EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

IRIS - Innovative Research Infrastructure on applied Superconductivity

PNRR - M4C2I3.1 (2022-2025): Innovative Research Infrastructure on applied Superconductivity (IRIS), Prot. IR0000003, Avviso n. 3264 del 28/12/2021 "Rafforzamento e creazione di IR nell'ambito del Piano Nazionale di Ripresa e Resilienza (PNRR), Total Funding 60 M€

UE-H2020-INFRADEV-2018-2020 (2020-2024): Improving the sustainability of the European Magnetic Field Laboratory (ISABEL), Grant **No. 871106**, **EC funding:** 4.9 M€, **Work programme topic addressed: Development and long-term sustainability of new pan-European research infrastructures), Topic: INFRADEV-03-2018-2019** - Individual Support To ESFRI And Other World-Class Research Infrastructures.

research@omnics.it
http://www.omnics.it/home/

Omnics / from quantum physics to lab on chip

UNIVERSITÀ DEL SALENTO INFN / OMNICS research group / IRIS EMFL European Magnetic Field Laboratory /

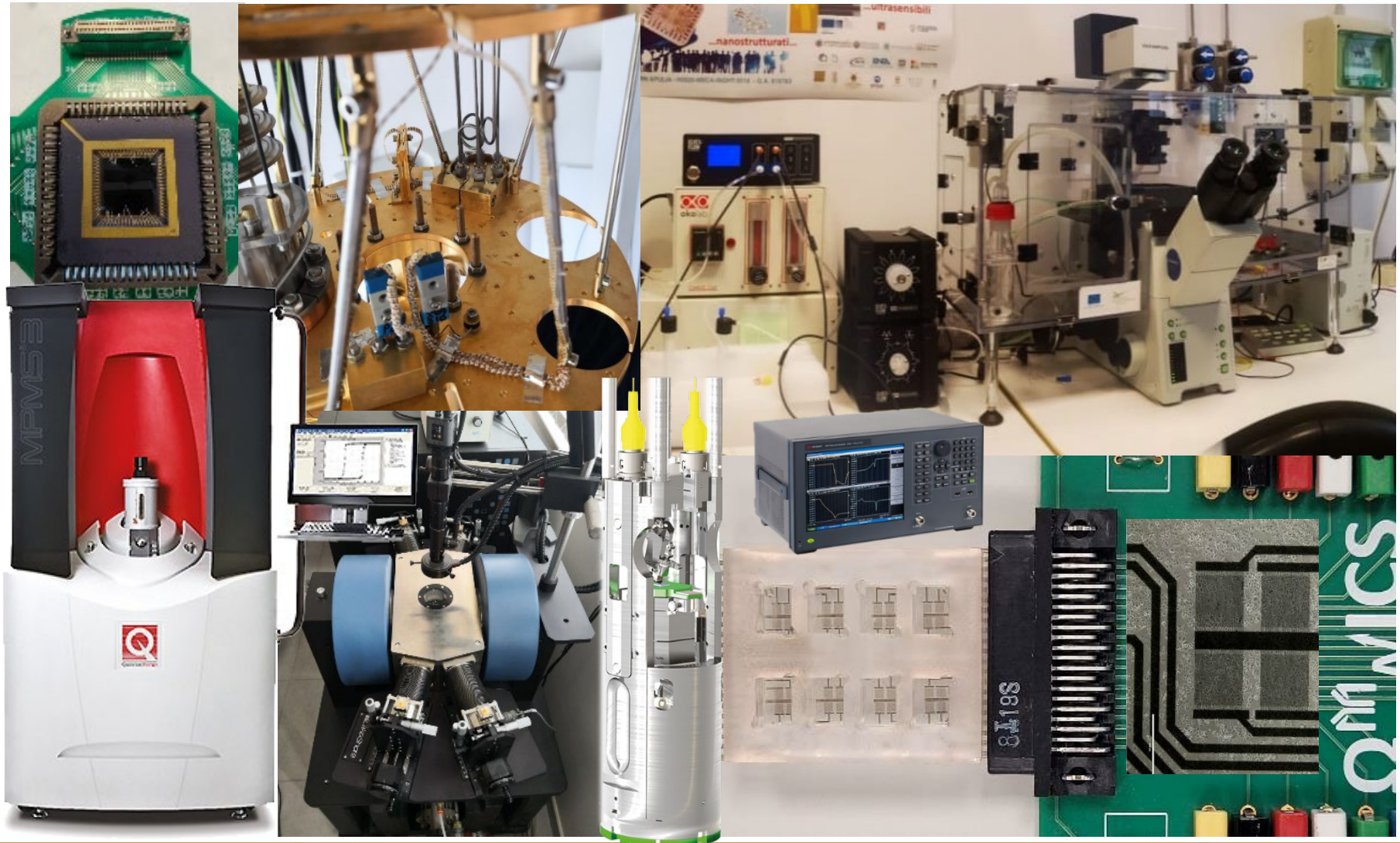
research@omnics.it

Omnics / from quantum physics to lab on chip

The ***Omnics Research group*** is an interdisciplinary research group established in joint labs among the University of Salento, CNR and INFN and operating as a EU and IT research infrastructure.

OMNICS research group

Electronics, Magnetism, Quantum Phys., Microscopy, Functional Materials, Sensing, Lab-on-chip, Prototyping



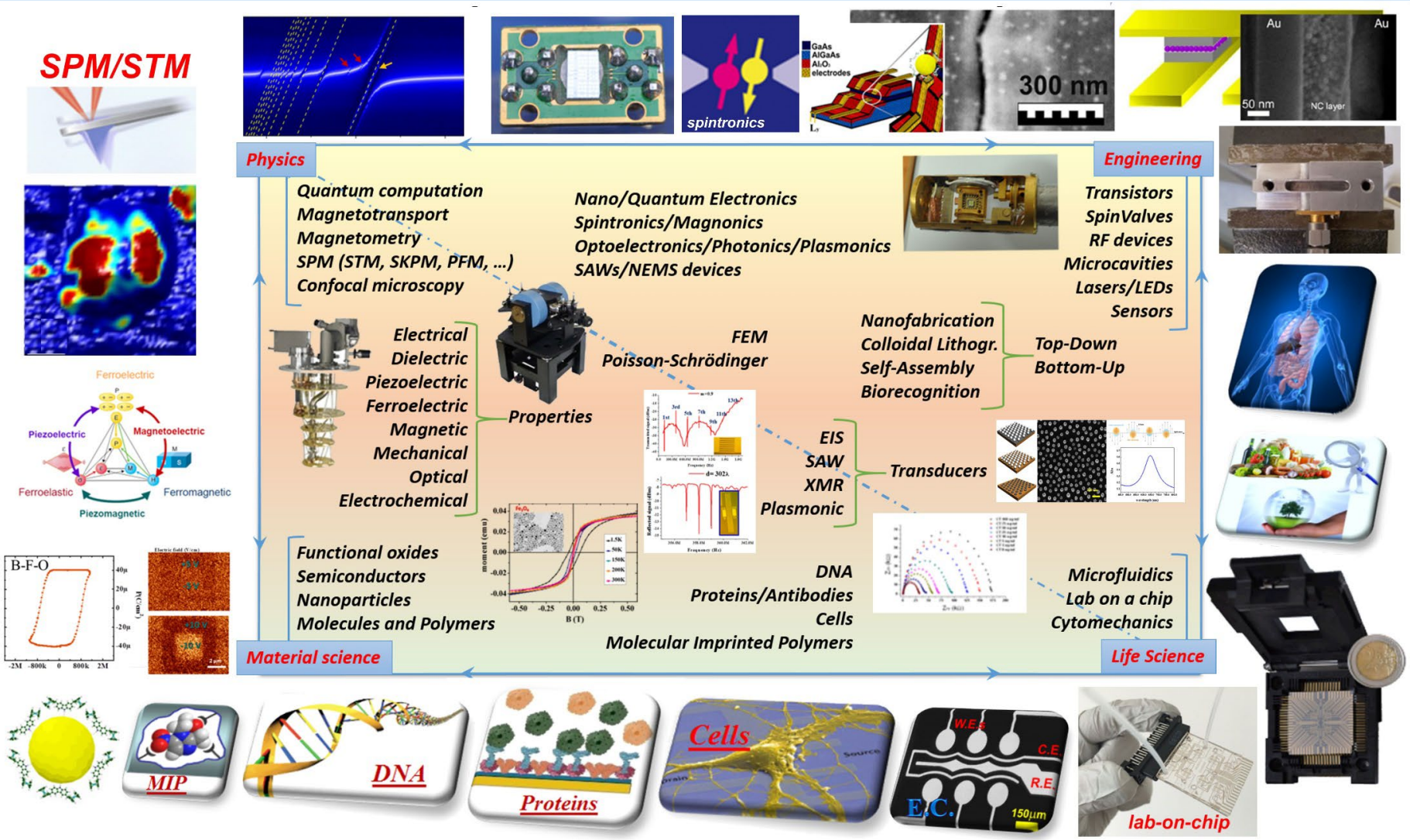
research@omnics.it
http://www.omnics.it/home/

Omnics / from quantum physics to lab on chip

The ***Omnics Research group*** is an interdisciplinary research group established in joint labs among the University of Salento, CNR and INFN and operating as a EU and IT research infrastructure.

OMNICS research group

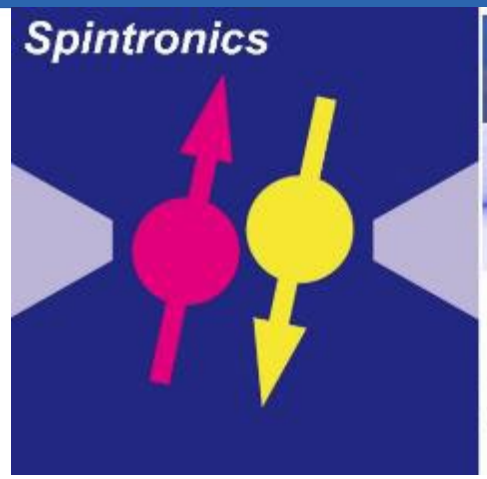
Electronics, Magnetism, Quantum Phys., Microscopy, Functional Materials, Sensing, Lab-on-chip, Prototyping

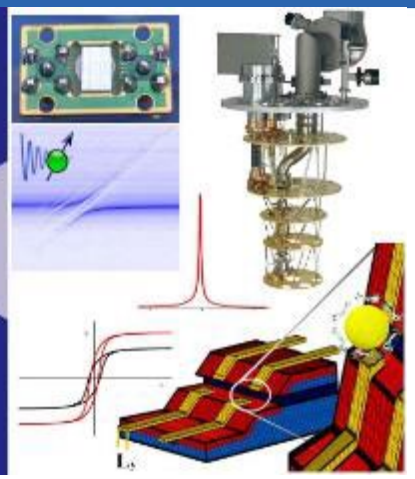


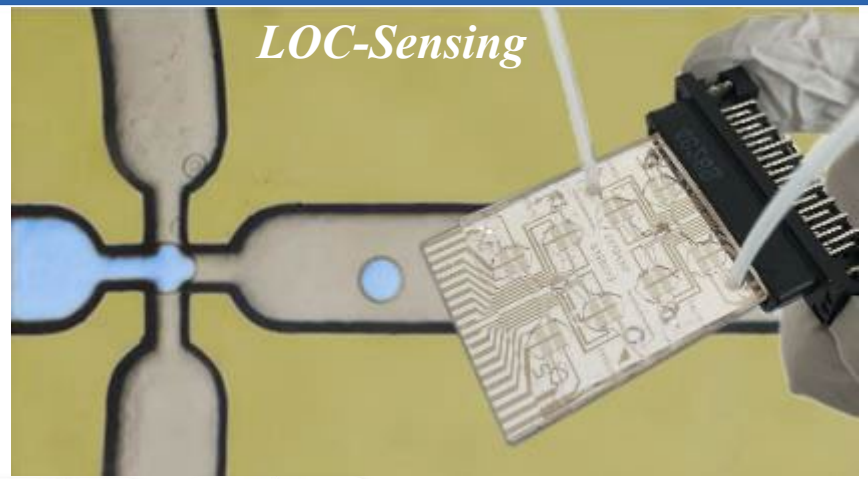
UNIVERSITÀ DEL SALENTO
INFN
OMNICS research group
IRIS
SAES
EMFL European Magnetic Field Laboratory
research@omnics.it
http://www.omnics.it/home/

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

O$^{m}_{n}$ics Research group








Giuseppe Maruccio


Anna Grazia Monteduro


Silvia Rizzato


Angelo Leo


Ritu Rawat


Sourav Kuila


Emanuele Piccinno


Saba Aziz


Andrea Margari


Giusi Caragnano


Noemi Petese


Antonella Giacovelli


Eleonora Giannotta

Past members: I. C. Lekshmi, S. Karmakar, E. Primiceri, M. S. Chiriacò, A. Turco, S. Kumar, Z. Ameer, F. Sirsi

Former PhD students:
G. Marzano, A. Milone, I. Buja, G. Siciliano, S. Zoupanou

UNIVERSITÀ DEL SALENTO INFN OMNICS research group IRIS EMFL European Magnetic Field Laboratory

research@omnics.it
http://www.omnics.it/home/

Omnics Labs as EU and IT research infrastructures

UNIVERSITÀ DEL SALENTO INFN / OMNICS research group / IRIS / EMFL European Magnetic Field Laboratory /

research@omnics.it

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

EMFL
European Magnetic Field Laboratory

The EMFL provides access to the **highest continuous and pulsed fields in Europe**.

Apply for Magnet Time - EMFL

EMFL and ISABEL partners provide new access schemes for :

- **Fast track access**
- **Long-term access**
- **Industrial access**
- **Dual access**
- **First-time access**

Deployment and test of a dual-access procedure to regional partner facilities and to EMFL

- **Selection Committee judges the proposed experiments on** scientific excellence.
- Proposals on a **broad range** of themes welcomed: magnetism, applied superconductors, semiconductors….

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

WP1
Project Management and Technical Coordination

WP2 Frascati – Magnetic Measurement Laboratory

WP3 Genova – Superconducting Cables and Material Laboratory

WP4 Milano LASA – Superconducting Magnets Laboratory

WP5 Napoli – Advanced Instrumentation Laboratory

WP6 Salento – Laboratory for Superconductivity and Magnetism

WP7 Salerno – Test facility for large magnet and superconducting line

WP8 Green Superconducting Line at zero emission

WP9 Energy Saving HTS Magnets f

Innovative Research Infrastructure on applied Superconductivity

IRIS

IRIS PNRR project

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

EMFL
European Magnetic Field Laboratory

Open and transational access to the infrastructure granted jointly with EMFL-ISABEL

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

Italian Community (magnetism) → **JRU**

About 20 institutions / research centers
8 Universities + CNR (8), INFN (2), INRIM, INSTM, IIT ***& AiMagn***

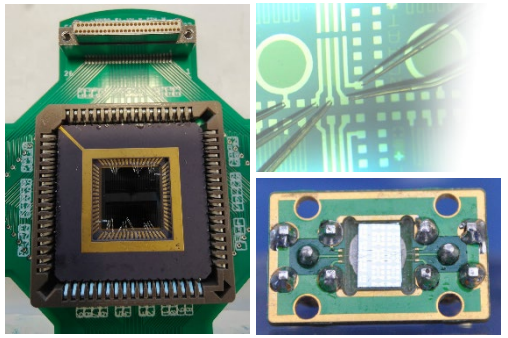
AiMagn Associazione Italiana di Magnetismo
UNIVERSITÀ DI PAVIA
POLITECNICO MILANO 1863
INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA
iit ISTITUTO ITALIANO DI TECNOLOGIA
UNIVERSITÀ DEGLI STUDI DI GENOVA
UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA
INSTM
Consiglio Nazionale delle Ricerche
UNIVERSITÀ DEGLI STUDI FIRENZE
INFN Istituto Nazionale di Fisica Nucleare
SAPIENZA UNIVERSITÀ DI ROMA
UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
OMNICS research group
UNIVERSITÀ DEL SALENTO
Consiglio Nazionale delle Ricerche
INFN
EMFL European Magnetic Field Laboratory
IRIS

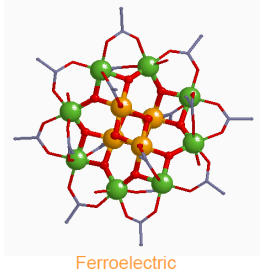
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

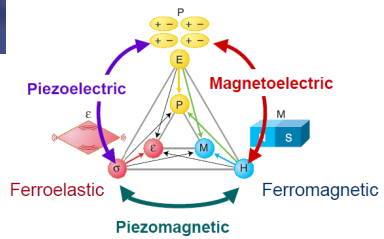
Motivation and Impact

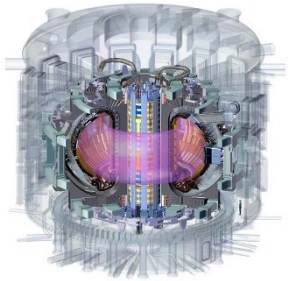
High magnetic fields are among the most powerful tools available to scientists today to

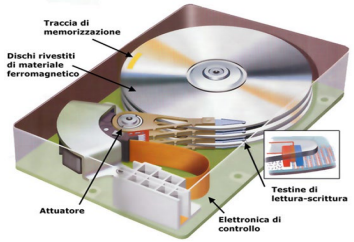
- study, modify and control states of matter in extreme conditions
- develop new materials and technologies capable of responding to the major challenges of modern society
- from basic research to applications in
- electronics and spintronics,
- data storage,
- quantum computing,
- energy,
- mobility,
- sensors,
- biomedical sector.

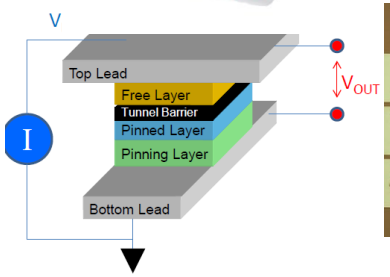


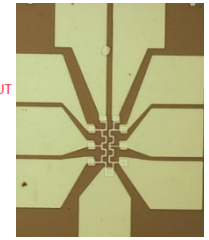


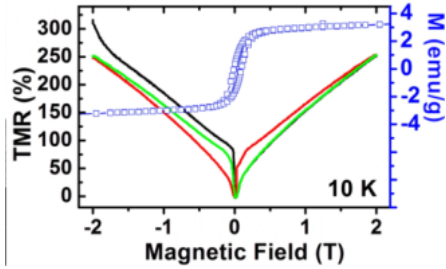


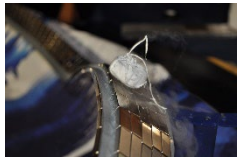


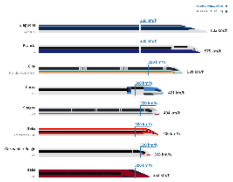


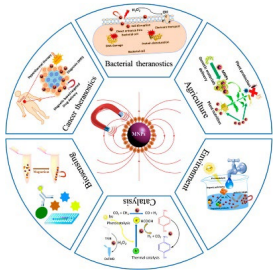


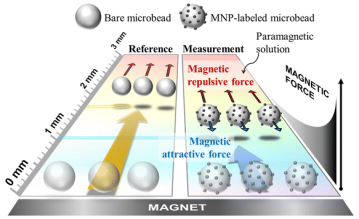


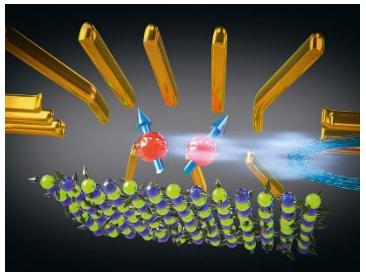


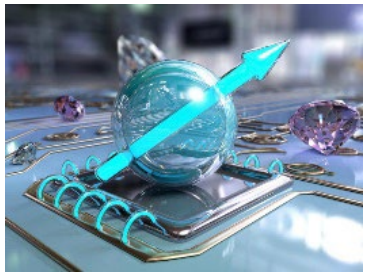












Omnics Labs : Facilities and Main Equipment

UNIVERSITÀ DEL SALENTO INFN / OMNICS research group / IRIS / EMFL European Magnetic Field Laboratory /

research@omnics.it

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

Laboratory for Magnetism and Superconductivity

Cryogenic superconducting magnet (10.5 T, 0.3-300 K)

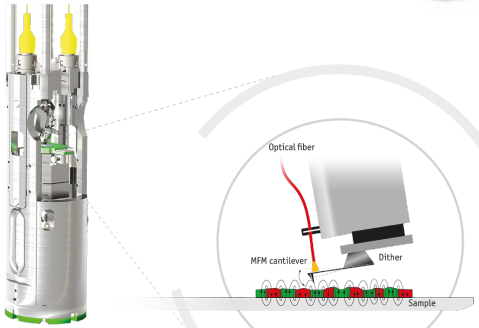
Lakeshore Cryogenic RF probe station (8 K, 0.5 T and 70 GHz)

Oxford dilution refrigerator (down to 10 mK, vector magnet 6T/1T/1T)

NEW INSTRUMENTATION @ 2024

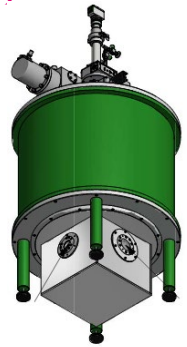
close-cycle SQUID magnetometer

close-cycle superconducting magnet for physical properties measurement



scanning probe microscope for material characterization

split pair cryogen-free magnet system for combined magneto-optical and FMR measurements



ZNA vector network analyzer @ 67 GHz

EU and IT infrastructures

EMFL European Magnetic Field Laboratory

EU / EMFL-ISABEL

IT Magnetism Network

IT / IRIS

research@omnics.it
http://www.omnics.it/home/

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

Infrastructure for Magnetism and Superconductivity

- present status

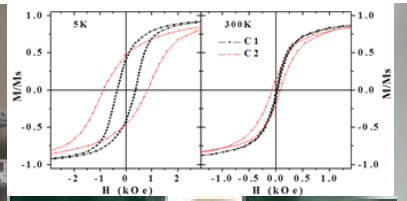
Cryogenic superconducting magnet (10.5 T, 0.3-300 K)

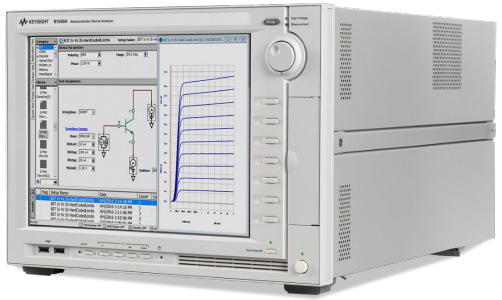
Oxford dilution refrigerator (down to 10 mK, vector magnet 6T/1T/1T)

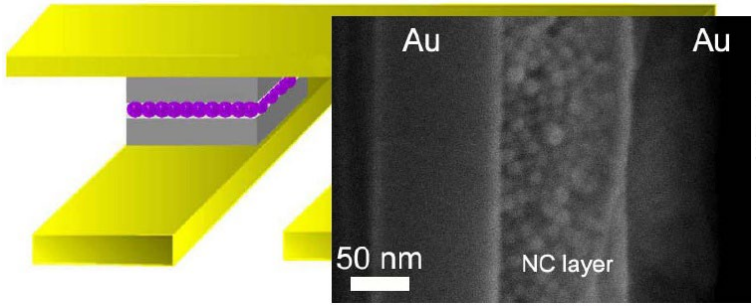
Lakeshore EMPX-HF Cryogenic RF probe station (8 K, 0.5 T and 70 GHz)

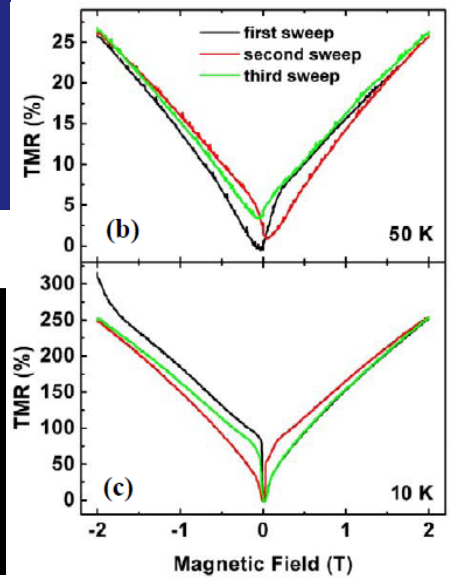
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

