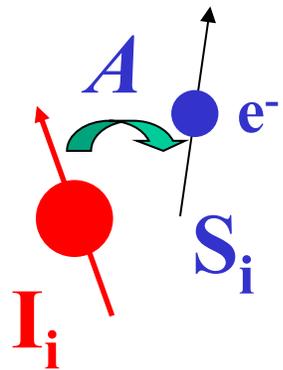


EXPERIMENTAL PHYSICS OF MATTER



Local probes of matter

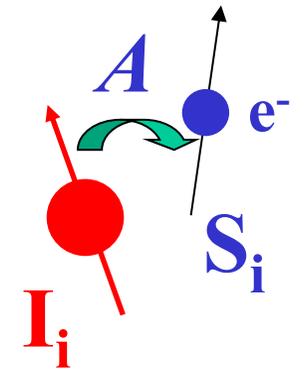


NMR
NQR

μ SR

ESR

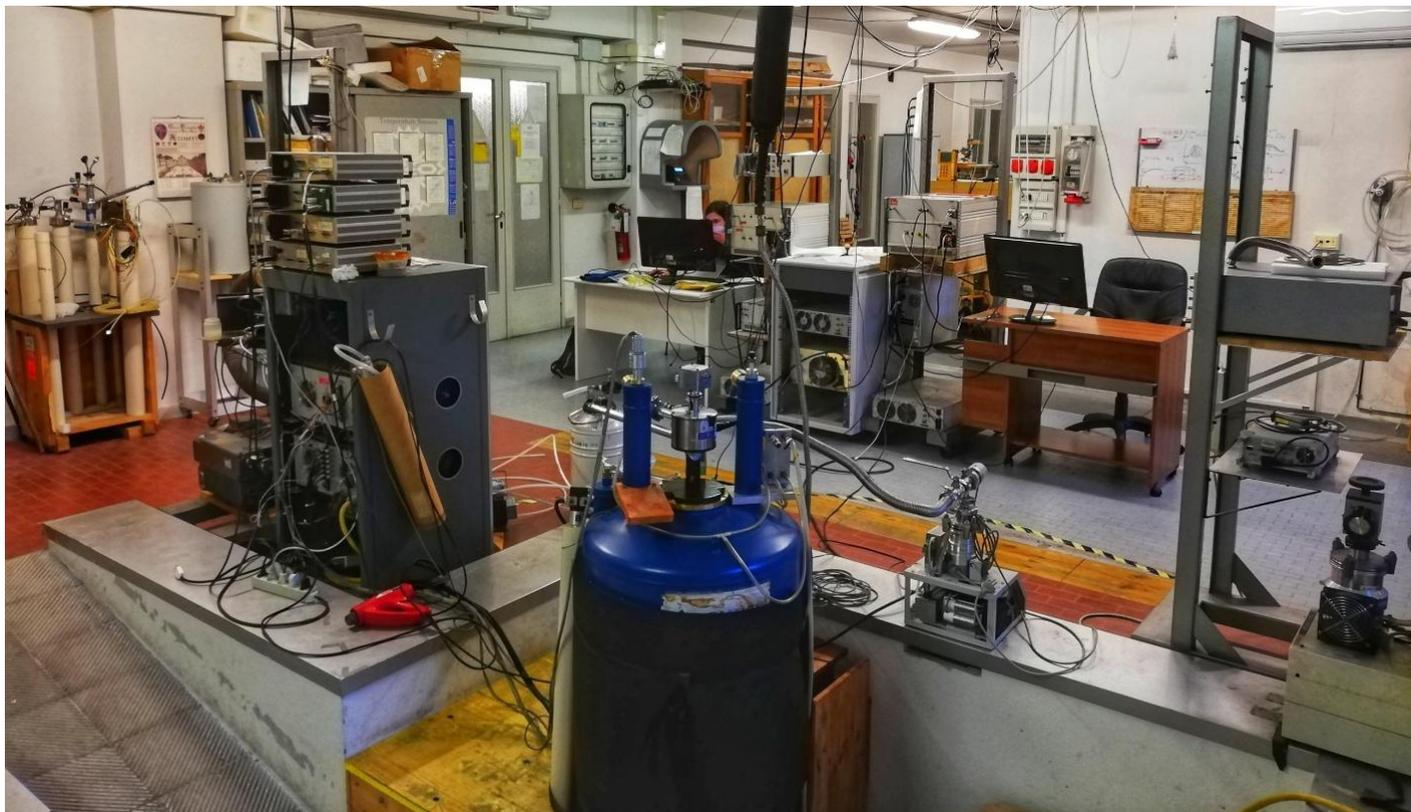
SQUID
Magnetometry



Probing static and dynamic (q-integrated, $0 \leq \nu \leq 10^{12} - 10^{14}$ Hz)
properties of matter

Where?

NMR-NQR Labs



SQUID Magnetometry Lab



ESR Lab



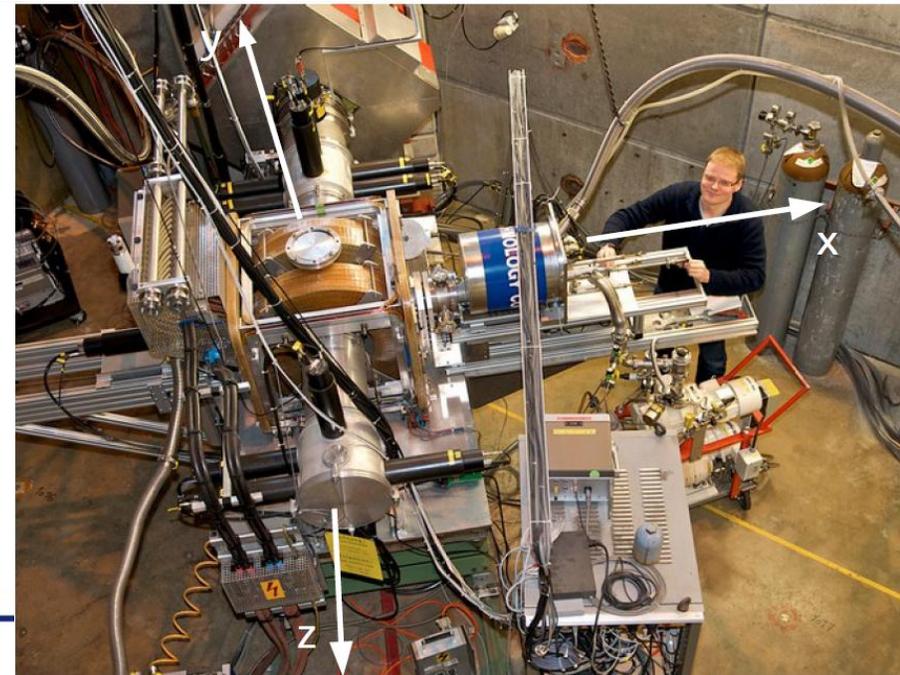
Where?

μ SR facilities



MUSR@ISIS(UK)

GPS@PSI(CH)



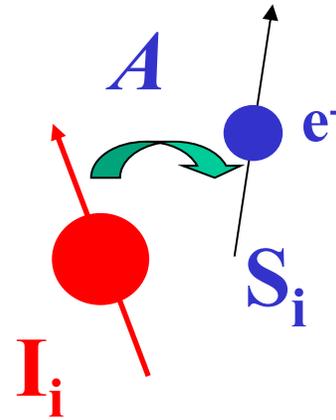
Who?

Francesca Brero

Simone Restelli

Pietro Carretta

Giacomo Prando



Pietro De Cristofaro

Maria Cristina Mozzati

Martina Foresti

Manuel Mariani Alessandro Lascialfari

Main research lines

- **Molecular Magnetism**
(Univ. Manchester, Firenze, Tuscia, INFN and CNR-ICCOM)
- **Hydrogen intercalated layered superconductors**
(PoliTO, Univ. L'Aquila, Genova, CNR-SPIN)
- **Metal-organic frameworks**
(Univ. Berkley, Princeton, MI Bicocca, Parma and MIT)
- **Hydrogen storage in biochar carbon nanostructures** (UNIPV-Chimica)



PNRR-PE4-NQSTI



MINISTERO DELL'AMBIENTE
E DELLA SICUREZZA ENERGETICA

PNRR-M2C2-CIRCOLARE

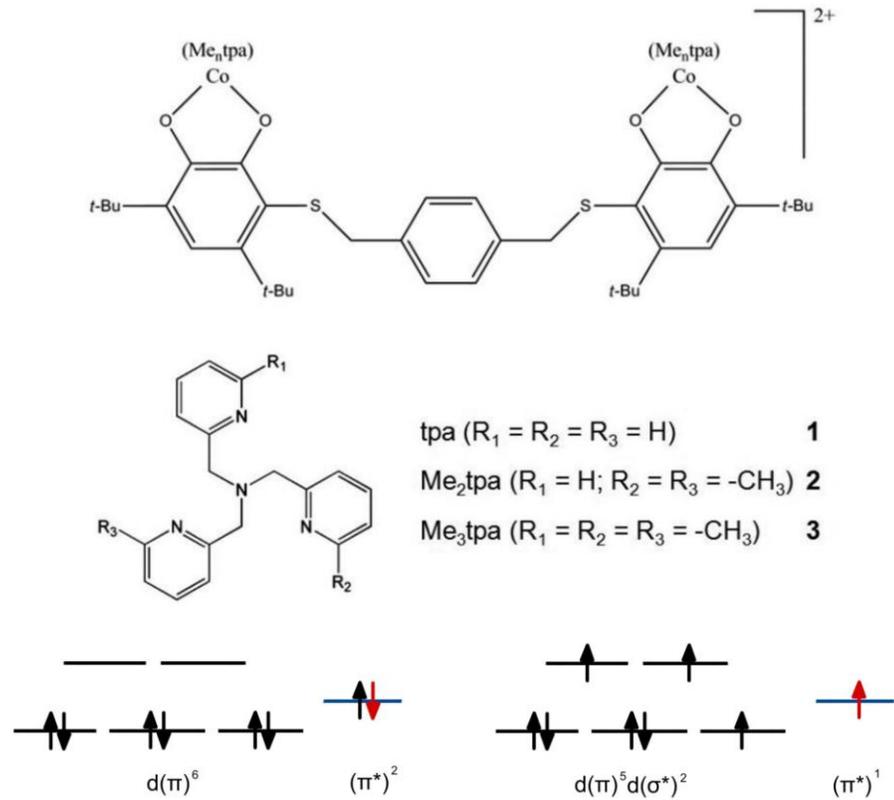


NAMASSTE and Next-NAMASSTE



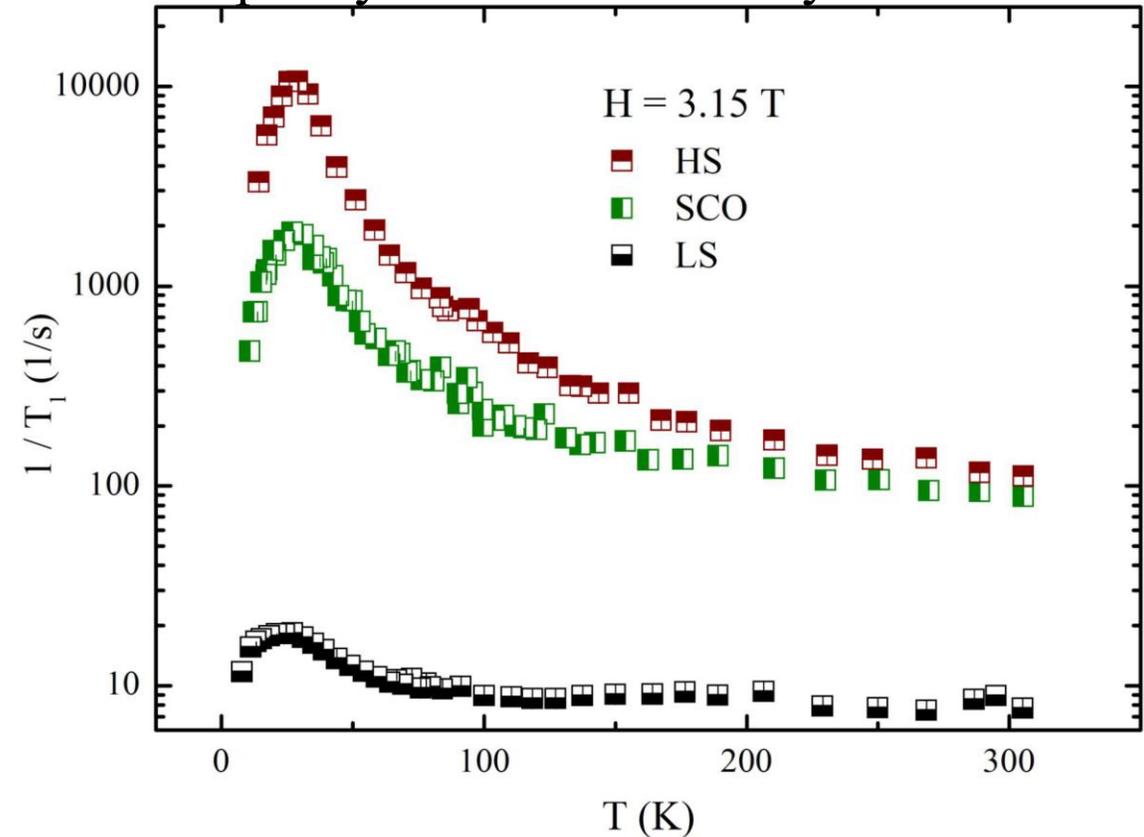
UNIVERSITÀ DI PAVIA
Department of Physics
"Alessandro Volta"

Molecular magnetism: valence tautomers



Spin-crossover in Co-based molecules
 (Poster 84 by M. Foresti, G. Prando et al.)

Spin dynamics detected by 1H -NMR



Valence tautomerism: electronic transition from magnetic ion to organic ligand leads to controllable modification of the magnetic state of the molecule

Molecular magnetism: single-ion magnets

Fundamental Physics (Poster n.51 A. Lascialfari, M. Mariani, F. Brero)

Comparative study of spin dynamics (**Tb-SQ**) (a) and (**Tb-Trp**) (b): semiquinonato (**SQ**) ligand is paramagnetic while tropolonato (**Trp**) is diamagnetic

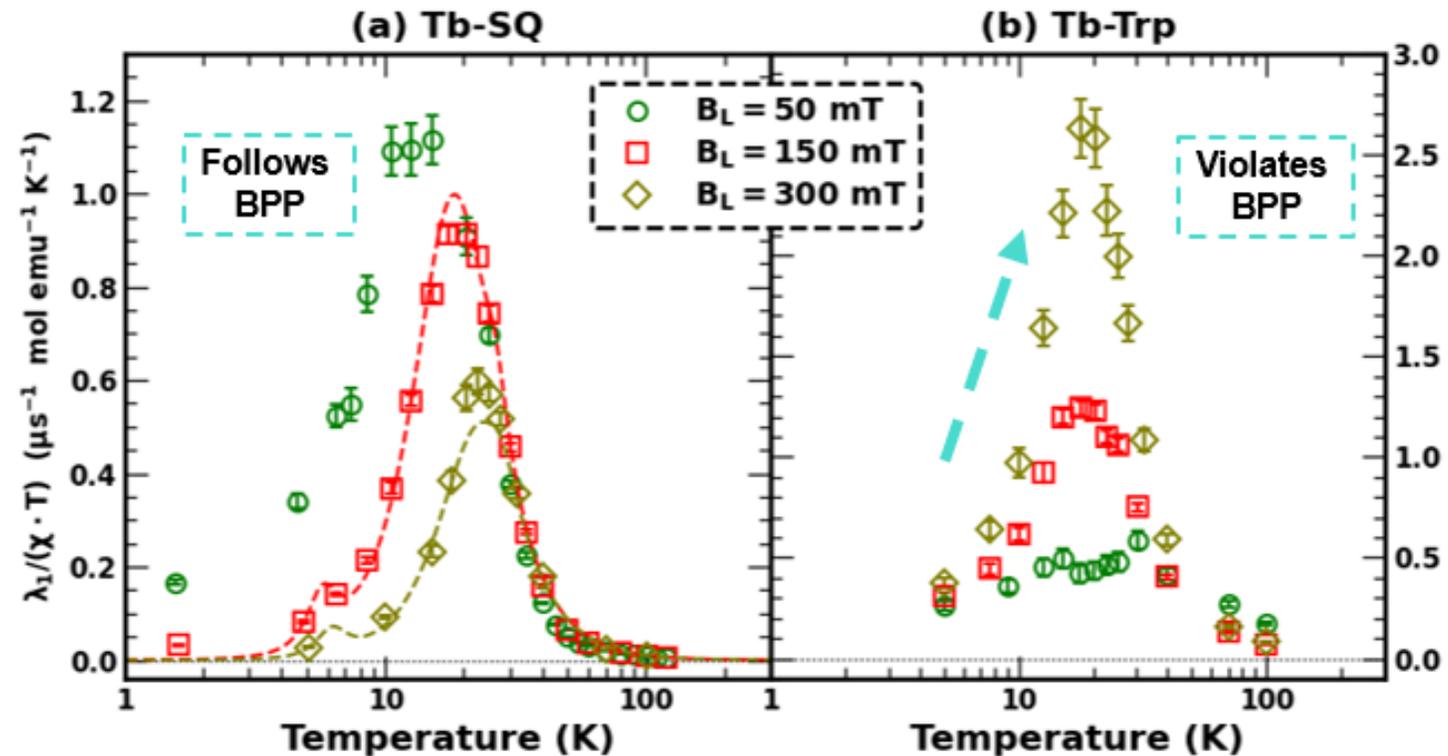
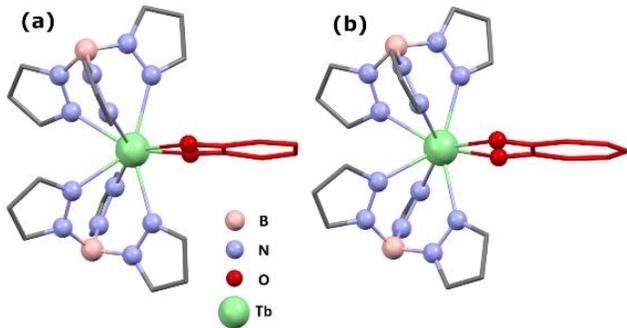
Experiments and Data Analysis

LF- μ^+ SR measurements of spin-lattice relaxation rate on powder samples: $1.5\text{K} < T < 200\text{K}$ at $B_L = 50, 150, 300\text{mT}$.

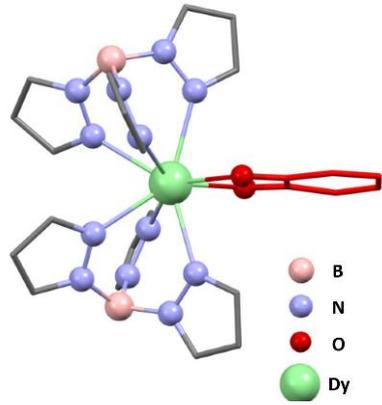
BPP law: $\lambda_1(T, B_L) = C \cdot \chi T \cdot \frac{\tau_c}{1 + (\gamma^\mu B_L \tau_c)^2}$

Conclusions

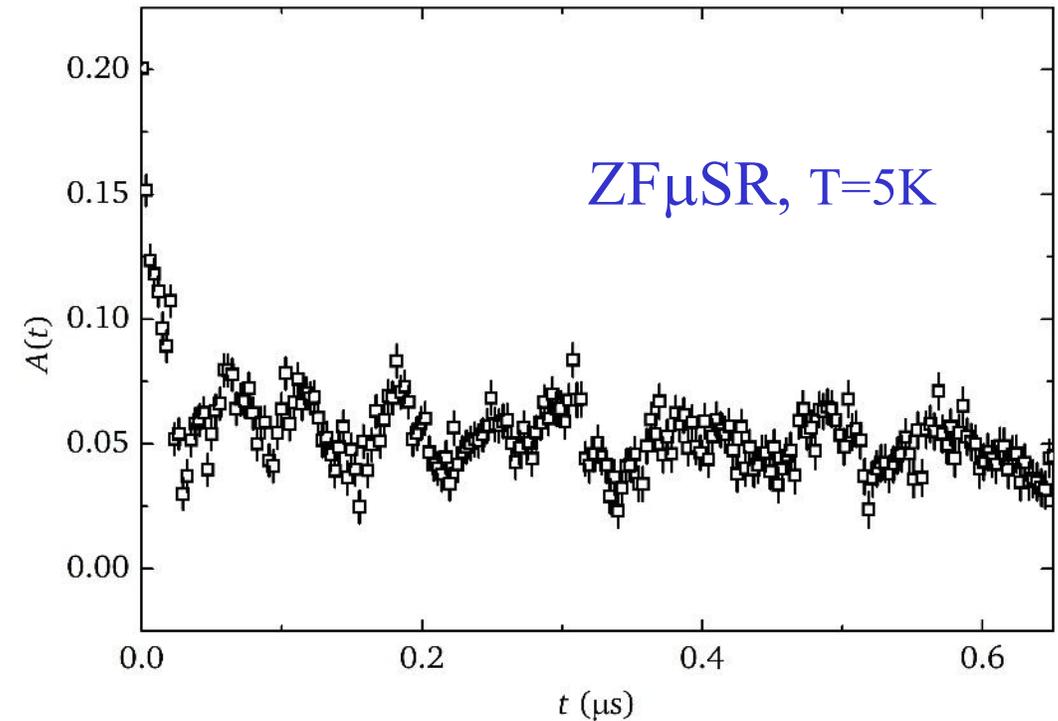
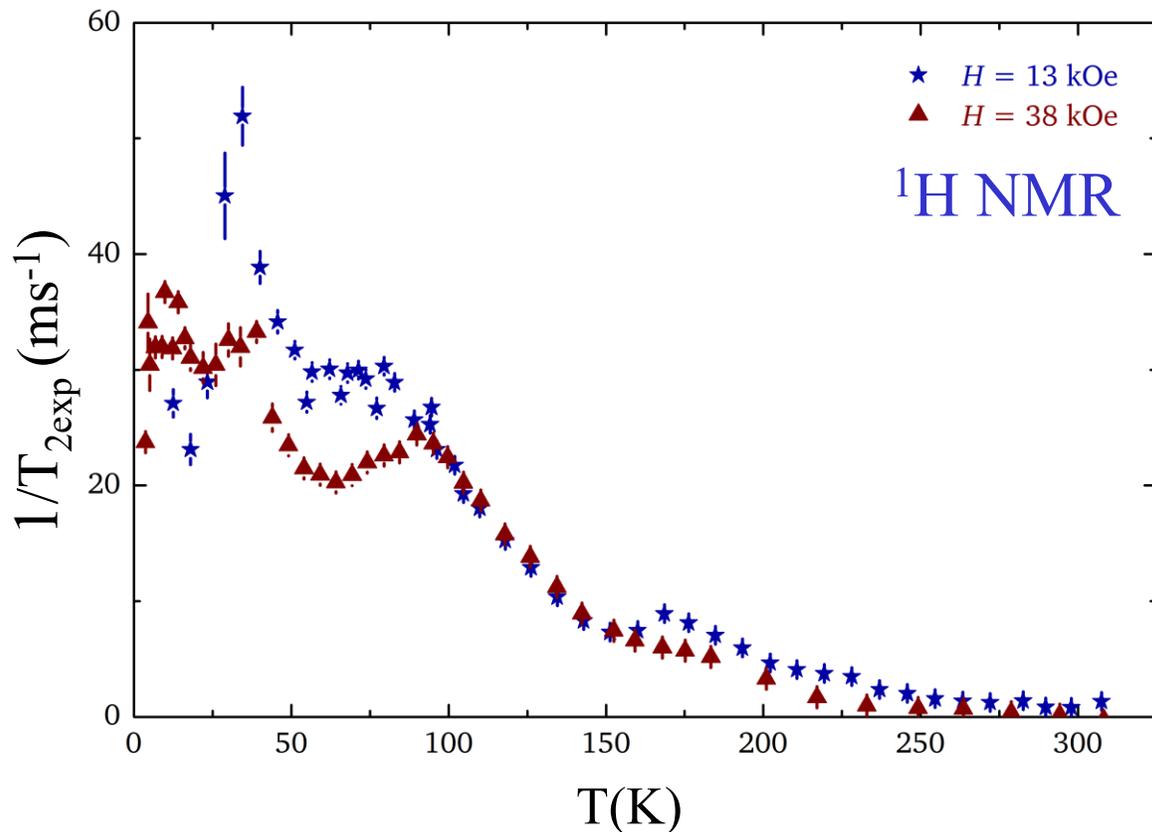
- (i) Influence of exchange interaction on the physical properties in Tb-SQ complex: presence of a magnetic anisotropy barrier
- (ii) Tb-Trp presents unusual spin dynamics



