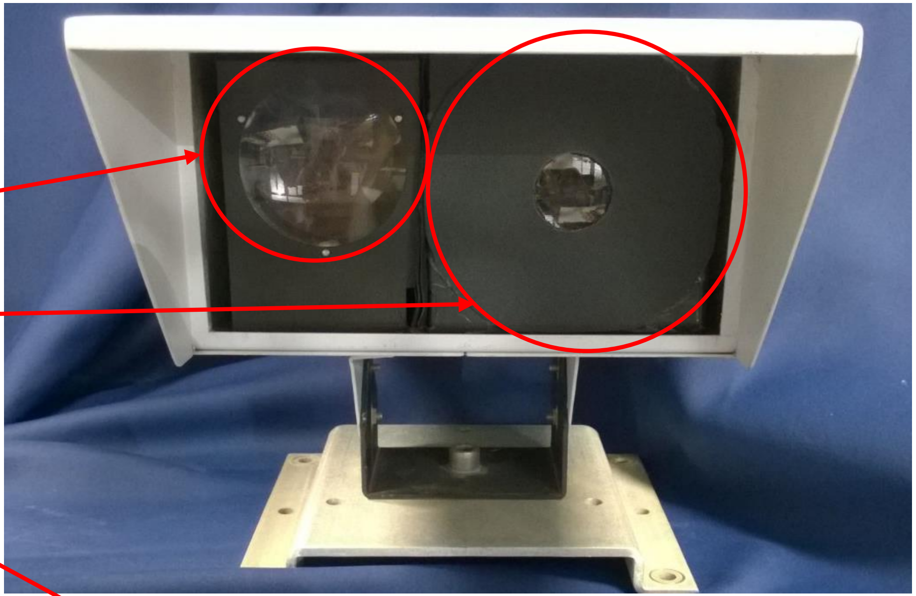
Lens for receiving with diaphragm

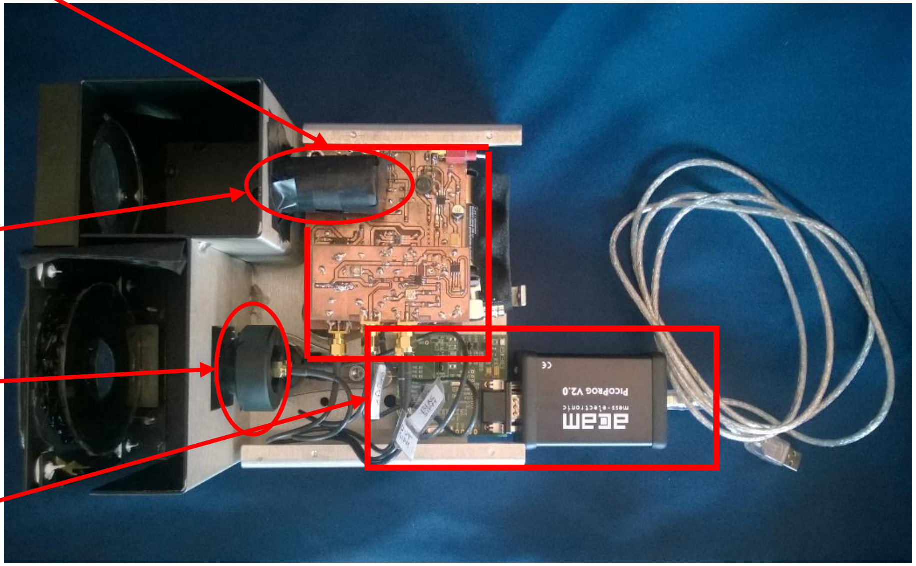
Laser model: Osram SPL LL90_3
Pulse duration: 36 ns
Peak optical power: 70 W
Emission wavelength: 905 nm
Pulse repetition frequency: < 25 kHz
(Laser class 1 IEC 60825-1)

Laser driving circuit + noise-removal filters + comparator + battery power supply

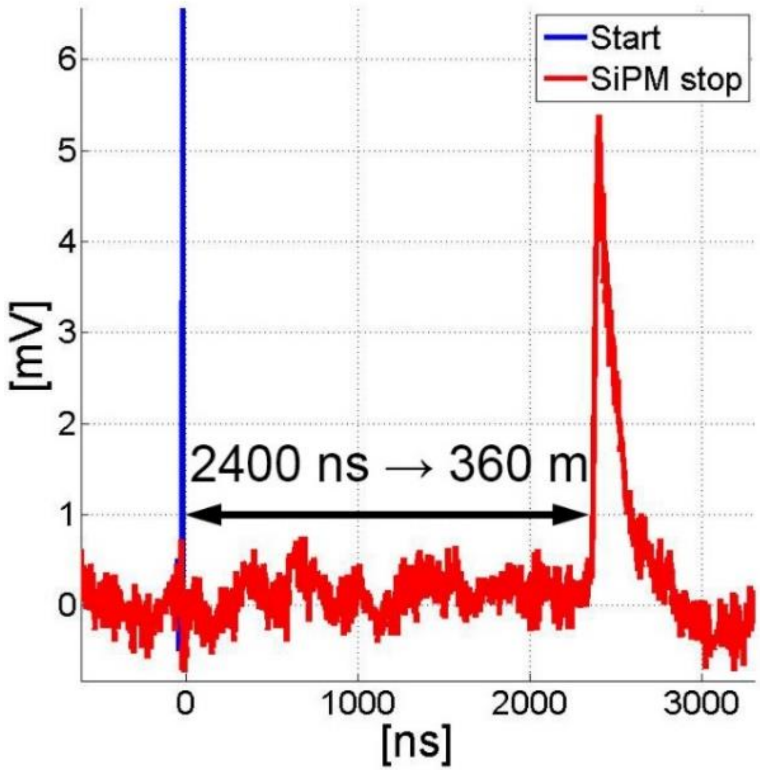
SiPM with 2 bandpass filters ($\Delta\lambda$ = 10nm centered at 905nm)

TDC + USB interface to PC





TOF Measurements - 360 m - Outdoor



Weather	Clear
Amb. Temp. [°C]	13
SNR SiPM	22
Accuracy SiPM [cm]	150
St. Dev. SiPM [cm]	150

Work in progress

- Optimization of our lens system in terms of performance, encumbrance and cost to get close to the state of the art
- Upgrade of the prototype in order to perform scans of the space employing MEMS mirrors and display the result
- Reduction of the encumbrance

Conclusions

- Presentation of facilities and activities at UNIPA
- **We are open to new collaborations**
- How to collaborate?
  - International Ph.D. program in *Information and Communication Technologies*
    - Call launched by the Italian National Program FSE-FESR Ricerca e Innovazione (PON RI 2014-2020) within the action I.1 "Dottorati Innovativi con caratterizzazione industriale" (Decreto Direttoriale 29 july 2016 n. 1540)
  - MISE – PON projects
  - POR projects
  - H2020 projects
    - ECSEL / ECSEL-Italy
    - ASTONISH project (Project reference: 692470, Funded under: H2020-EU.2.1.1.7. – ECSEL)
  - Direct contracts on specific themes

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