Cryogenic Lab for spintronics, magnetotransport and magnetometry





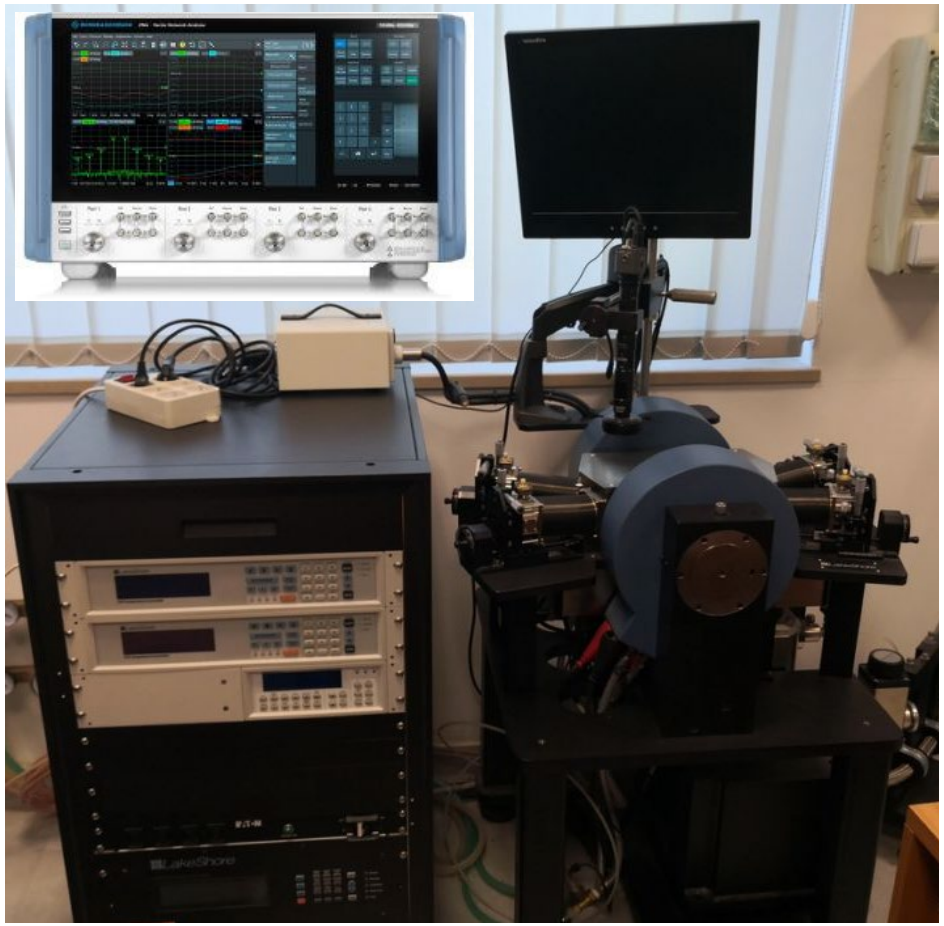


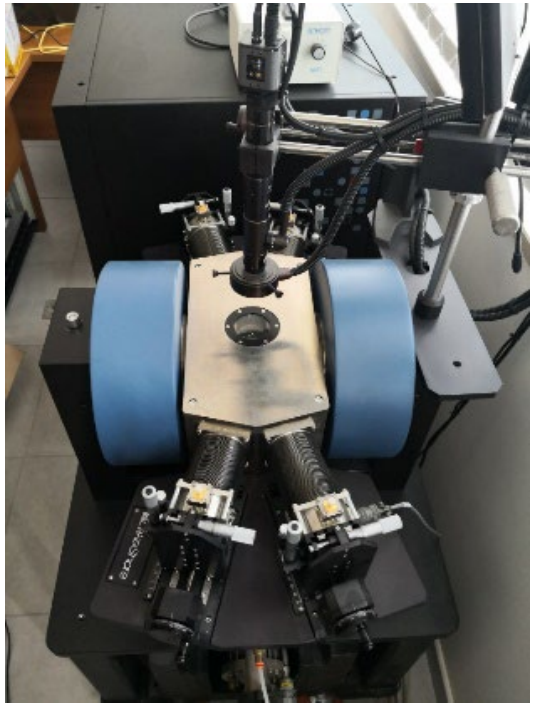


Cryogenic superconducting magnet (10.5 T, 0.3-300 K)

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

LT/RF spintronics Lab for magnonics and quantum computation



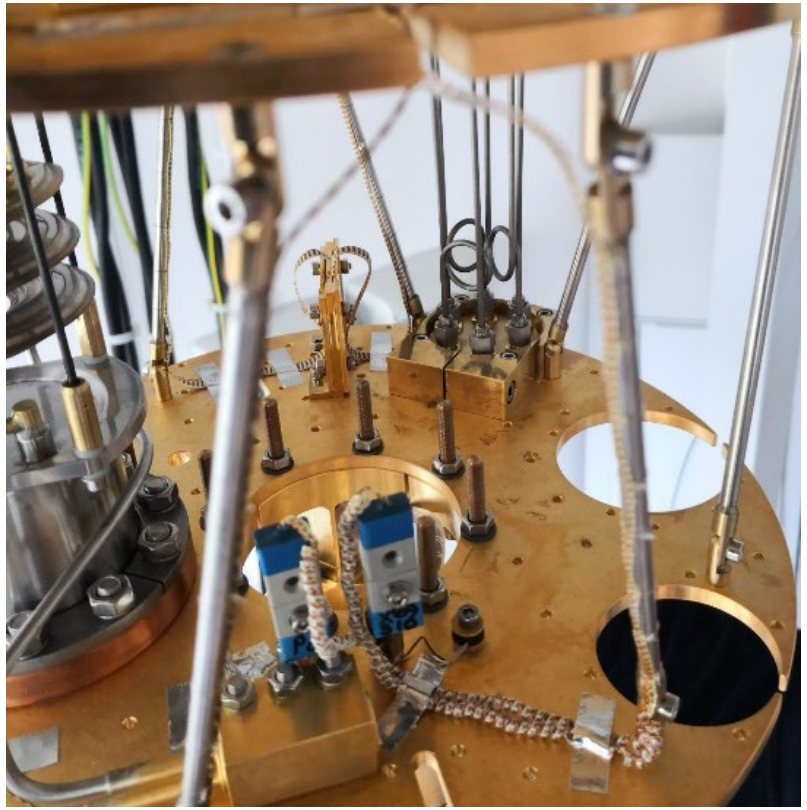


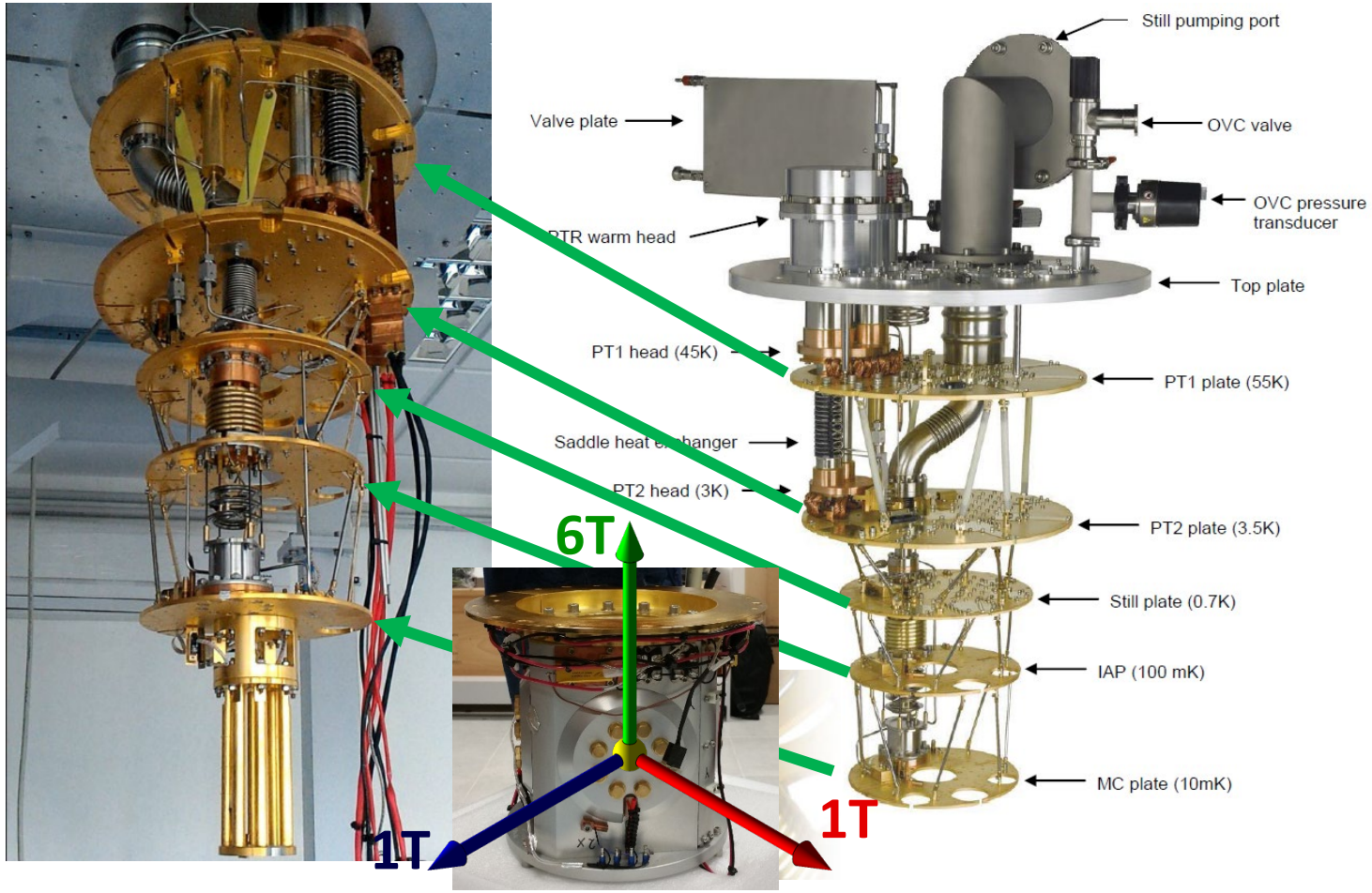
Lakeshore EMPX-HF Cryogenic RF probe station (8 K, 0.5 T and 70 GHz)

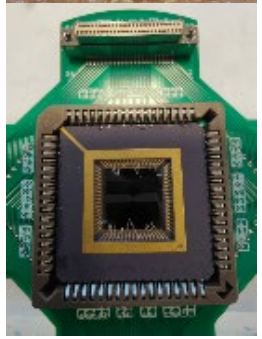
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

LT/RF spintronics Lab for magnonics and quantum computation

Oxford dilution refrigerator (down to 10 mK, vector magnet 6T/1T/1T)

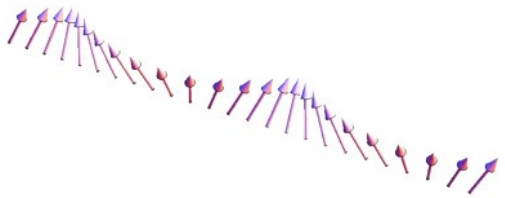


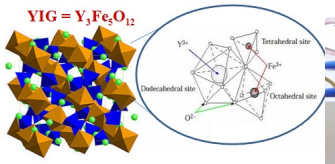


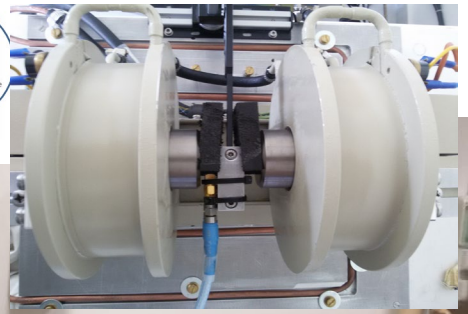


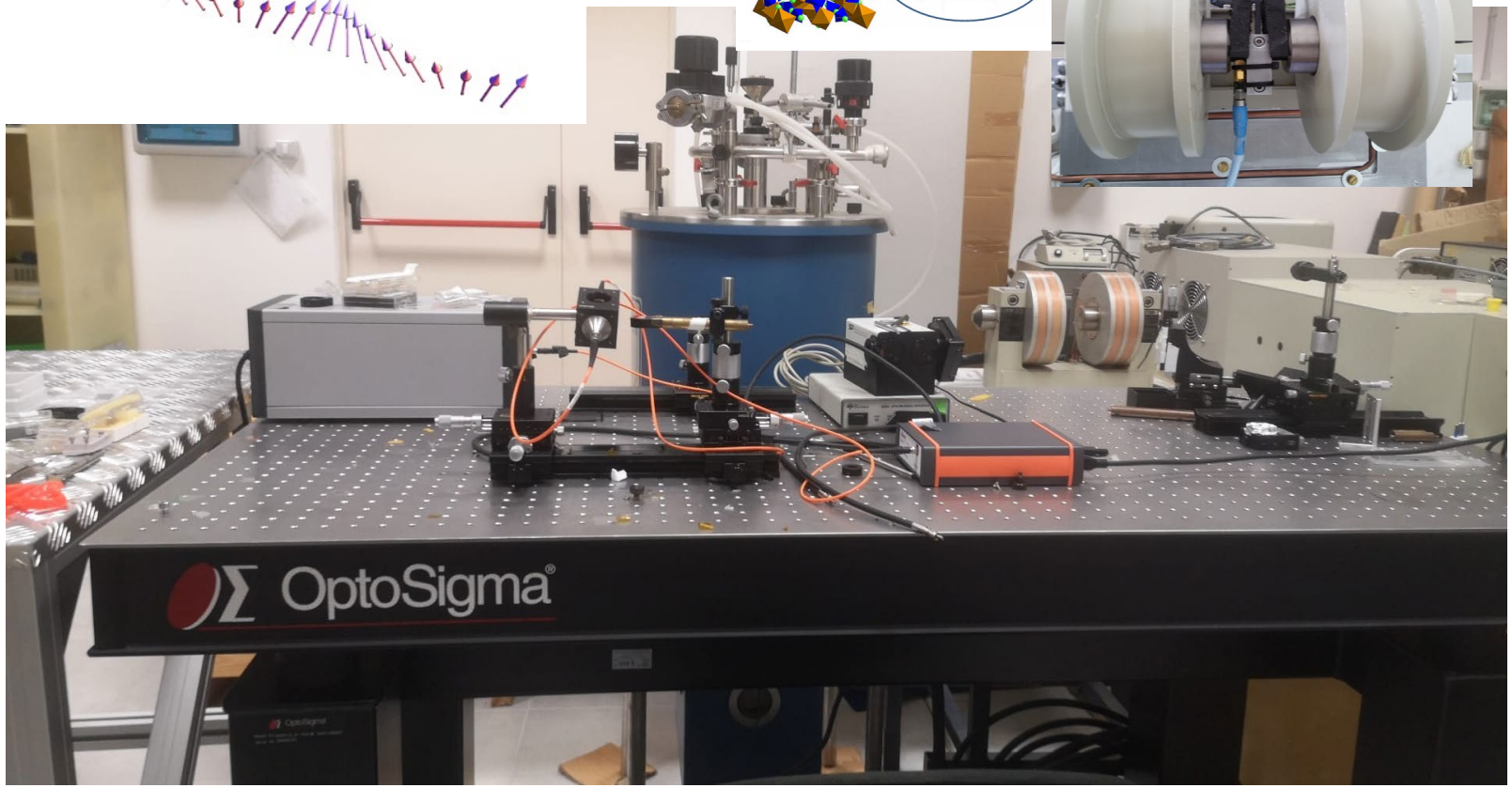
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

Lab for magneto-optical, magnonic and FMR measurements

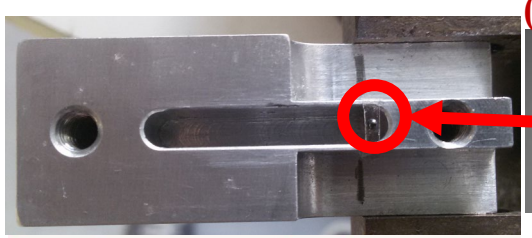


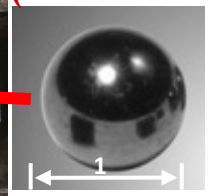


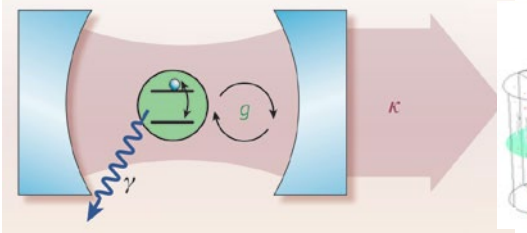


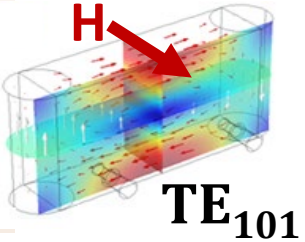


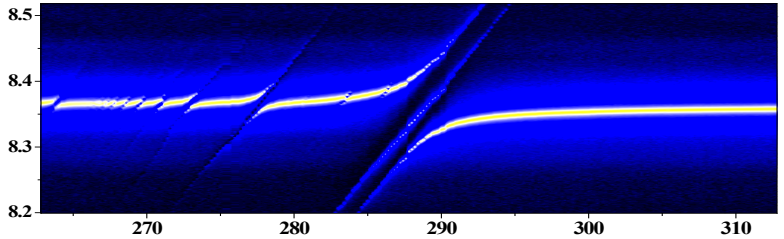
YIG sphere
(1 mm diam.)

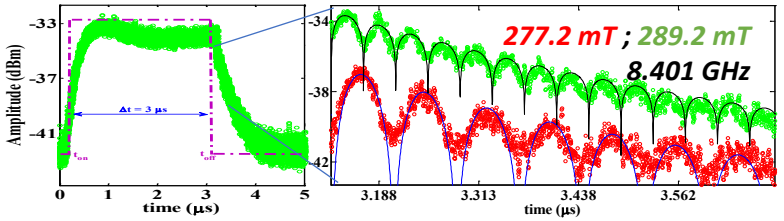








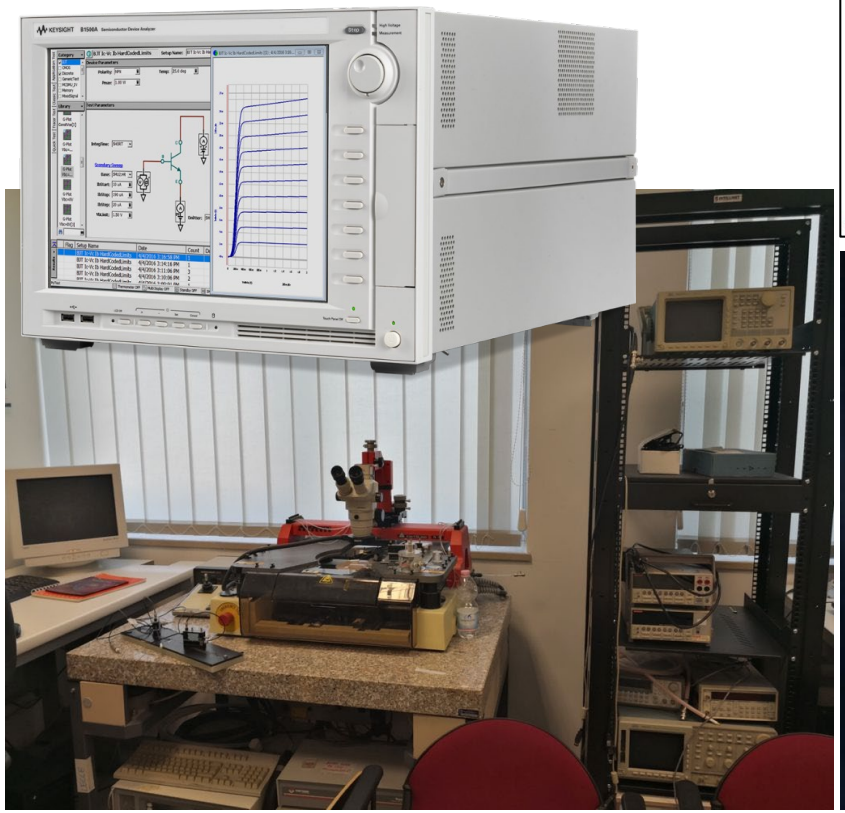


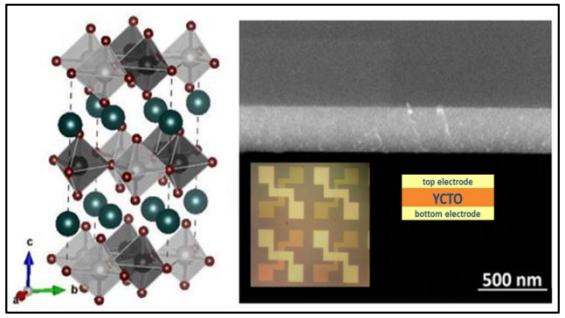


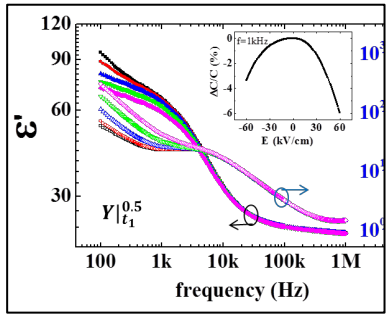
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

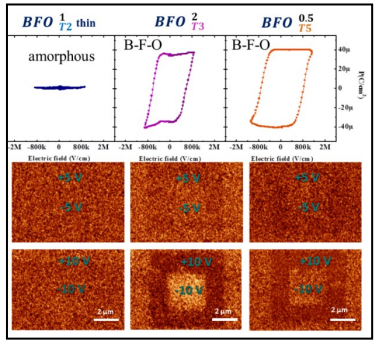
Transport / Electronics Lab

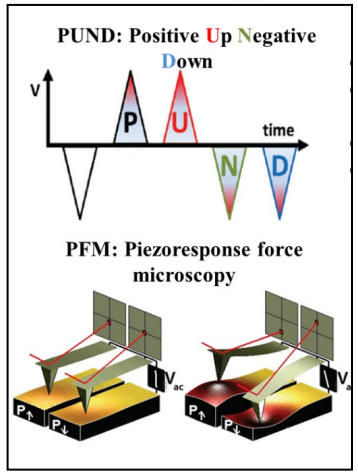
B1500 Parameter Analyzer

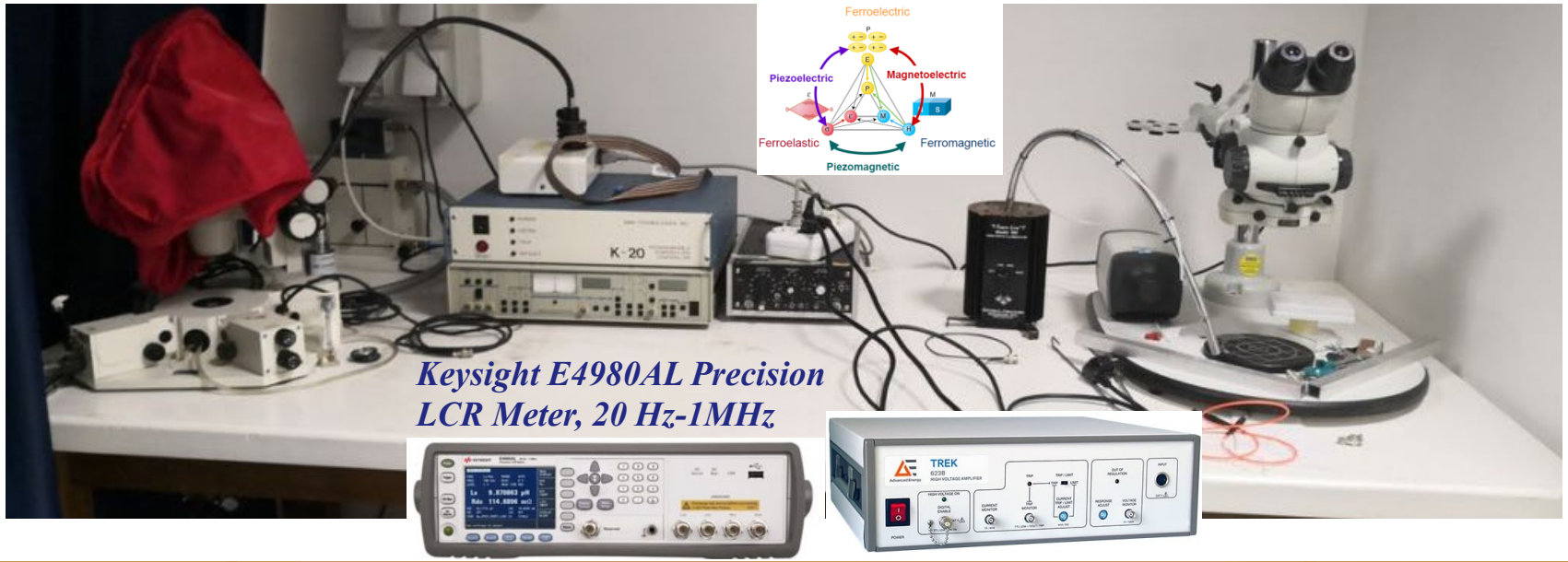












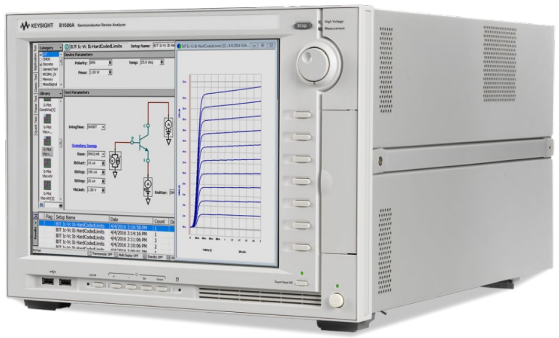
Keysight E4980AL Precision LCR Meter, 20 Hz-1MHz

Trek High Voltage amplifier

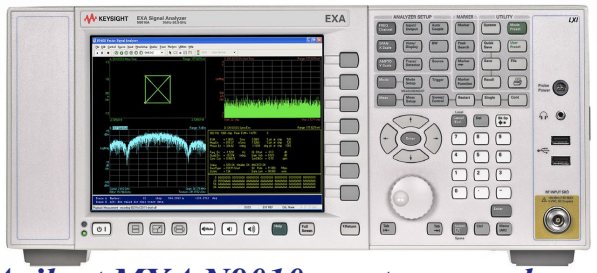
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

Transport / Electronics Lab

- ***Present Status – Main Electronics Equipment***



B1500 Parameter Analyzer

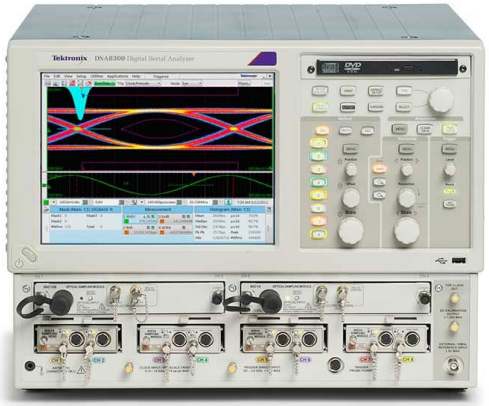


Agilent MXA N9010 spectrum analyzer, 10kHz-26.5GHz

Agilent MXG N5183A signal generator, 100kHz-20GHz

Rohde & Schwarz SMA100B Signal Generator, 8kHz-20 GHz

Keysight ENA Network/Impedance Analyzer E5061B



ultrafast digital sampling oscilloscope (Tektronix DSA8300)

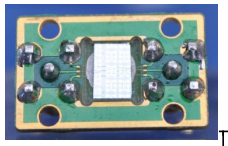
Trek High Voltage amplifier

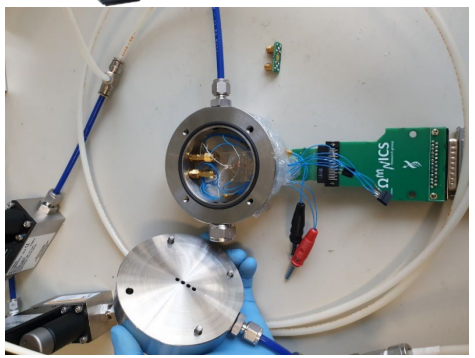
Keysight E4980AL Precision LCR Meter, 20 Hz-1MHz