Molecular magnetism: single-ion magnets



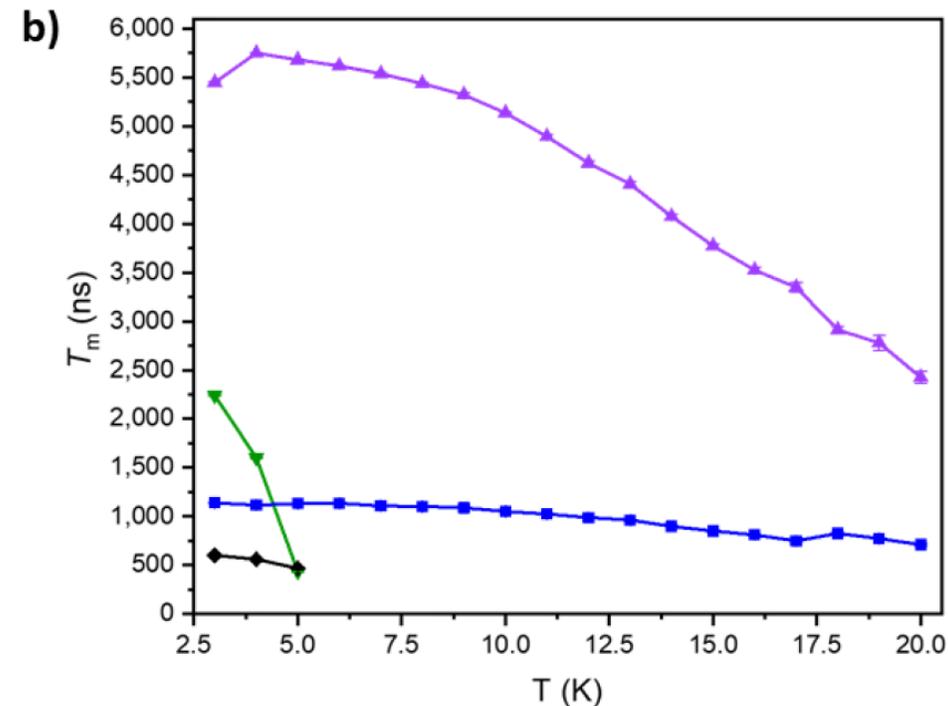
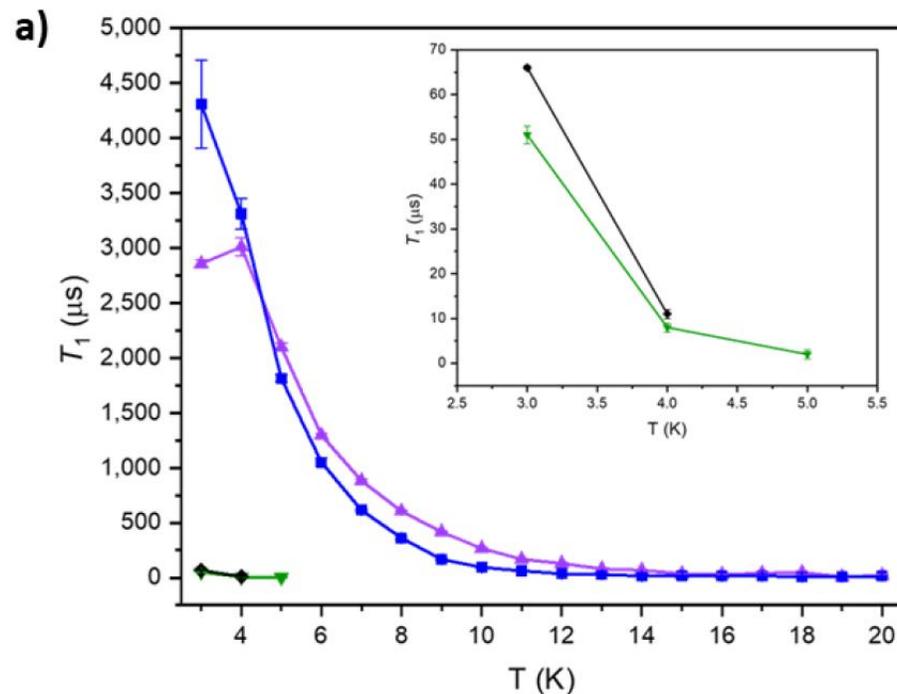
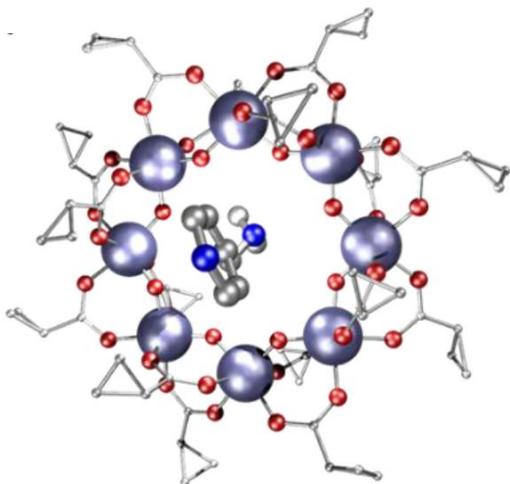
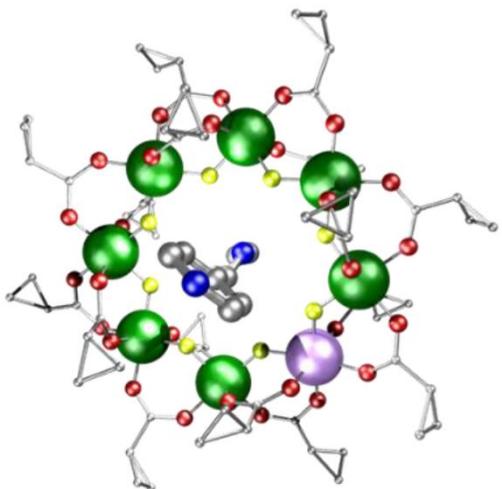
- **Dy-based single-ion magnet** with diamagnetic or paramagnetic organic ligand
- Ongoing study of spin dynamics with ^1H -NMR and μSR (master thesis P. De Cristofaro, supervisor G. Prando)



Molecular magnetism: rings

Ti^{IV}₇Ti^{III} rings with different organic ligands:
improved coherence times

Ongoing ¹H-NMR measurements (PhD project
M. Foresti, supervisor G. Prando)

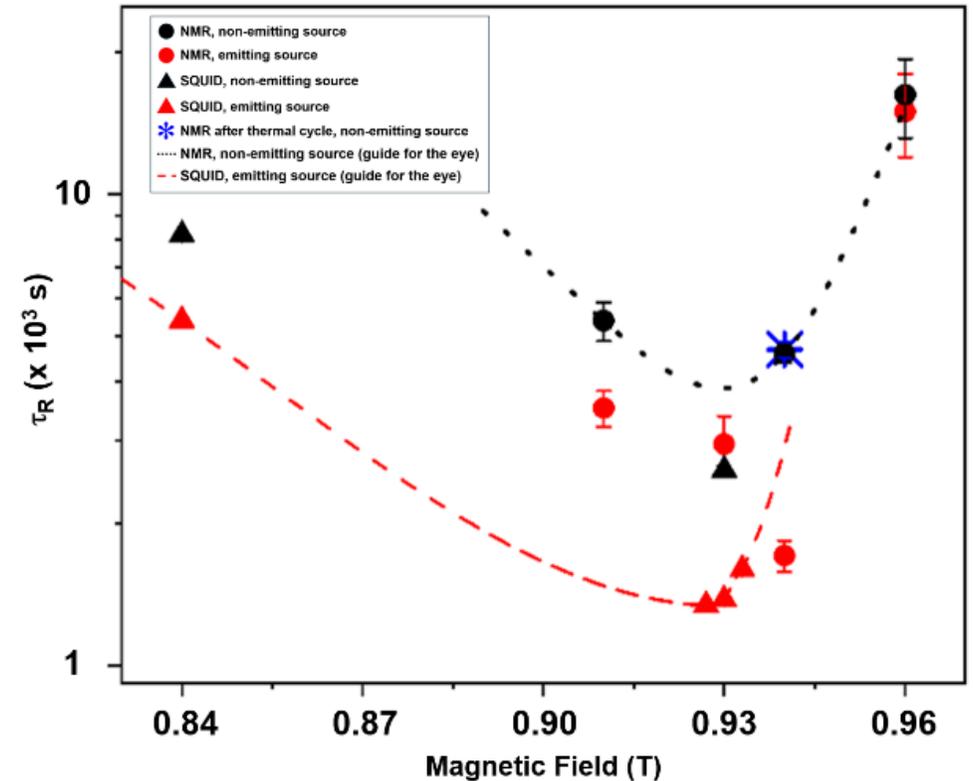
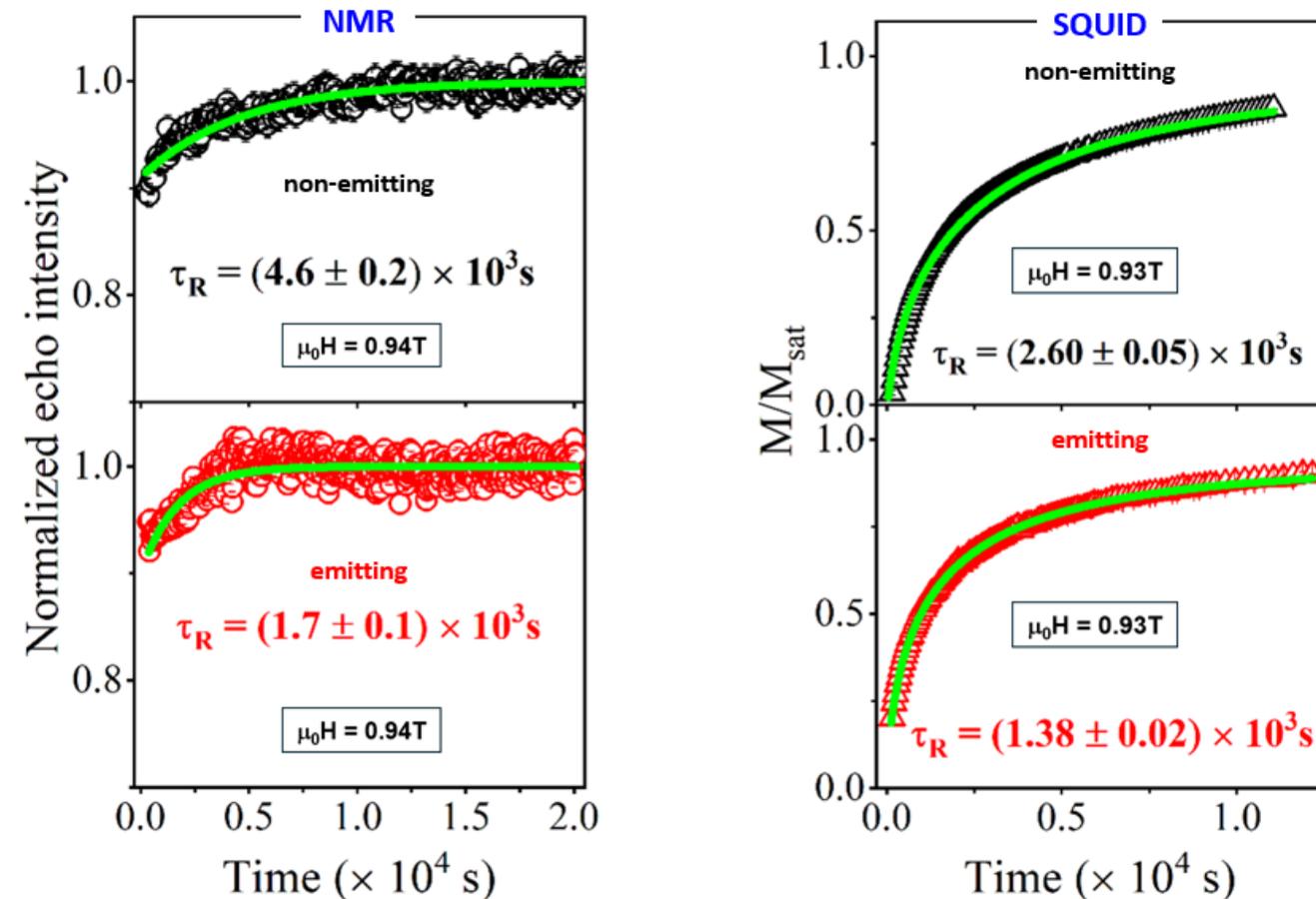


Molecular magnets as radiation detectors

(Poster n.52 A. Lascialfari, M. Mariani, F. Brero)

Mn¹²BuAc single crystals hit by α and β particles, and γ radiation.

Effect on NMR echo signal and SQUID magnetization relaxation time τ_R .

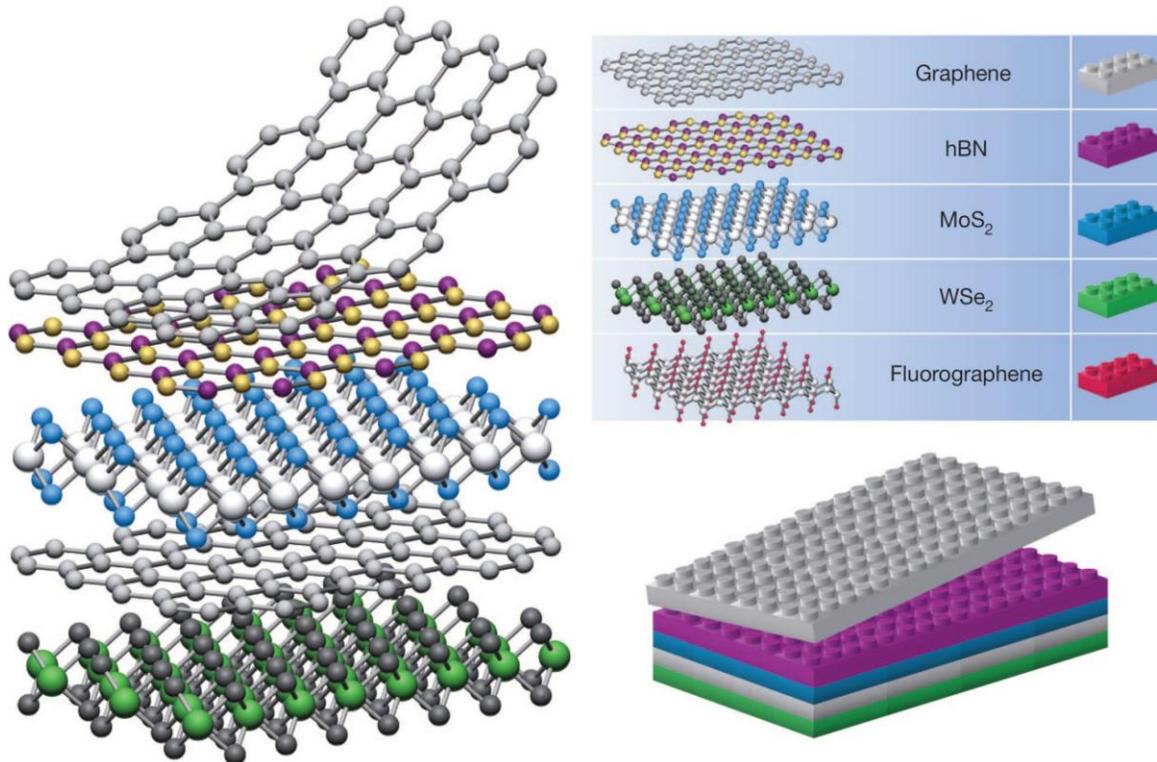


- (i) For both techniques under irradiation τ_R significantly decreased.
- (ii) Effect on the NMR spin echo decay is more pronounced.

Superconductivity in transition-metal dichalcogenides

Fundamental electronic properties in the 2D limit

Towards scalable devices (Van der Waals heterostructures)



C. Gong, X. Zhang, *Science* **363**, eaav4450 (2019)
 A. K. Geim, I. V. Grigorieva, *Nature* **499**, 419 (2013)

VOLUME 92, NUMBER 18

PHYSICAL REVIEW LETTERS

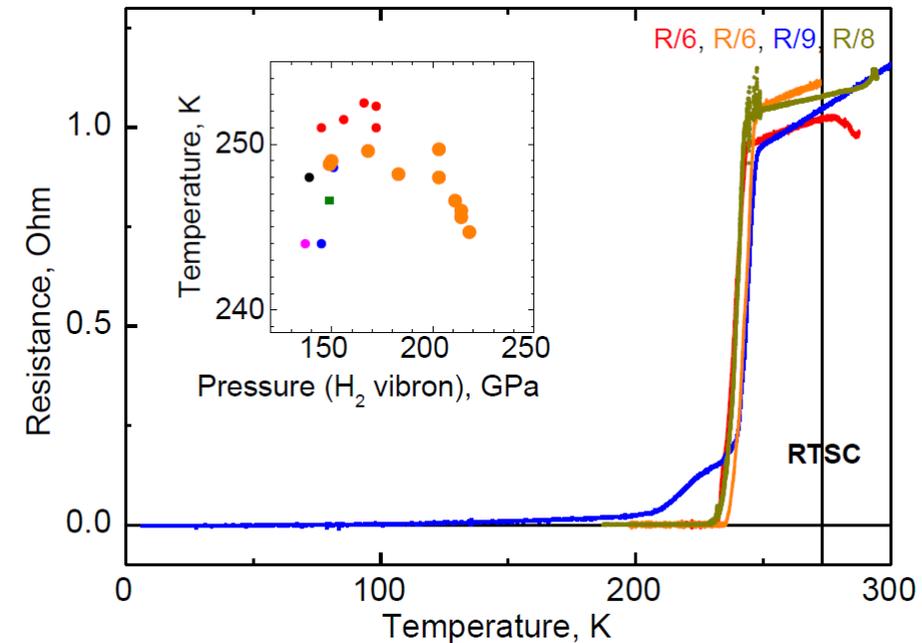
week ending
7 MAY 2004

Hydrogen Dominant Metallic Alloys: High Temperature Superconductors?

N.W. Ashcroft

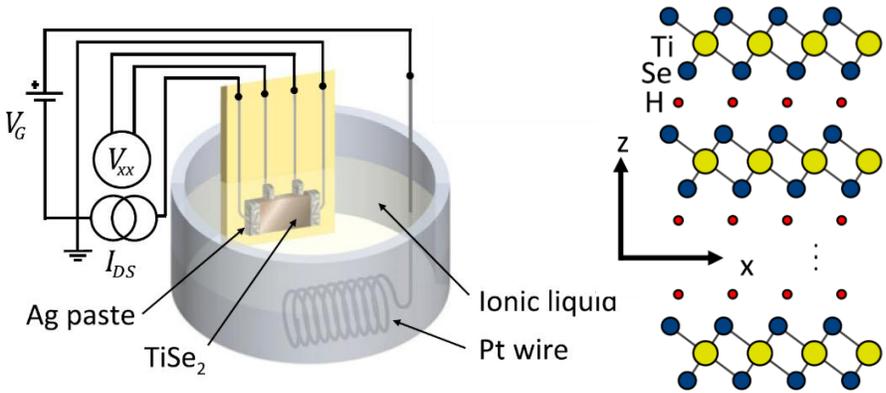
Hydrogen enhances frequency of phononic modes and critical temperature in turn

$$T_c = \frac{1.14\hbar\omega_D}{k_B} \exp[-1/D(E_F)V]$$



J. A. Flores-Livas *et al.*, *Phys. Rep.* **856**, 1 (2020)
 A. P. Drozdov *et al.*, *Nature* **569**, 528 (2019)

Superconductivity in transition-metal dichalcogenides



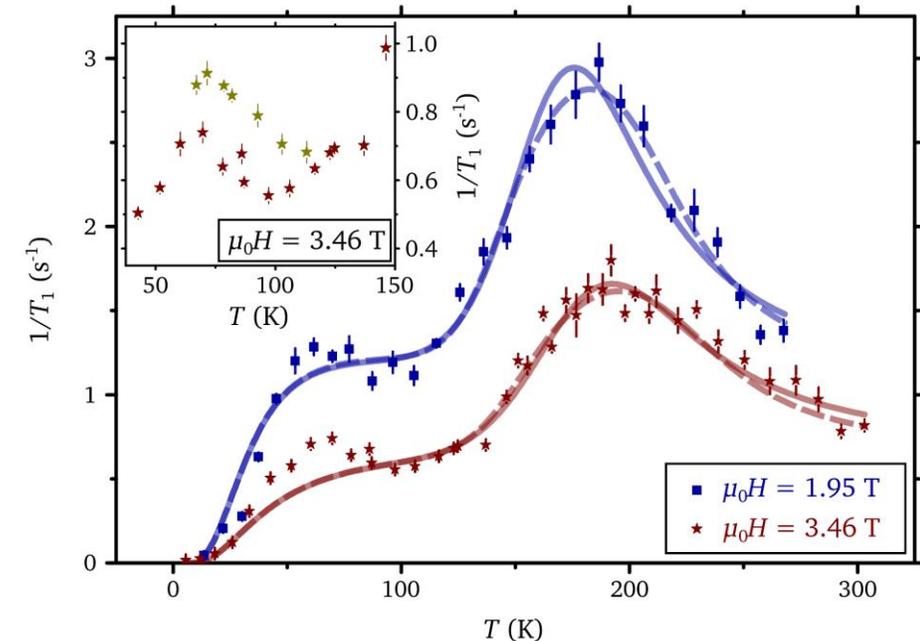
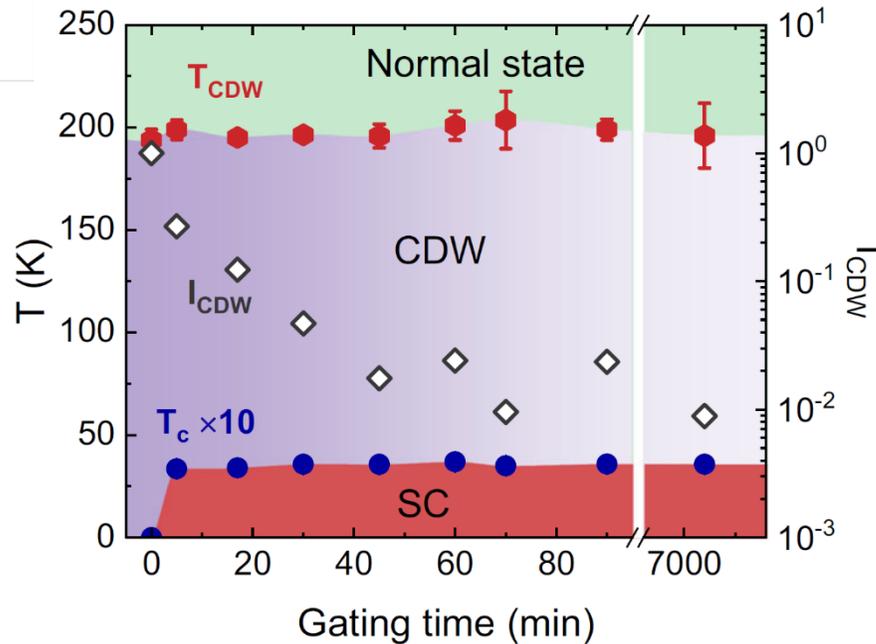
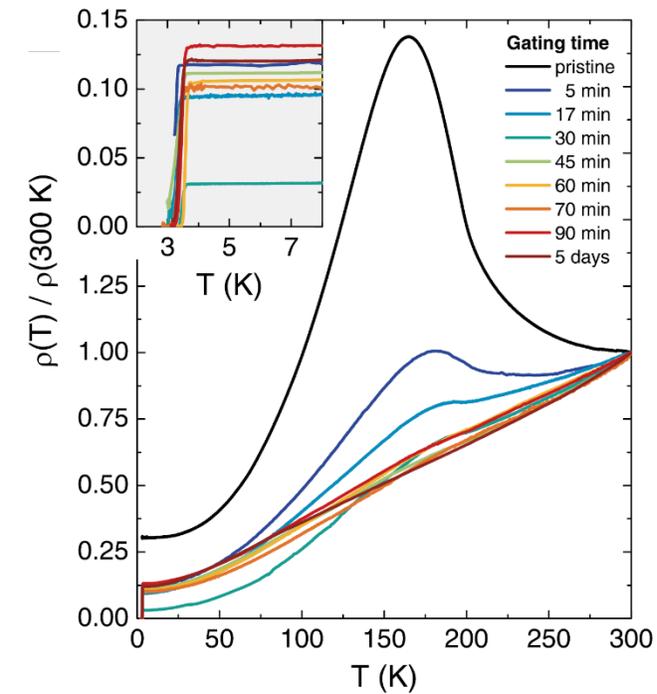
Effect of hydrogen intercalation in 1T-TiSe₂ (**Poster 32** by G. Prando et al.)

Induction of non-volatile superconductivity

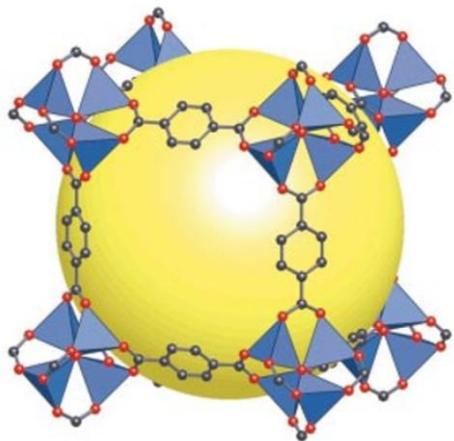
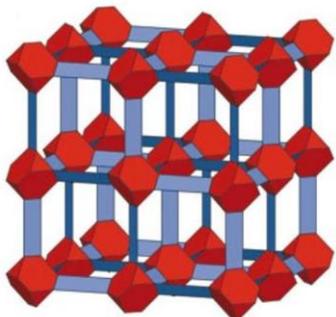
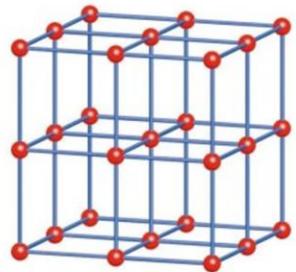
Microscopic coexistence with disordered charge-density wave from ¹H-NMR

E. Piatti, G. Prando *et al.*, *Commun. Phys.* **6**, 202 (2023)

G. Prando, E. Piatti *et al.*, *Phys. Rev. Mater.* **7**, 094002 (2023)



Metal-organic frameworks



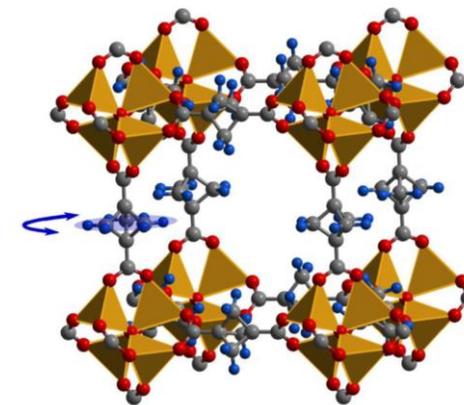
- Bravais lattice: inorganic clusters at vertices
organic ligands as “bonds”
- Very high porosity and surface/volume ratios
- Relevant for catalysis, gas adsorption/storage
- Exceptional chemical flexibility corresponds
to tailored, ad-hoc electronic properties
- Magnetism typically confined at cryogenic
temperatures (weak exchange coupling
through organic ligands)

Nobel Prize in Chemistry 2025

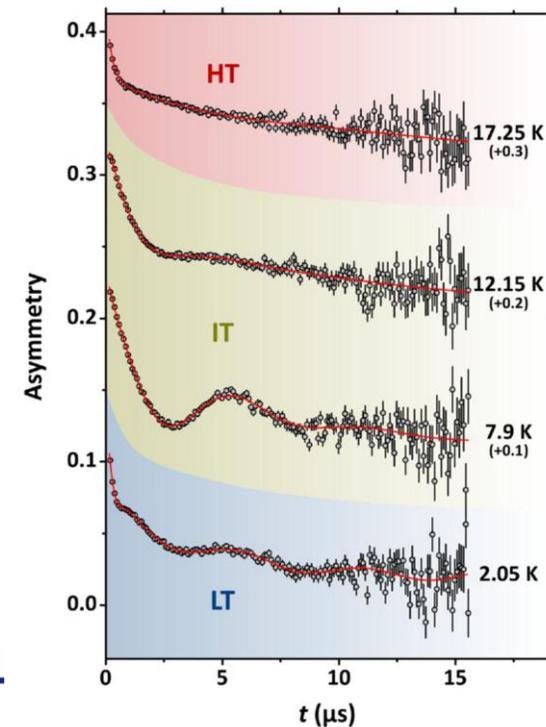
O. Yaghi *et al.*, *Nature* **423**, 705 (2003)