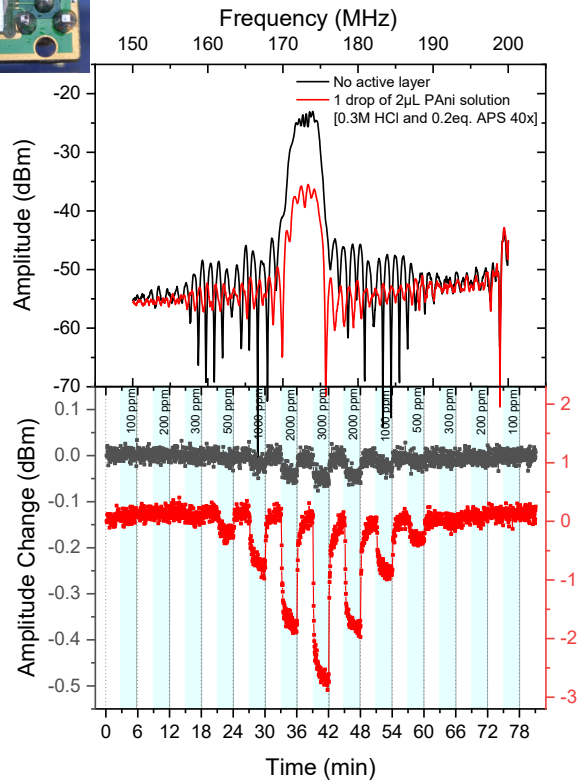
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

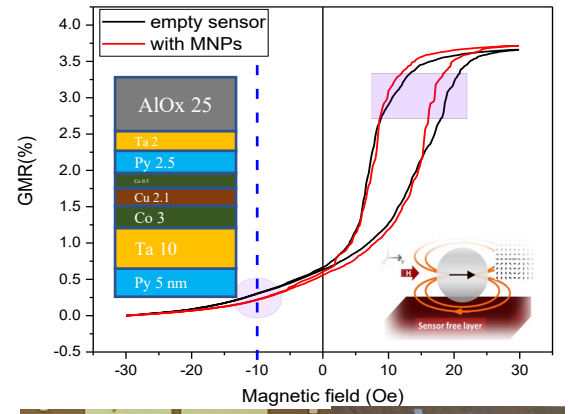
Physical Sensors & Detectors Lab

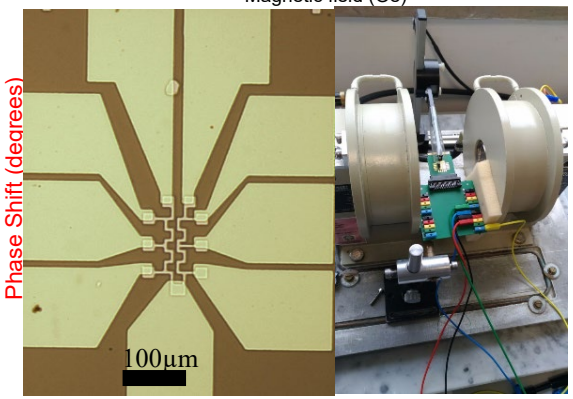
Keysight ENA Network/Impedance Analyzer E5061B

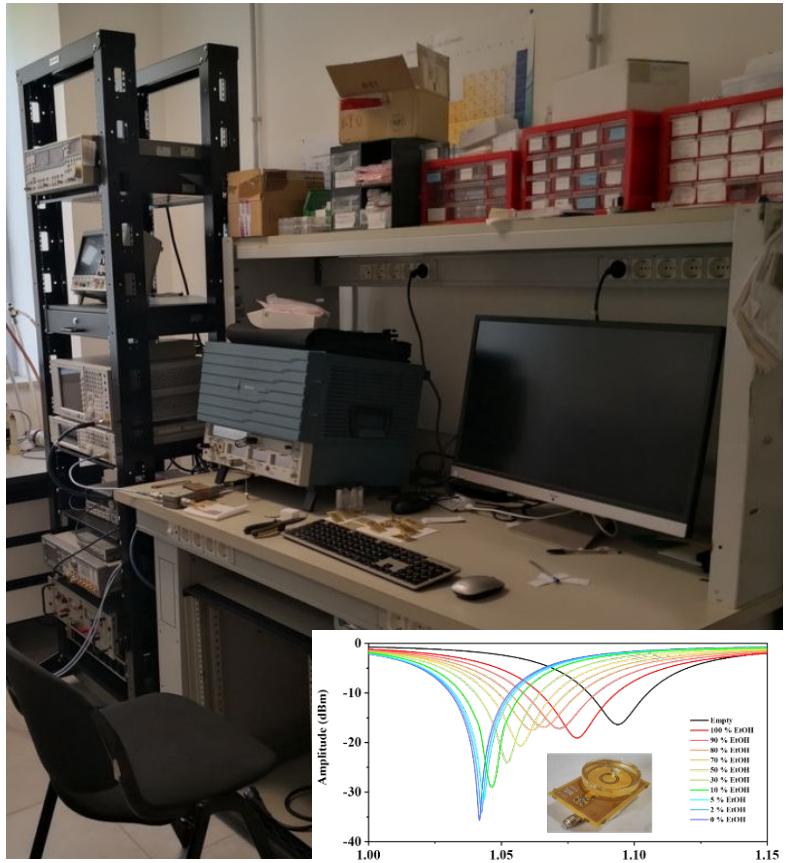






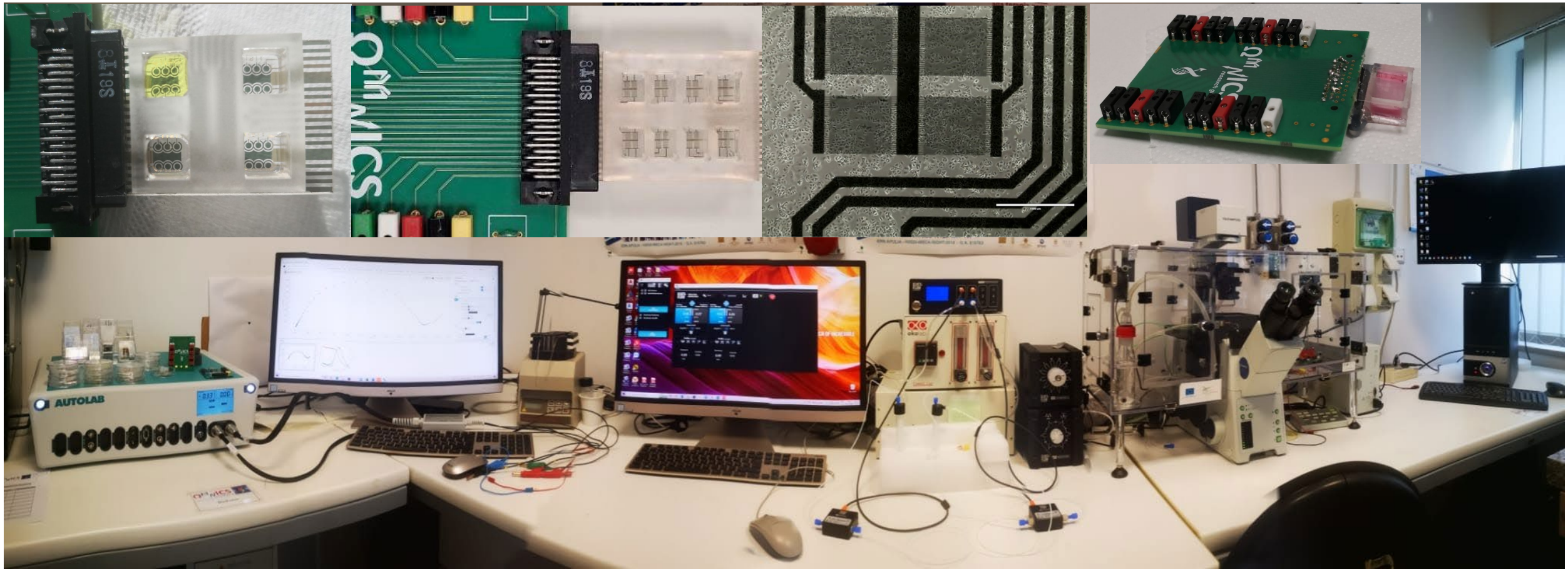






EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

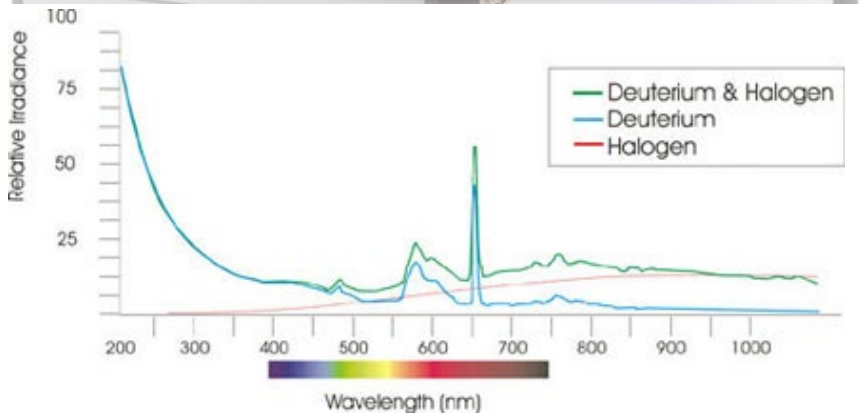
Lab-on-chip & Biosensors Lab



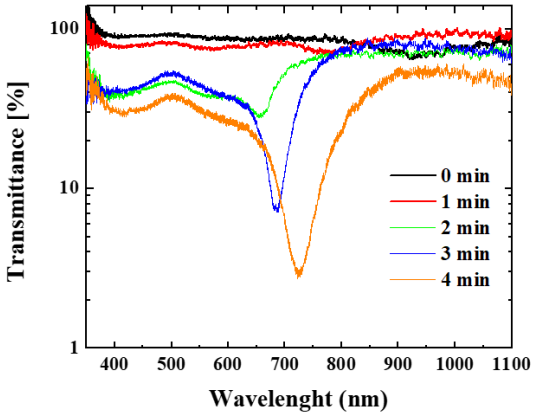
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

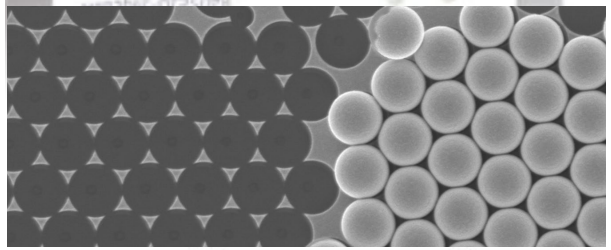
Spectroscopy Lab - UV/VIS/NIR & SPR

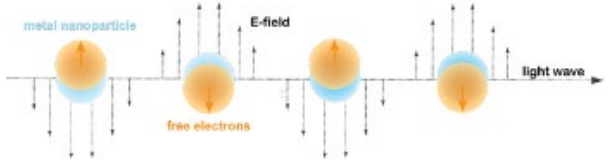
Deuterium-Halogen light source, 190-2500 nm



UV/VIS/NIR spectrometer, 200-1100 nm

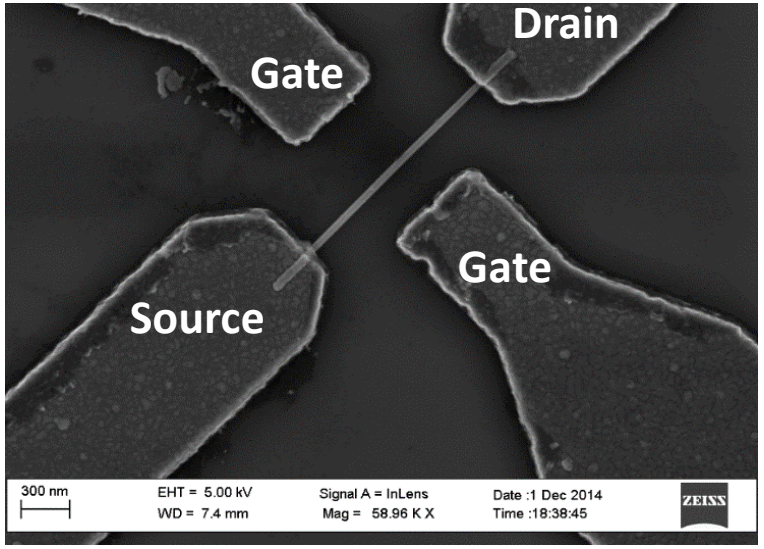


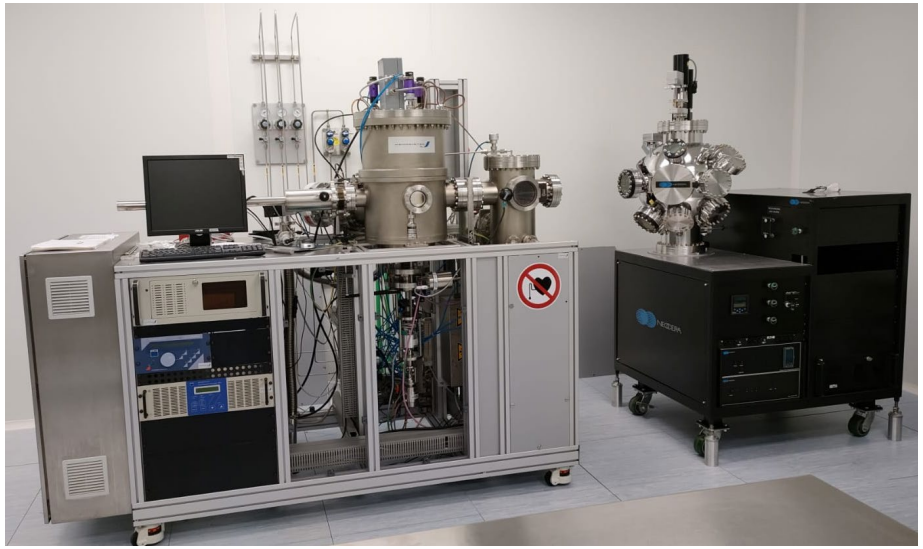


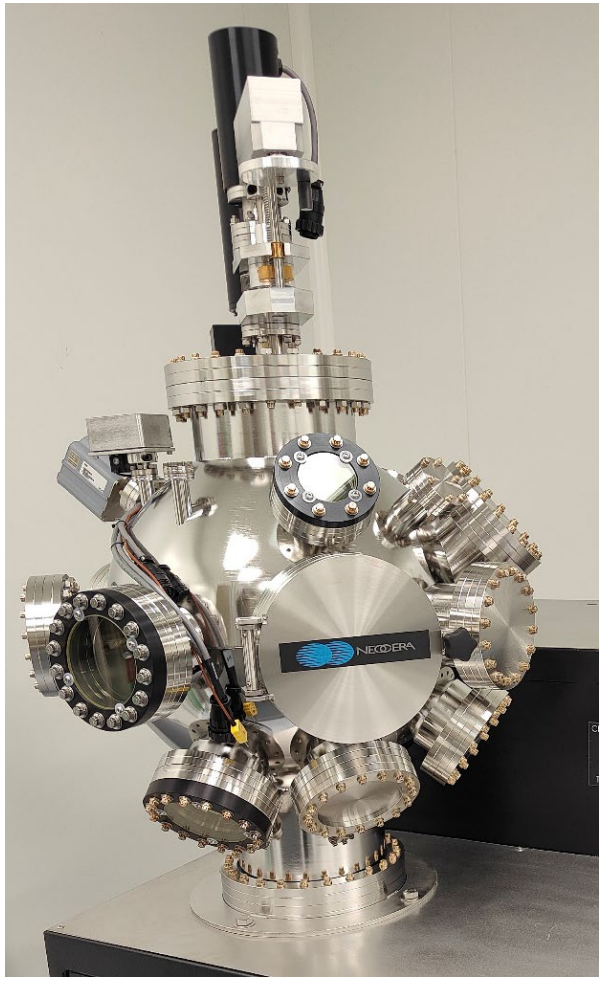


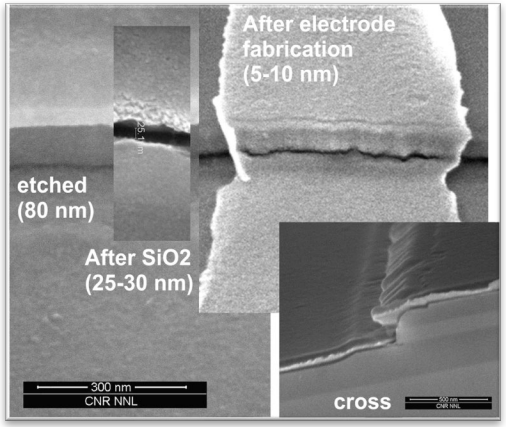
EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

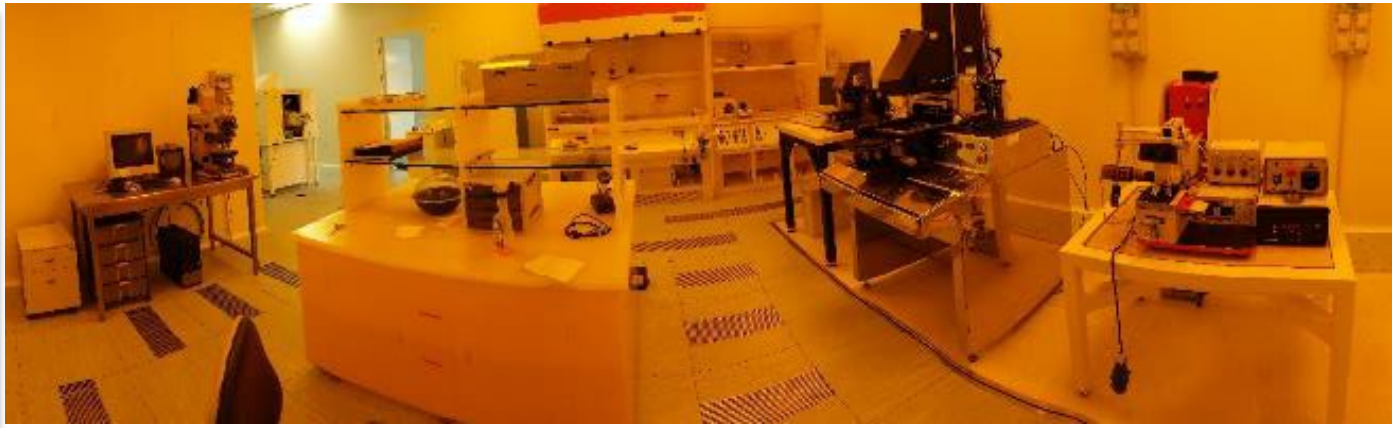
Materials Dep. Lab & Clean Room facility











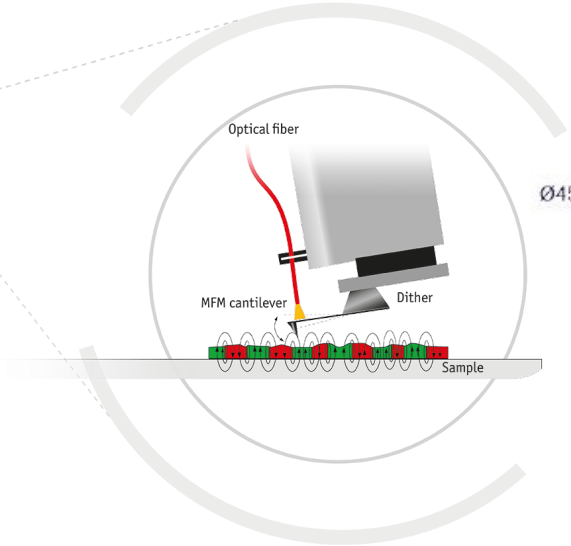
2024 Development

Innovative Research Infrastructure on applied Superconductivity
IRIS

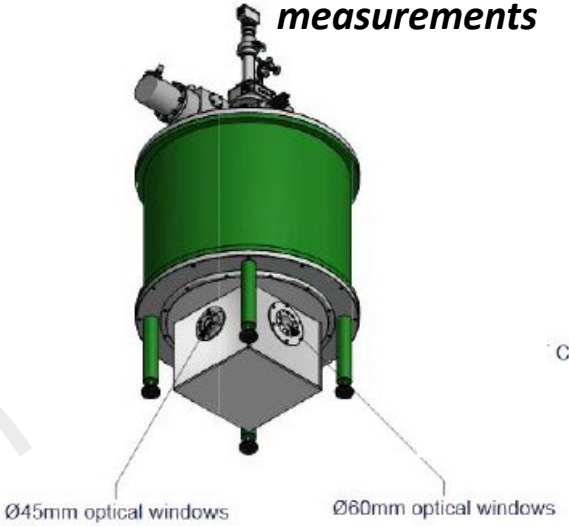
close-cycle SQUID magnetometer

close-cycle superconducting magnet for physical properties measurement

scanning probe microscope for material characterization



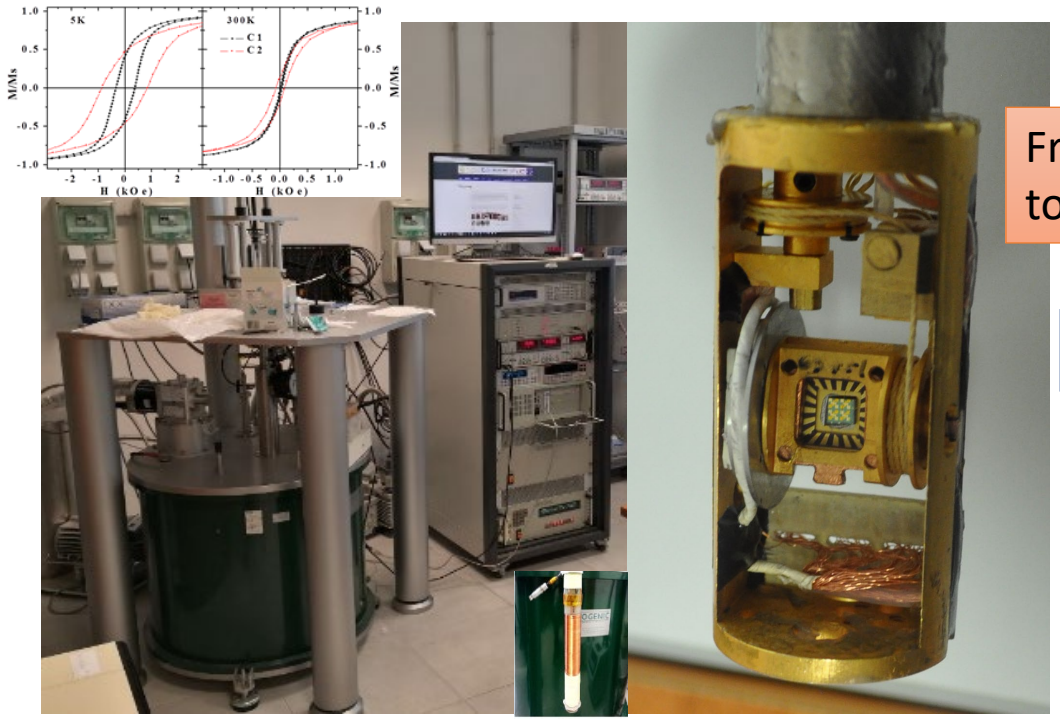
split pair cryogen-free magnet system for combined magneto-optical and FMR measurements



ZNA vector network analyzer @ 67 GHz

Joint Lab with Quantum Design

- **Magnetometry**



Cryogenic superconducting magnet (10.5 T, 0.3-300 K)

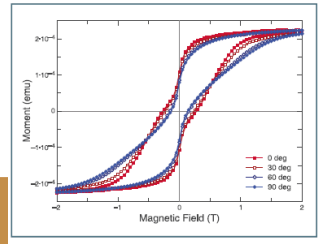
From 10^{-6} emu to 10^{-8} emu

+ more options

close-cycle SQUID magnetometer

a. VSM sensibility: better than 1 x 10^{-8} emu (at <0.25 T) with average on less than 10 sec
b. VSM sensibility: better than 8 x 10^{-8} emu (at >0.25 T) with average on less than 10 sec
c. DC sensibility: 5 x 10^{-8} emu (at <0.25 T)
d. DC sensibility : 6 x 10^{-7} emu (at >0.25 T)

- DC extraction
  - Rotator
  - Pressure cell
  - 1000 K oven
  - Electrical excitation
  - Optical excitation
- Vibrating sample magnetometry (VSM)
  - FORC option
  - 1000 K oven
  - Fiber optic sample mount
  - Electrical excitation
  - Optical excitation
- Ultra-low field measurements
- AC susceptibility
- He3 option & sub-mK capability

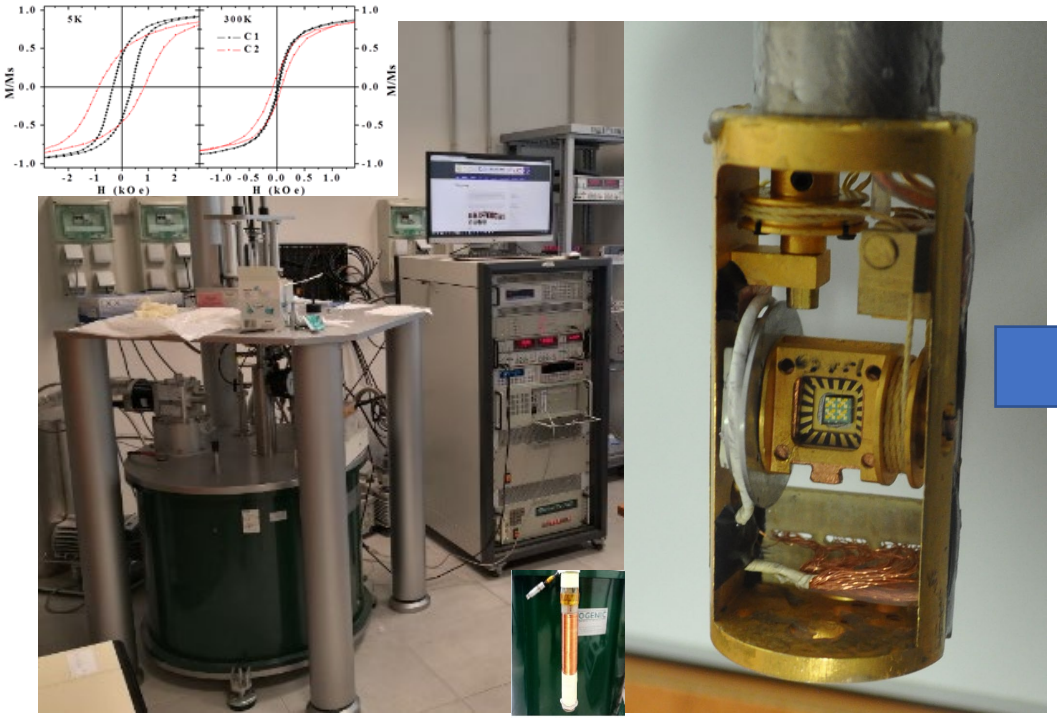


Measurement of a ferromagnetic thin film sample with perpendicular anisotropy on a substrate. Results are shown for ±2 T moment versus field loop at 4 different angles from 0 to 90 degree sample rotation.

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INFN

Joint Lab with Quantum Design

- Magnetotransport and Physical Properties Measurements



Cryogenic superconducting magnet (10.5 T, 0.3-300 K)

close-cycle superconducting magnet for physical properties measurement

Features

- No need for liquid cryogens
- Temperature range of 1.8 K – 400 K
- 9 T magnets available
- Continuous Low-Temperature Control
- Controlled temperature Sweep Mode

PPMS options

Electrical Transport
Magnetometry
Thermal Measurements
Sub-Kelvin Capabilities
Multi-Function Probes
FMR Spectroscopy
Optics

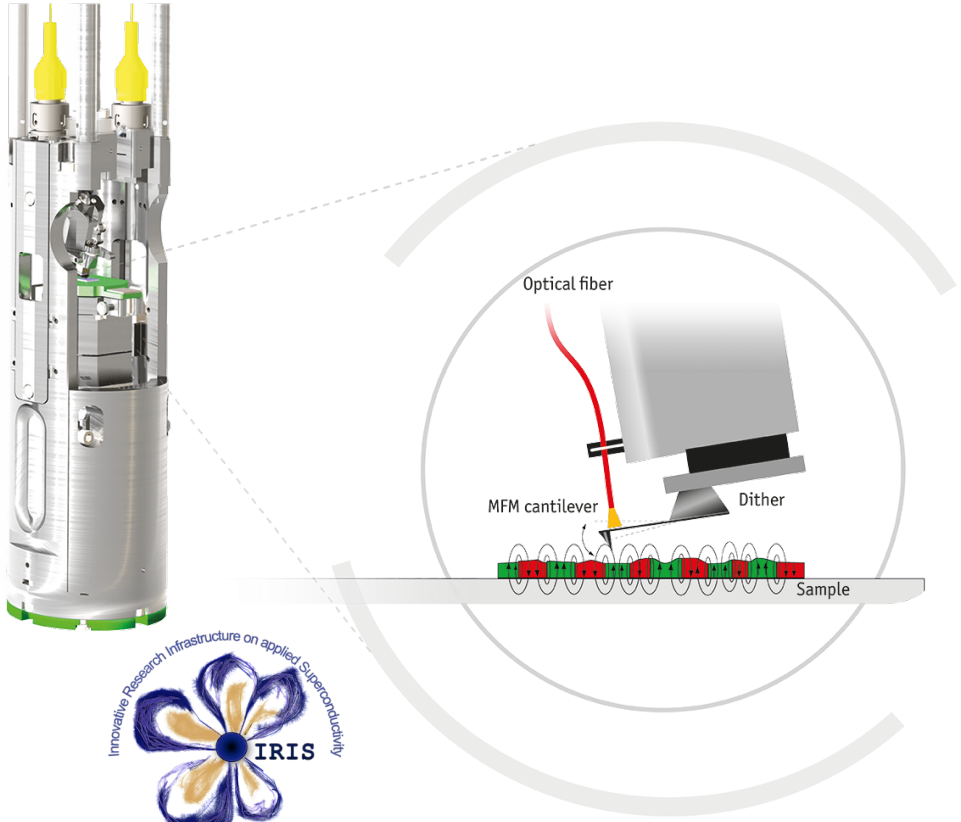
Sample space, more possibilities for phys. properties measurements with dedicated probes

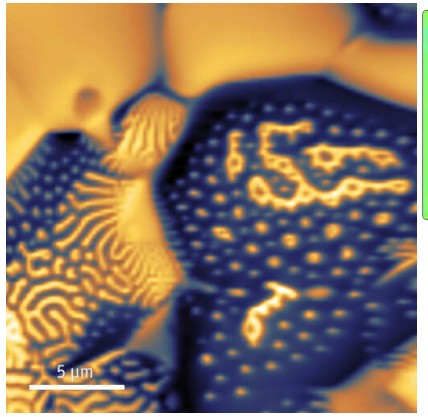
IRIS
UNIVERSITÀ DEL SALENTO
INFN
OMNICS research group

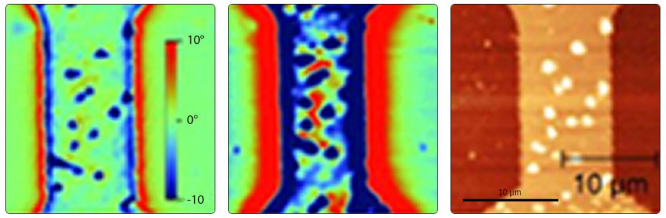
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INFN

attocube attoDRY2200 AFM/MFM/PFM Lab

- scanning probe microscope for material characterization

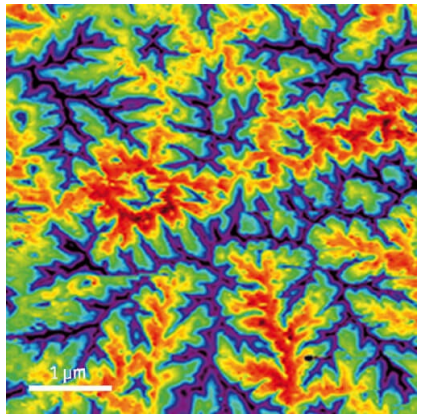






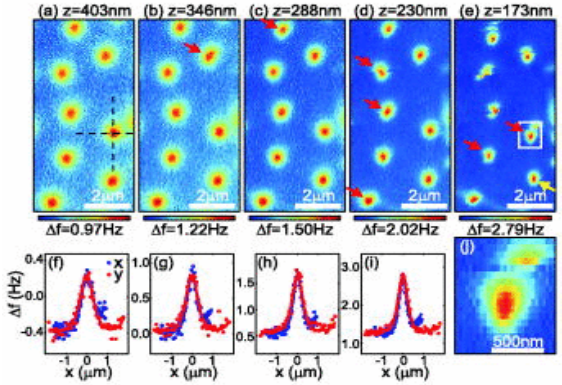
Visualization of Edge State in LPCMO Manganite Strip
K. Du, K. Zhang, and J.Shen, Fudan University, Shanghai, China

MFM for Optimization of Sintered Magnets
T. Helbig and O. Gutfleisch, Functional Materials Group, TU Darmstadt, Germany and Fraunhofer IWKS Hanau, Germany



Magnetic domain structure in the ferrimagnetic state of Co doped Mn_2Sb single crystal
Rajeev Rawat, UGC-DAE Consortium for Scientific Research, Indore, India

Literature examples from users



Controlled manipulation of individual vortices in a superconductor
Appl. Phys. Lett. **93**, 172514 (2008); https://doi.org/10.1063/1.3000963
E. W. J. Straver, J. E. Hoffman, O. M. Auslaender, D. Rugar, *and* Kathryn A. Moler

Laboratory for Magnetism and Superconductivity

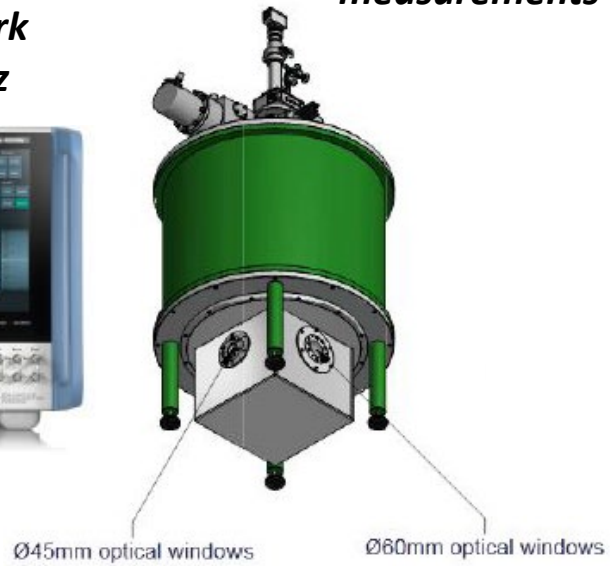
- **Magneto-optical and FMR measurements**

Lakeshore EMPX-HF Cryogenic RF probe station (8 K, 0.5 T and 70 GHz)

+

ZNA vector network analyzer @ 67 GHz

split pair cryogen-free magnet system for combined magneto-optical and FMR measurements



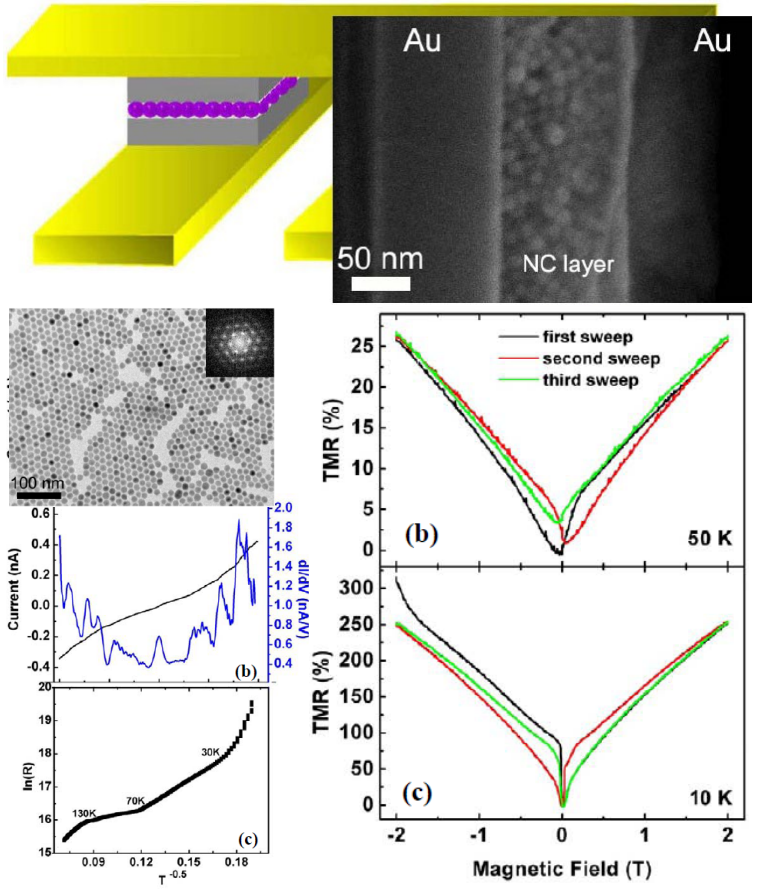
Omnics Labs : Main Research Activities

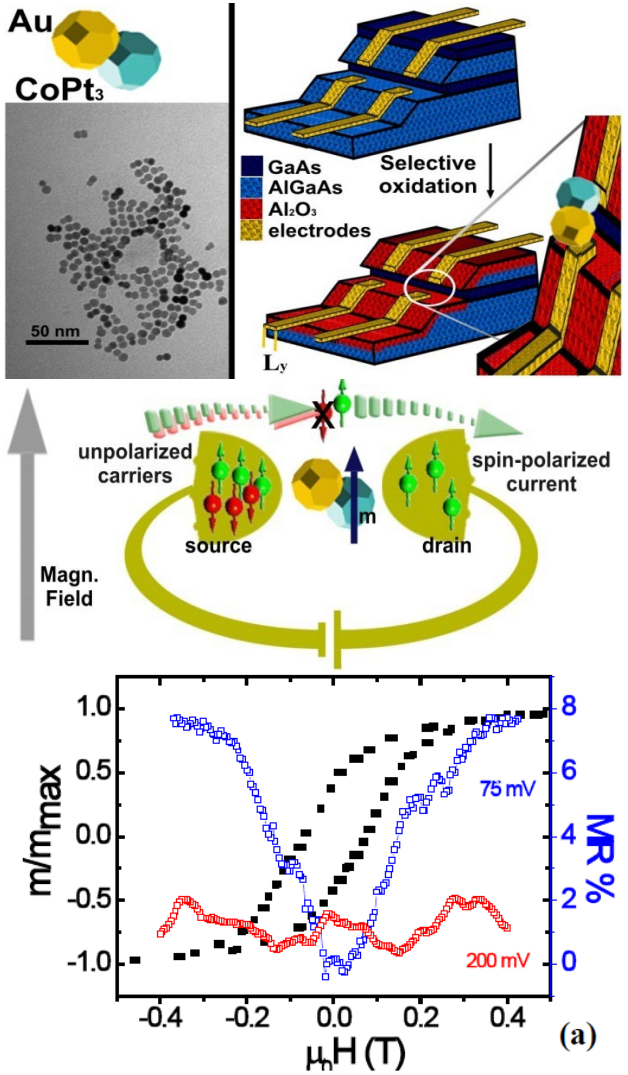
UNIVERSITÀ DEL SALENTO INFN / OMNICS research group / IRIS / EMFL European Magnetic Field Laboratory /

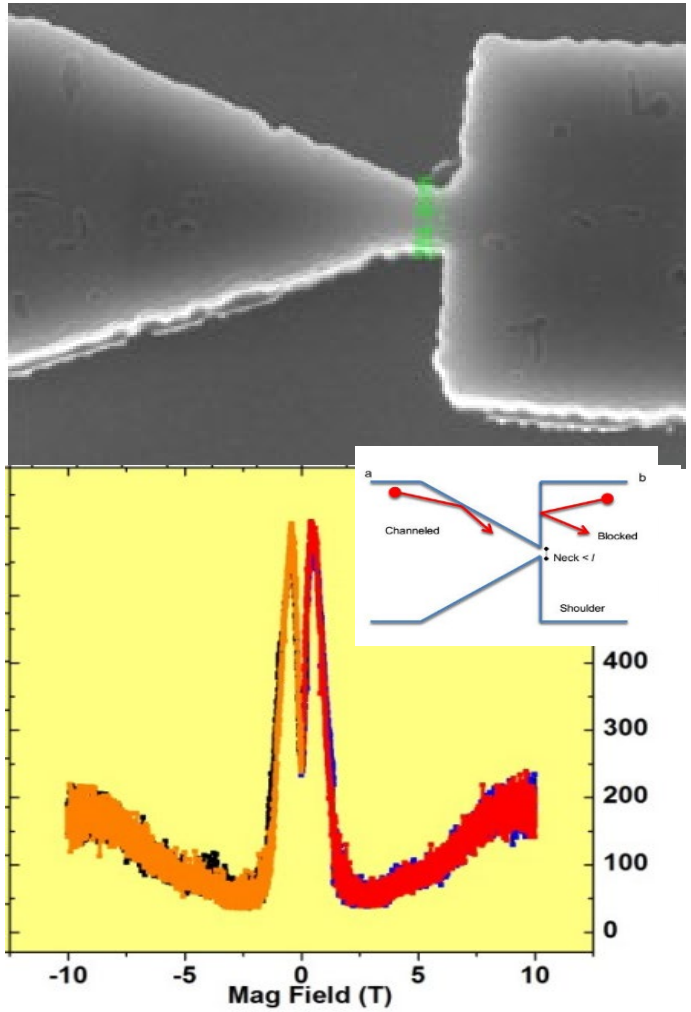
research@omnics.it

Nanospintronics

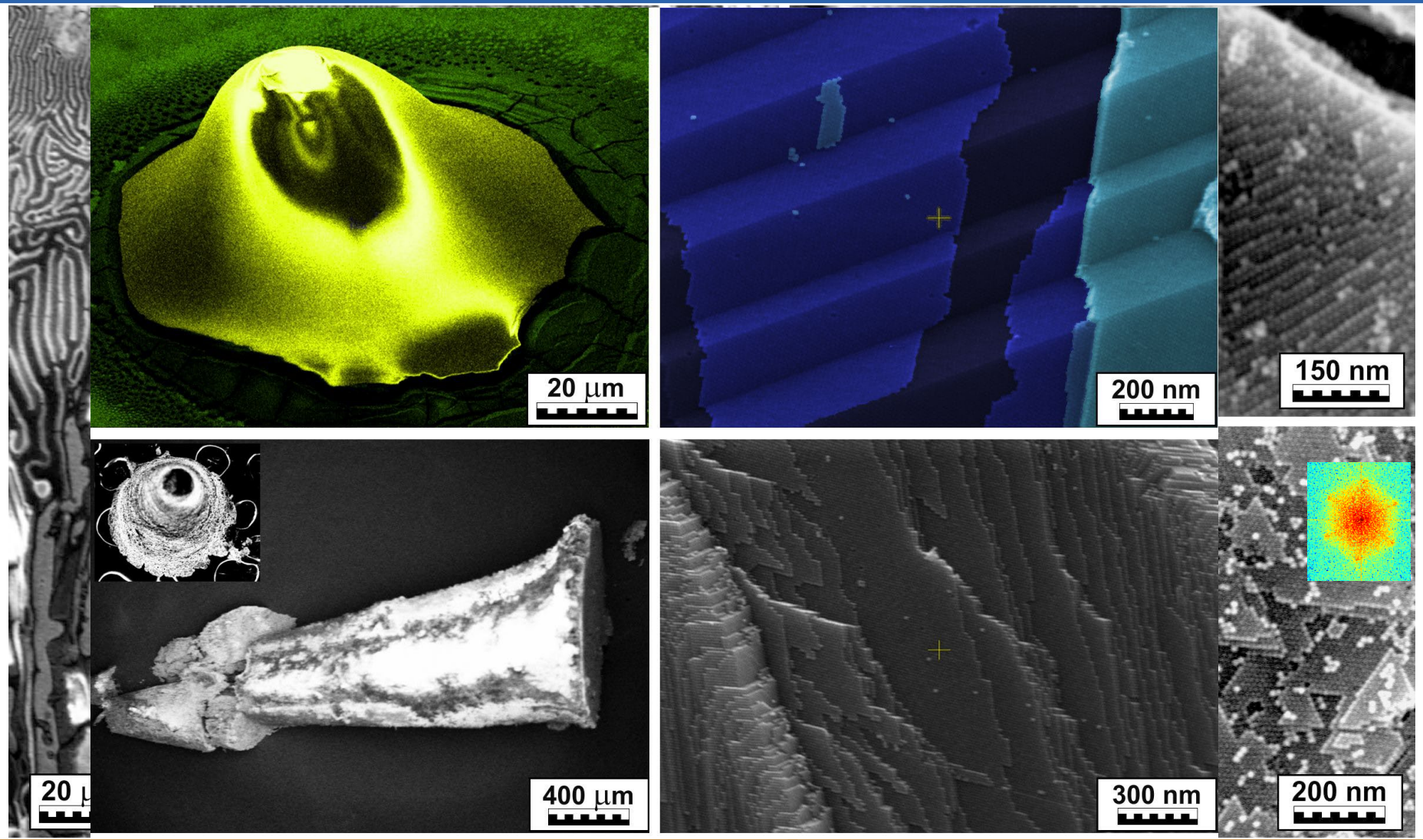
I. C. Lekshmi et al., Acs Nano, 5, 1731-1738 (2011)







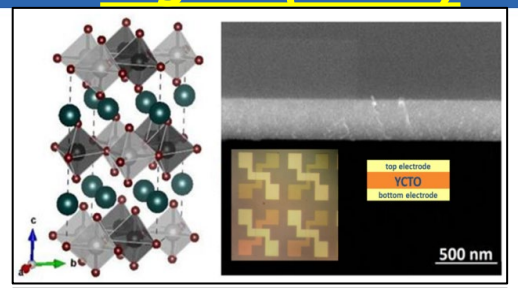
Supercrystals

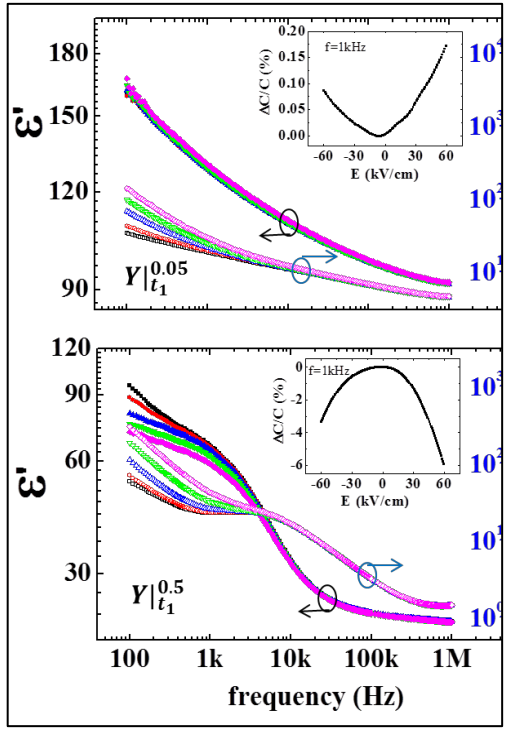


I. C. Lekshmi et al., Science of Advanced Materials 5, 2015-2020 (2013)

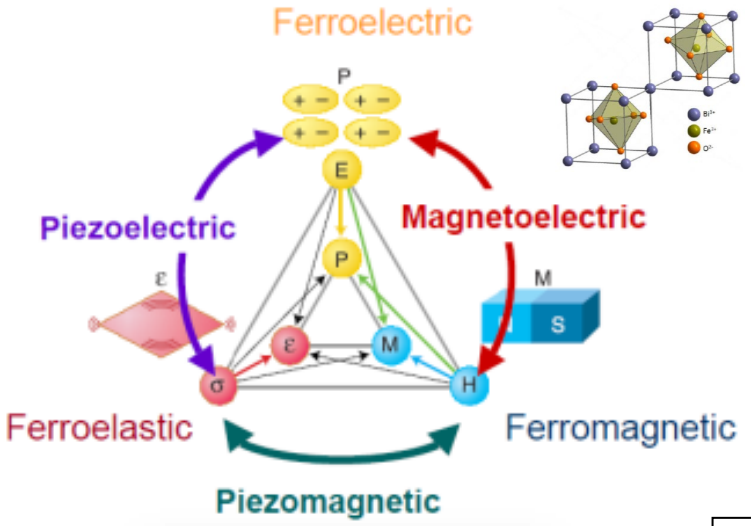
Functional materials for electronics/spintronics

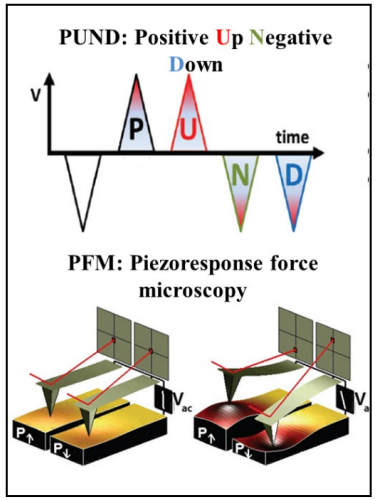
High k (YCTO)

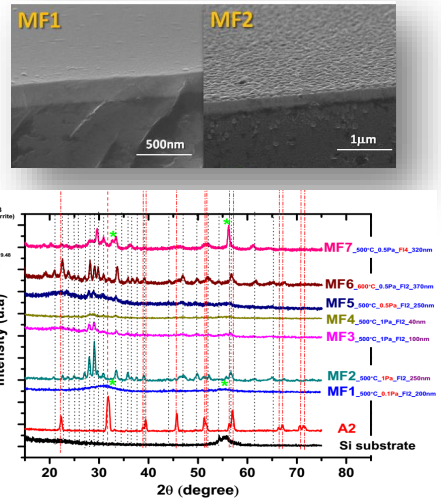


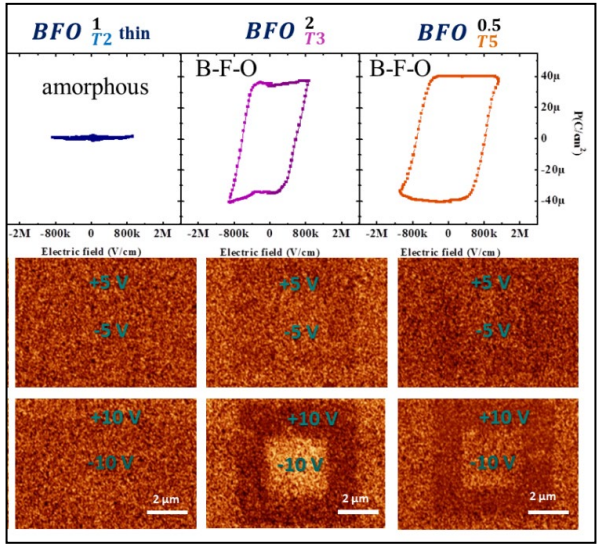


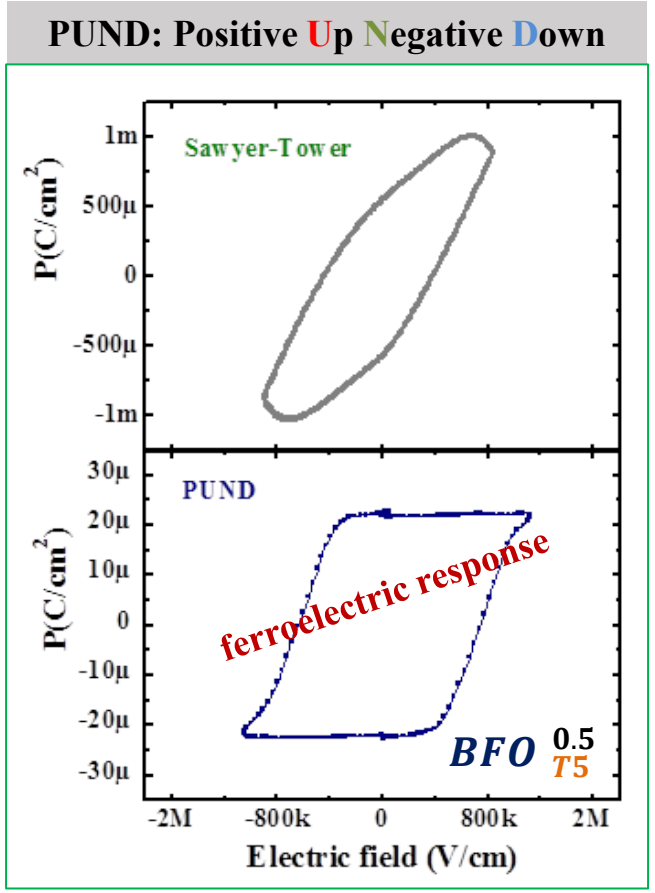
Multiferroics ($BiFeO_3$)