J. Perego *et al.*, *Nature Chemistry* **12**, 845 (2020)

G. Prando *et al.*, *Nano Lett.* **20**, 7613 (2020)



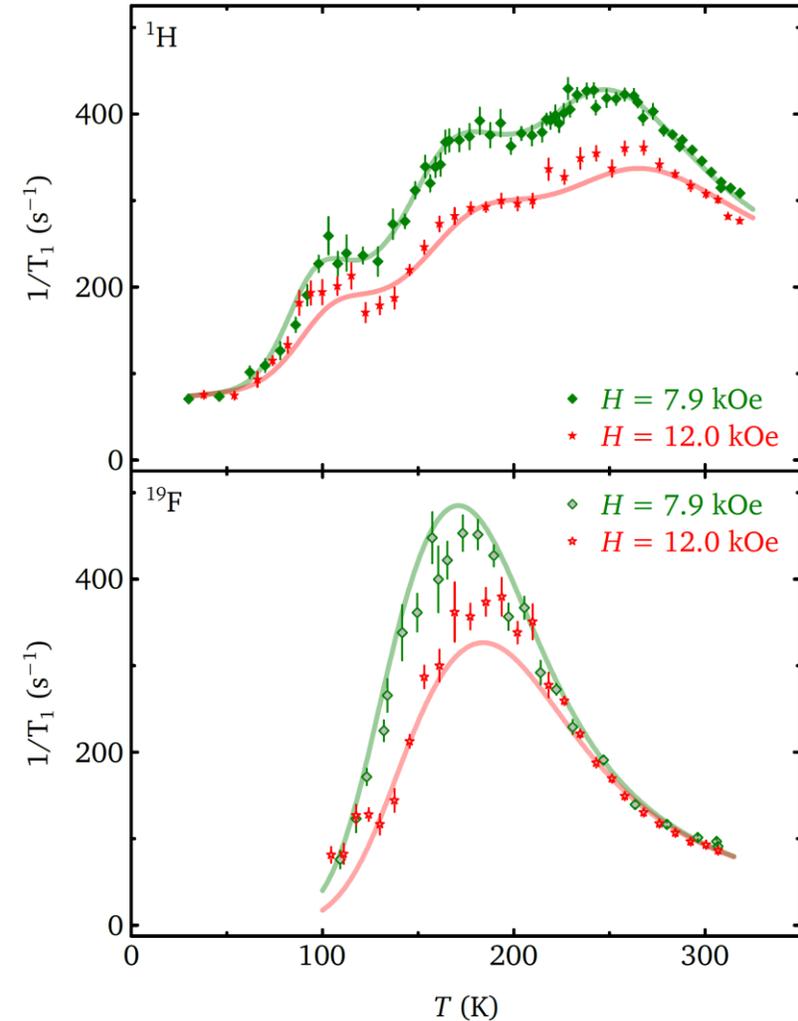
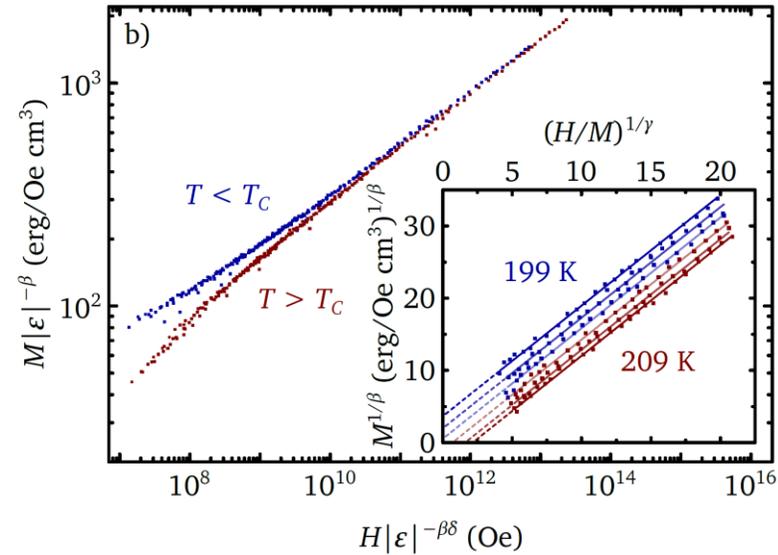
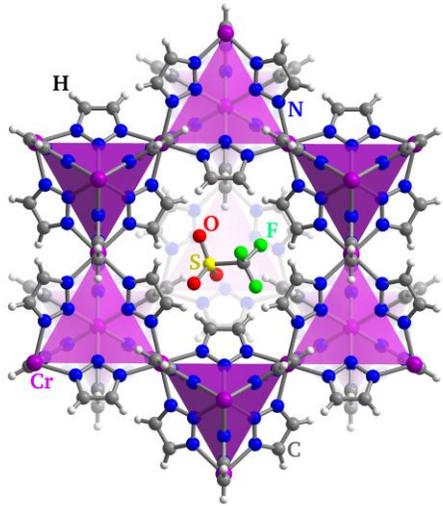
Ultra-fast molecular rotors probed by $^1\text{H-NMR}$
and μSR at cryogenic temperatures



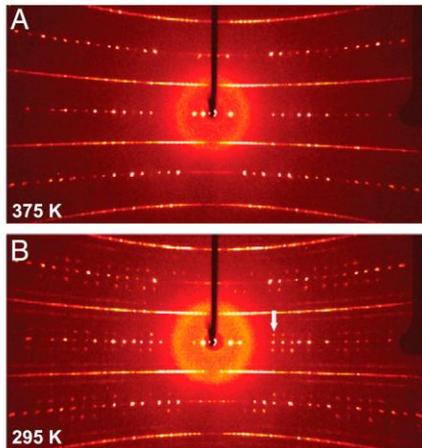
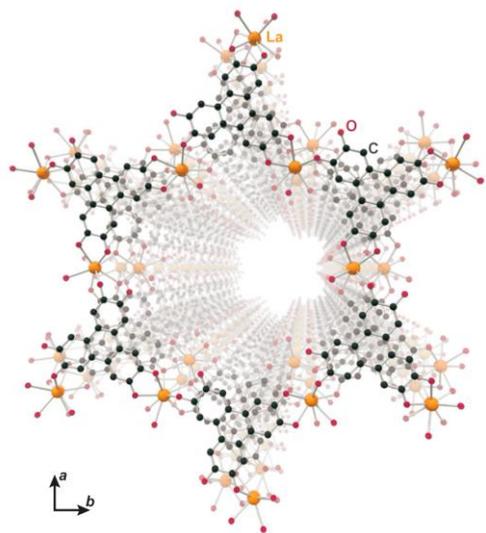
Metal-organic frameworks

High-temperature ferromagnetism (T_C around 220 K)

Magneto-electronic phase segregation (e.g. manganites)



G. Prando *et al.*, *arXiv:2512.00980* (2025)



Structural hints of **high-temperature Peierls instability** in 1D conductor

Ongoing NMR/NQR measurements

G. Skorupskii *et al.*, *PNAS* 119, e2205127119 (2025)



Ultrafast *microscopy* across length scales

Giulia Fulvia Mancini

Laboratory for Ultrafast X-ray and Electron Microscopy (LUXEM)

Department of Physics, University of Pavia (IT)



ULTRAIMAGE

ERC Starting
851154

HYPER

ERC Proof-of-Concept
101123123 & 101271431



FARE
R207A8MNNJ
PRIN
2022PR7CCY

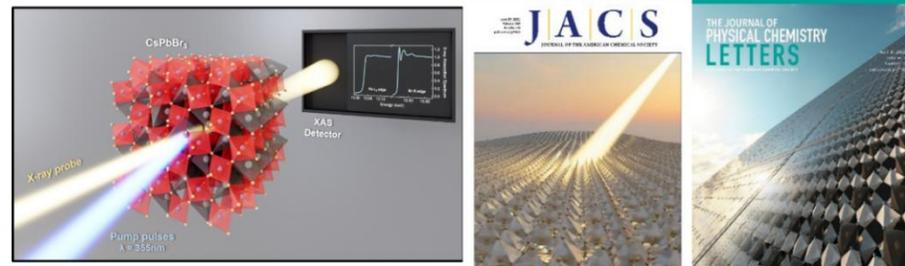
Fondazione
CARIPLO



2020 - 2544

Characterization

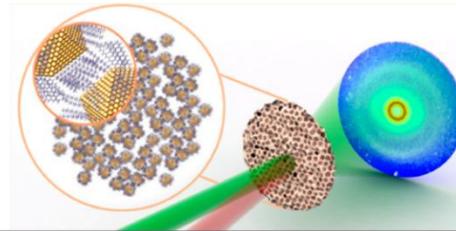
- I. Understanding the role of heterogeneity, interfaces, disorder.



O. Cannelli et al., J. Am. Chem. Soc. **143**, 9048–9059 (2021) & J. Phys. Chem. Lett. **13**, 3382–3391 (2022)

Control

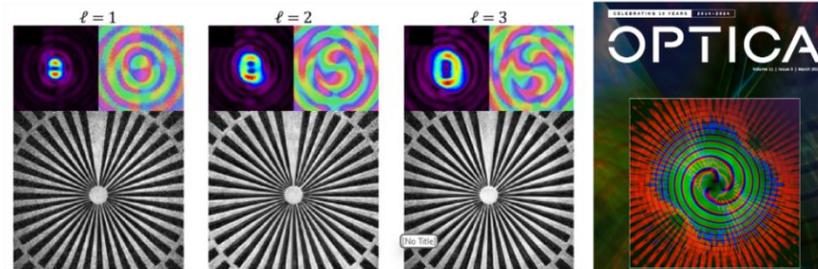
- II. Mastering hierarchical architectures beyond equilibrium.



G. F. Mancini et al., Nano Lett. **16**, 2705–2713 (2016) & Nat. Photonics **16**, 570–574 (2022)

Imaging

- III. Exploiting advances in imaging capabilities across multiple scales.



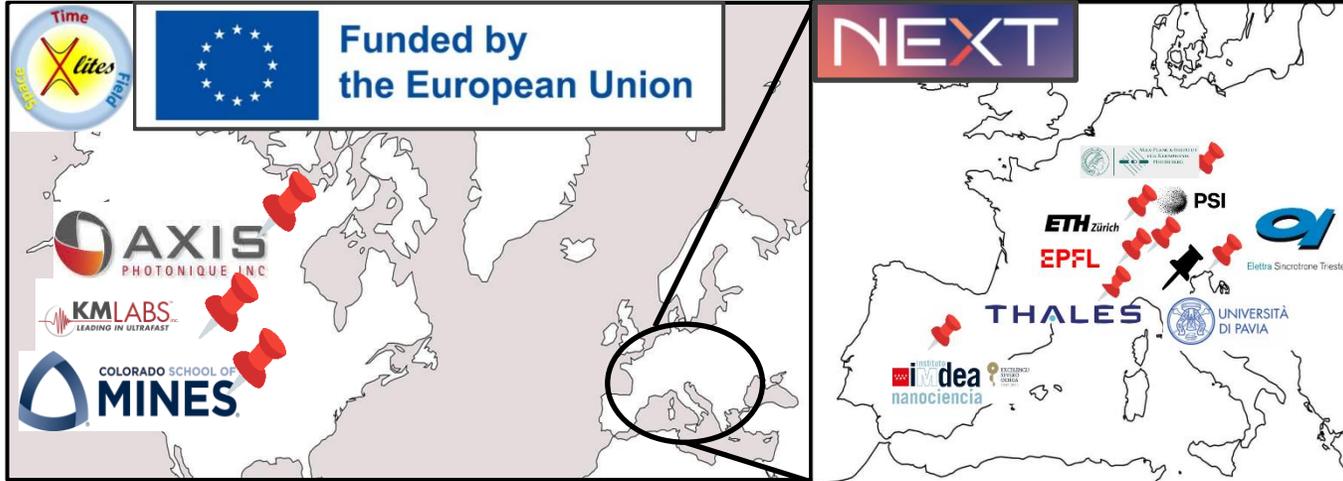
M. Pancaldi et al., Optica **11**, 403–411 (2024)



LUXEM Team → Posters!

<https://www.osti.gov/biblio/1283188-challenges-frontiers-matter-energy-transformative-opportunities-discovery-science>

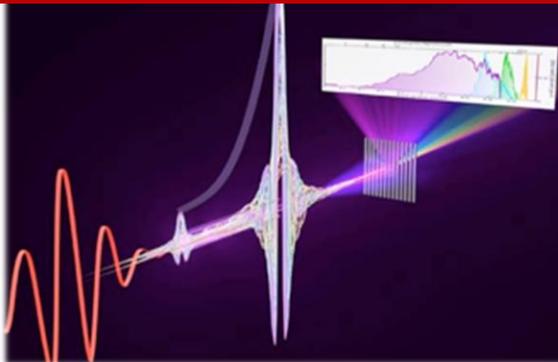
New ultrafast microscopy methods



International Network & Facilities:

- **NEXT (EU COST):** Development of Nonlinear, Tabletop & FEL Methods
- **X-lites (USA NSF):** Use of Extreme Light in Intensity, Time, and Space

Tabletop (HHG)



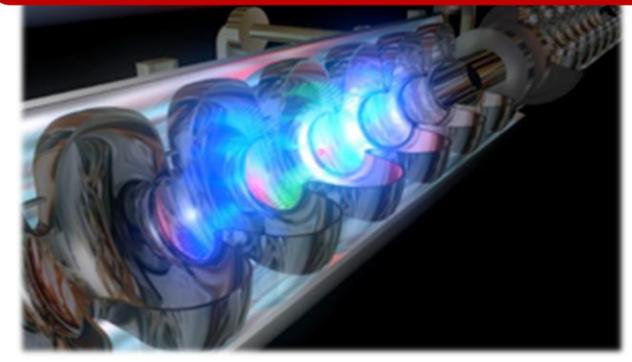
CLEO: Science and Innovations **SM2H.5** (2024) ; Sci. Adv. **4**, eaau4295 (2018); Nat. Photonics **11**, 259–263 (2017); Nano Lett. **16**, 5444 (2016)

Synchrotrons



J. Am. Chem. Soc. **143**, 9048–9059 (2021)
J. Phys. Chem. Lett. **13**, 3382–3391 (2022)
Nat. Photonics **16**, 570–574 (2022)

Free Electron Lasers



Optica **11**, 403–411 (2024); Struct. Dyn. **11**, 024308 (2024); Phys. Rev. Res. **3**, 033211 (2021); Nat. Photonics **15**, 499–503 (2021); Nat. Photonics **14**, 748–754 (2020)

Nobel Prize in Chemistry
Femtochemistry, 1999

Nobel Prize in Physics
Chirped-Pulse Amplification, 2018

Nobel Prize in Physics
Attosecond technology, 2023

Coherent Diffractive Imaging

- Direct-space imaging

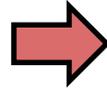


Microscope objective lens

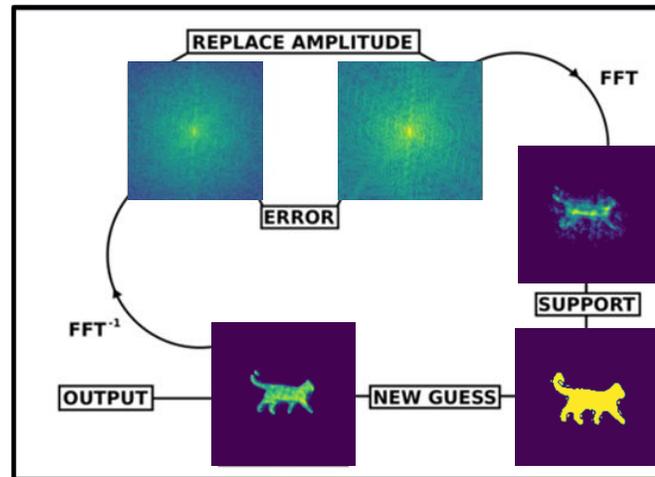


Image formation

- Imaging with phase retrieval



Computer



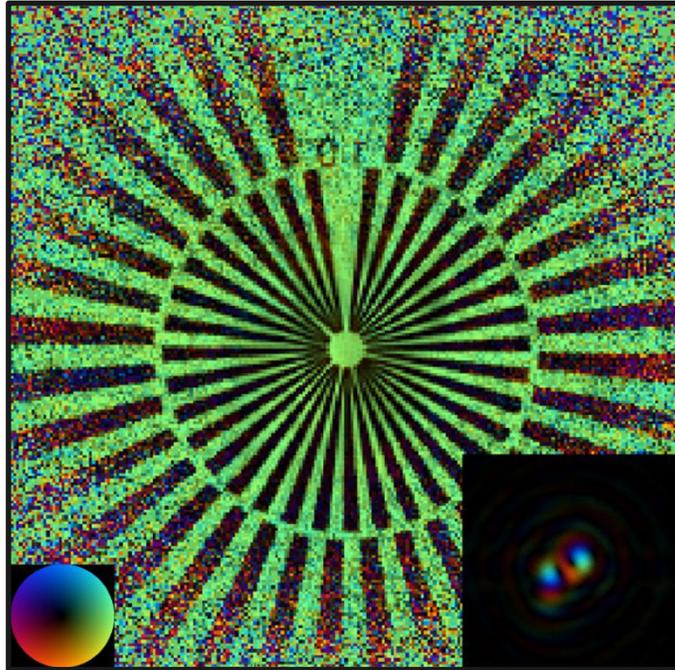
Phase Retrieval algorithm

Iterate between Fourier and image space, apply constraints:

- Fourier space: **amplitude constraint** - Ensures amplitude consistent with data
- Image space: **isolation constraint** - Enforces Nyquist sampling on detector

Sayre, Acta Crystallogr. **5**, 843–843 (1952)
Fienup, Opt. Lett. **3**, 27–29 (1978)
Miao et al., Nature, **400**, 342 (1999))

Chapman et al., Nature Photonics, **4**, 833 (2010)
Rodenburg et al. Phys. Rev. Lett. **98**, 034801 (2007)
Chao et al., Nature **435**, 03719 (2005)

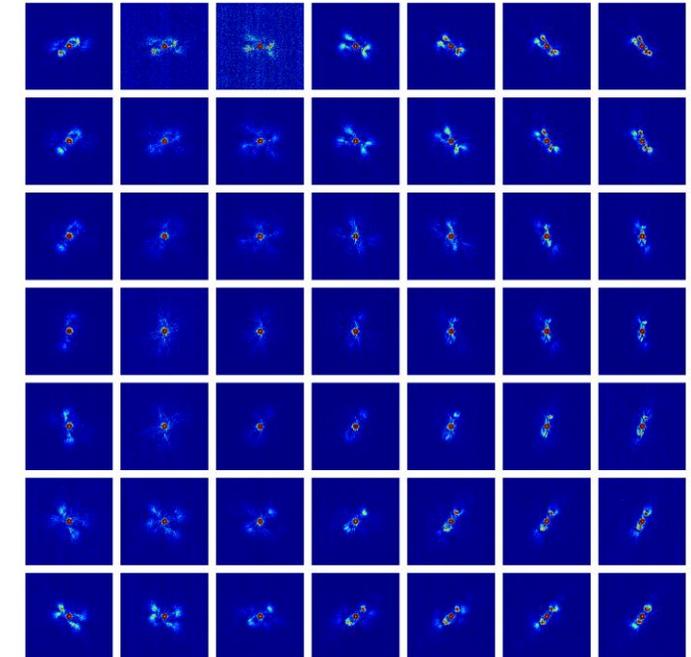


Scattered Wave:

$$\psi_s = A e^{i\phi}$$

Amplitude \rightarrow Absorption

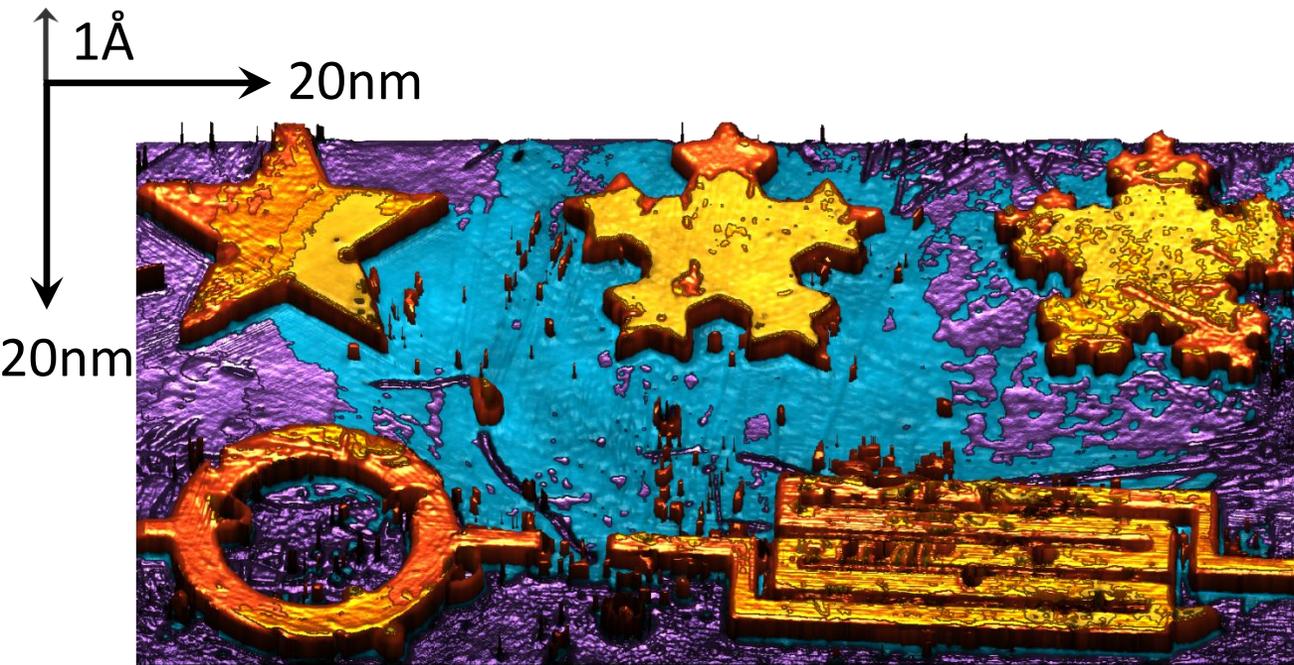
Phase \rightarrow Structure



- Beam scatters at overlapping positions
- Oversampled diffraction at the detector captures $I = \psi_s \psi_s^* = |A|^2$
- Multiple patterns provide information redundancy that supports phase retrieval

Algorithm *simultaneously* retrieves amplitude and phase of **beam** (“probe”) and **object** (“sample”)
The reconstructed amplitude and phase images are directly linked to the **complex refractive index** of the sample

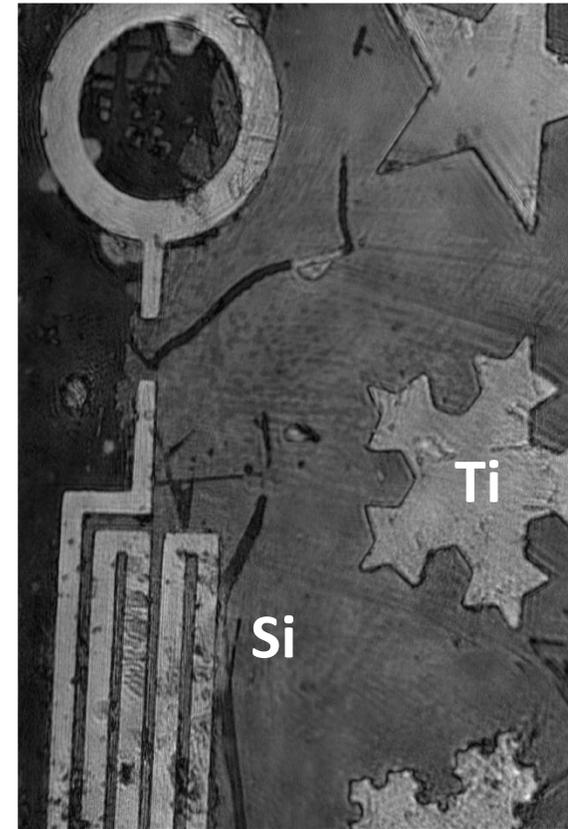
Ptychography: spatial resolution



From the phase we can generate a 3D topology map of the surface with 1 Å axial resolution

Zhang et al., Ultramicroscopy **158**, 98 (2015)

2 in 1



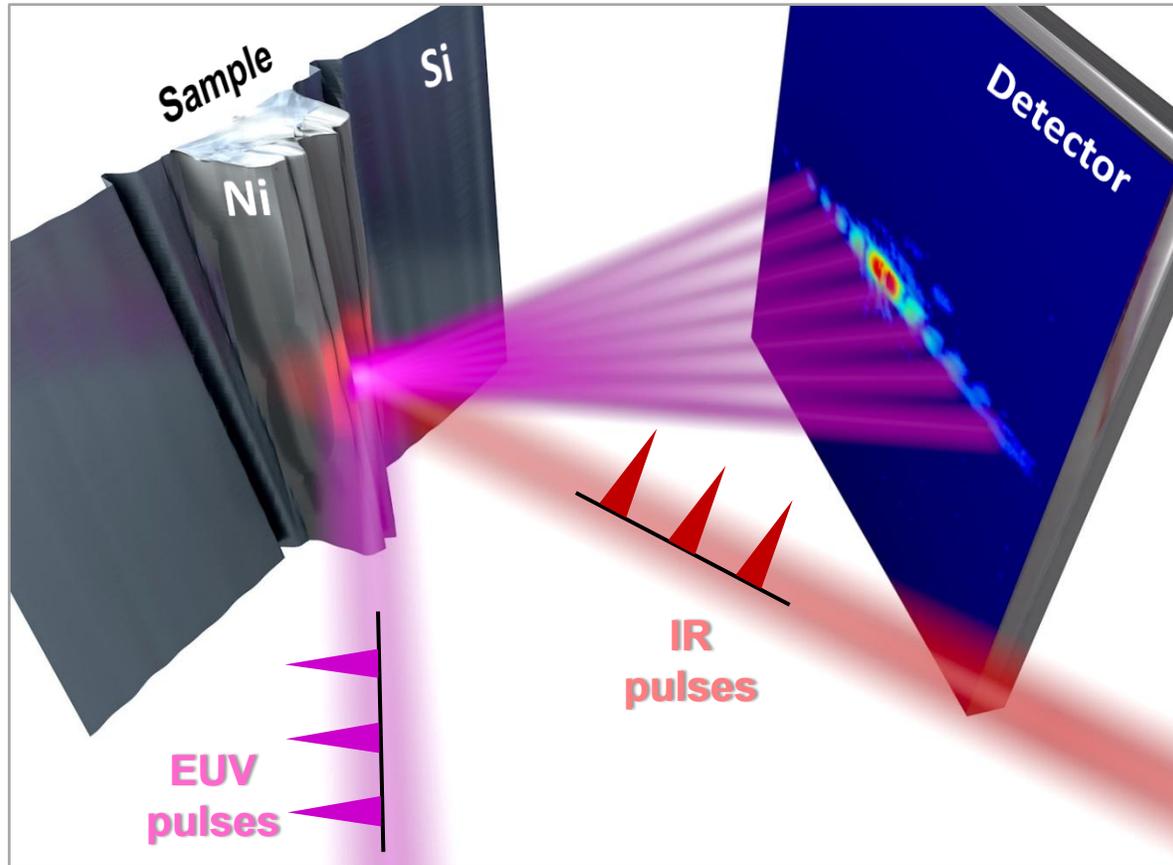
Amplitude:
Material composition



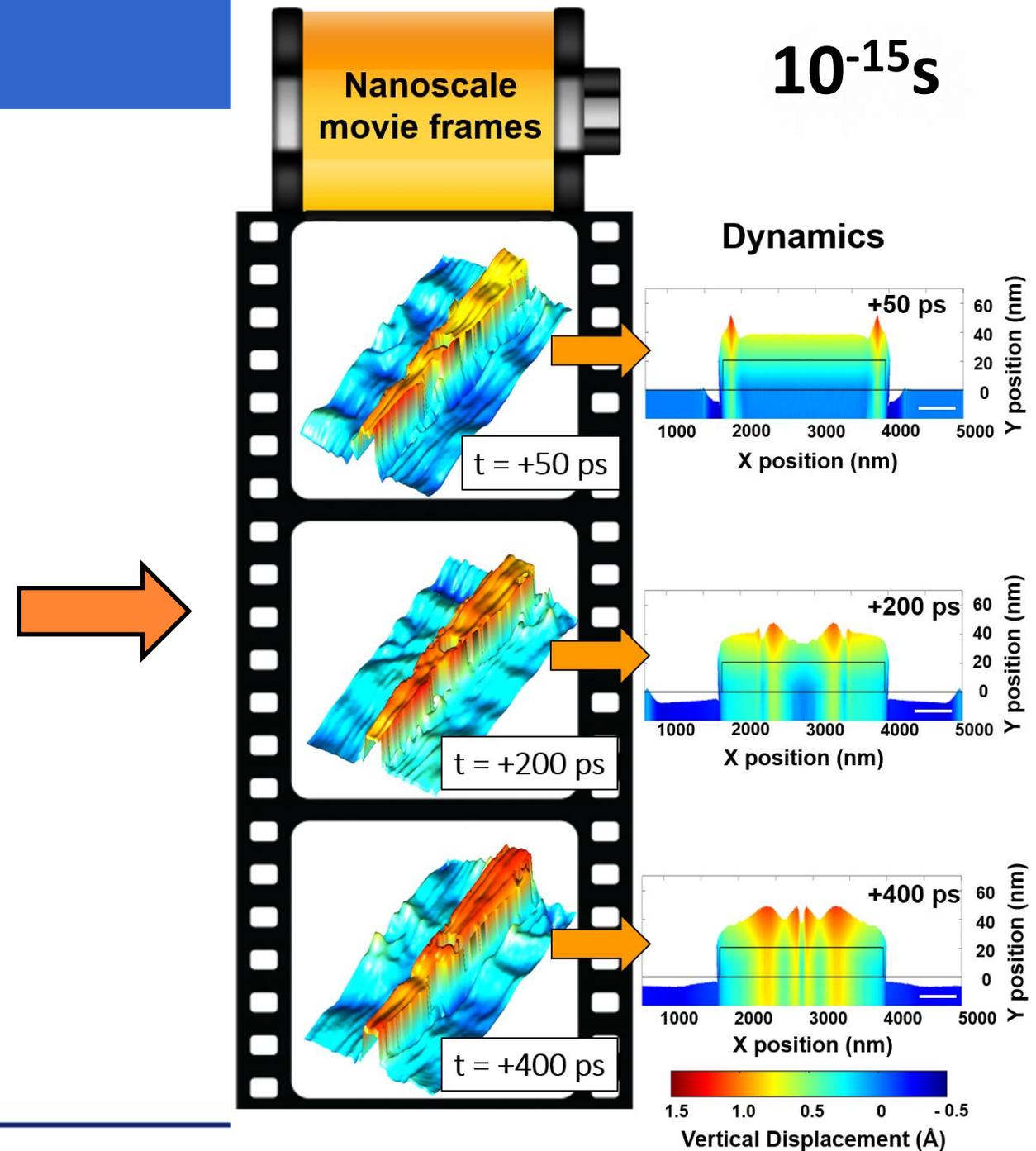
Phase:
Topography

Ptychography: time resolution

Snapshots of the 3D topology map upon impulsive excitation unravels nanomaterials dynamics

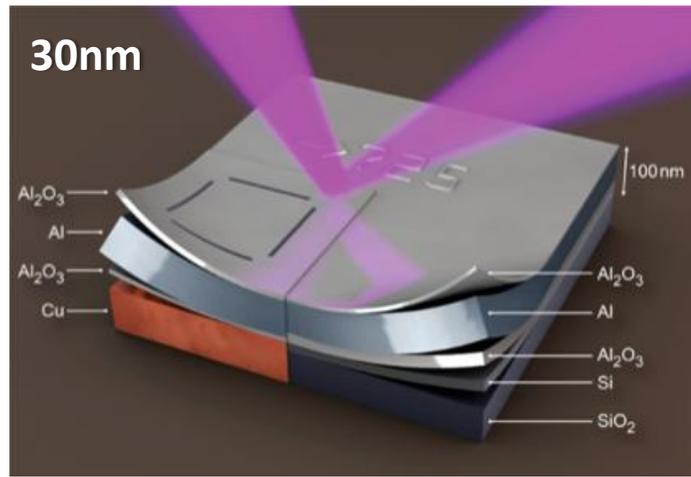


G. F. Mancini, R. Karl et al., *Sci. Adv.* **4**, eaau4295 (2018)



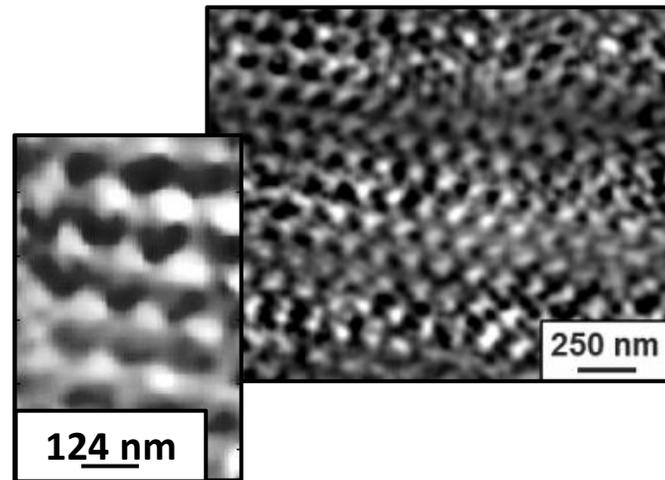
Ptychography & experimental materials science

Chemical reactions at buried interfaces



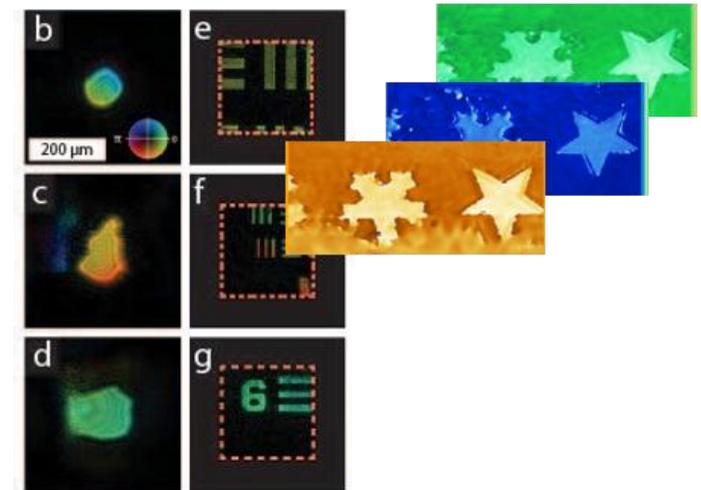
E. Shanblatt, G. F. Mancini et al., *Nano Lett.* **16**, 5444 (2016)

Quantitative sub-wavelength imaging



Gardner, G. F. Mancini et al., *Nat. Photonics* **11**, 259–263 (2017)
G. F. Mancini et al., *Opt. Express* **26**, 11393–11406 (2018)

Multi-mode Multiple colors or beams



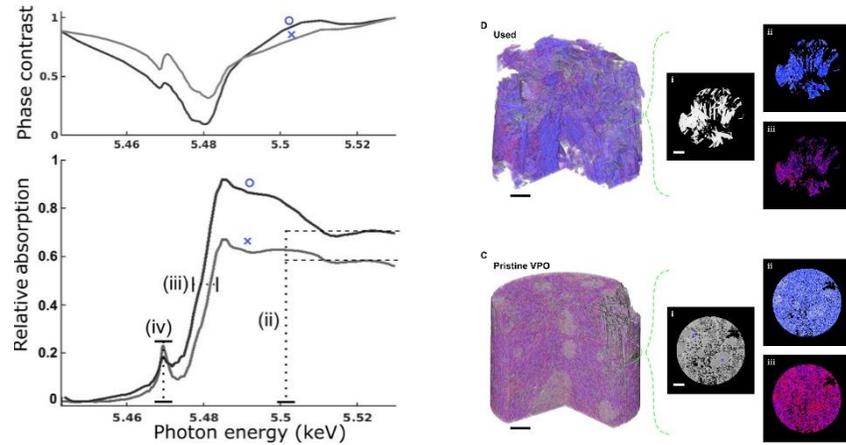
C. Bevis, G. F. Mancini et al., *Ultramicroscopy*, **184**, 164 (2017)
R. Karl, G. F. Mancini et al., *Opt. Expr.* **23**, 30250 (2015)

Anne L’Huillier Nobel Lecture: The route to attosecond pulses, *Rev. Mod. Phys.* **96**, 030503 (2024)

Opening High-Harmonic Generation to different research fields

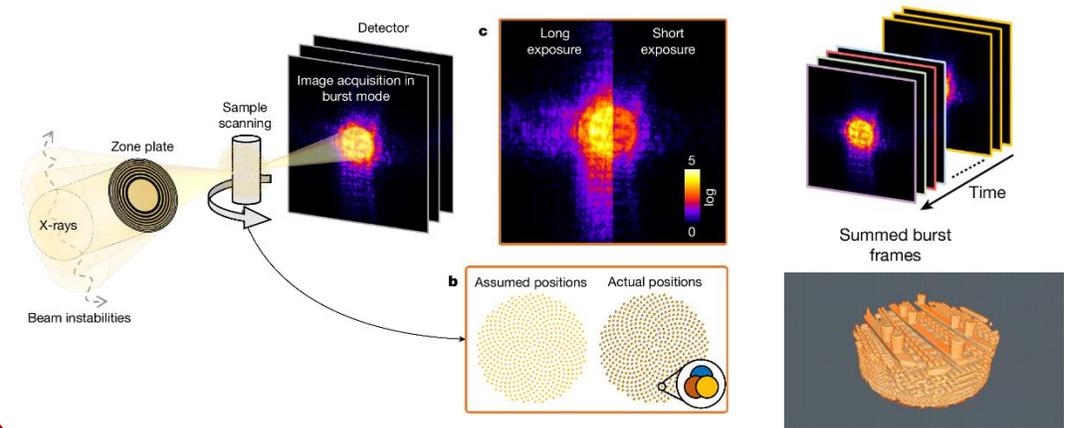
Ptychography & experimental materials science

Chemical contrast & *in operando*



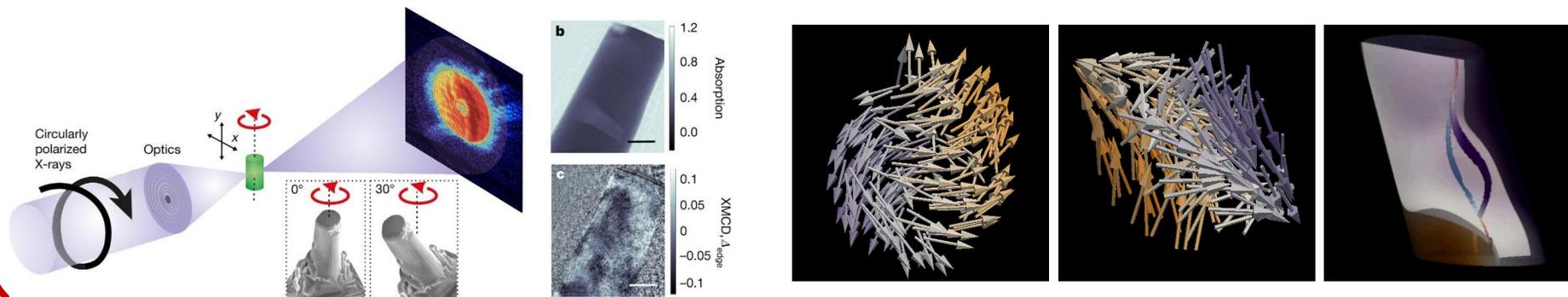
Z. Gao et al., *Sci. Adv.* 7, eabf6971 (2021)

Nm & 3D resolution



T. Aidukas et al., *Nature* 632, 81–88 (2024)

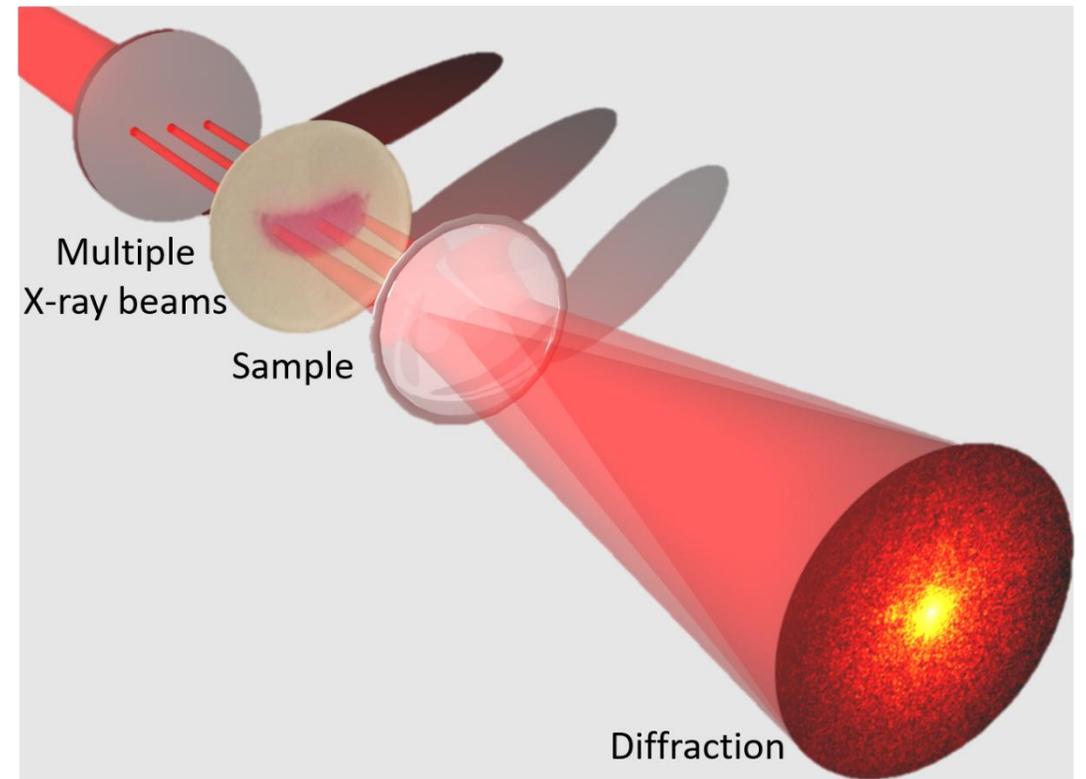
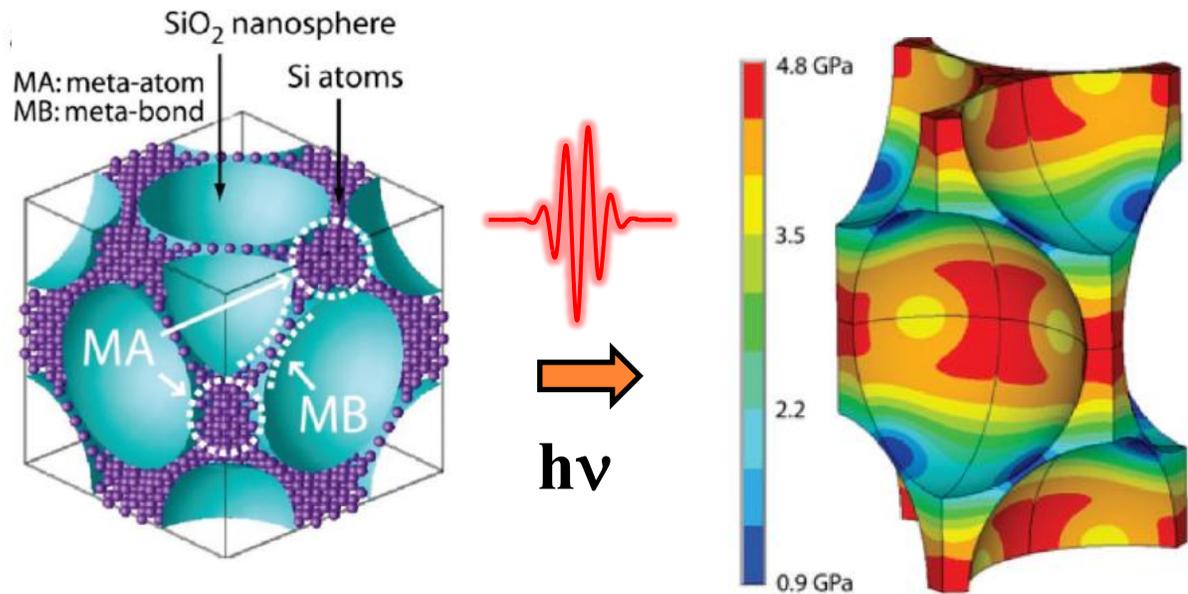
Bloch topologies → Vector field reconstructions



C. Donnelly et al., *Nature* 547, 328–331 (2017)

Imaging extreme bandgap tuning through light-induced stress design

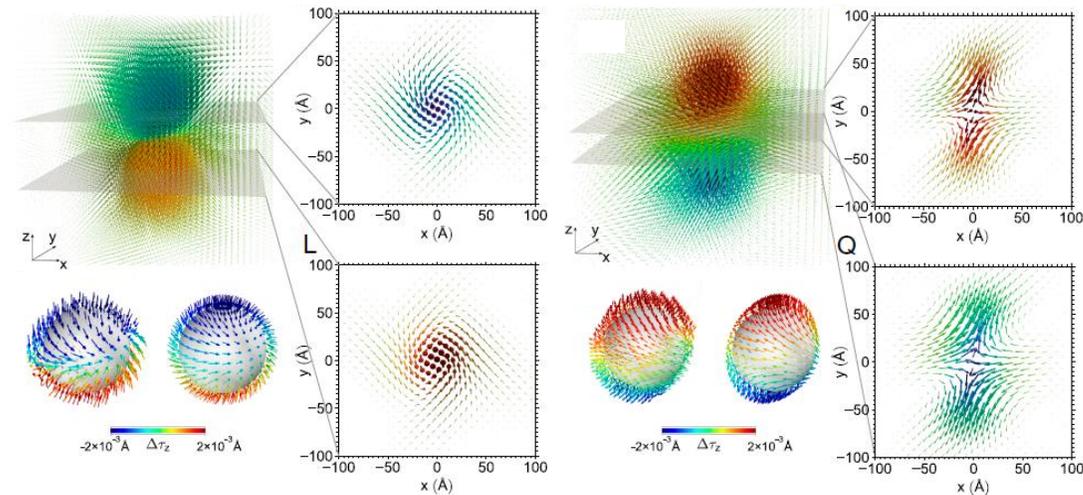
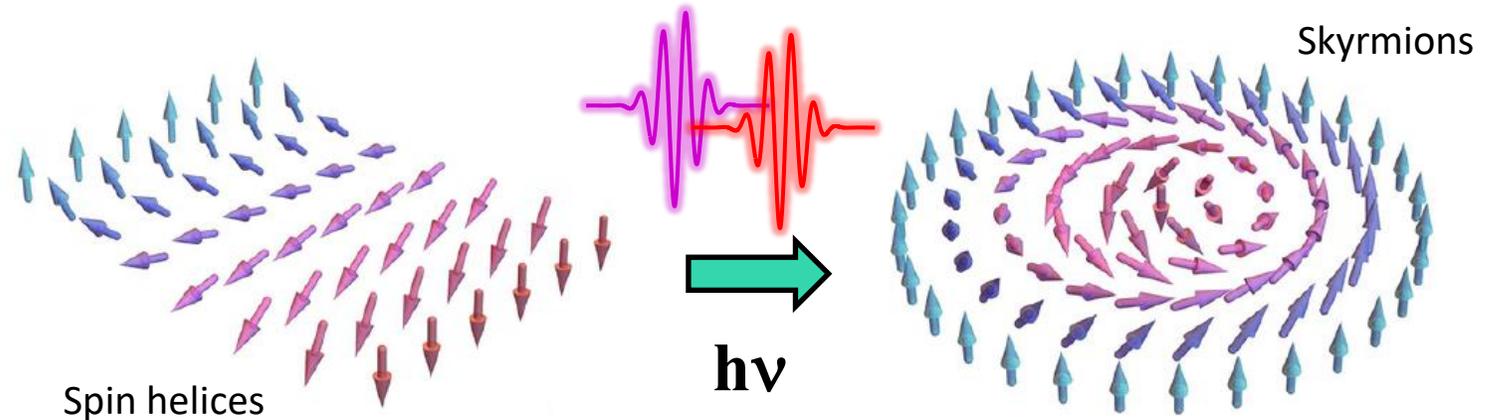
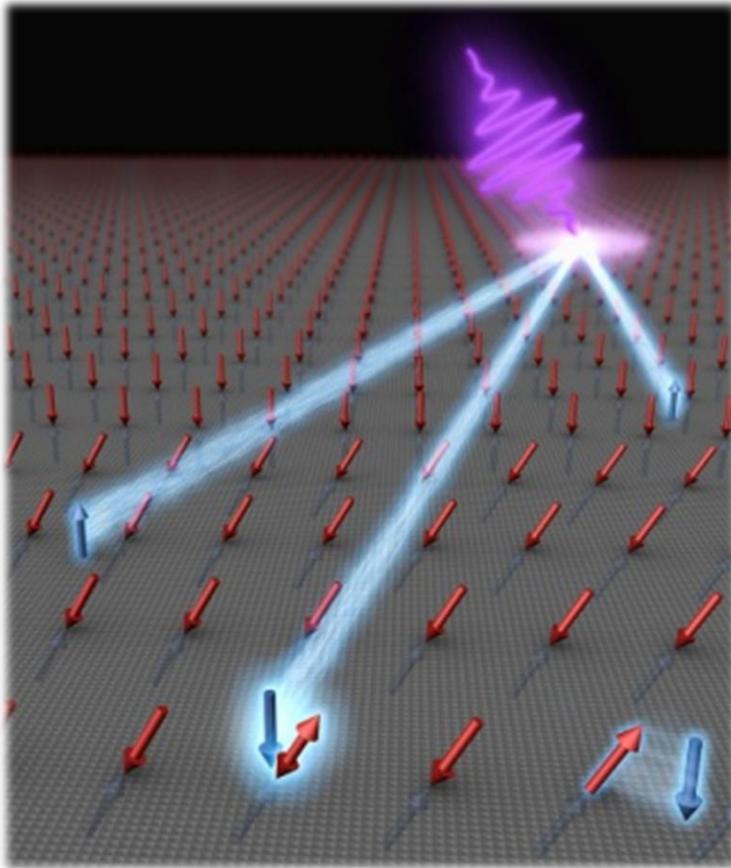
X-ray multiplexed and hyperspectral microscopy



Nano-to-mesoscale: order/disorder relations,
electron-phonon coupling, elasticity

Imaging protected topologies in magnetic and energy materials

Control of spin and charge topologies with light



Polar vortices
Polaron
topologies

Proc. Natl. Acad. Sci. U.S.A. **121** e2318151121 (2024)
Proc. Nat. Acad. Sci. **112**, 14212-14217 (2015)

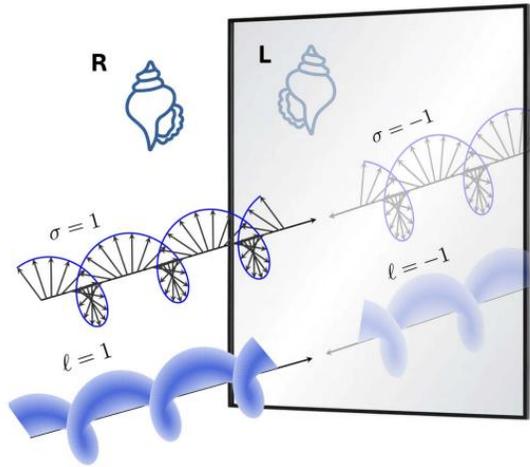
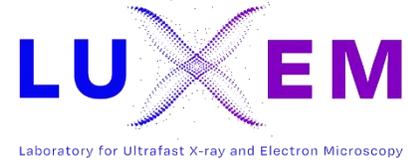
Nano Lett. **18**, 5167-5171 (2018)

Phys. Rev. Lett. **120**, 117201 (2018)