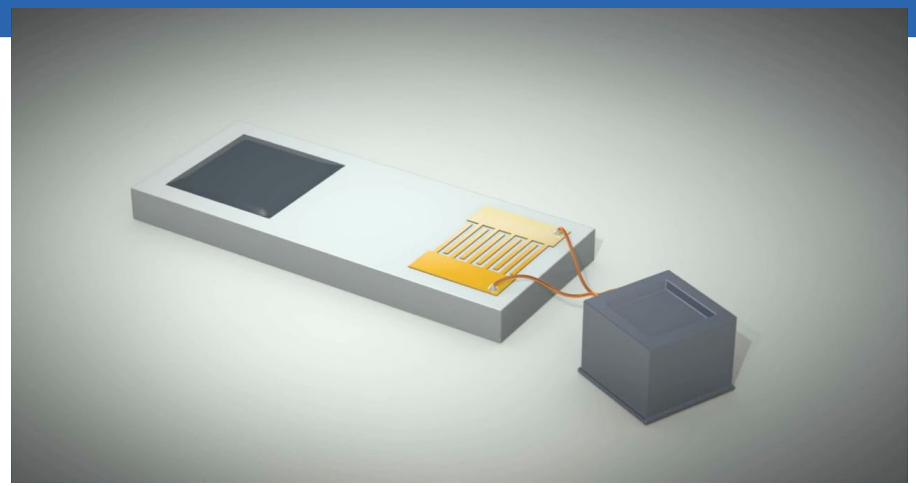




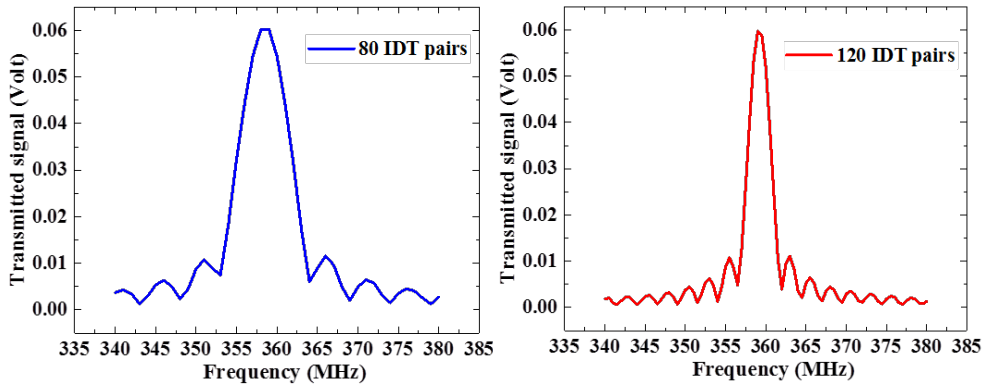
J. Mater. Chem. C, 4, 1080-1087 (2016)
J. Phys. D: Appl. Phys. 49, 405303 (2016)
Microelectron. Eng. 194, 15-18 (2018)
Phys. Status Solidi A-Appl. Mat. 216, 3 (2019).

SAW devices – delay lines

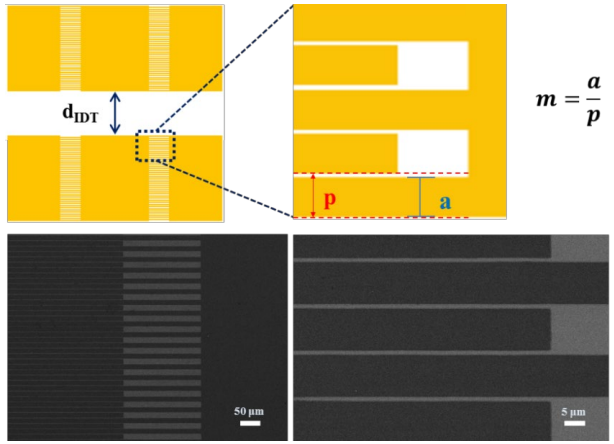
J. Micromech. Microeng. 27, 125002 (2017)
Microelectron. Eng. 202, 31-36 **(2018)**
Biosensors 13, 197 **(2023)**

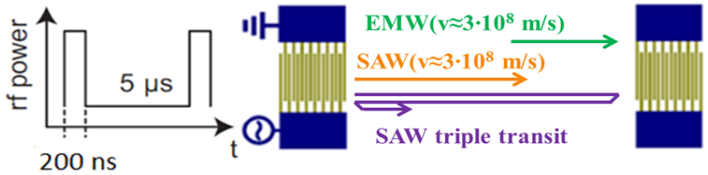


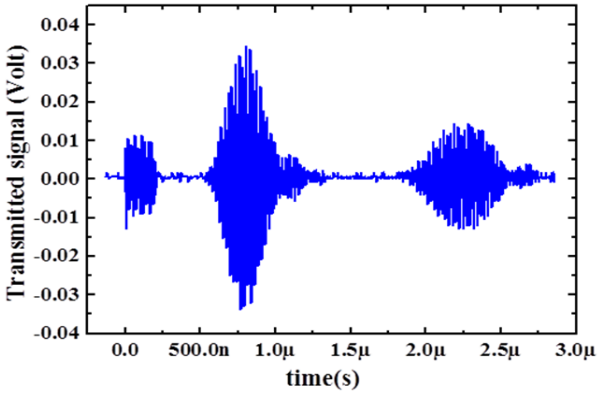
Optimization



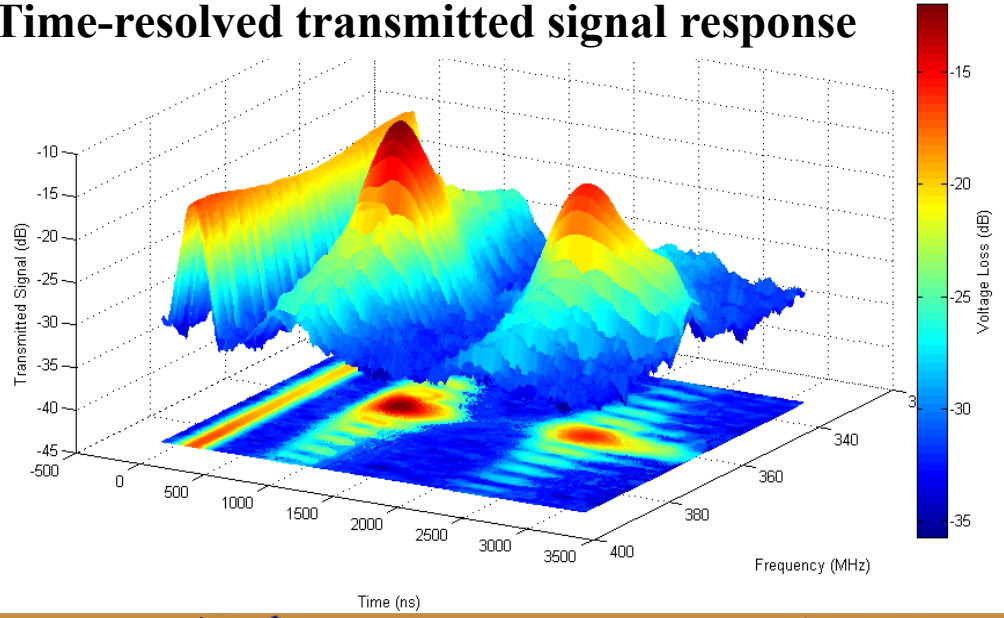
Harmonics

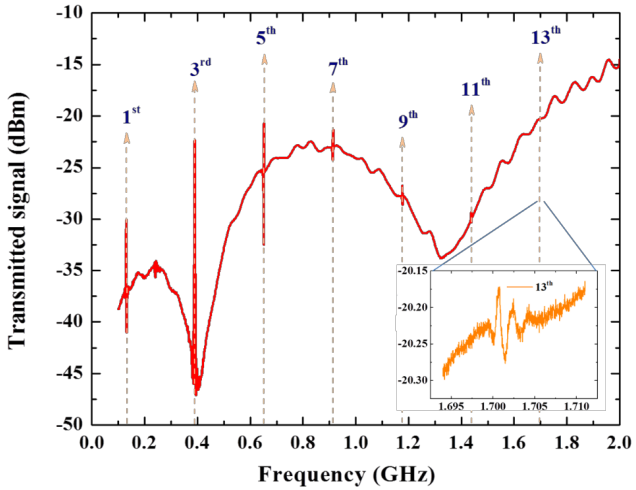




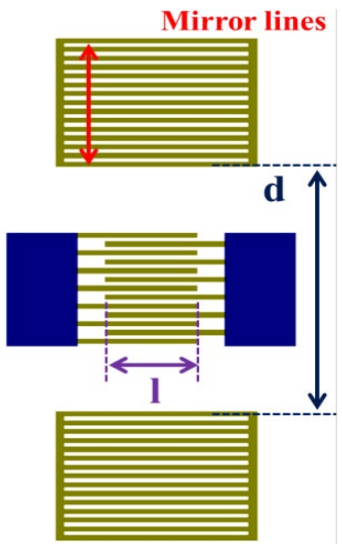


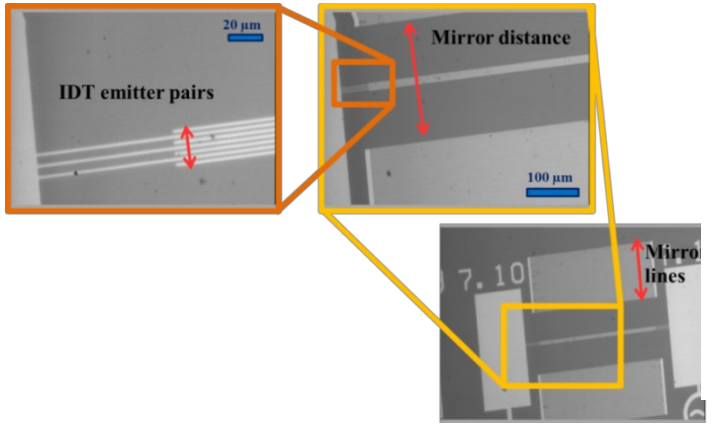
Time-resolved transmitted signal response

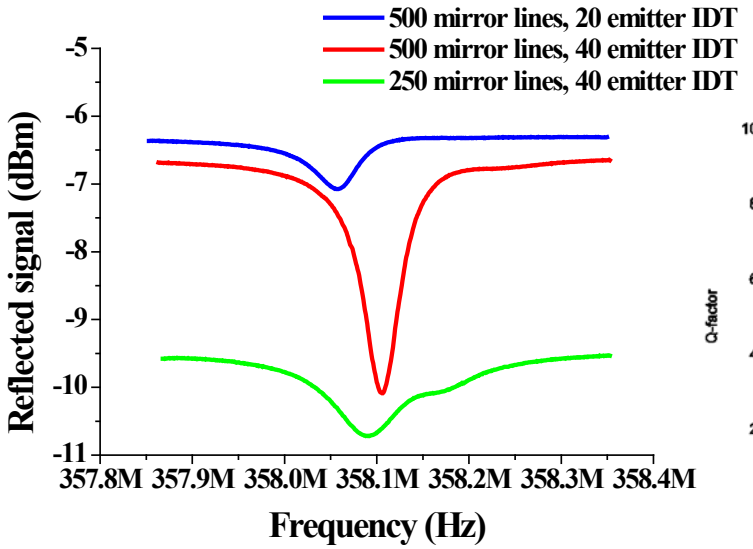




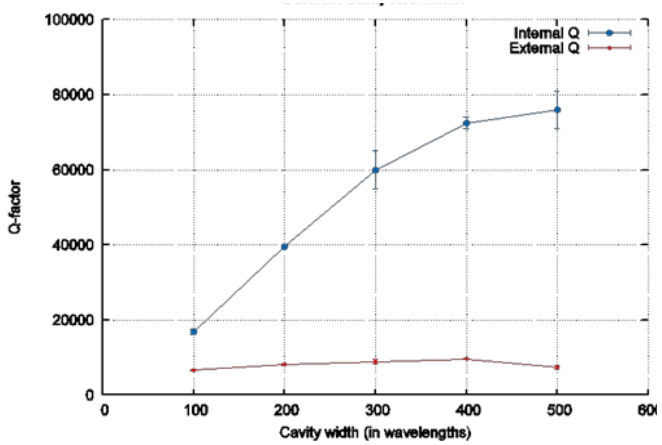
SAW devices - resonators

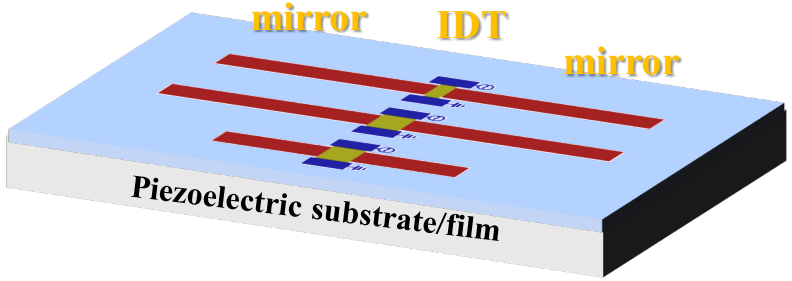


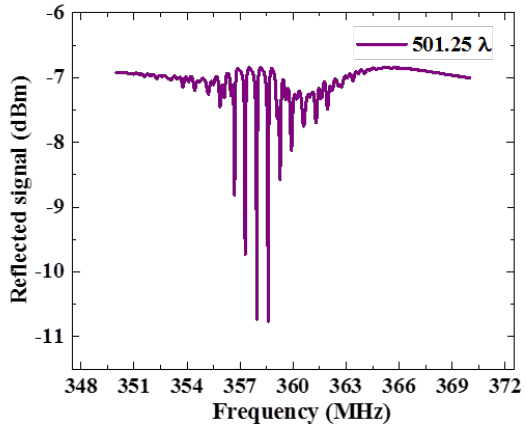


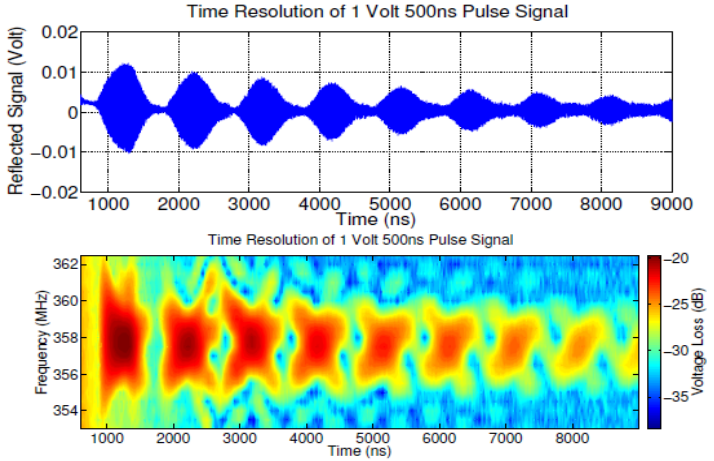


J. Micromech. Microeng. 27, 125002 (2017)
Microelectron. Eng. 202, 31-36 **(2018)**
Biosensors 13, 197 **(2023)**

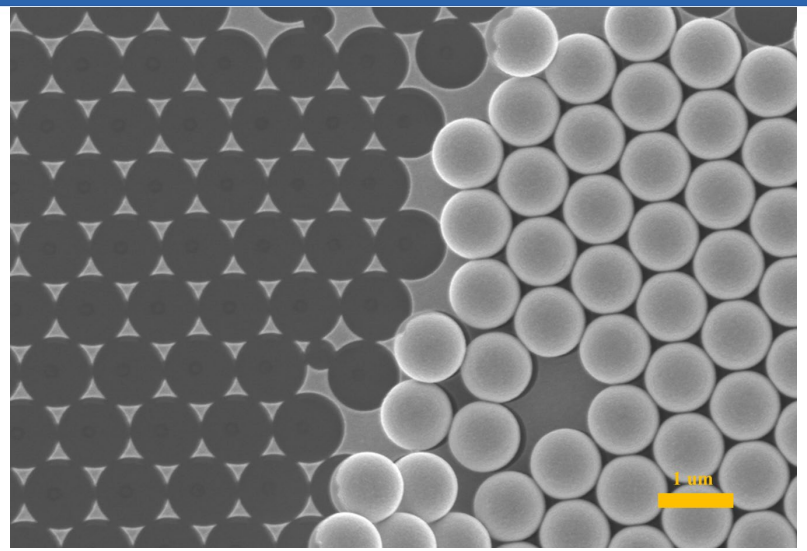


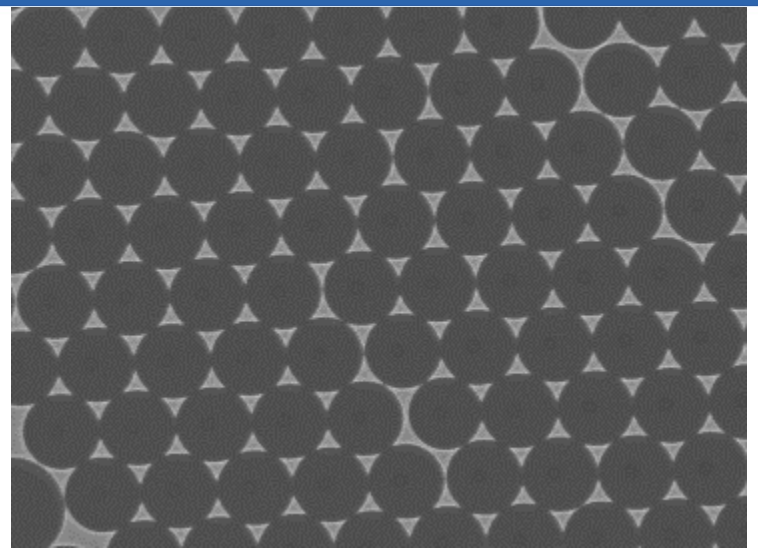


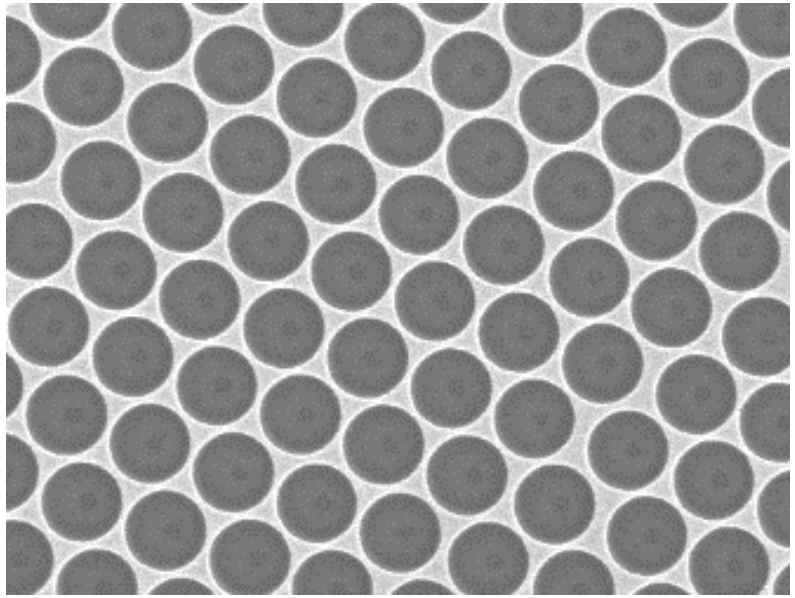


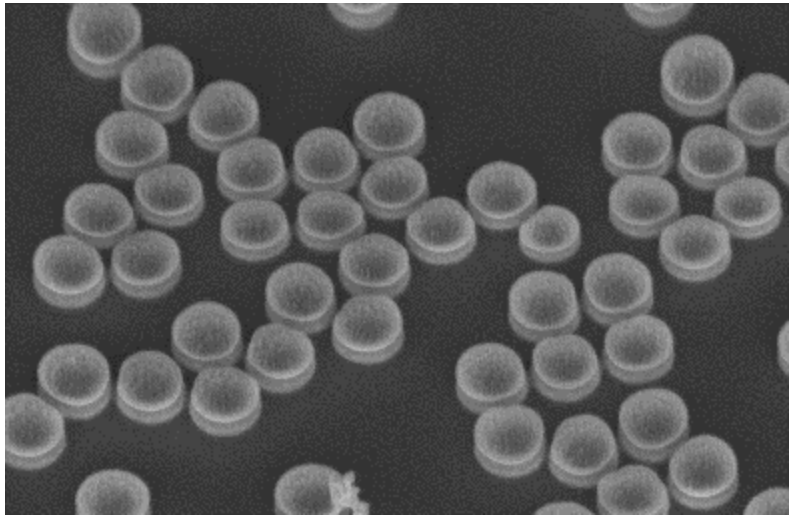


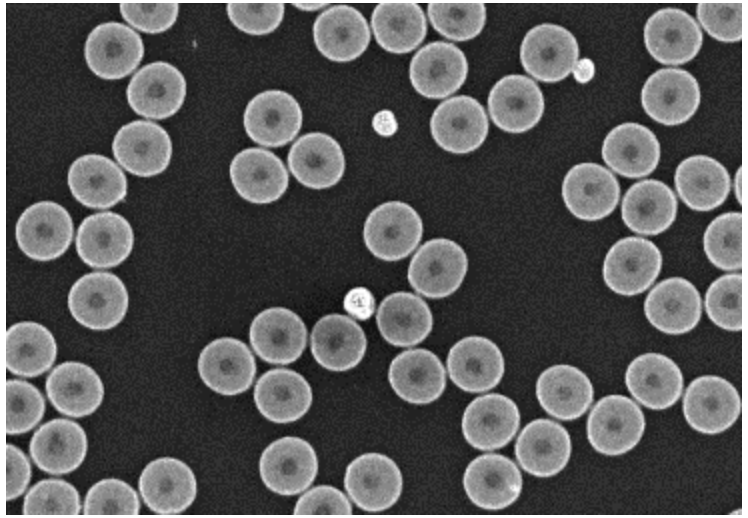
Nanotriangle, nanoholes, nanodisks by colloidal lithography







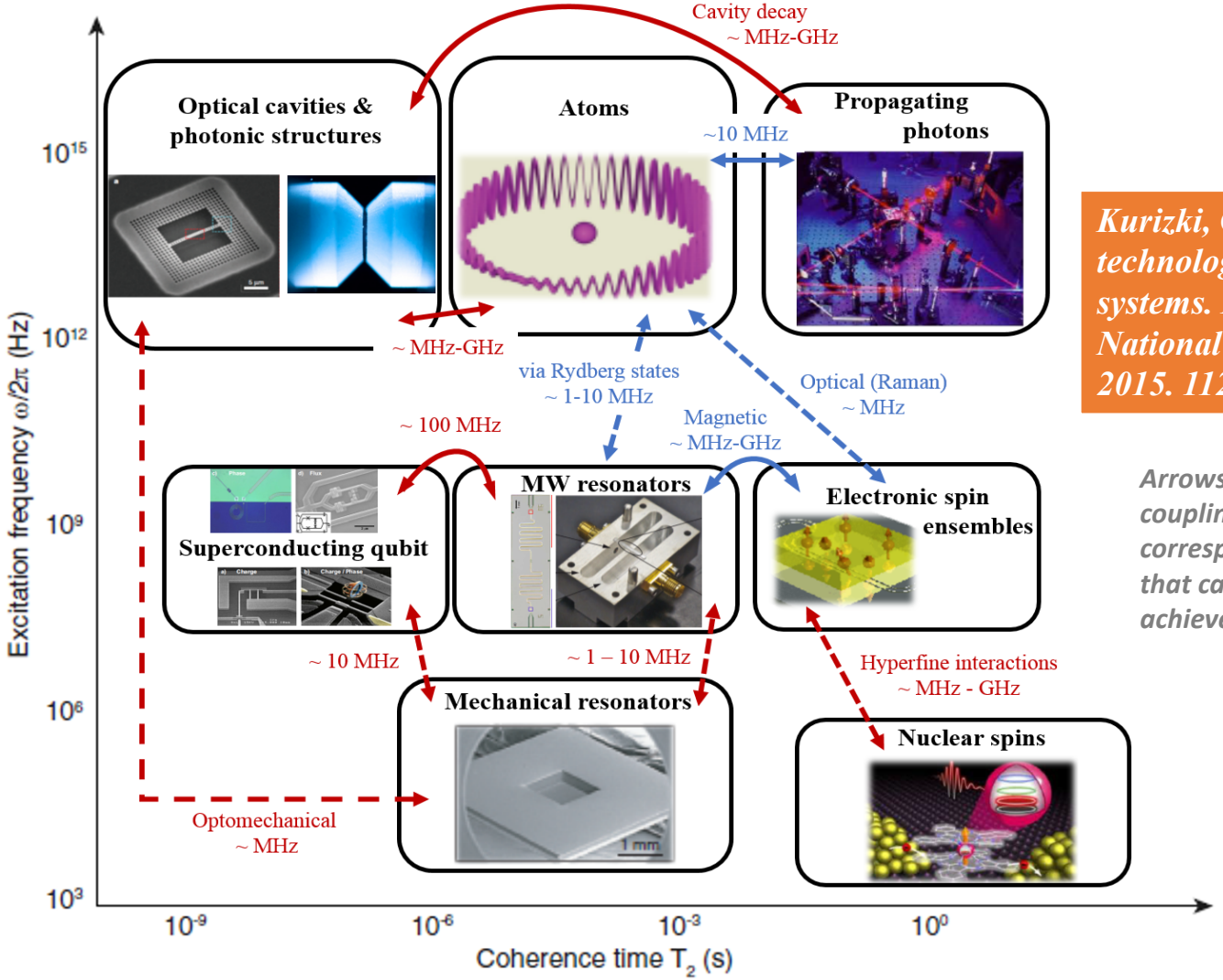




+etching

Beilstein J. Nanotech., **2018,** *9*, 1582
Chemosensors **2021,** *9, 10*

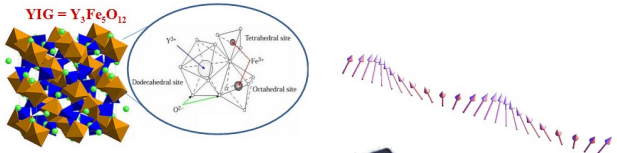
Towards quantum technologies with hybrid systems

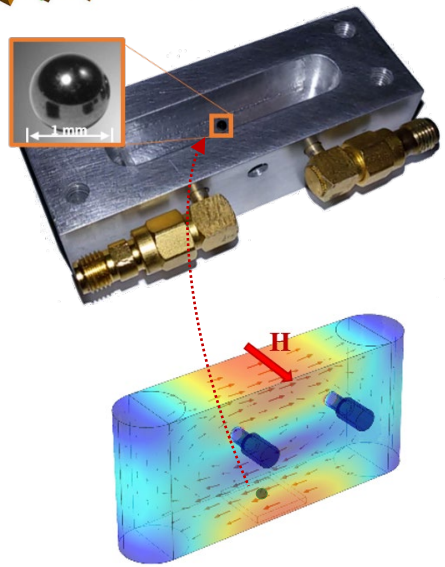


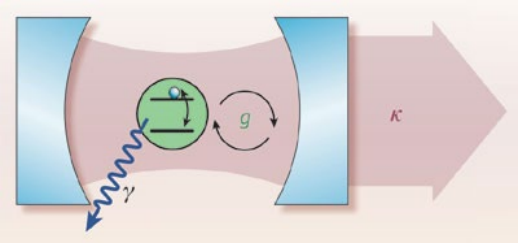
Kurizki, G., et al., Quantum technologies with hybrid systems. Proceedings of the National Academy of Sciences, 2015. 112(13): p. 3866-3873.