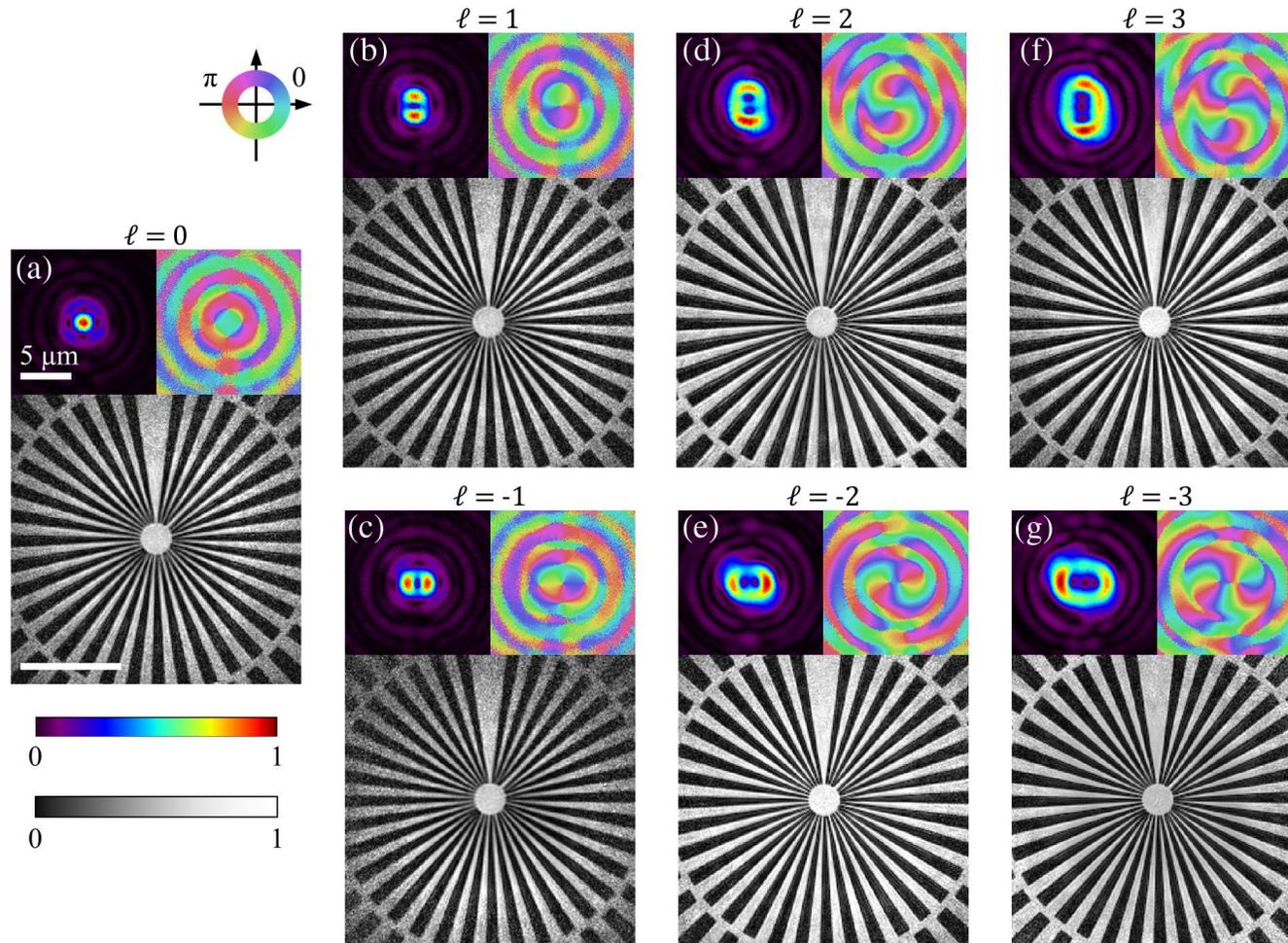
Imaging chirality with twisted light



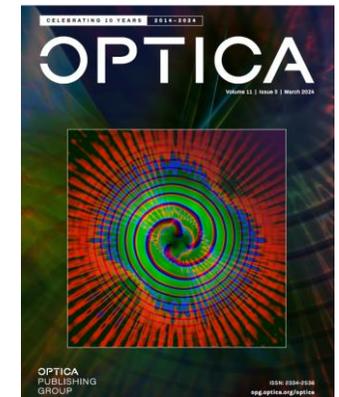
Elettra Sincrotrone Trieste

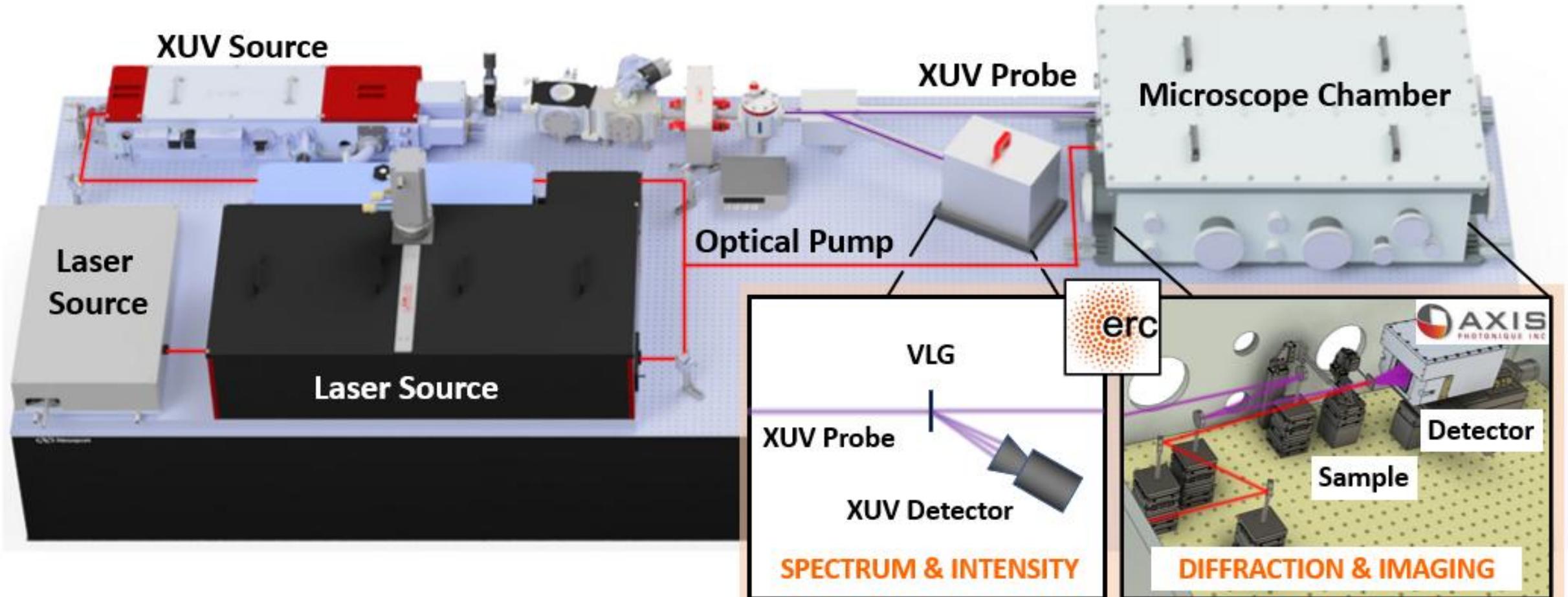


K. Forbes, Photon. Res. **14**, B193-B208 (2026)



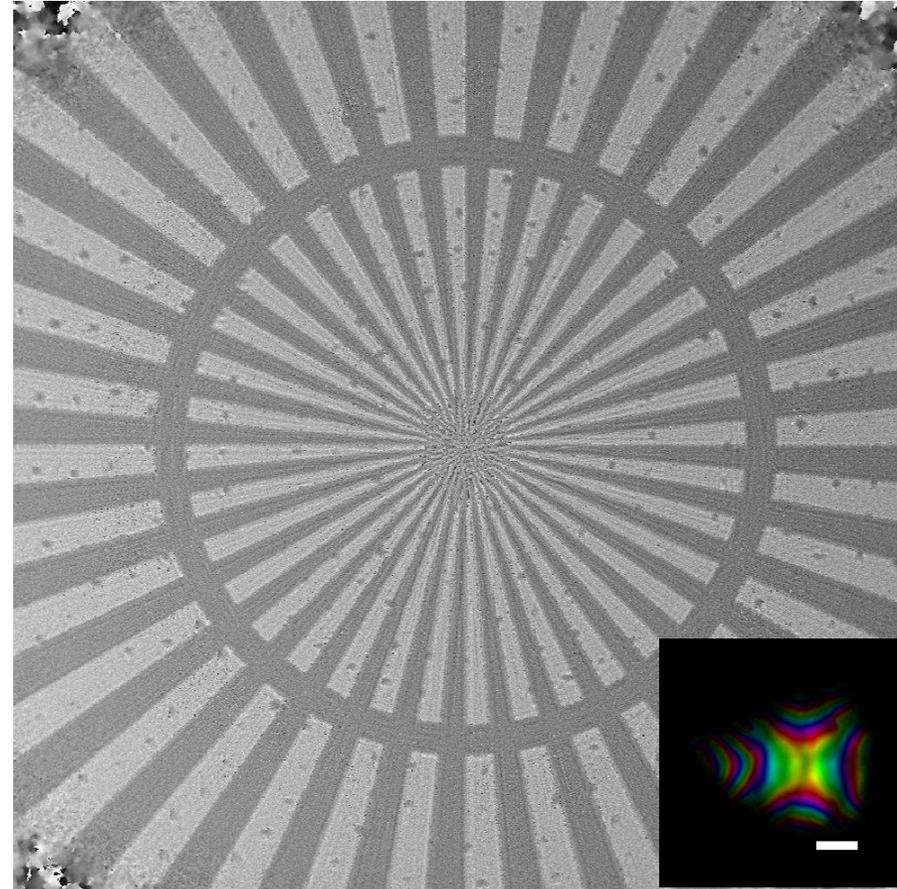
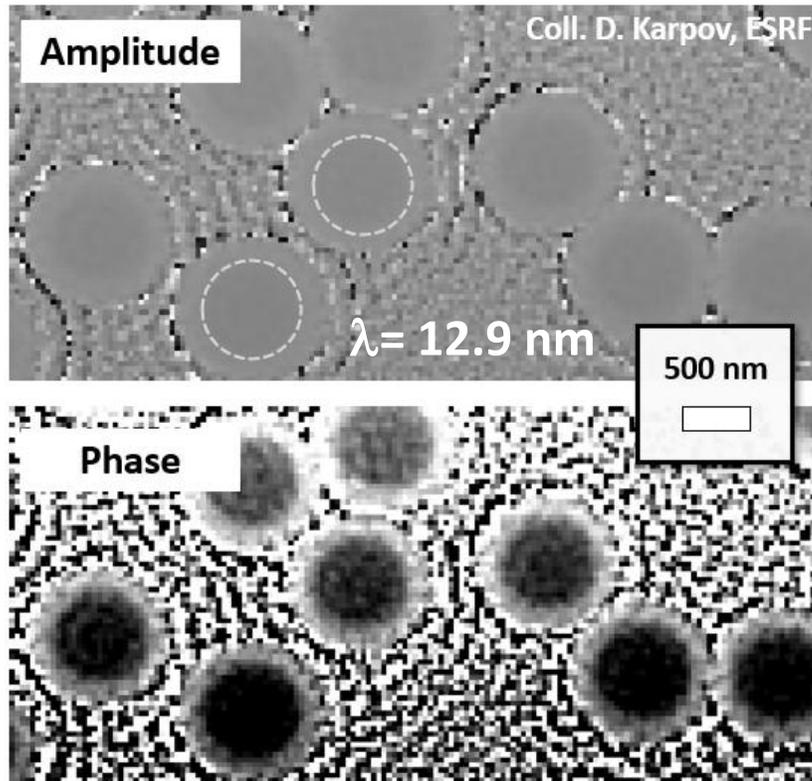
M. Pancaldi, F. Guzzi, C. S. Bevis, M. Manfredda, J. Barolak, S. Bonetti, I. Bykova, D. De Angelis, G. De Ninno, M. Fanciulli, L. Novinec, E. Pedersoli, A. Ravindran, B. Rosner, C. David, T. Ruchon, A. Simoncig, M. Zangrando, D. E. Adams, P. Vavassori, M. Sacchi, G. Kourousias, G. F. Mancini and F. Capotondi, *Optica* **11**, 403-411 (2024)





Proc. SPIE 2024 13127, Physical Chemistry of Semiconductor Materials and Interfaces XXIII, 1312706
CLEO 2024, Optica Publishing Group, paper SM2H.5, paper SM2H.3
HILAS 2024, Optica Publishing Group, paper JTU4A.26





- $300\text{nm} \pm 10\text{nm}$ cores, 3% density variation
- $50\text{nm} \pm 4\text{nm}$ ligand shell, 20% density variation
- $30 \text{ nm Si}_3\text{N}_4$ substrate

Proc. SPIE 2024 13127, Physical Chemistry of Semiconductor Materials and Interfaces XXIII, 1312706

CLEO 2024, Optica Publishing Group, paper SM2H.5, paper SM2H.3

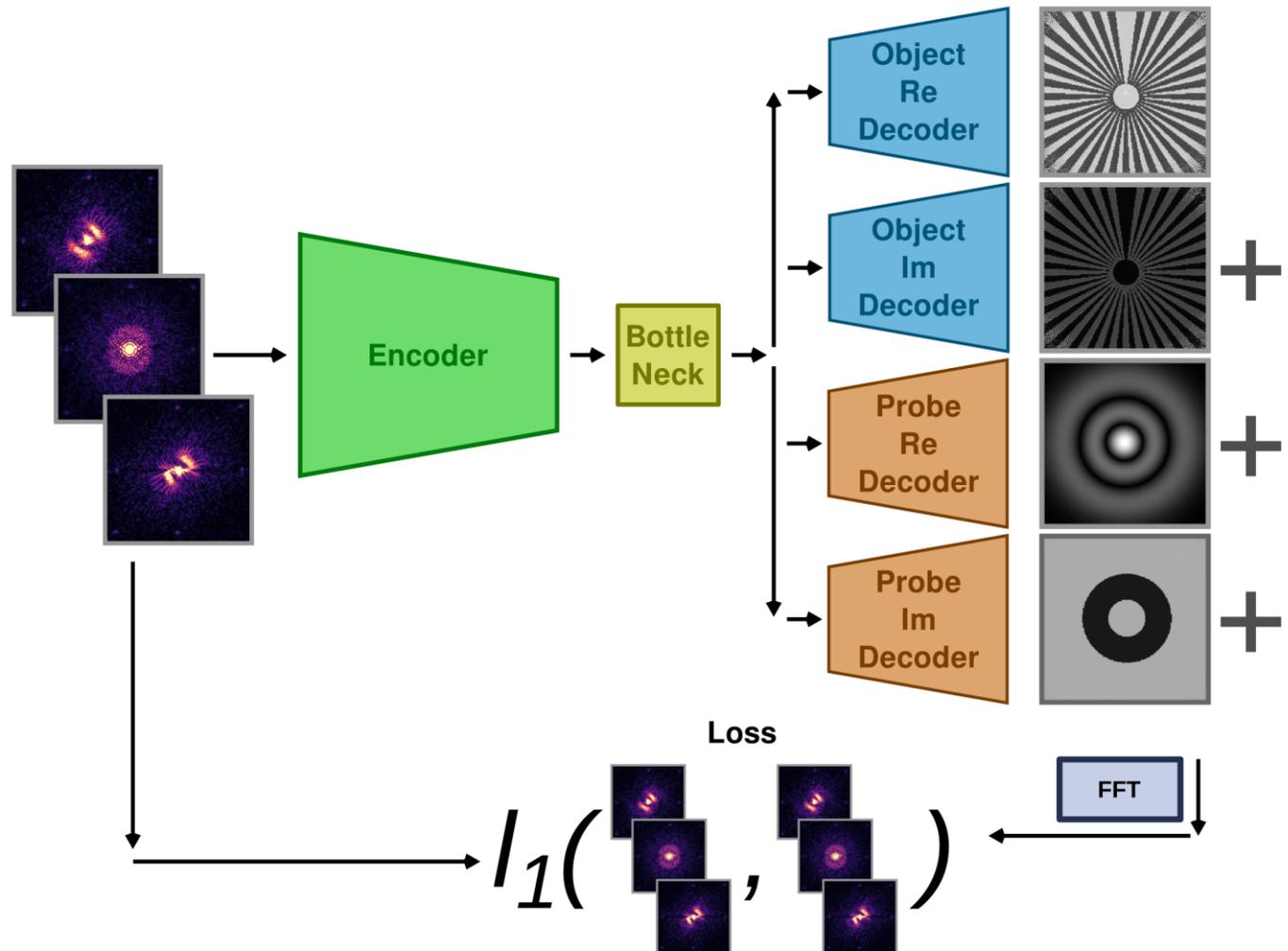
HILAS 2024, Optica Publishing Group, paper JTU4A.26

D. Karpov, A. E. Mazzarone, C. A. M. Schrama, N. Giani, G. F. Mancini, *in preparation*

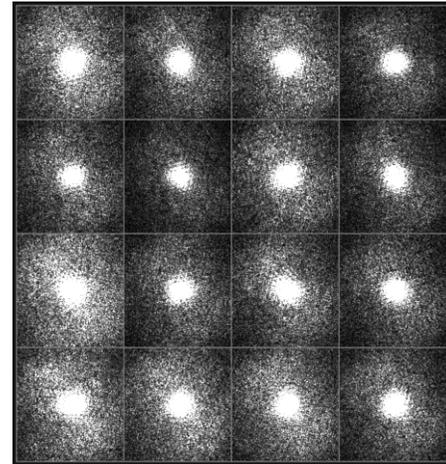
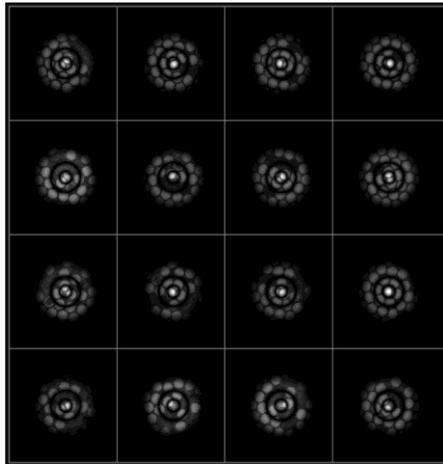
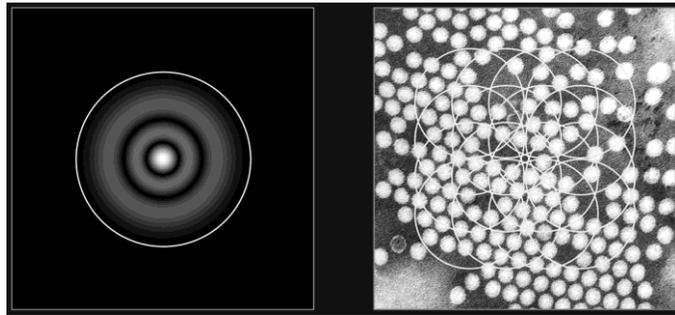


Unsupervised, physics informed neural networks for ptychography (PINNs)

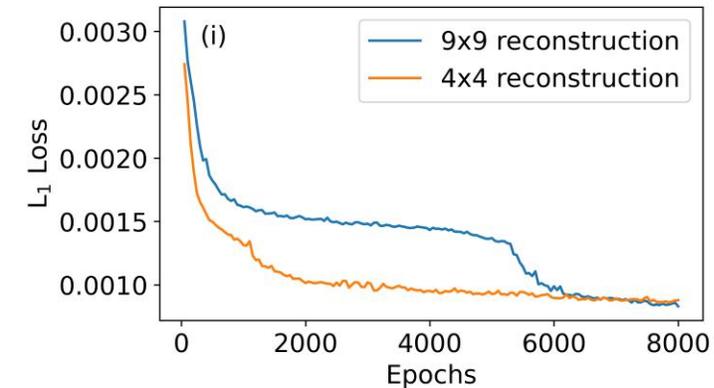
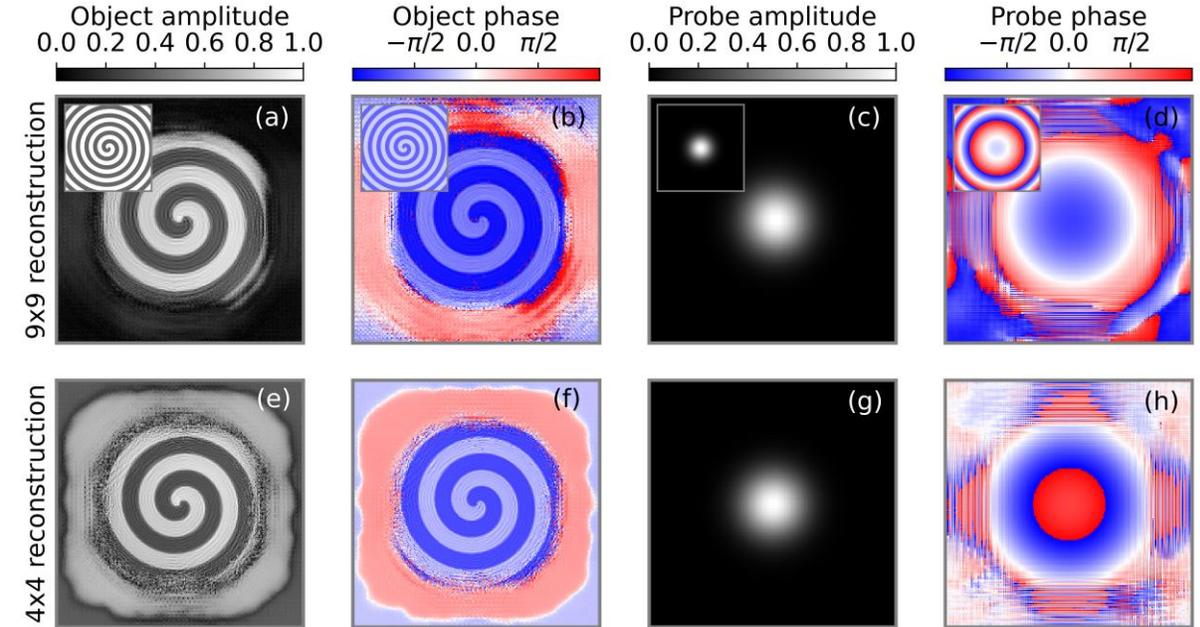
- We adopt a deep convolutional autoencoder based on the DeepLabV3+ architecture with a L1 loss computed on the input and reconstructed autocorrelations



PINNs: robustness against sampling grid sparsity

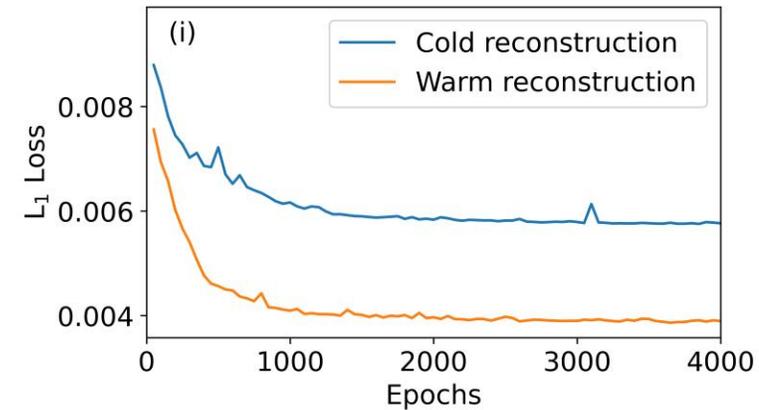
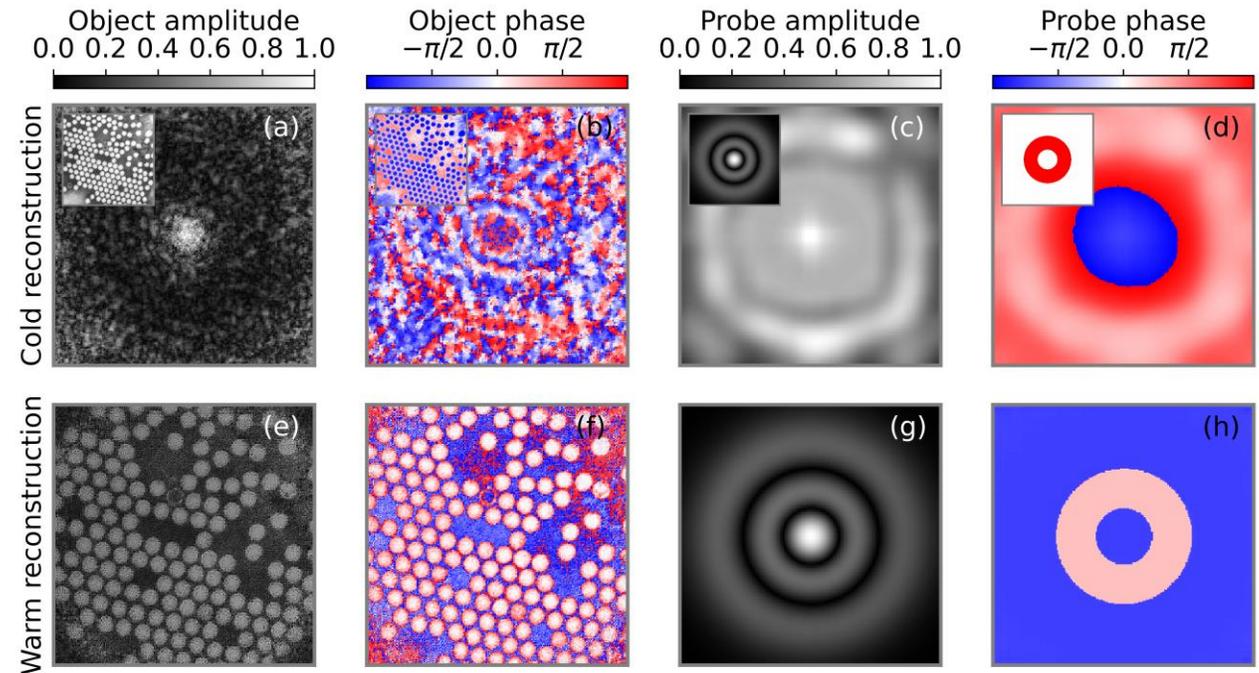


- We tested the reconstruction performance against different probe grids
- The physics informed neural network approach apparently allows for reconstructions with very sparse gridding



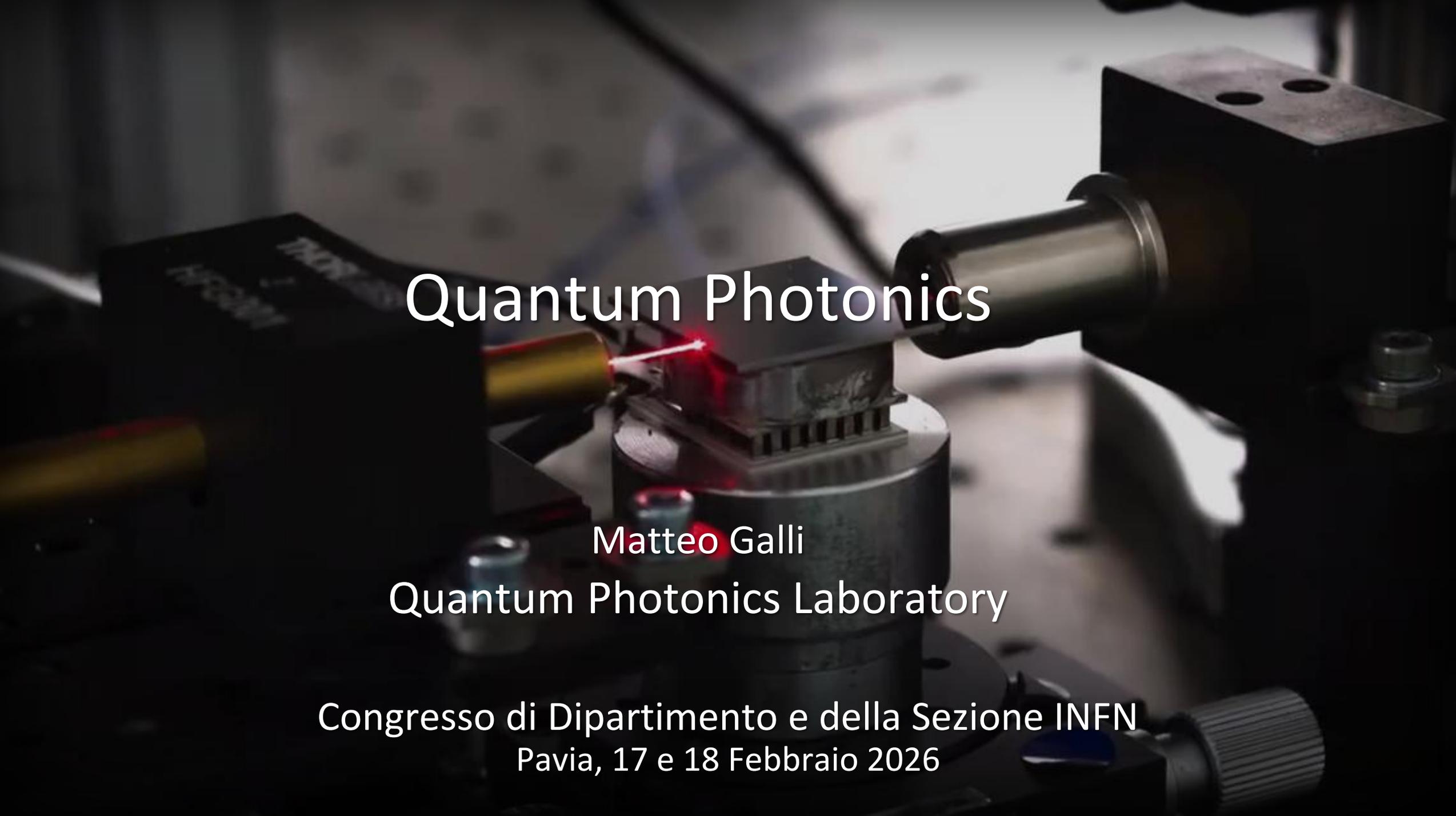
PINNs: probe warmup for improved convergence

- Without warmup the reconstruction features a slow convergence
- With warmup the reconstruction quickly reaches convergence



C. Grova, C. S. Bevis, N. Giani, D. E. Adams, G. F. Mancini, and G. Pellegrini
Optica Publishing Group, paper SM2H.3
DOI: [10.1364/CLEO_SI.2024.SM2H.3](https://doi.org/10.1364/CLEO_SI.2024.SM2H.3)

C. Grova, C. S. Bevis, N. Giani, D. E. Adams, G. F. Mancini and G. Pellegrini
Optica Publishing Group, paper JTU4A.26
DOI: [10.1364/EUVXRAY.2024.JTu4A.26](https://doi.org/10.1364/EUVXRAY.2024.JTu4A.26)



Quantum Photonics

Matteo Galli

Quantum Photonics Laboratory

Congresso di Dipartimento e della Sezione INFN
Pavia, 17 e 18 Febbraio 2026

Quantum Photonics Laboratory



Professori

- Matteo Galli
- Daniele Bajoni

Ricercatori

- Massimo Borghi
- Marco Clementi

Dottorandi

- Noemi Tagliavacche
- Sara Congia
- Marcello Bacchi
- Emanuele Brusaschi
- Andrea Bernardi
- Domenico Compagnini

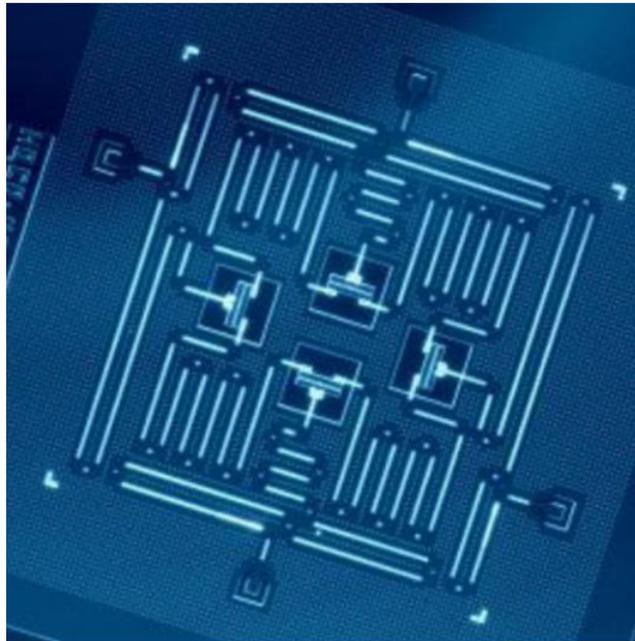
Alumni

- Dr Andrea Barone
- Dr Linda Gianini
- Eduardo Lima

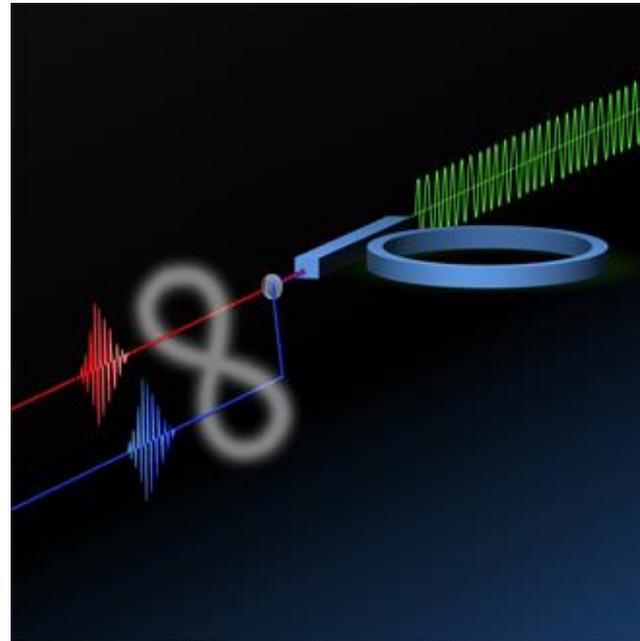
Quantum Technologies

Coherent control of single quantum objects

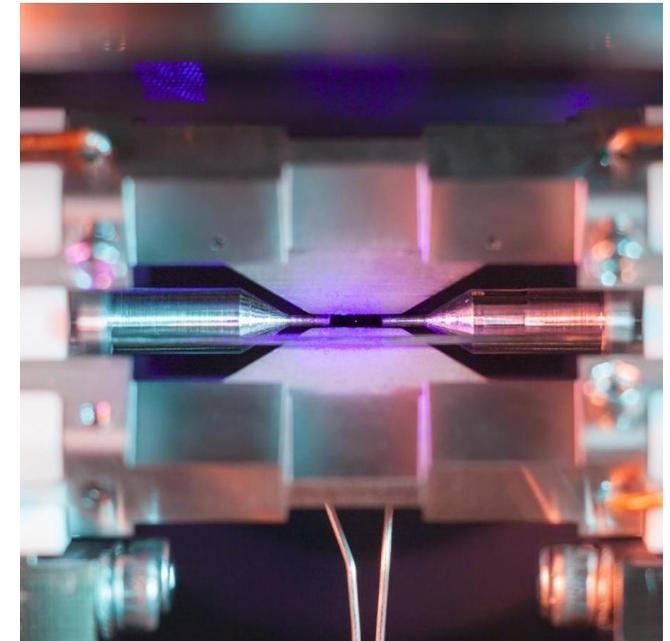
Single atoms, single photons, single quantum dots, superconducting qubits etc..



Qubit superconduttori in un quantum computer (IBM)

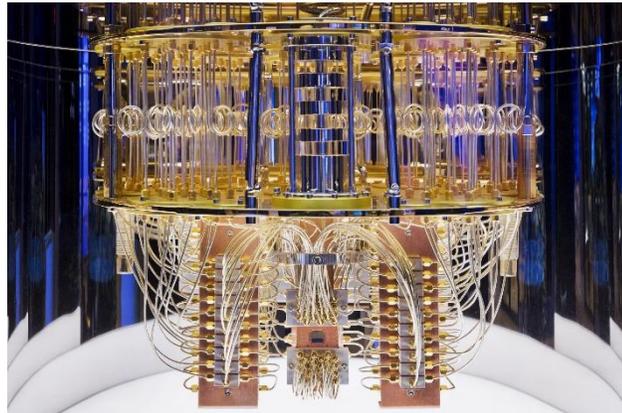
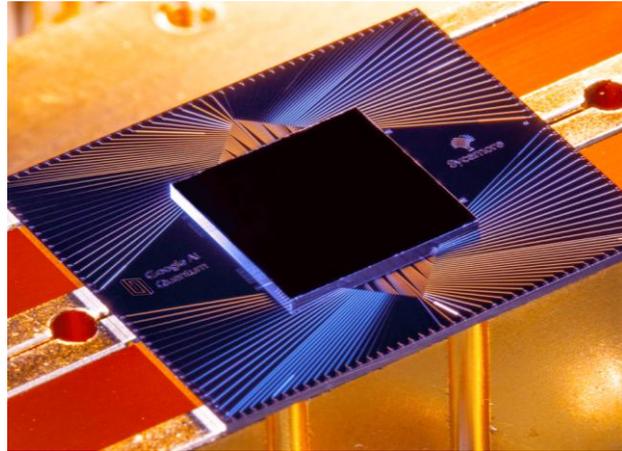


Generazione di coppie di fotoni da un micro-anello (UniPV)



Singolo atomo di Sr in trappola ionica (University of Oxford)

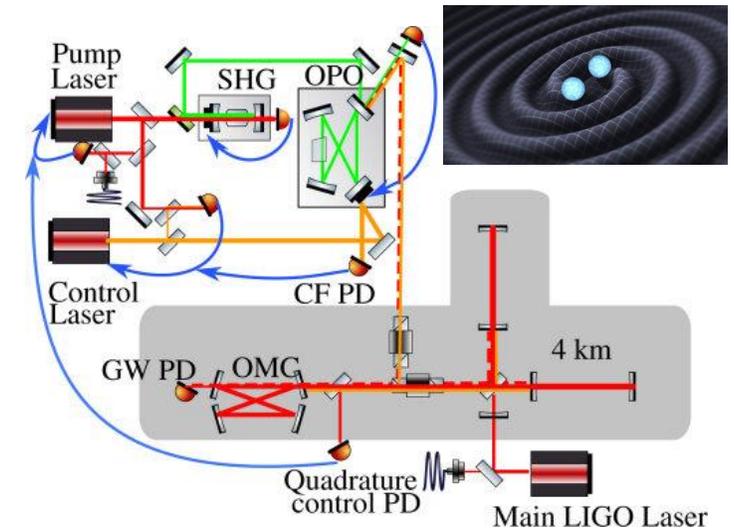
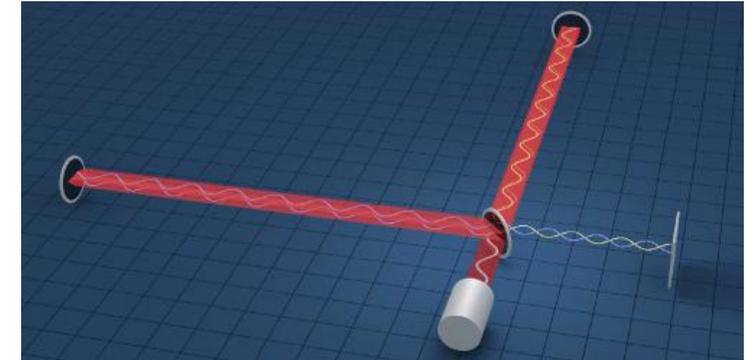
Quantum Tecnonologies



Quantum computing

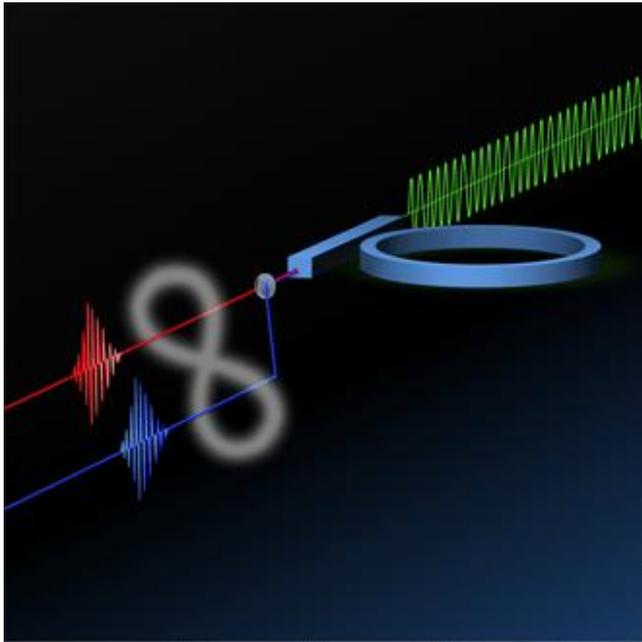


Quantum communication



Quantum sensing/metrology

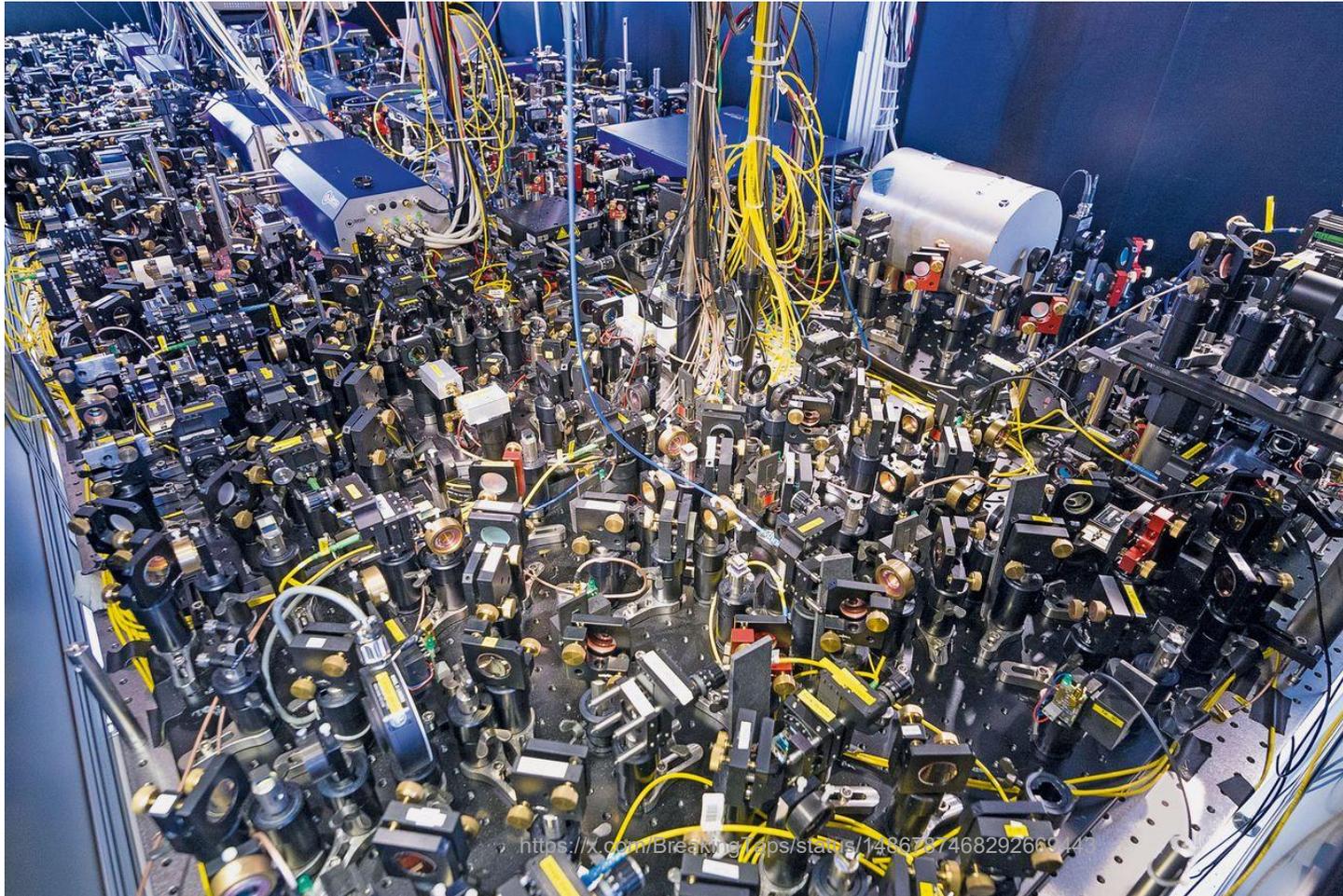
Why using light?



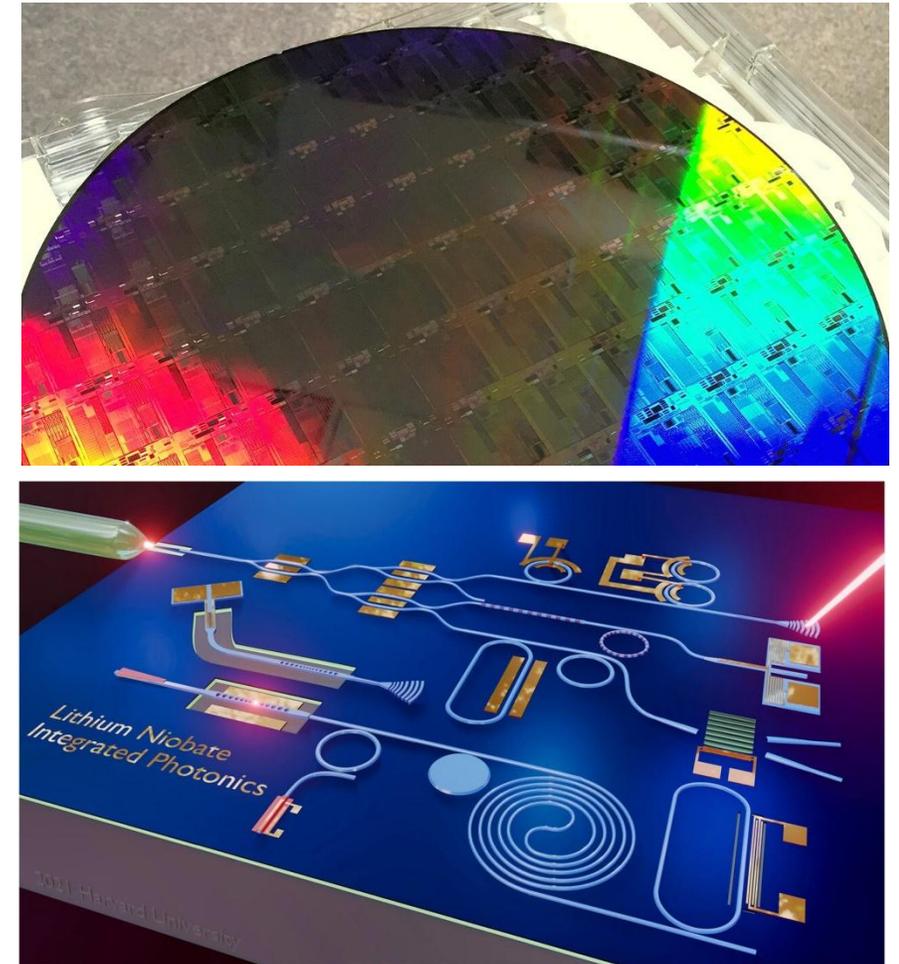
- Light has many **degrees of freedom** that can be used to encode quantum information.
- Light can maintain its quantum properties for a very **long time**.
- Light **propagates fast** (still maintaining its quantum properties).
- Light is **compatible** with several existing technologies and other quantum systems.

Integrated Quantum Photonics

Bulk quantum optical experiment



Integrated quantum optical experiment

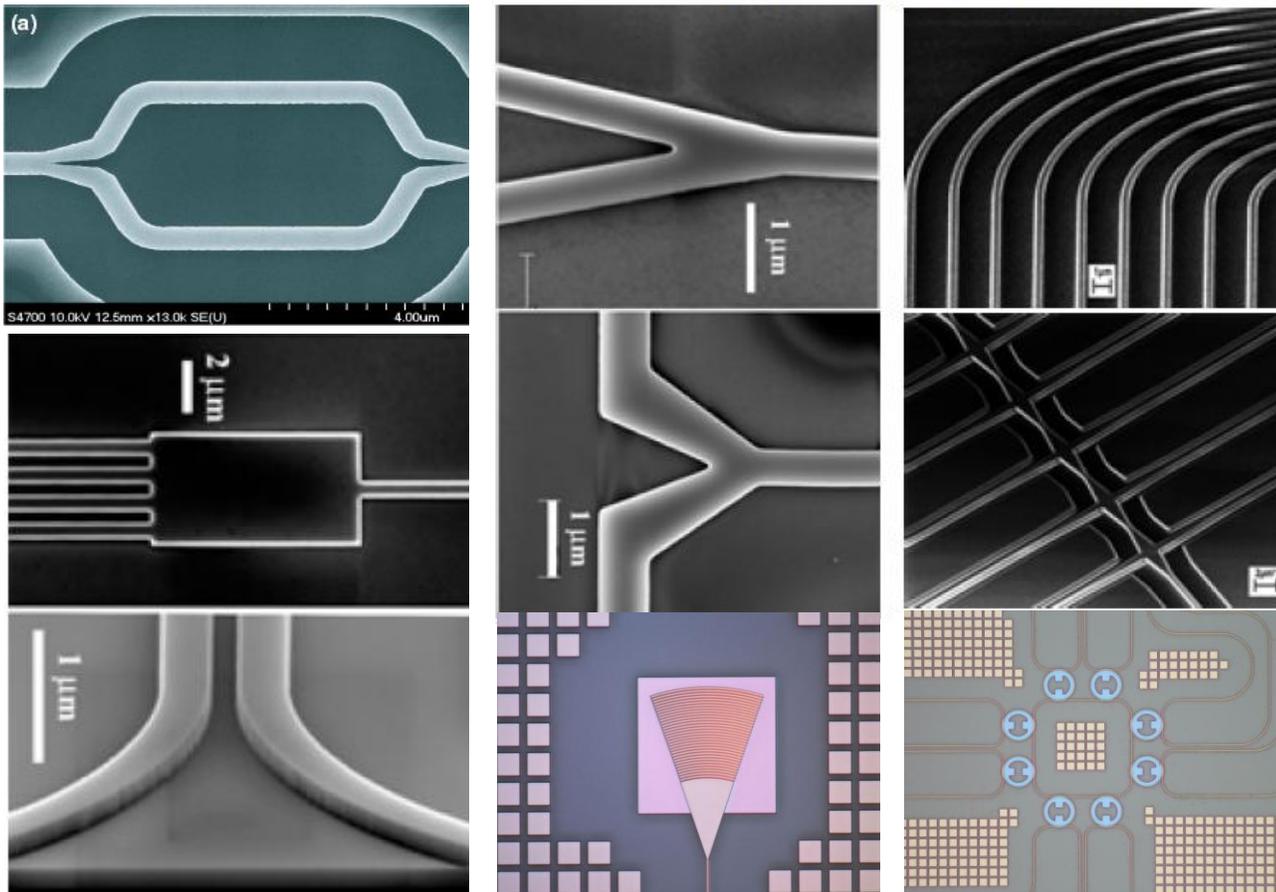


<https://sites.usc.edu/mjlab/about/integrated-optoelectronic-platform/>

Integrated Quantum Photonics

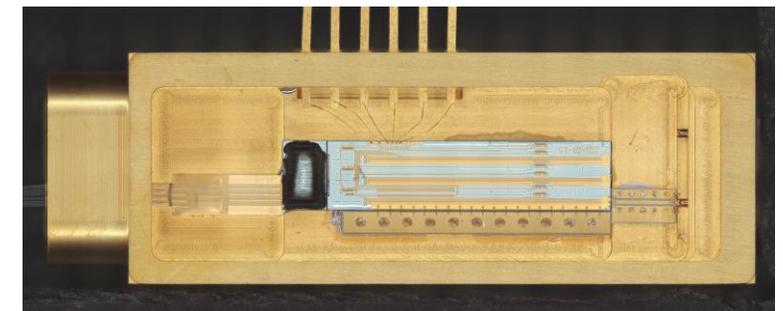
Passive integrated components

Waveguides, couplers resonators, splitter/combiner etc.



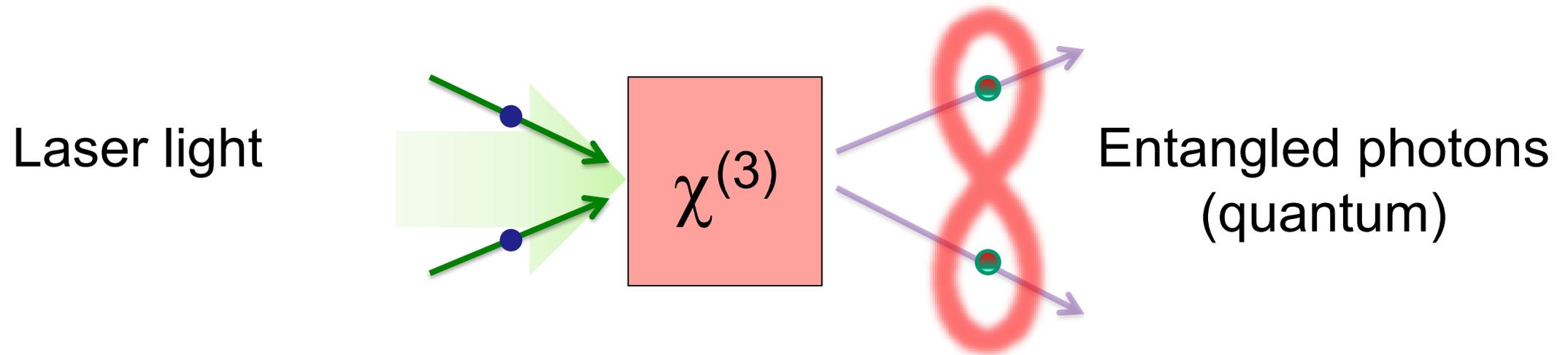
Active integrated components

Lasers, amplifiers, modulators, etc.