Arrows indicate possible coupling mechanisms and the corresponding coupling strength that can be realistically achieved.

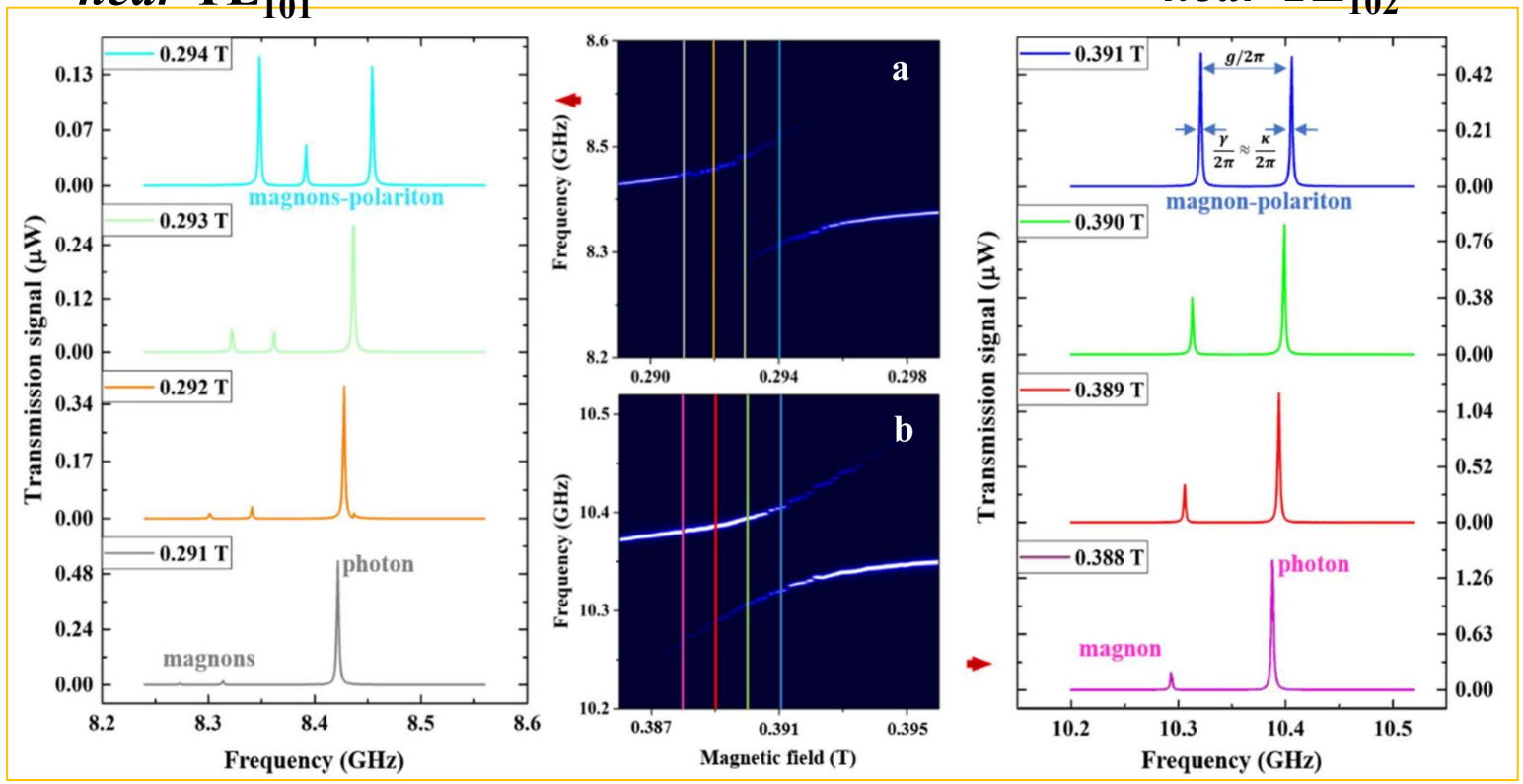
Magnon Polaritons / Strong coupling (1/2)





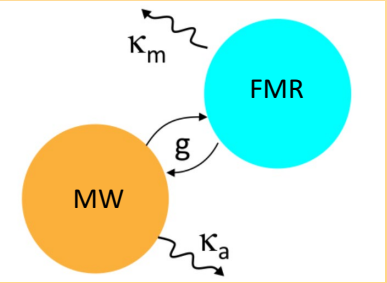


Anticrossing and magnon-polaritons



Strong coupling between fundamental mode in the YIG sphere and the TE_{101} and TE_{102} cavity modes.

Magnon mode damping rate:
κ_m (m = FMR, MSMs)
Magnon mode at
ω_m (m = FMR, MSMs)



Cavity mode at:
ω_c
Total cavity decay rate:
$\kappa_c = \frac{1}{2}(2\kappa_{i,o} + \kappa_{int})$

Coupling strength
g_m (m = FMR, MSMs)

A. Leo et al. Phys Rev B 101, 014439 (2020)

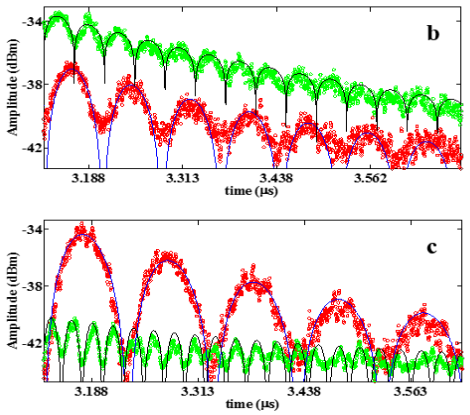
Magnon Polaritons / Strong coupling (2/2)

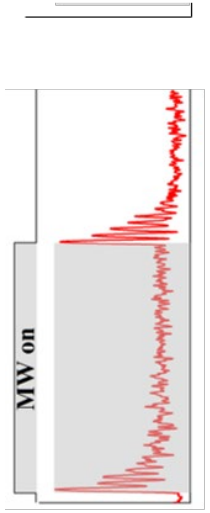
Rabi oscillations

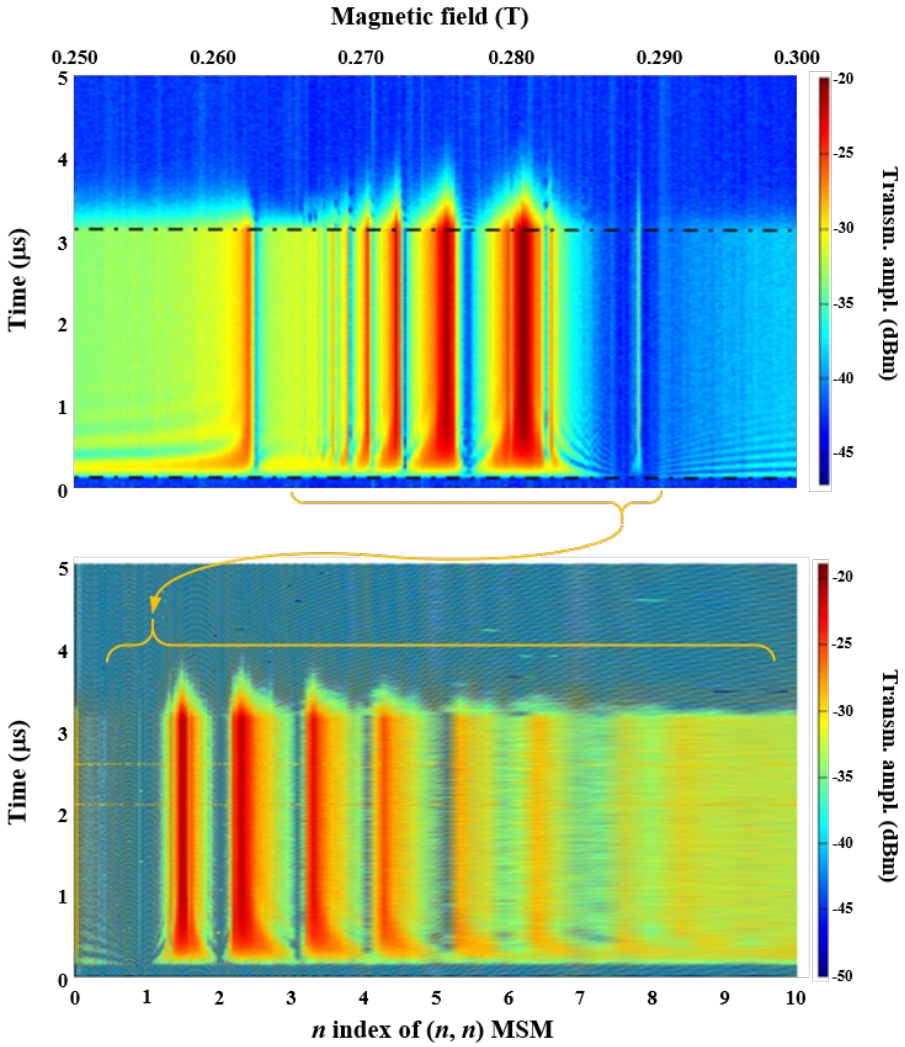
$$P\left(\frac{\omega_i}{2\pi}\right) \propto A_i \cdot log\left[sin^2\left(\frac{g_i}{2\pi}t\right) \cdot exp\left(-\frac{2\kappa_c - \kappa_{int}}{2\pi}t\right)\right]$$

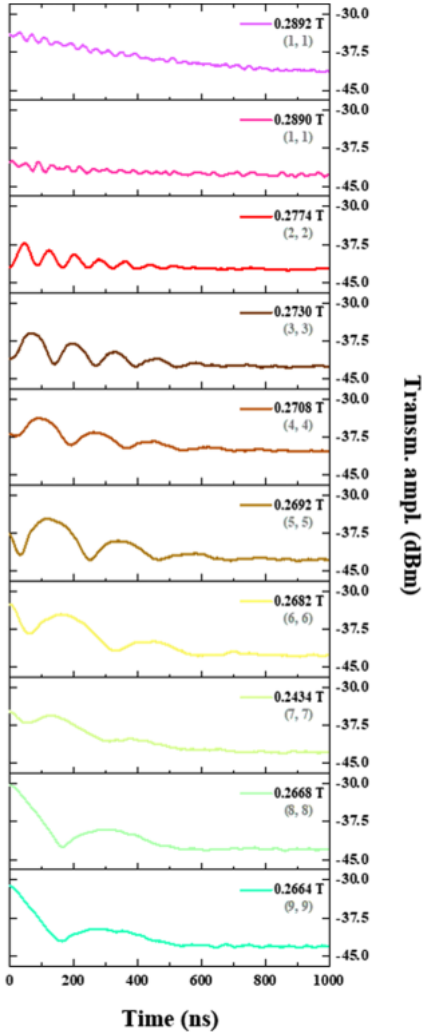
Coupling among resonators **MW cavity relaxation**

Rabi's oscillations between TE_{101} and Kittel mode









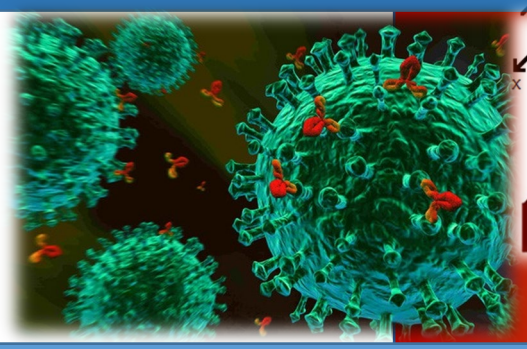
A. Leo et al. Phys Rev B 101, 014439 (2020)

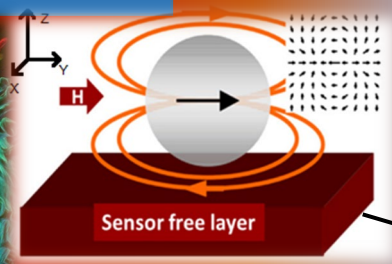
MADiA
MAgnetic DIagnostic Assay for neurodegenerative diseases

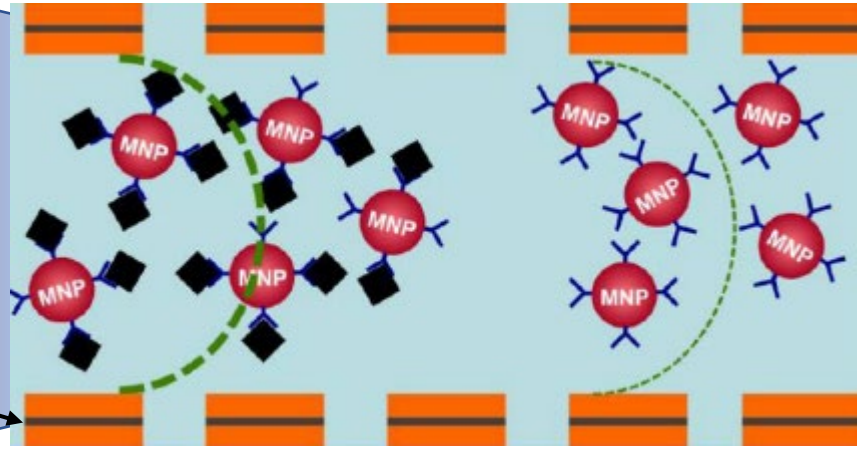
UE-H2020-ICT project MADIA (Grant No. 732678).

Magnetoresistive sensors

Detection of neurodegenerative diseases biomarkers from biological fluids

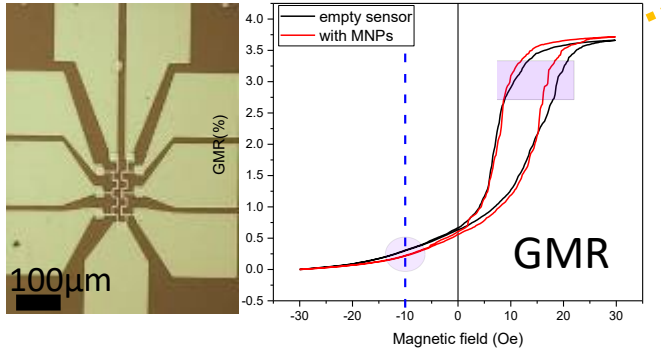


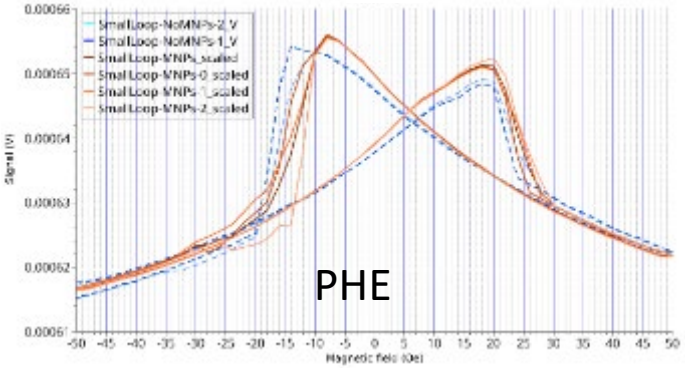




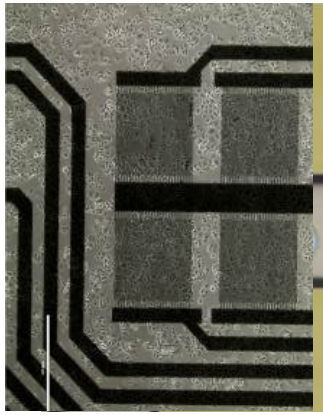
Magnetoresistive sensors

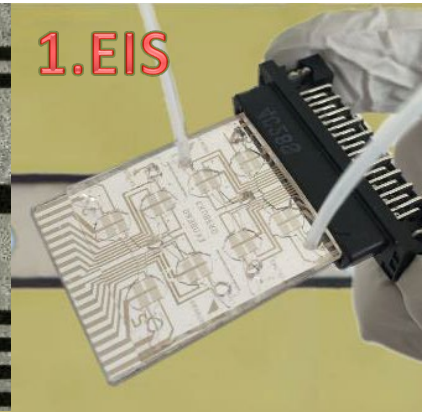
Magnetic nanoparticles functionalized with antibodies

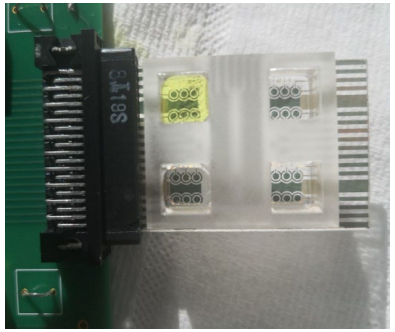


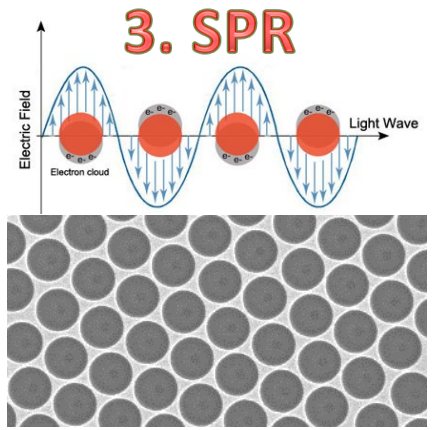


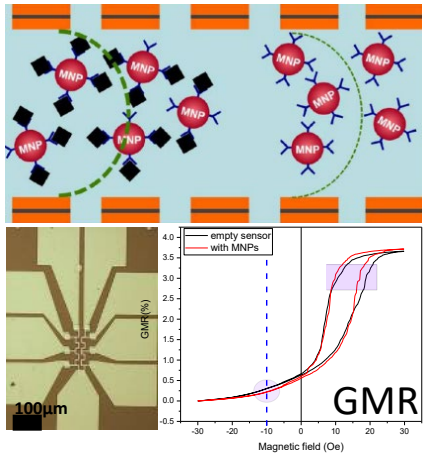
Sensors & Biosensors

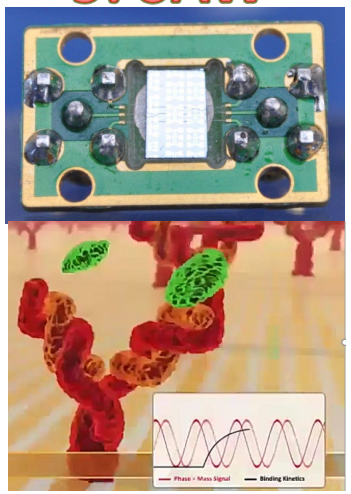


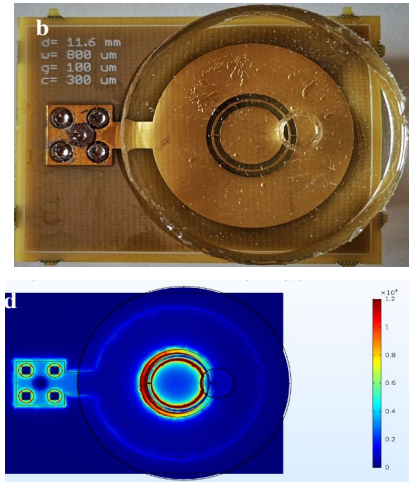


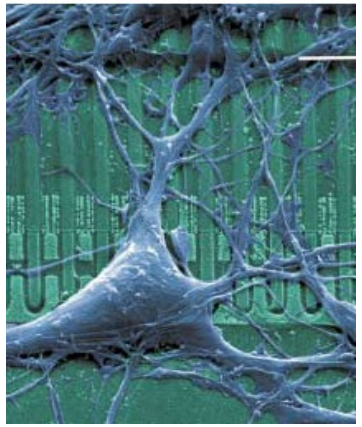








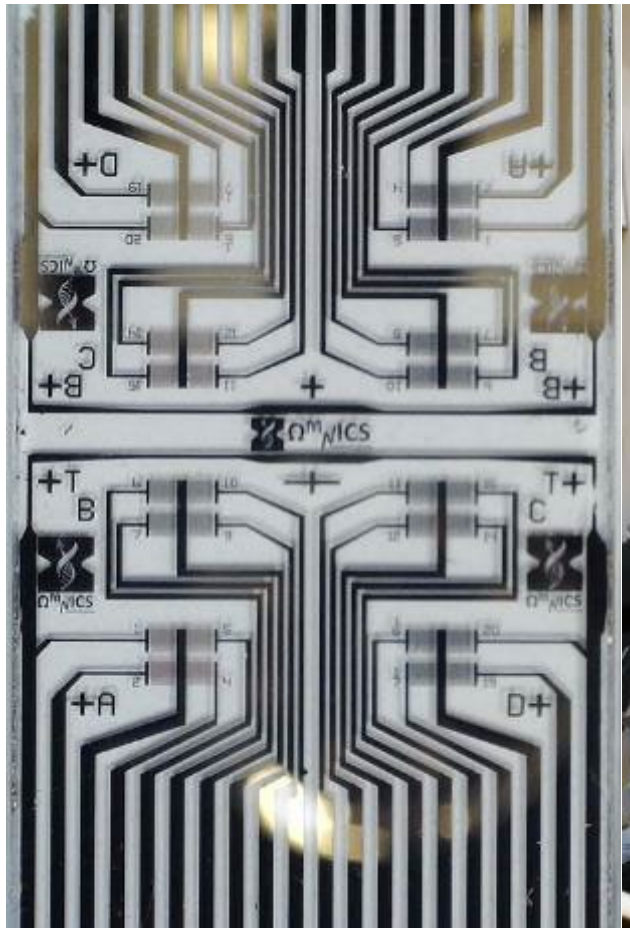


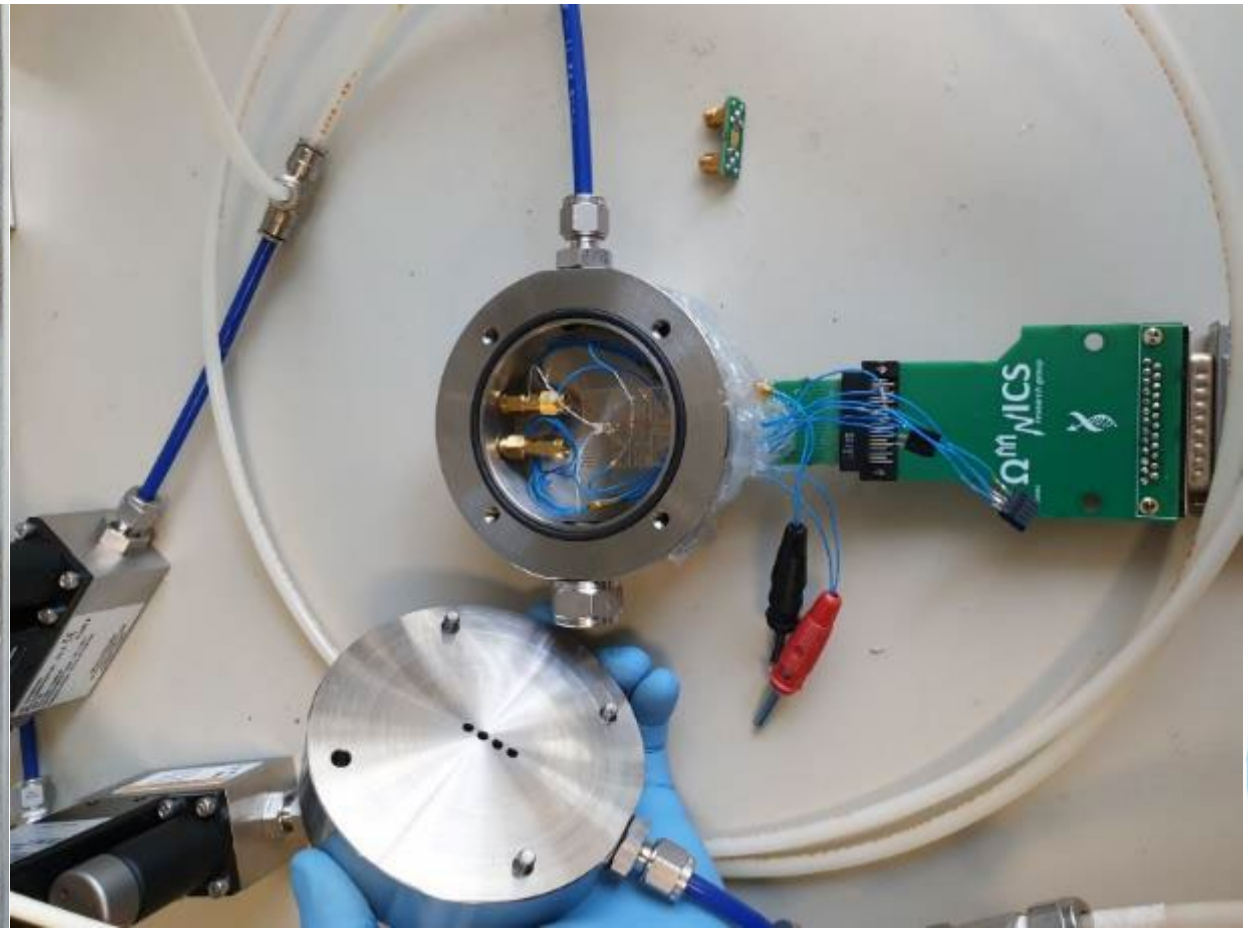


Diagnostics

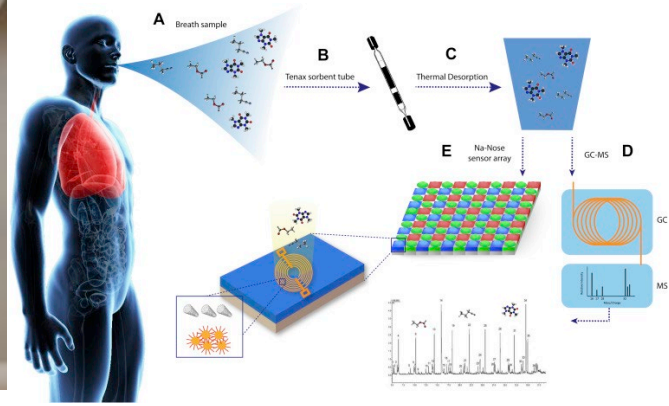
Food & Environment

Gas Sensors (in collaboration with IBM)