Generating Quantum States of Light

$$P_i = \epsilon_0 [\chi_{ij}^{(1)} E_j + \chi_{ijk}^{(2)} E_j E_k + \chi_{ijkl}^{(3)} E_j E_k E_l + \dots]$$



Elastic scattering between two photons
in a $\chi^{(3)}$ nonlinear medium

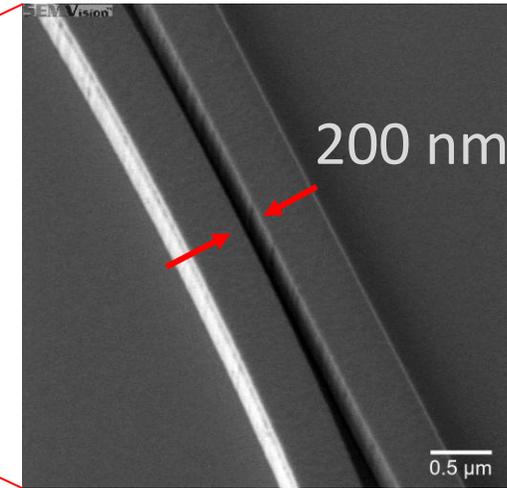
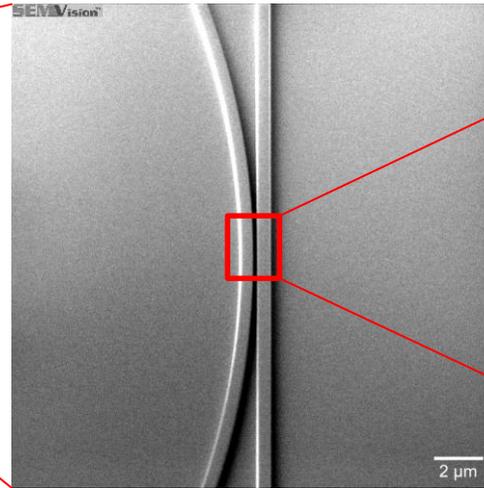
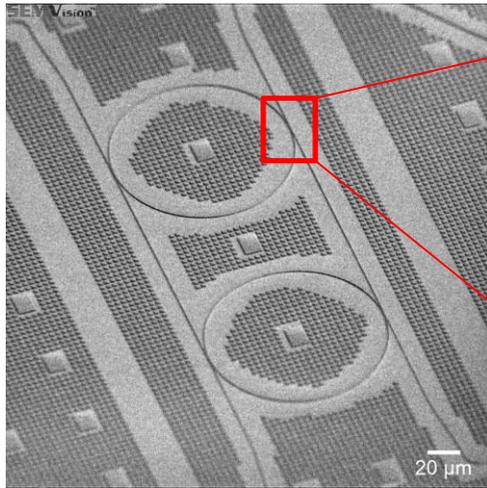
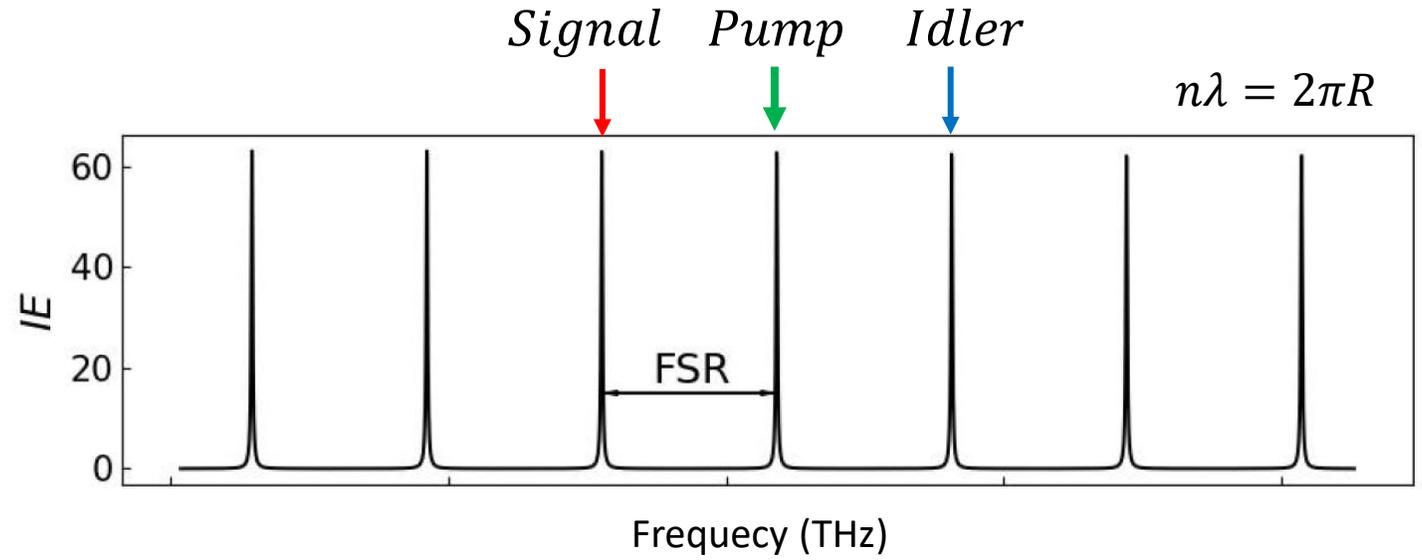
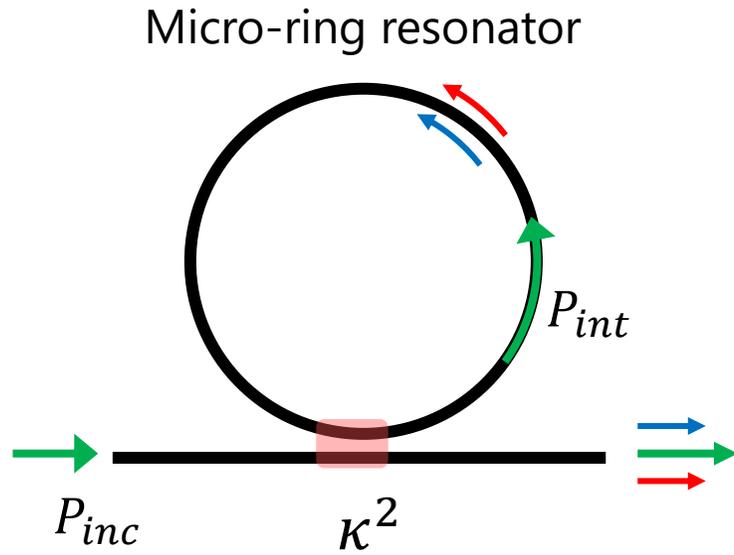
Spontaneous four-wave mixing

Very inefficient process

$$\eta \sim 10^{-15}$$



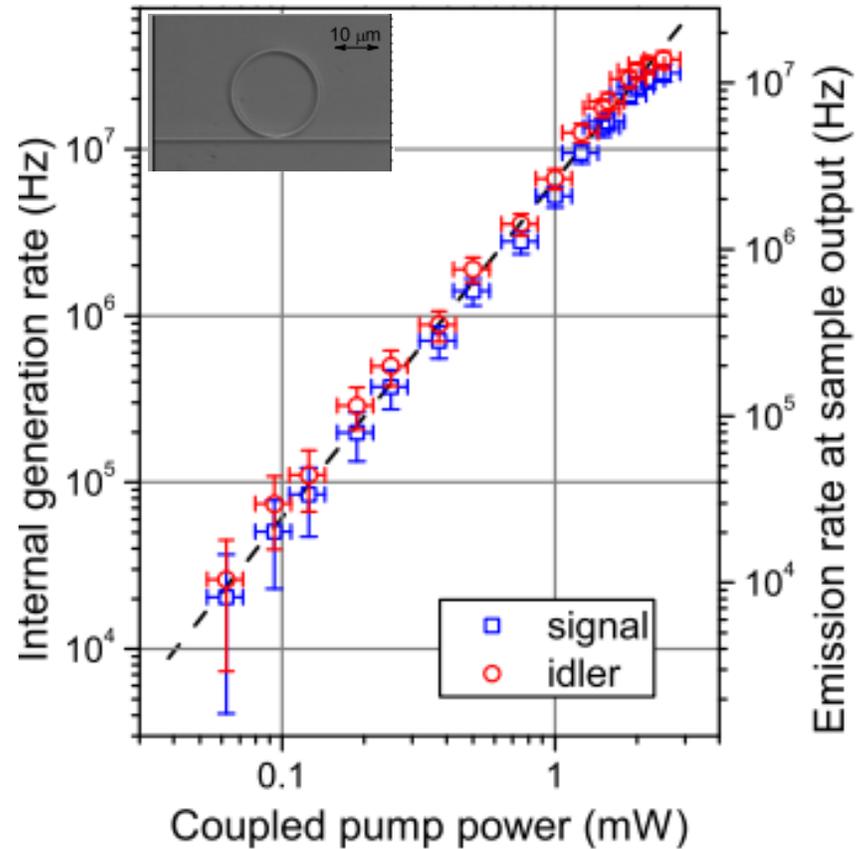
Enhancing Quantum Light Generation



Ultrabright sources of photon pairs



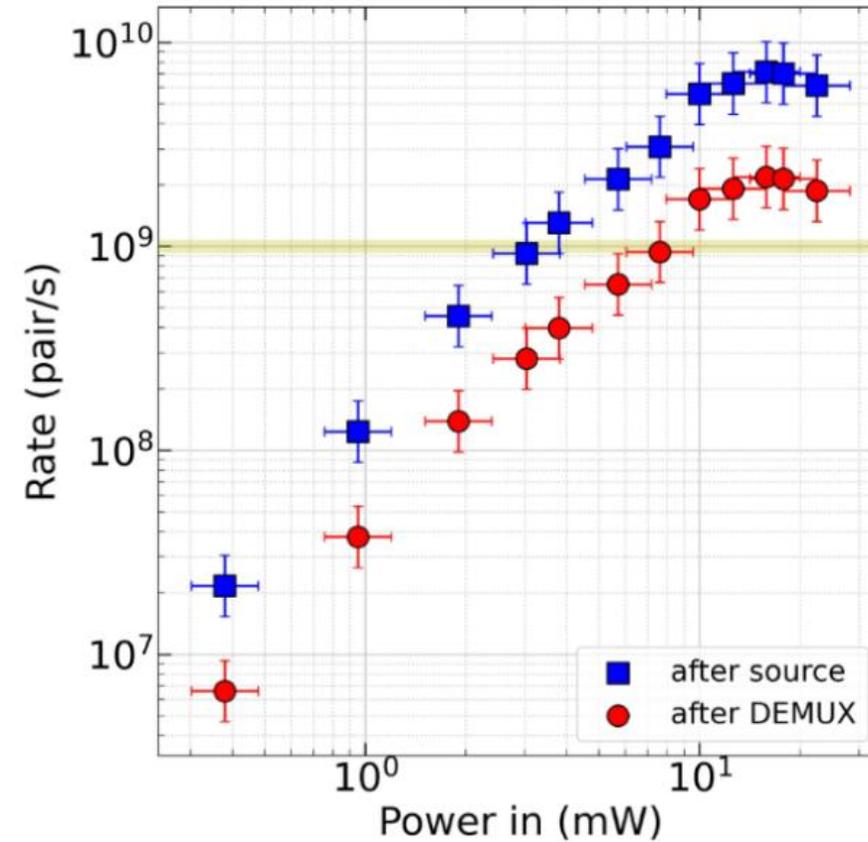
10^7 pairs/s
1 mW pump



Grassani, Davide, et al. "Micrometer-scale integrated silicon source of time-energy entangled photons." *Optica* 2.2 (2015): 88-94.



$>10^9$ pairs/s (multiplexed)
10 mW pump

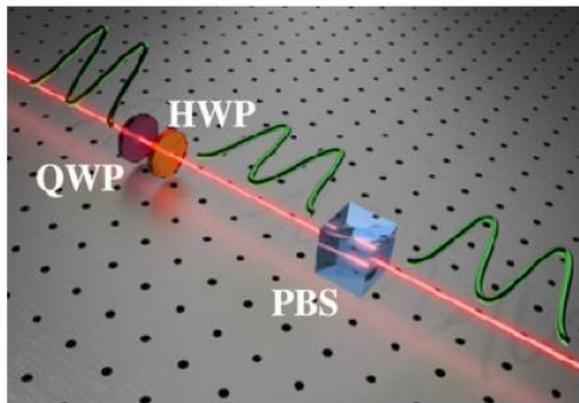
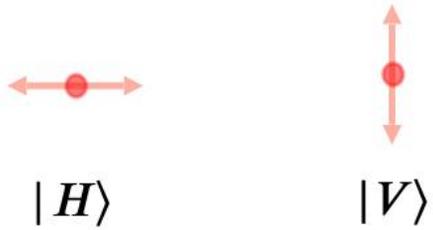


Gianini, Linda, et al. "Hyperentangled photon pairs emitted from an integrated source delivering more than 1 Gpair/s." *CLEO: Fundamental Science*. Optica Publishing Group, 2024.

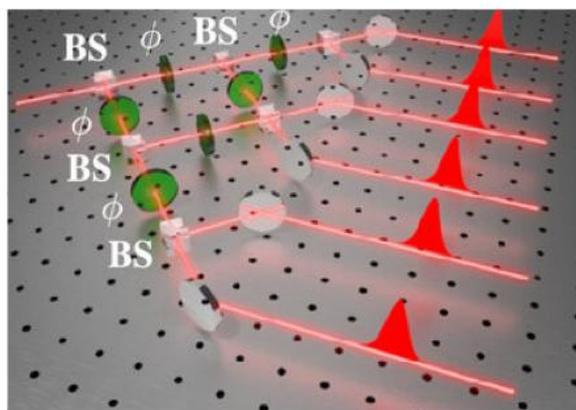
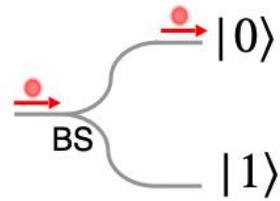


Quantum State Encoding

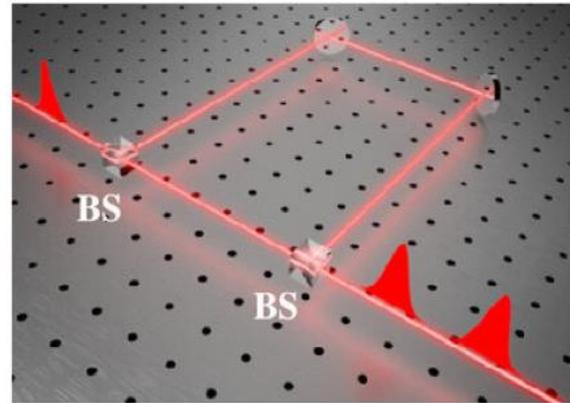
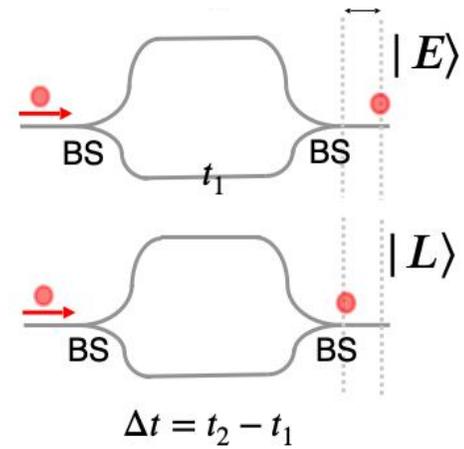
Polarization



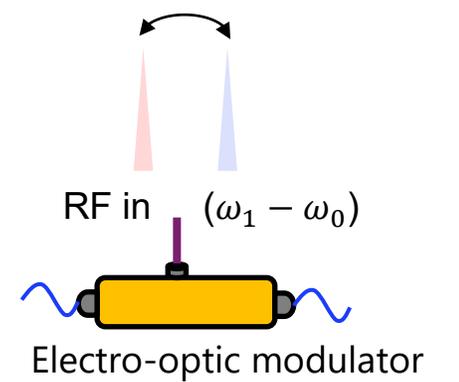
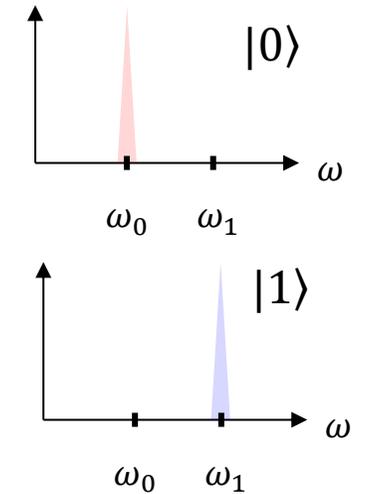
Path



Time-bin

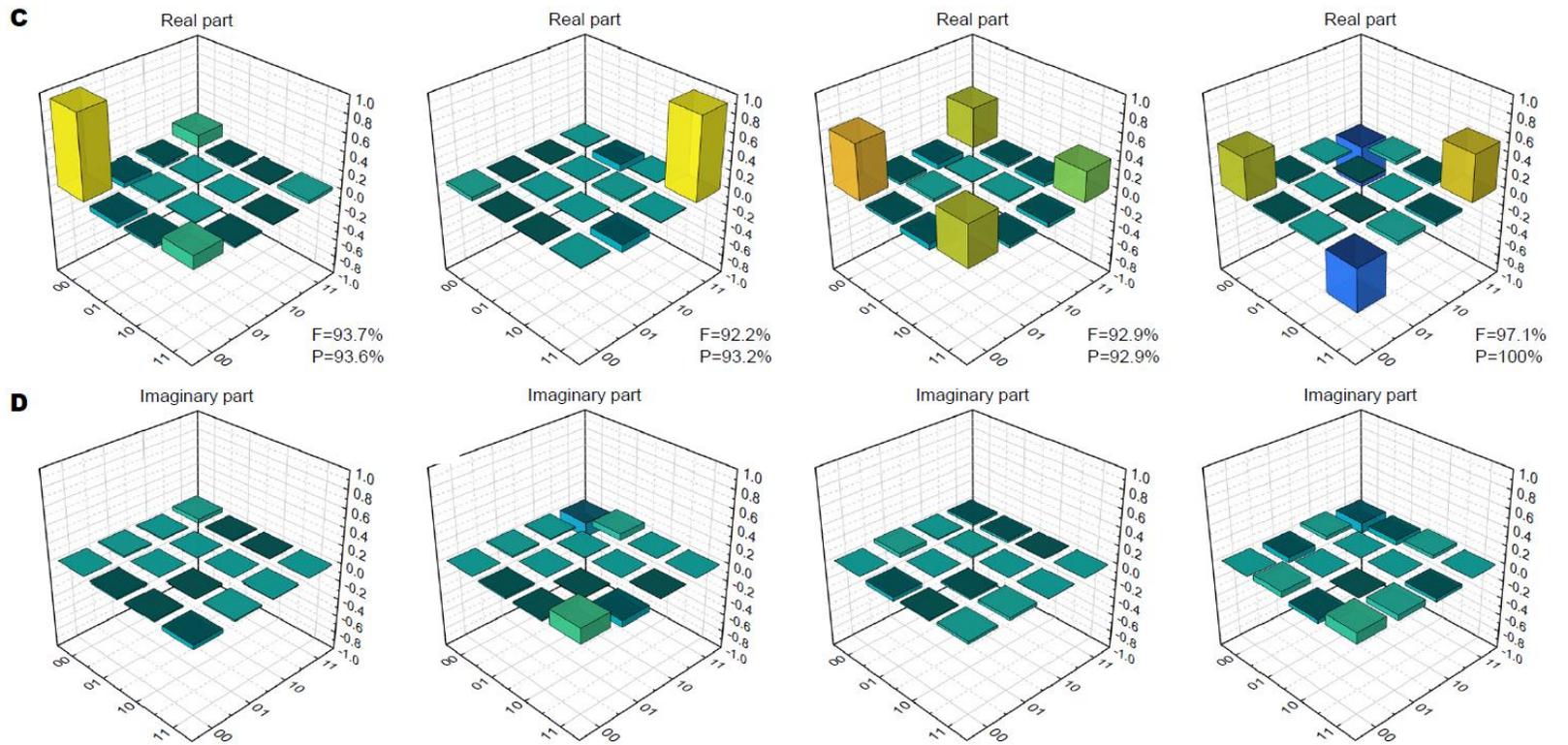
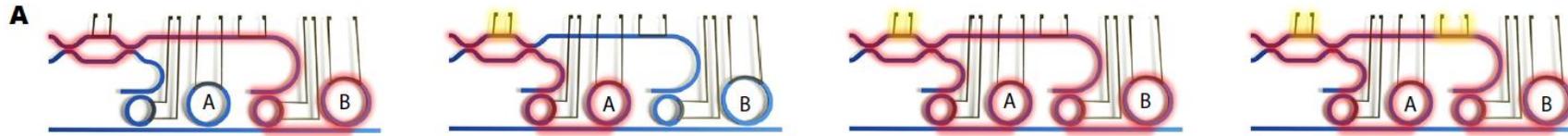


Frequency-bin



Programmable quantum state generation on a silicon chip

Source configuration



Target state:

$$|00\rangle_{si}$$

$$|11\rangle_{si}$$

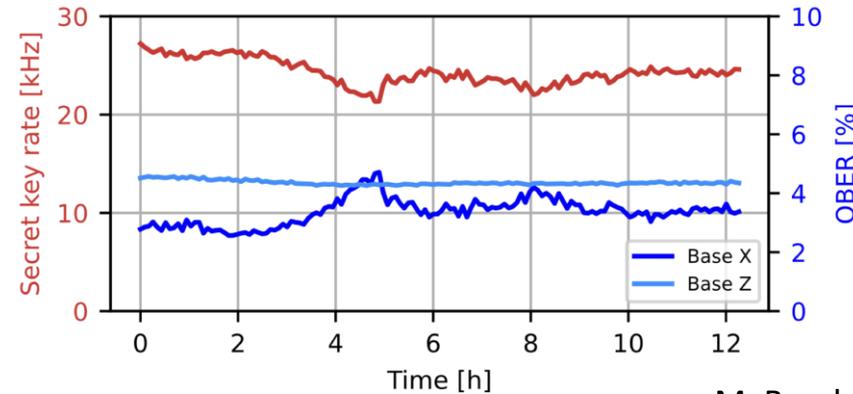
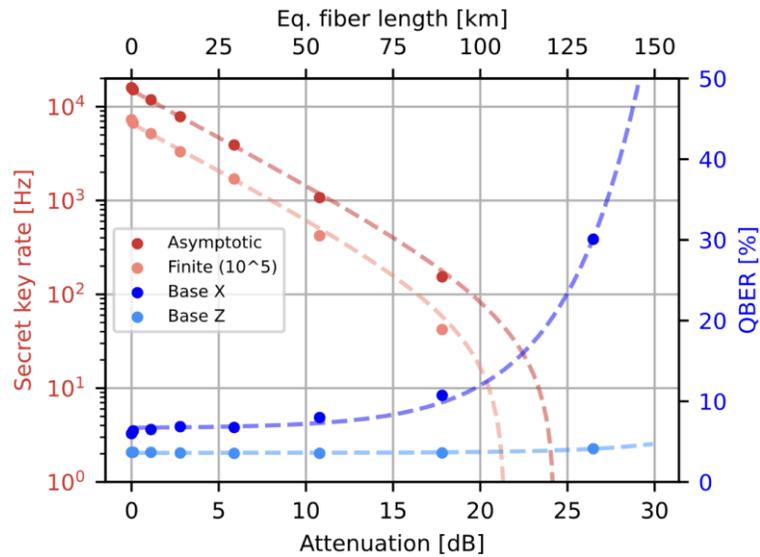
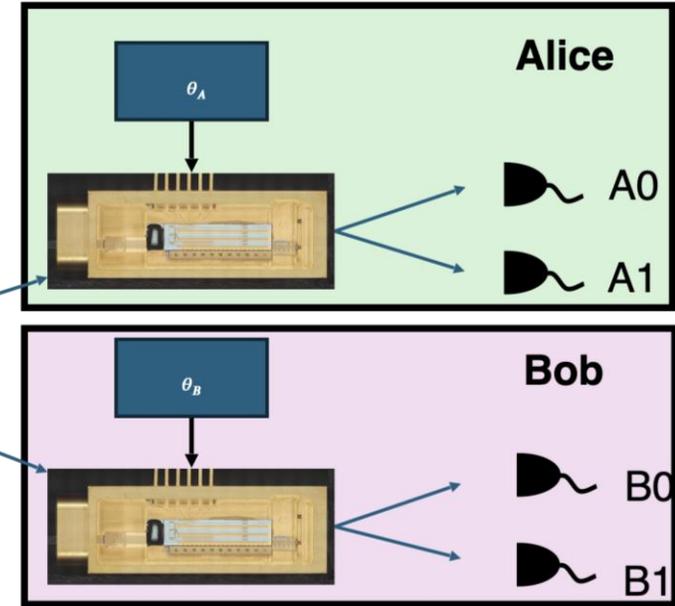
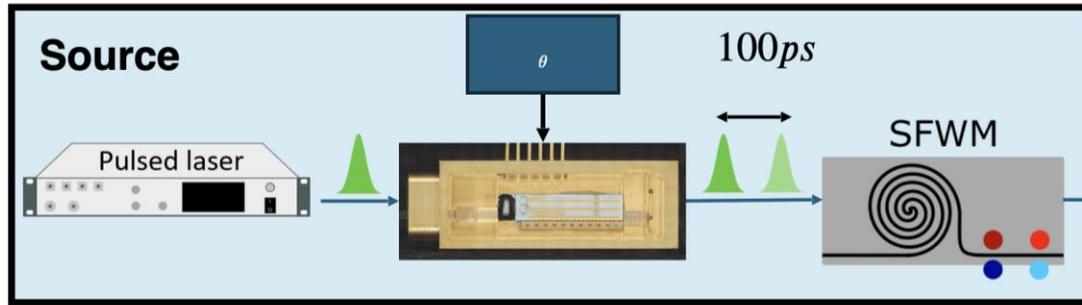
$$\frac{|00\rangle_{si} + |11\rangle_{si}}{\sqrt{2}}$$

$$\frac{|00\rangle_{si} - |11\rangle_{si}}{\sqrt{2}}$$

Integrated Tjin Film Lithium Niobate devices

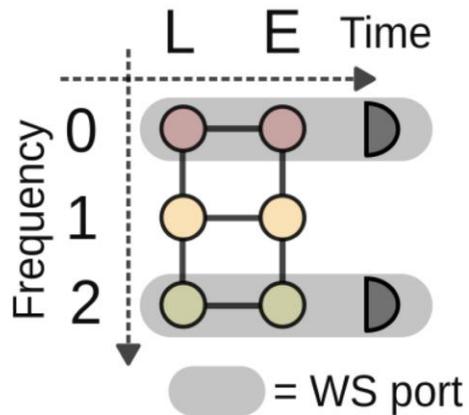
Entanglement certification / QKD protocol BBM92

$$|\Phi(\theta)\rangle = \frac{|00\rangle + |11\rangle e^{i\theta}}{\sqrt{2}}$$

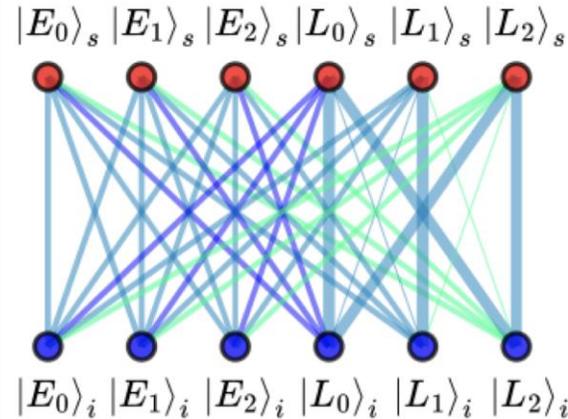


M. Bacchi et al. submitted.

Gaussian boson sampling in time-frequency modes



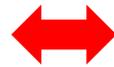
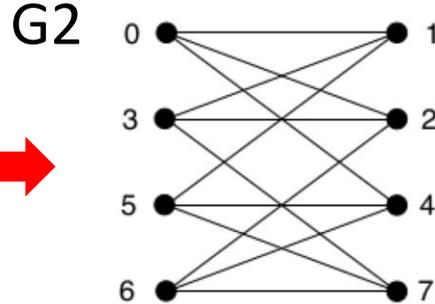
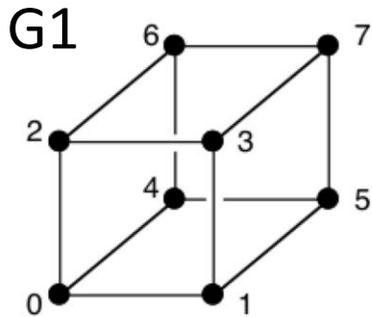
Signal modes



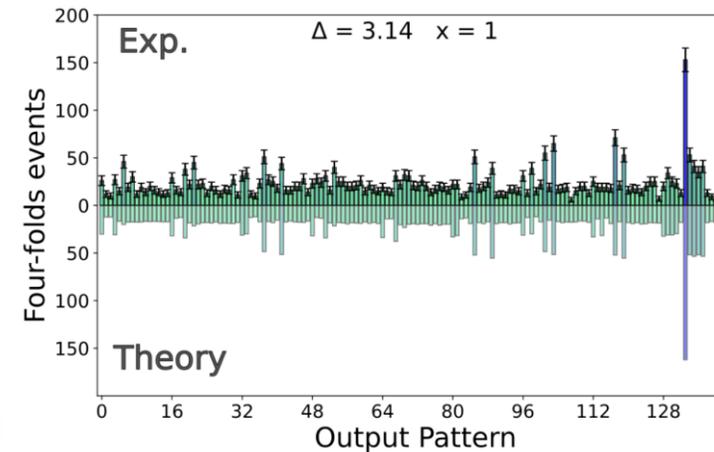
E = Early
L = Late

0,1,2 frequency –bin label

Application to graph isomorphism



G1 \rightarrow G2 by vertex relabeling is computationally hard



Borghini, M. et al. npj Quantum Inf 11, 135 (2025).

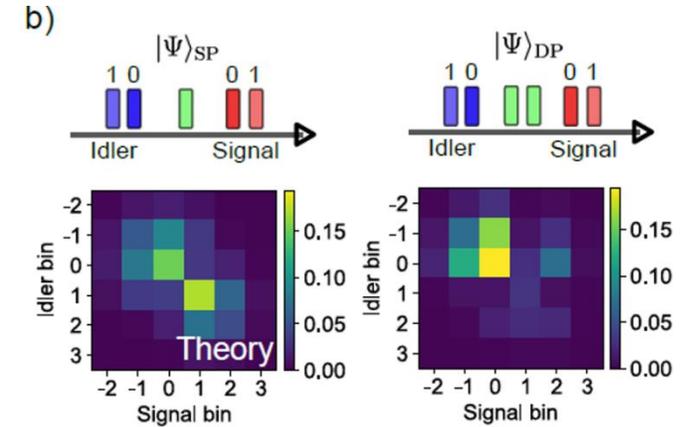
Much more at the poster session!