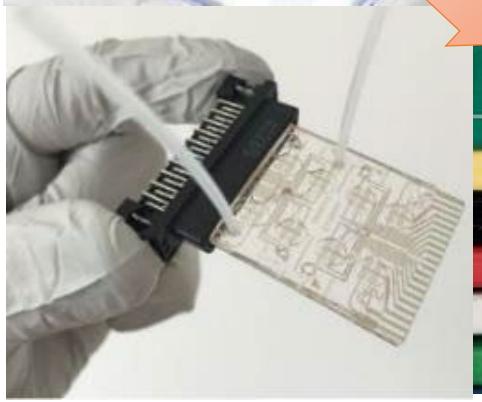


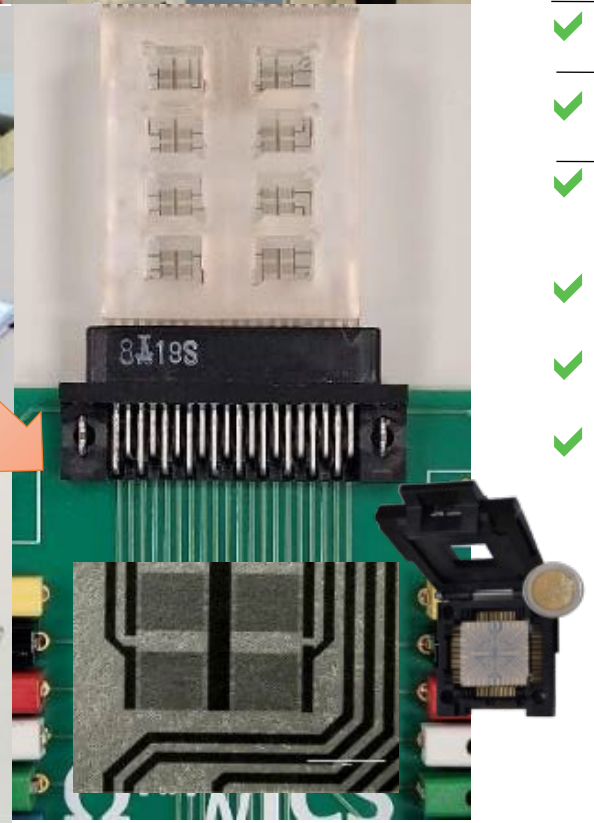


A. Milone, A. G. Monteduro, S. Rizzato, A. Leo, C. Di Natale, S. S. Kim and G. Maruccio, *Advances in Materials and Technologies for Gas Sensing from Environmental and Food Monitoring to Breath Analysis*, ***Advanced Sustainable Systems*** **2023**, Vol. 7, p. 2200083, **issn.** 2366-7486, http://dx.doi.org/https://doi.org/10.1002/adsu.202200083.



Lab on a chip





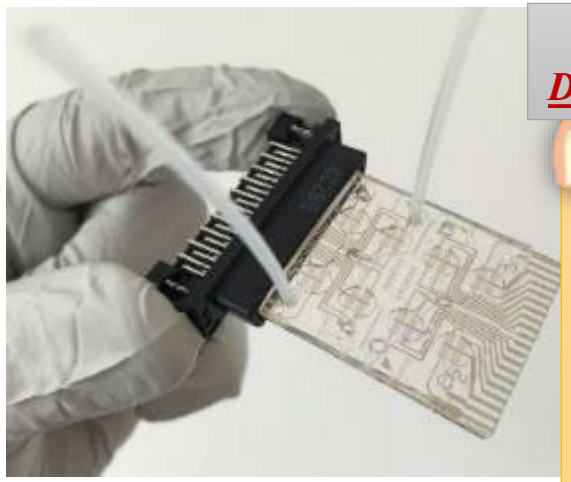
MULTIGNOSTICS

- ✓ Response time < 1 hour
- ✓ Cost < 5 euros
- ✓ Multi - parameters tests +
- ✓ Low reagents consumption
- ✓ No skilled people
- ✓ Portability
- ✓ Modularity / scalability
- ✓ Automated sample handling

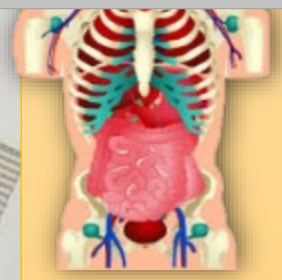
APPLICATION AREAS

- ✓ Diagnostics
- ✓ Pharmaceutics
- ✓ Chemical Synthesis
- ✓ Drug tests
- ✓ Cell biology
- ✓ Water & food quality
- ✓ Environmental monitoring

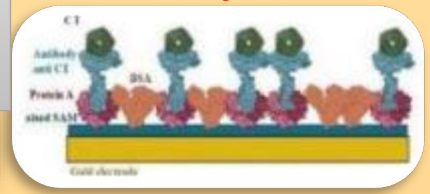
Multipurpose applications

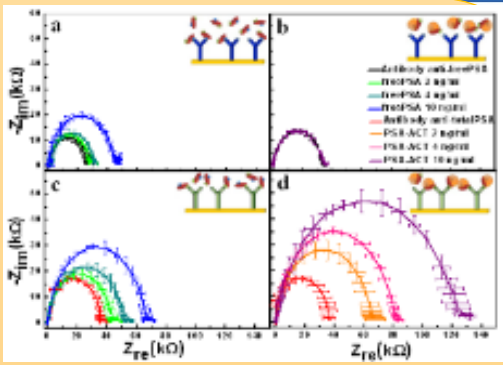


MEDICAL DIAGNOSTICS



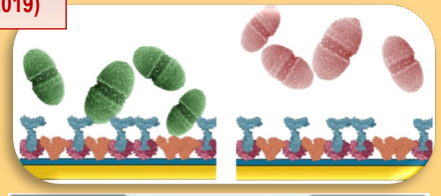
1. Immunoassay: PSA & PDAC

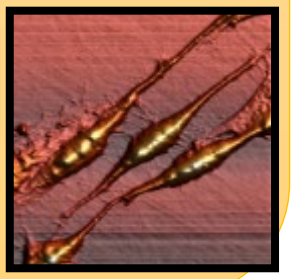




Lab on a Chip 13, 730 (2013).
Analyst 138, 5404 (2013)
[R] Sensors 18, 3175 (2018)
[R] Sensors 18, 3607 (2018)
Biosens. Bioelectron. 128, 122 (2019)

2. Cytotoxicity, Migration & Proliferation assays

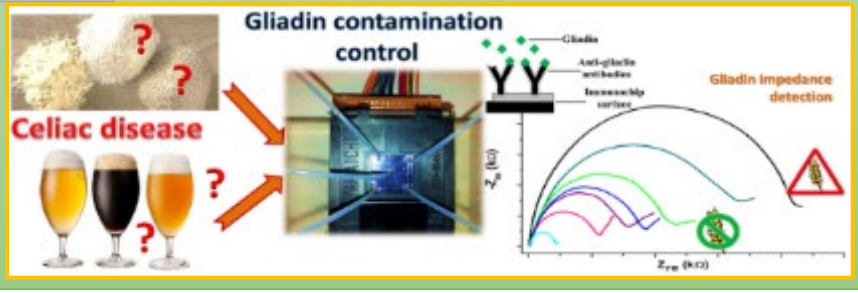




Biosens. Bioelectron. 25, 2711–2716 (2010)
Lab on a chip, 11, 4081, (2011)
Lab on a Chip 13, 3789 (2013)
Biosens. Bioelectron. 79, 9-14 (2016)
[R] Biotechnology Advances 40, 107498 (2020)
International Journal of Molecular Sciences 22, 12 (2021)

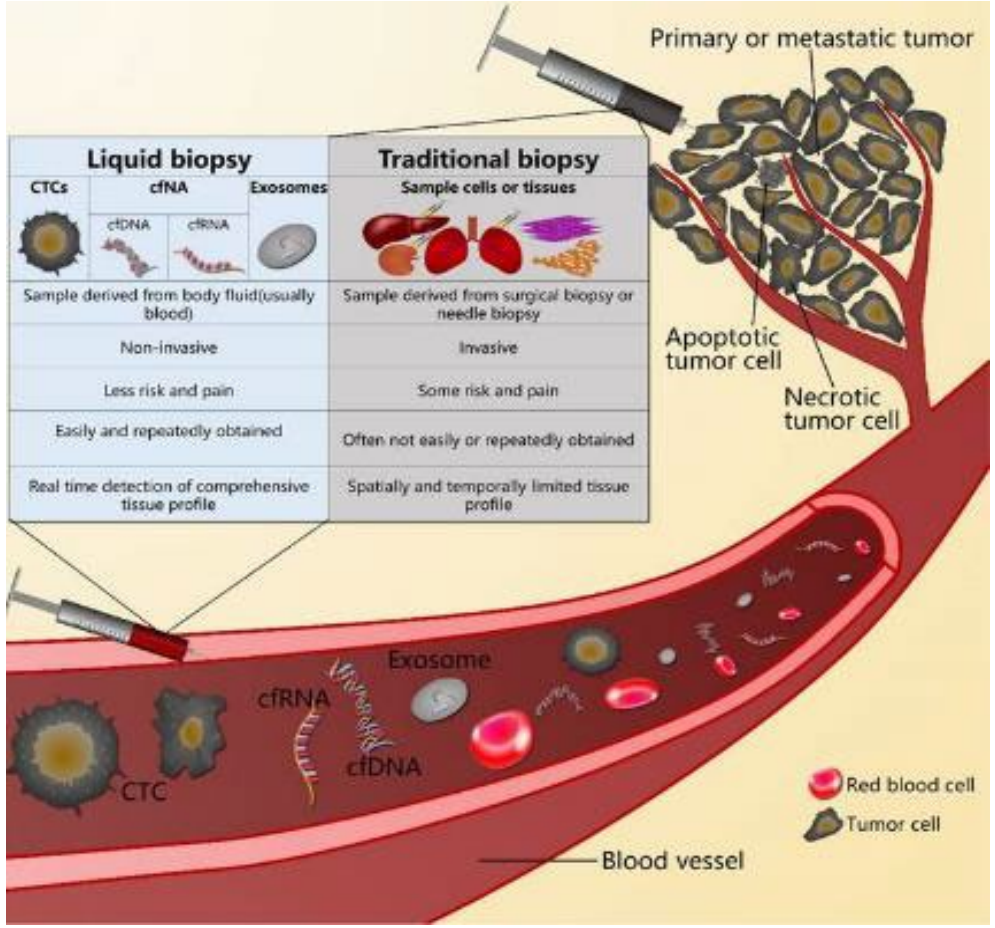
OMNICS research group

FOOD / ENVIRONMENT



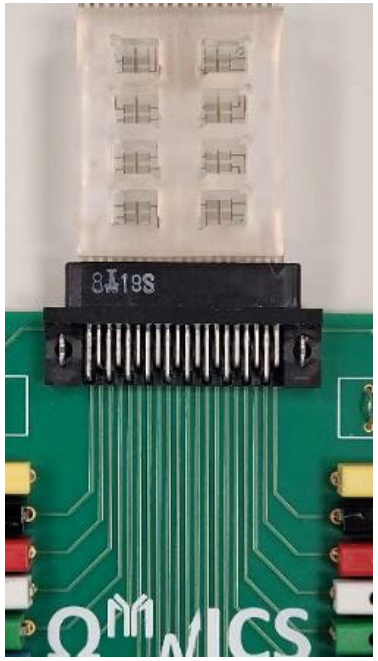
Talanta 2015, 142, 57-63.
Analytical Methods, 2016, 8, 3055-3060.
[R] Foods 2014, 3 (3), 511
Sci Rep 8, 7376 (2018)
[R] Micromachines 11, 491 (2020)
Biosensors 10, 64 (2020)
[R] Sensors 21, 22 (2020)
Biosensors 12, 12 (2022)

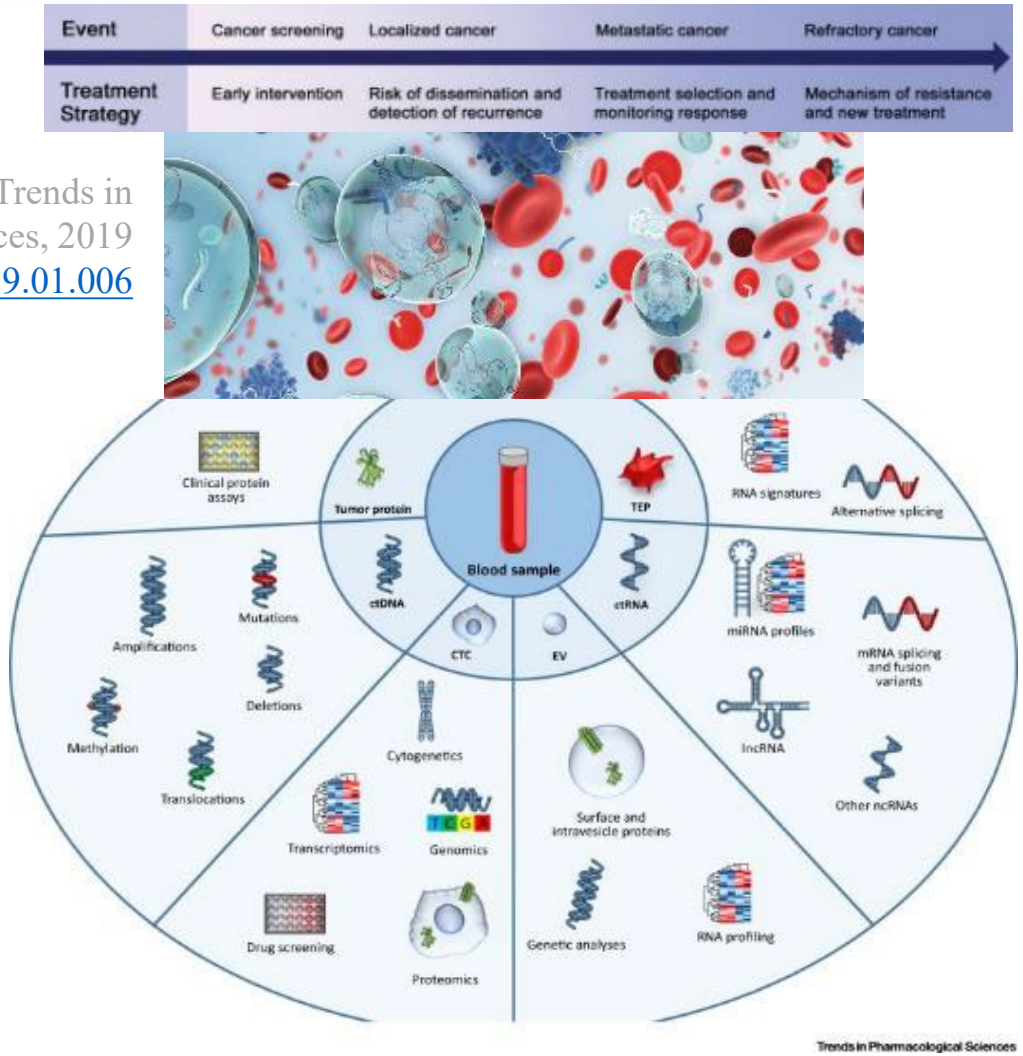
Liquid Biopsies



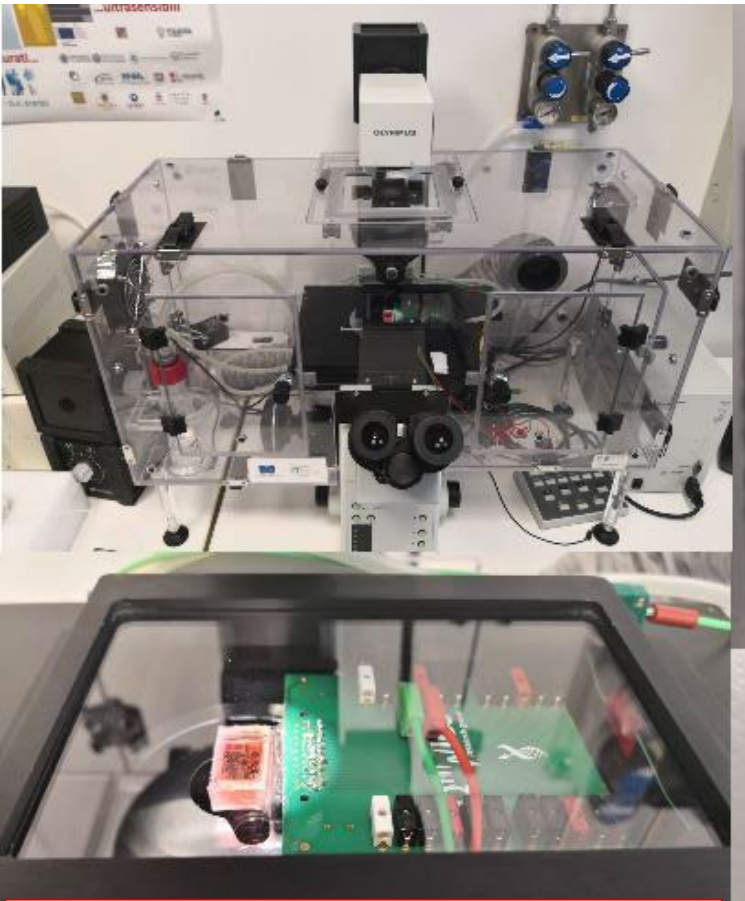
Z. Qi et al., *J Cancer* 2018; 9(18):3417-3426, doi:10.7150/jca.24591

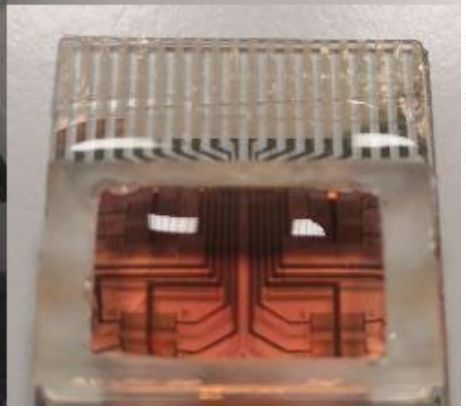
G. De Rubis et al, Trends in Pharmacological Sciences, 2019
doi.org/10.1016/j.tips.2019.01.006

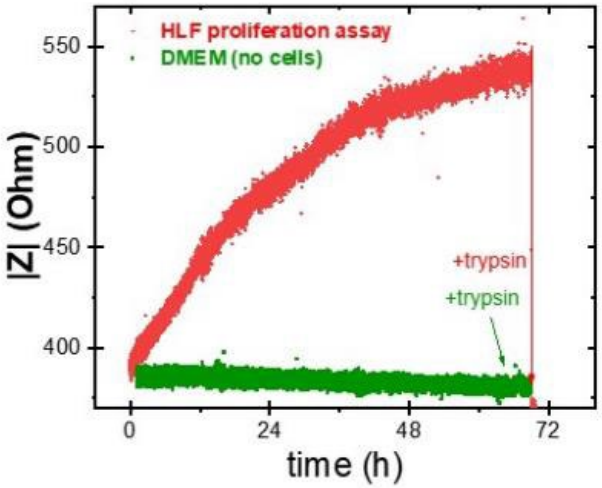


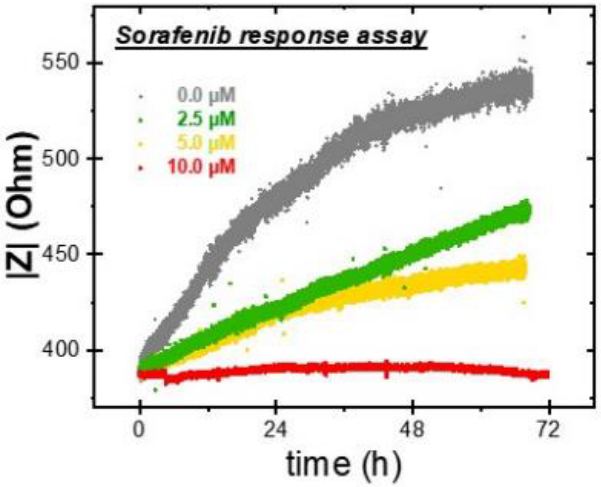


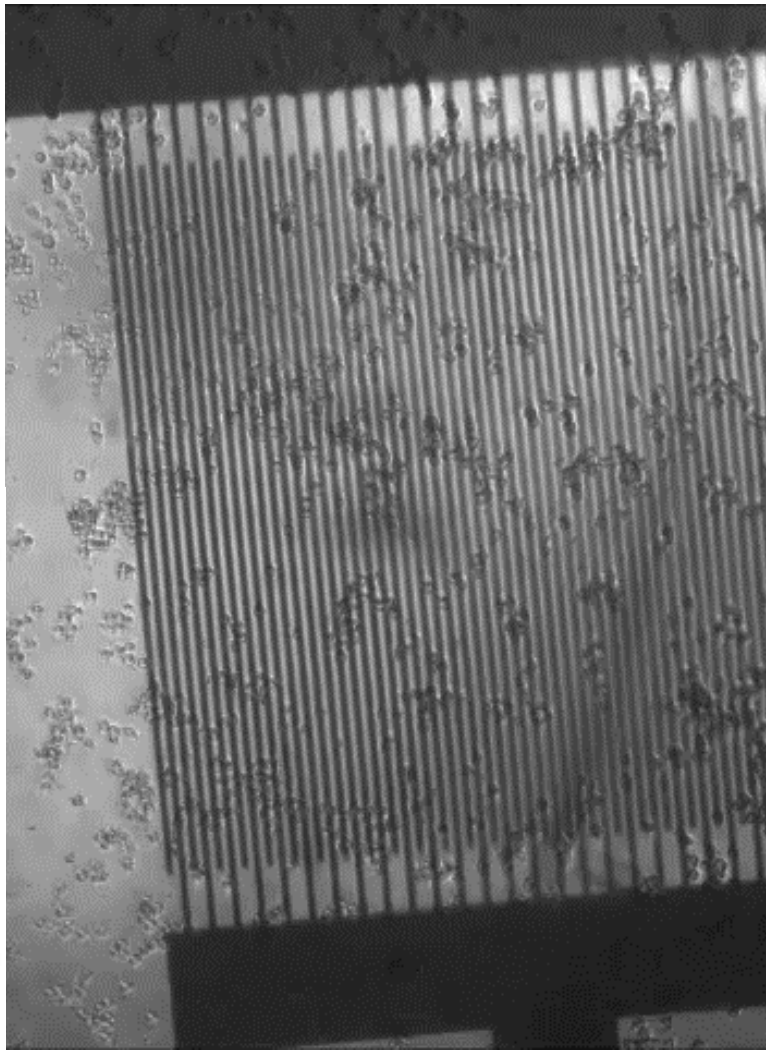
Drug screening on chip





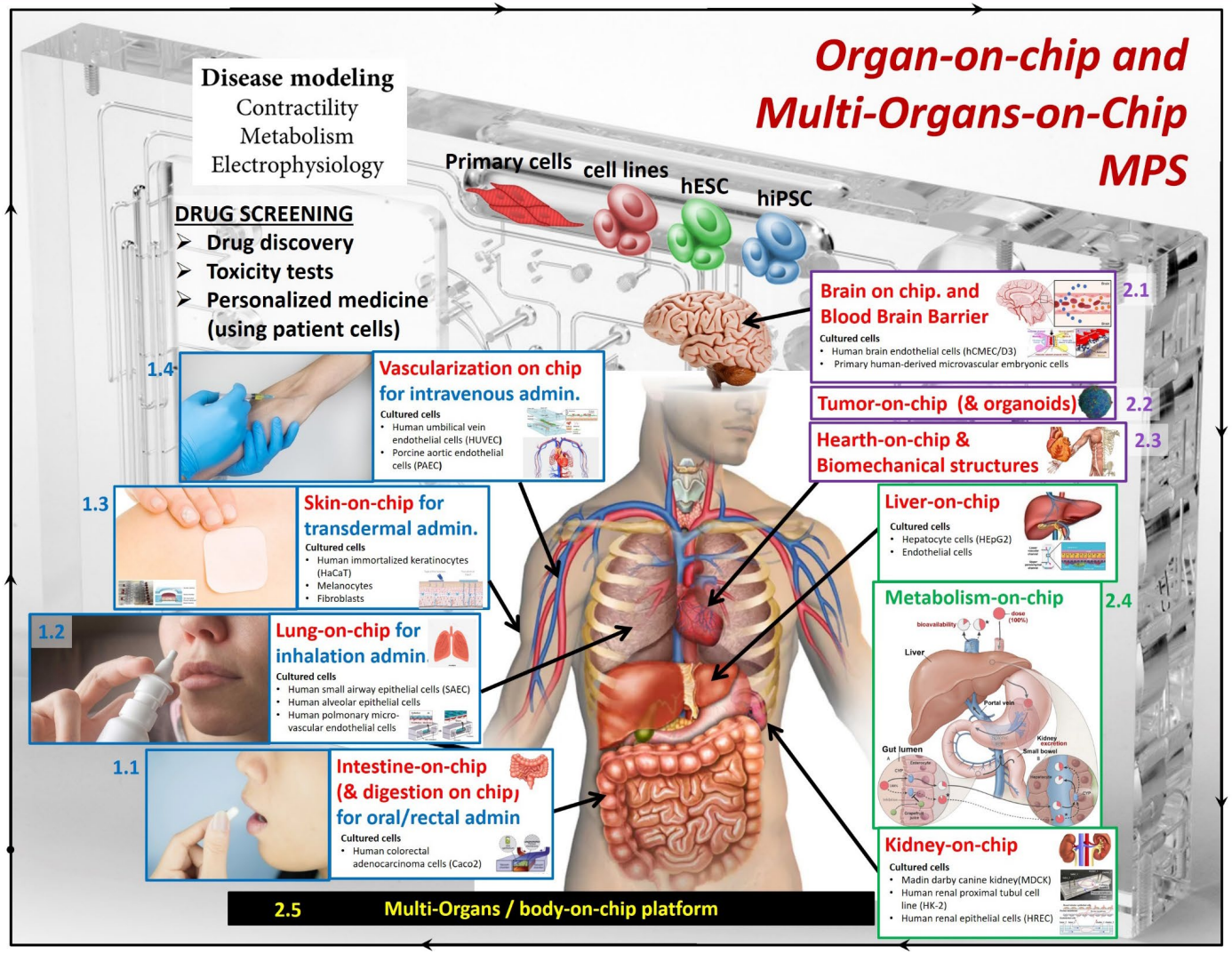


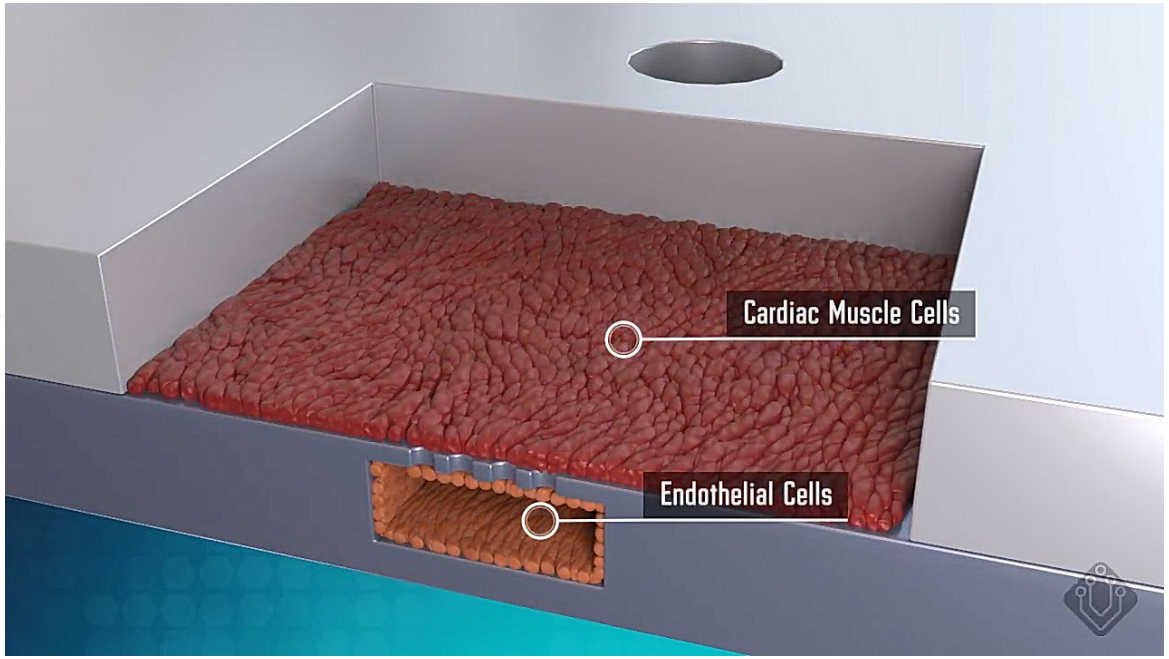




E. Piccinno et al., International Journal of Molecular Sciences **2021**, *22*, 13090, doi:10.3390/ijms222313090.

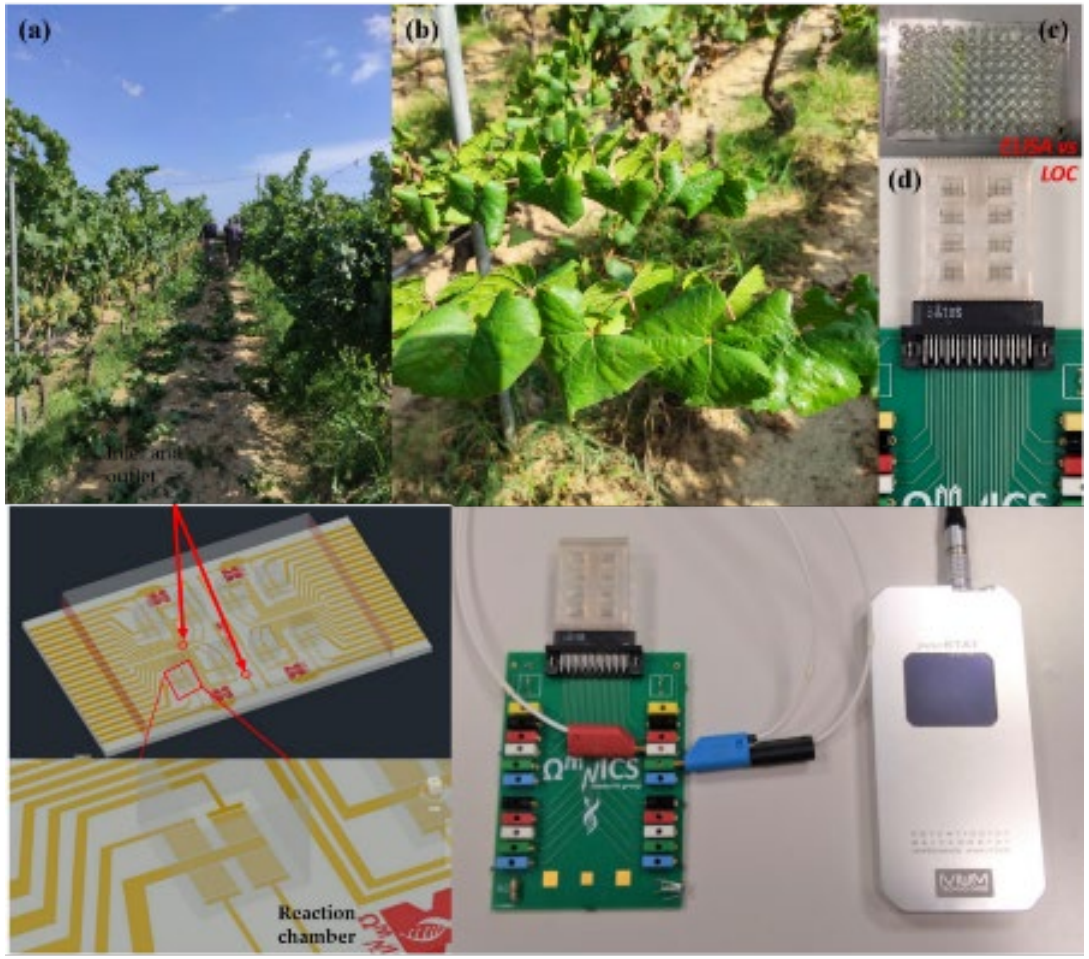
Organ-on-chip

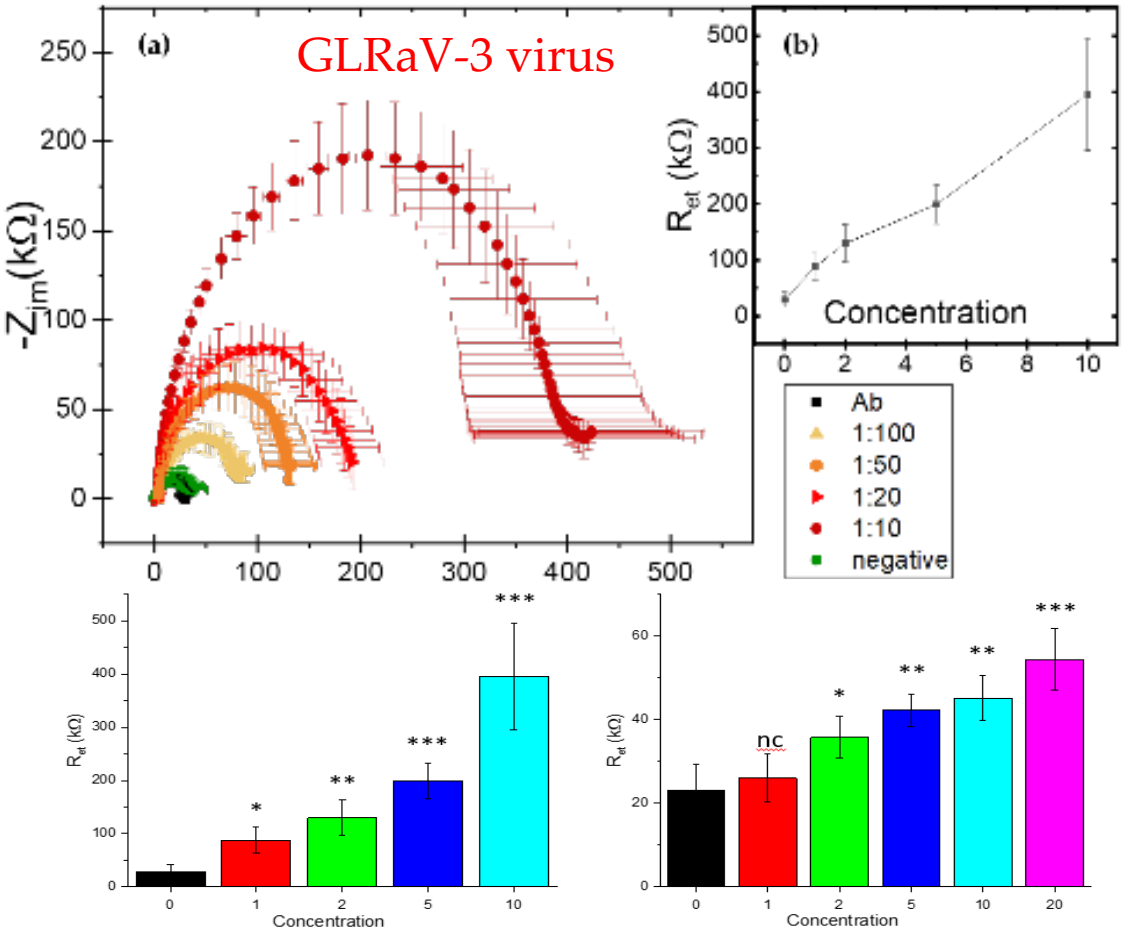




A. G. Monteduro, S. Rizzato, G. Caragnano, A. Trapani, G. Giannelli and G. Maruccio, *Organs-on-chips technologies – A guide from disease models to opportunities for drug development*, **Biosensors and Bioelectronics 2023**, Vol. *231*, p. 115271, **issn.** 0956-5663, http://dx.doi.org/https://doi.org/10.1016/j.bios.2023.115271.

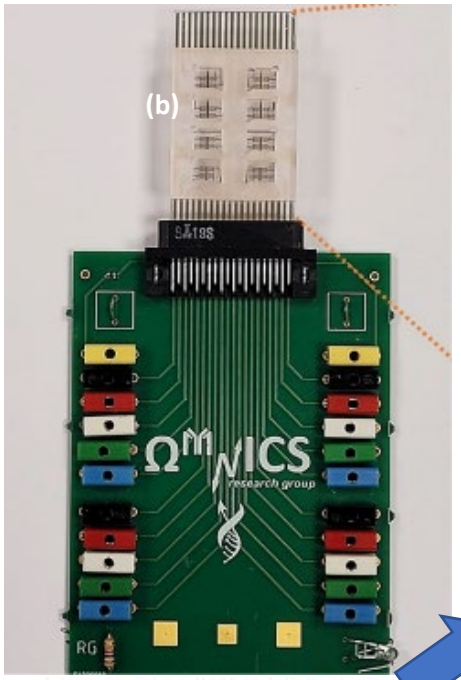
LOC Detection of Ampelovirus and Nepovirus

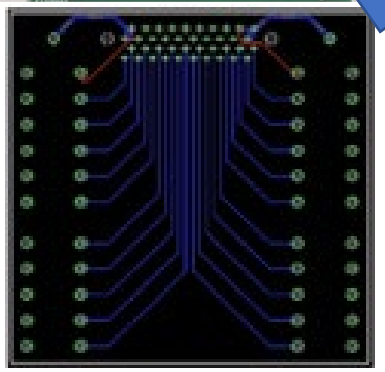


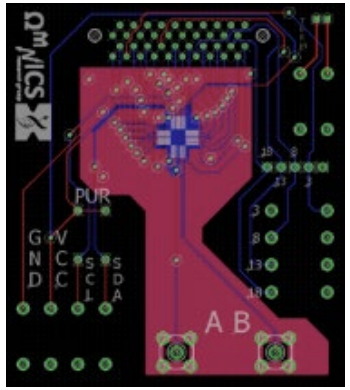


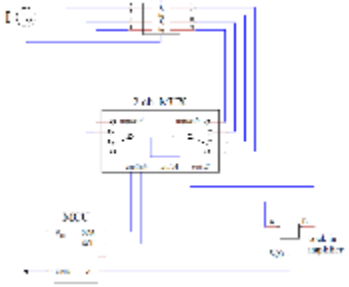
Buja et al., Biosensors **2022**, *12*(3), 147; https://doi.org/10.3390/bios12030147

Prototyping









Omnics Labs : Dissemination

UNIVERSITÀ DEL SALENTO INFN / OMNICS research group / IRIS / EMFL European Magnetic Field Laboratory / research@omnics.it

Omnics Lab Exhibits - European Researchers Night

ERN APULIA MARIE CURIE ACTIONS
NOTTE EUROPEA DEI RICERCATORI E DELLE RICERCATRICI

European Commission

https://www.ern-apulia.it/enti/infrastrutture-di-ricerca-emfl-isabel-iris/

UNIVERSITÀ DEL SALENTO | Consiglio Nazionale delle Ricerche | INFN Istituto Nazionale di Fisica Nucleare | OMNICS research group | IRIS | SAPE | EMFL European Magnetic Field Laboratory

research@omnics.it
http://www.omnics.it/home/

Omnics Lab Exhibits - MagLev demonstrator

ERN APULIA MARIE CURIE ACTIONS
NOTTE EUROPEA DEI RICERCATORI E DELLE RICERCATRICI

https://www.ern-apulia.it/enti/infrastrutture-di-ricerca-emfl-isabel-iris/

UNIVERSITÀ DEL SALENTO | Consiglio Nazionale delle Ricerche | INFN Istituto Nazionale di Fisica Nucleare | OMNICS research group | IRIS | EMFL European Magnetic Field Laboratory

research@omnics.it
http://www.omnics.it/home/

Omnics Lab Exhibits - MagLev demonstrator

ERN APULIA MARIE CURIE ACTIONS
NOTTE EUROPEA DEI RICERCATORI E DELLE RICERCATRICI

European Commission

https://www.ern-apulia.it/enti/infrastrutture-di-ricerca-emfl-isabel-iris/

UNIVERSITÀ DEL SALENTO | Consiglio Nazionale delle Ricerche | INFN Istituto Nazionale di Fisica Nucleare | OMNICS research group | IRIS | SAPE | EMFL European Magnetic Field Laboratory

research@omnics.it
http://www.omnics.it/home/

Omnics Lab Exhibits - MagLev demonstrator

ERN APULIA MARIE CURIE ACTIONS
NOTTE EUROPEA DEI RICERCATORI E DELLE RICERCATRICI

https://www.ern-apulia.it/enti/infrastrutture-di-ricerca-emfl-isabel-iris/

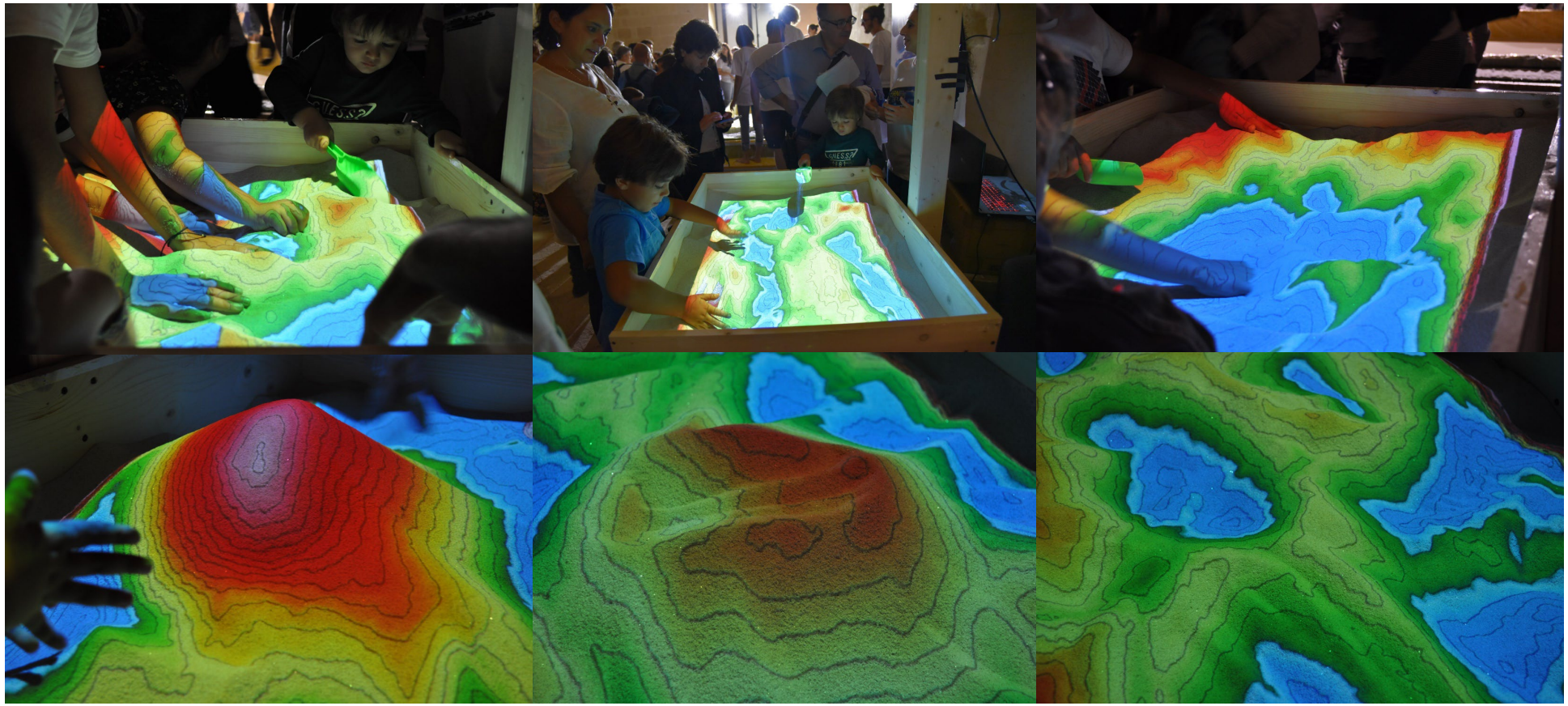
UNIVERSITÀ DEL SALENTO | Consiglio Nazionale delle Ricerche | INFN Istituto Nazionale di Fisica Nucleare | OMNICS research group | IRIS | EMFL European Magnetic Field Laboratory

research@omnics.it
http://www.omnics.it/home/

Omnics Lab Exhibits - SandBox demonstrator

ERN APULIA MARIE CURIE ACTIONS
NOTTE EUROPEA DEI RICERCATORI E DELLE RICERCATRICI

https://www.ern-apulia.it/enti/infrastrutture-di-ricerca-emfl-isabel-iris/



UNIVERSITÀ DEL SALENTO | Consiglio Nazionale delle Ricerche | INFN Istituto Nazionale di Fisica Nucleare | OMNICS research group | IRIS | EMFL European Magnetic Field Laboratory

Omnics Lab Exhibits - Non-Newtonian Pool

ERN APULIA MARIE CURIE ACTIONS
NOTTE EUROPEA DEI RICERCATORI E DELLE RICERCATRICI

European Commission

https://www.ern-apulia.it/enti/infrastrutture-di-ricerca-emfl-isabel-iris/

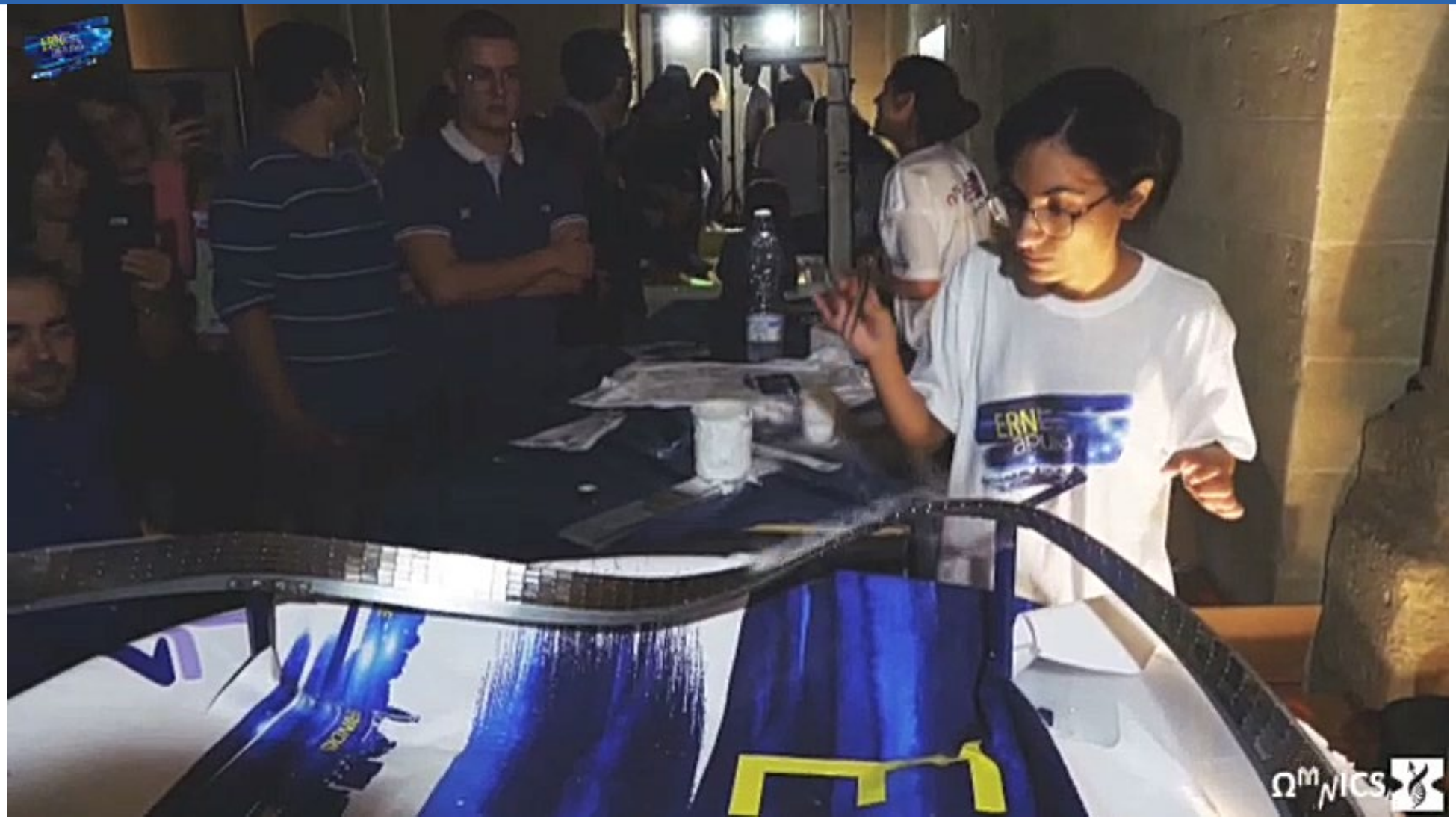
UNIVERSITÀ DEL SALENTO | Consiglio Nazionale delle Ricerche | INFN Istituto Nazionale di Fisica Nucleare | OMNICS research group | IRIS | SAPE | EMFL European Magnetic Field Laboratory

research@omnics.it
http://www.omnics.it/home/

Omnics Lab Exhibits - European Researchers Night

ERN APULIA MARIE CURIE ACTIONS
NOTTE EUROPEA DEI RICERCATORI E DELLE RICERCATRICI

https://www.ern-apulia.it/enti/infrastrutture-di-ricerca-emfl-isabel-iris/



Omnics Labs : Thanks

UNIVERSITÀ DEL SALENTO INFN / OMNICS research group / IRIS EMFL European Magnetic Field Laboratory / research@omnics.it

EMFL-ISABEL-IRIS Infrastructure / Omnics Lab

Thanks to:

- Prof. Giuseppe Maruccio
- Dr. Anna Grazia Monteduro (RTD-A)
- Dr. Silvia Rizzato (RTD-A)
- Dr. Angelo Leo (RTD-A)

European Researchers Night – ERN-Apulia


Otranto, Lecce
nature
art
hystory