Massimo Borghi

P70

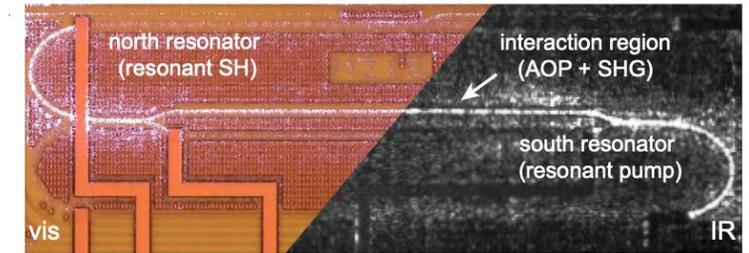
Classical Training of a Quantum Extreme Learning Machine



Marco Clementi

P12

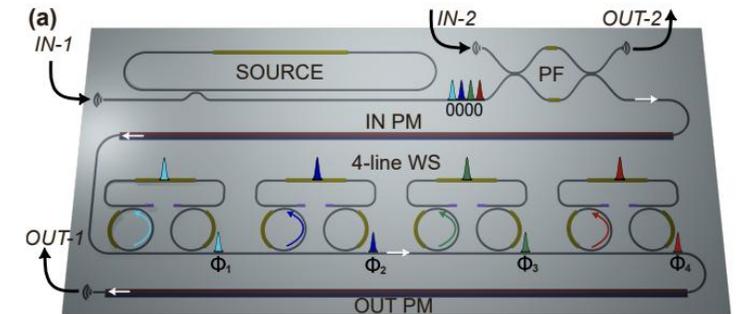
Classical and quantum light generation in silicon nitride photonics via photoinduced second-order nonlinearities



Sara Congia

P79

Generation and processing of quantum optical microcombs on a silicon chip



Acknowledgements



Ongoing Collaborations UnipPV - INFN



Global Collaboration (Europe, Americas, Asia) - > 100 Institutions

DRD5 (Detectors R&D) - Quantum Sensors & Emerging Technologies



- WP1** Exotic systems in traps & beams (HCI's, molecules, Rydberg systems, clocks, interferometry, ...)
- WP2** Quantum materials (0-, 1-, 2-D) (Engineering at the atomic scale)
- WP3** Quantum superconducting systems (4K electronics; MMC's, TES, SNSPD, KID's/...; integration challenges)

- WP4** Scaling up to macroscopic ensembles (spins; nano-structured materials; hybrid devices, opto-mechanical sensors,...)
- WP5** Quantum techniques for sensing (back action evasion, squeezing, entanglement, Heisenberg limit)
- WP6** Capability expansion (cross-disciplinary exchanges; infrastructures; education)



UNIVERSITÀ DI PAVIA



Istituto Nazionale di Fisica Nucleare
SEZIONE DI ROMA TOR VERGATA



Istituto Nazionale
di Fisica Nucleare

TIFPA

Trento
Institute for
Fundamental
Physics and
Applications

CNS5 - Ultrafast PHOtonics for quantum Simulation (UPHOS)

Durata proposta: 3 anni

Area di ricerca: RIVELATORI-ELETTRONICA

Responsabile nazionale: Andrea Salamon

Unità partecipanti: RM2 – 3.1 FTEs , PV – **2.2 FTEs**, TIFPA – 1.5 FTEs



UNIVERSITÀ DI PAVIA
Department of Physics
"Alessandro Volta"

Scanning tunneling microscopy (STM) group

Nobel Prize in Physics 1986



Photo: Marianne Kischke, Fritz Haber Institut der Max Planck Gesellschaft. Nobel Foundation archive.

Ernst Ruska

Prize share: 1/2



Photo from the Nobel Foundation archive.

Gerd Binnig

Prize share: 1/4



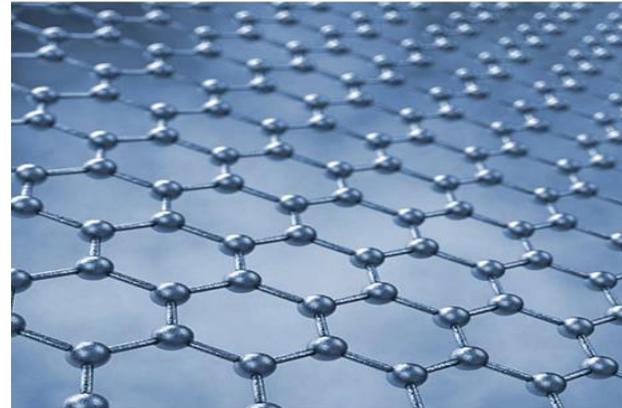
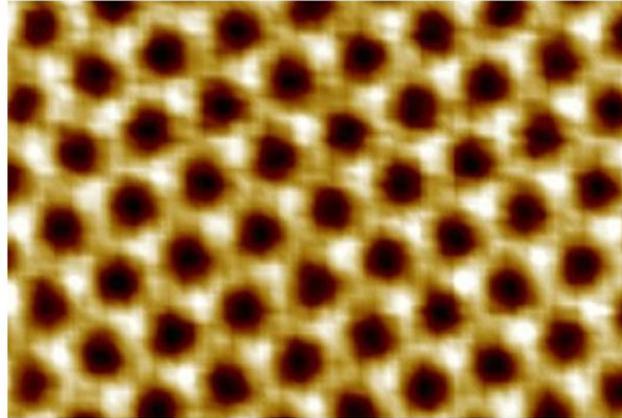
Photo from the Nobel Foundation archive.

Heinrich Rohrer

Prize share: 1/4

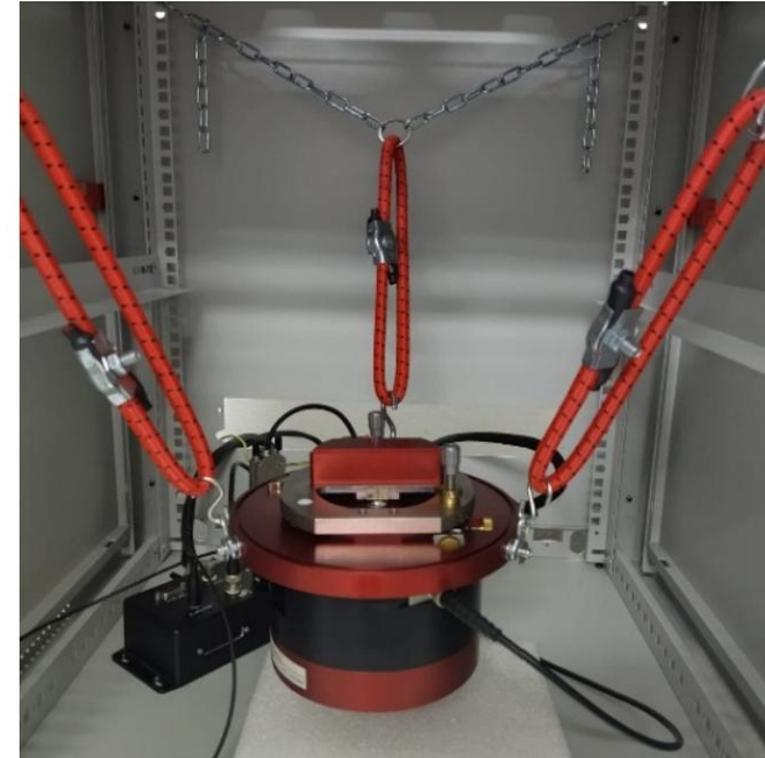
The Nobel Prize in Physics 1986 was divided, one half awarded to Ernst Ruska "for his fundamental work in electron optics, and for the design of the first electron microscope", the other half jointly to Gerd Binnig and Heinrich Rohrer "for their design of the scanning tunneling microscope"

STM image of a single carbon layer, called «graphene»



Picture of the carbon atoms in graphene

The STM in our laboratory



Principal investigator
Vittorio Bellani

Scanning tunneling microscopy (STM) group

Nobel Prize in Chemistry 2016



© Nobel Prize Outreach. Photo: A. Mahmoud
Jean-Pierre Sauvage
Prize share: 1/3



© Nobel Prize Outreach. Photo: A. Mahmoud
Sir J. Fraser Stoddart
Prize share: 1/3

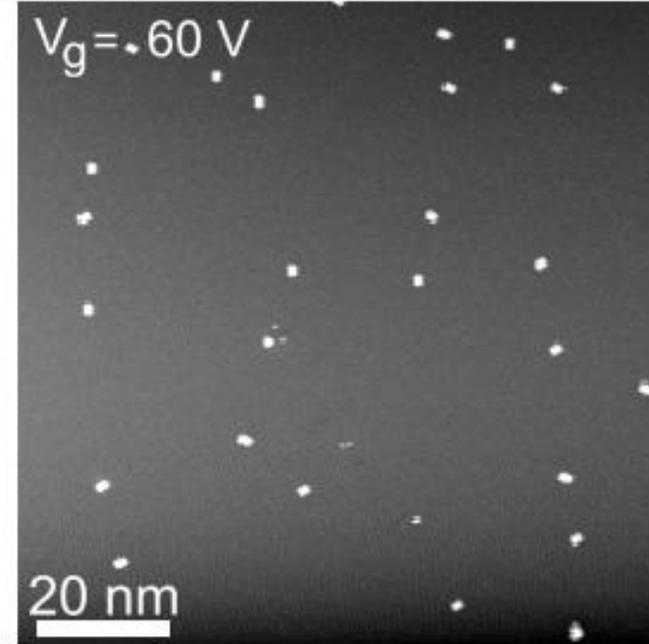
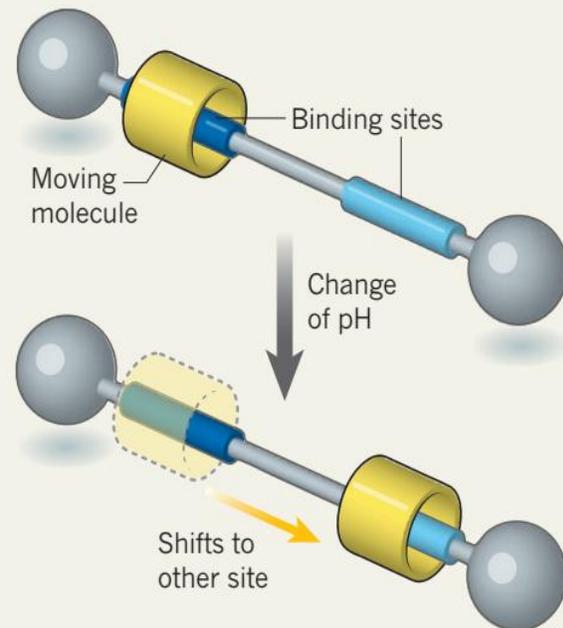


© Nobel Prize Outreach. Photo: A. Mahmoud
Bernard L. Feringa
Prize share: 1/3

The Nobel Prize in Chemistry 2016 was awarded jointly to Jean-Pierre Sauvage, Sir J. Fraser Stoddart and Bernard L. Feringa "for the design and synthesis of molecular machines"

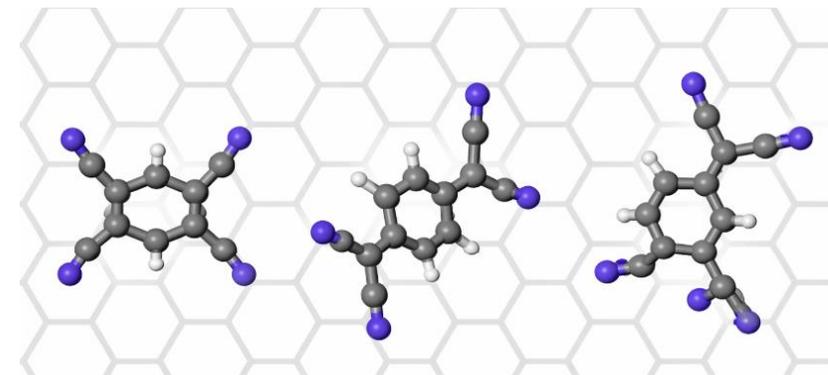
NANOMACHINES

Mechanisms the size of molecules are governed by the rules of chemistry, rather than Newtonian mechanics. An example is this switch called a rotaxane. A ring-shaped molecule is threaded onto a linear molecule and shifts between two binding sites as the acidity of the surrounding solution is altered.



Video with STM images of a molecule moving on graphene

F. Liou. ... V. Bellani... et al. ACS Nano 18, 24262 (2024).



Spectroscopies for materials - S4M labs Research interest

Semiconductors, Oxides and Dielectrics for management of electromagnetic radiation propagation, photovoltaic cells, optical coatings

Plasmonics: dimensionality from 3D to 0D, for light management, sensing, and biomedical applications

Carbon-based compounds: DLC, (B)CN, graphitic & graphenic

what?

Polymer structures and hybrid composites, for both photonic applications (flexible/plastic photonics) and visible-NIR sensing

inorganic or hybrid Perovskites (films, nanocrystals) for both photovoltaic and photonic applications

Cultural Heritage conservation and restoration issues and materials related

functional Oxides for applications in energy and sensing

spectral Analysis & spectral simulation and modeling of the electrical, optical, magnetic material responses - Dedicated theoretical approaches

who? P. Galinetto, E. Giulotto, M.C. Mozzati, M. Patrini, G. Pellegrini

Spectroscopy & Microscopy approach

microRaman-SERS
spectroscopy



UV-vis-IR
spectroscopies

AFM & SPM
microscopies



how?

Vis-NIR
Fluorescence



Electronic param
Resonance

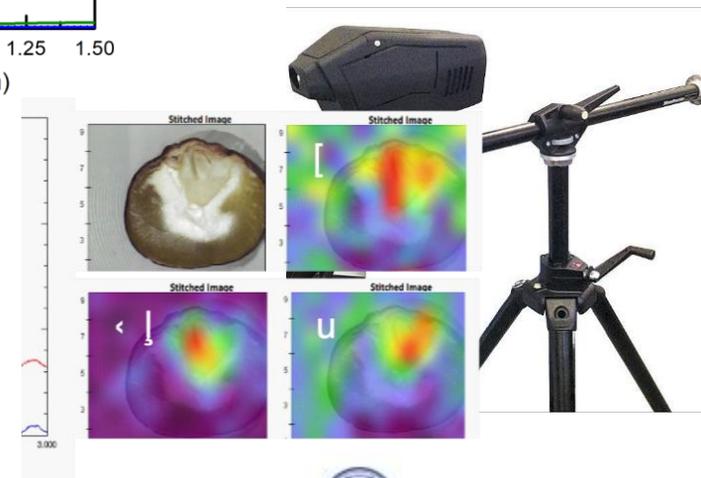
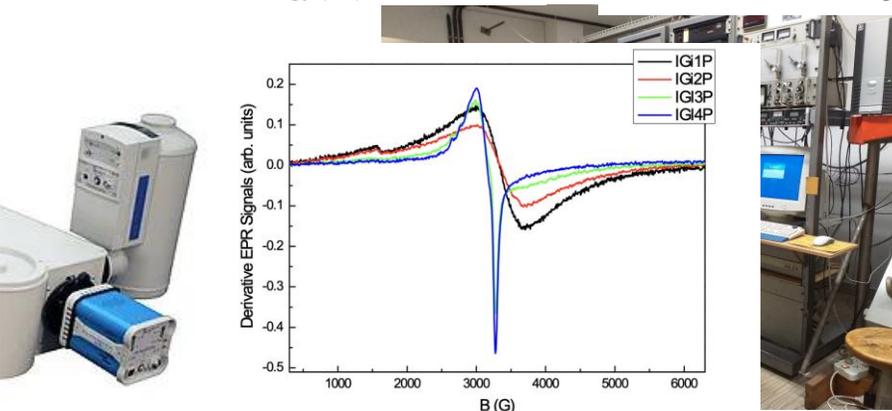
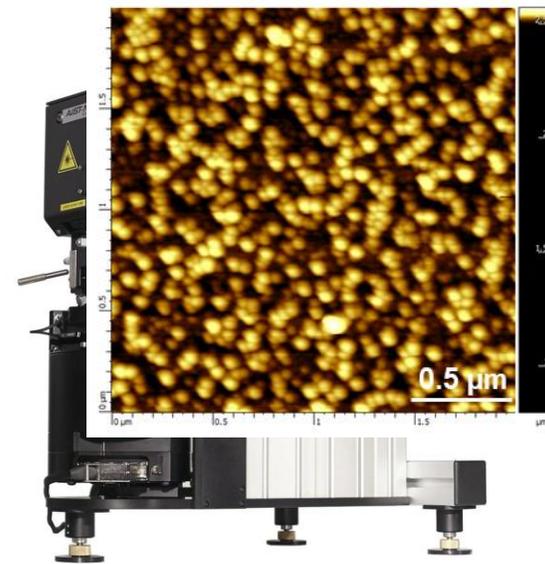
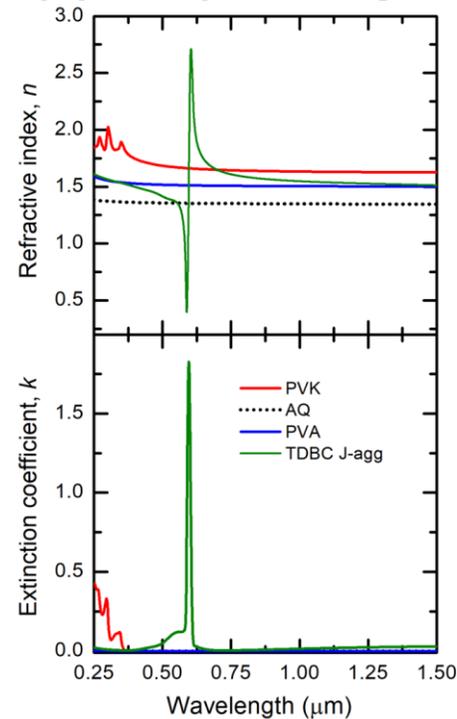
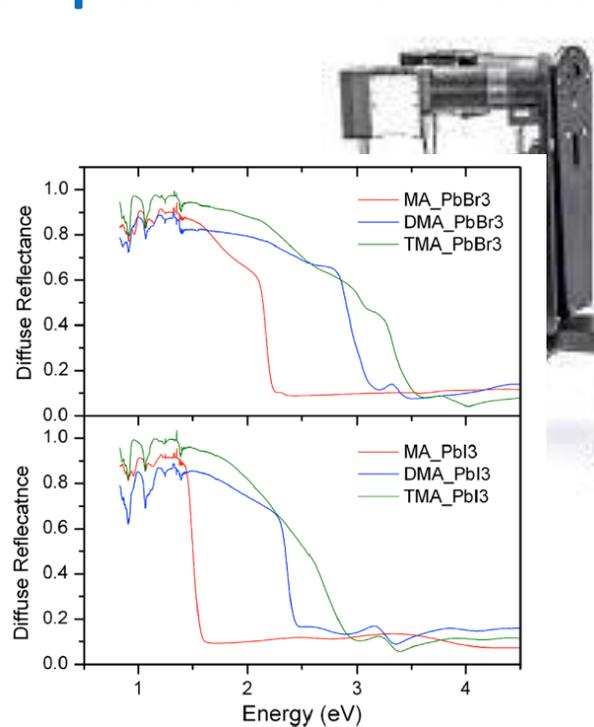
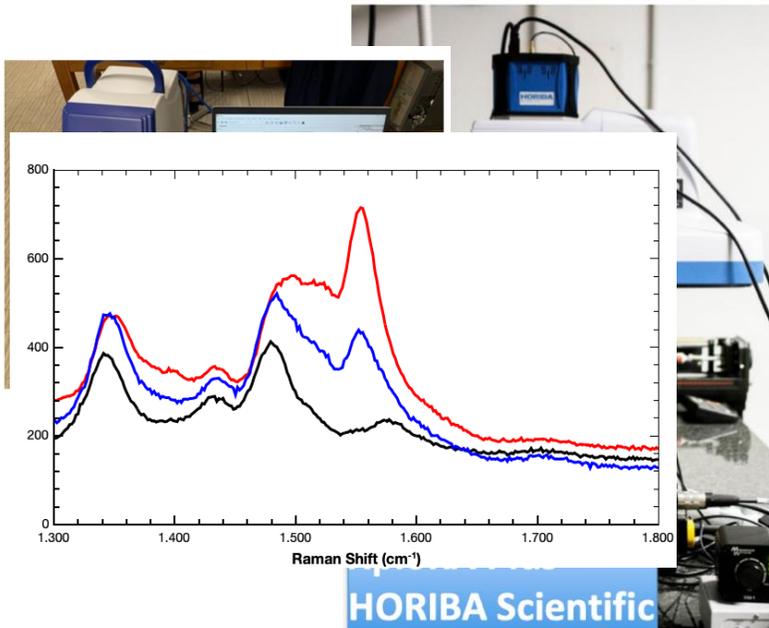


Xray
Fluorescence



Dielectric & Magnetic Material response

with Composition and Microscopy maps imaging



Physical results examples

Materials Science know-how

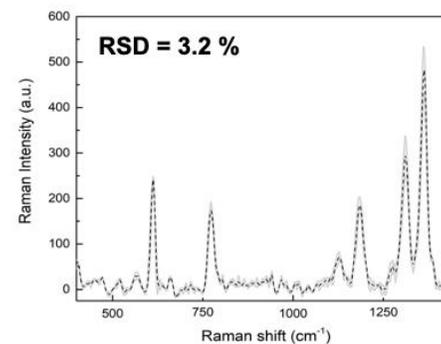
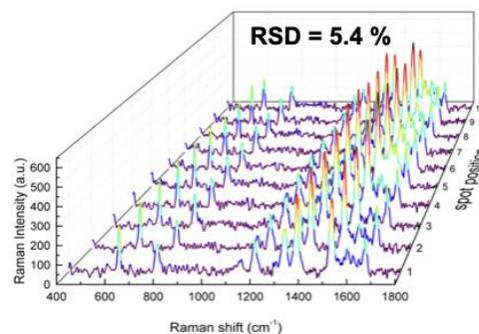
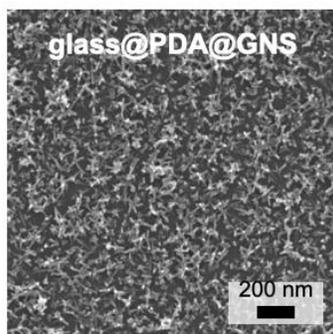
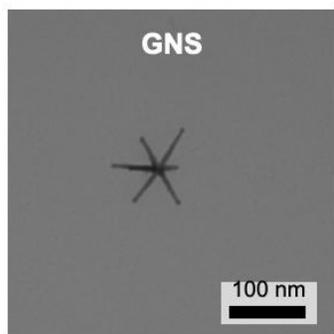
Samples: bulk materials, thin films, heterostructures
solutions, pellets, micro- and nanostructured composites

PDA based substrate for nanoplastics detection

Detection of smaller nanoplastics (\varnothing 15 nm)



Nanoscale, 2025, 17, 26855



Exploring the possibility to reveal nanoplastics by SERS approach



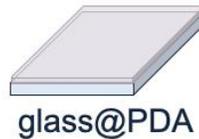
Physical results examples

Materials Science know-how

Samples: bulk materials, thin films, heterostructures
solutions, pellets, micro- and nanostructured composites

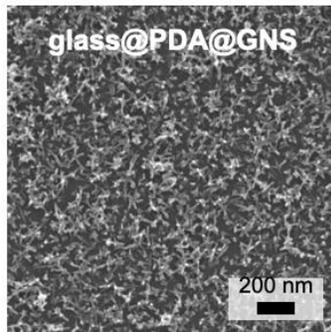
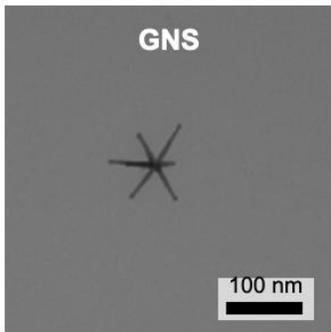
PDA based substrate for n

Detection of smaller



★
pH

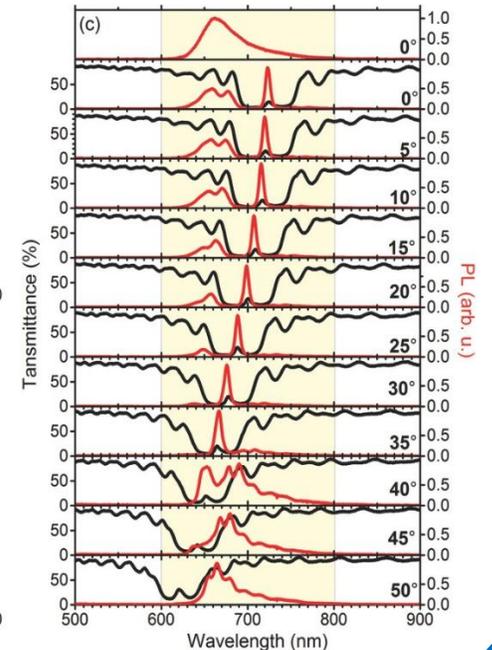
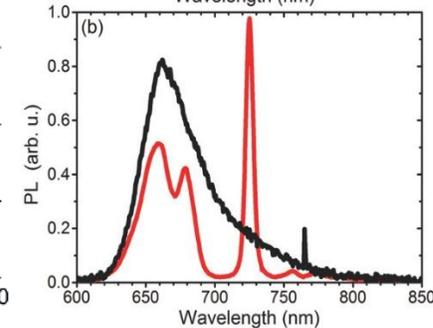
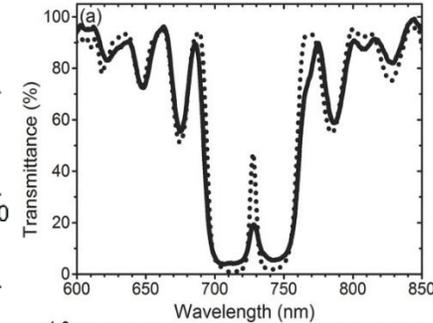
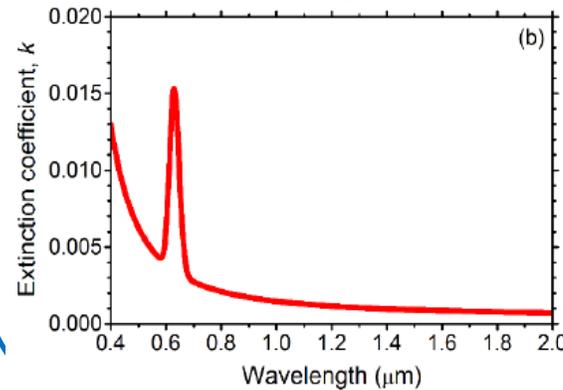
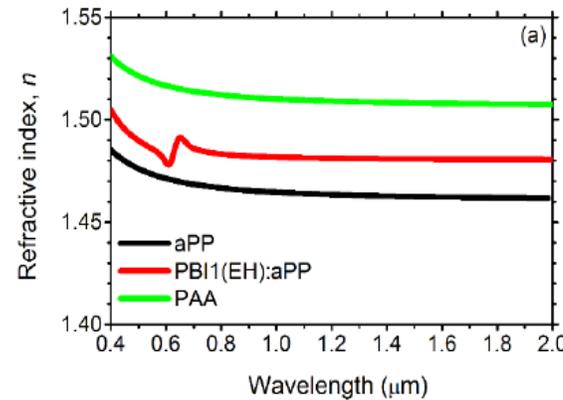
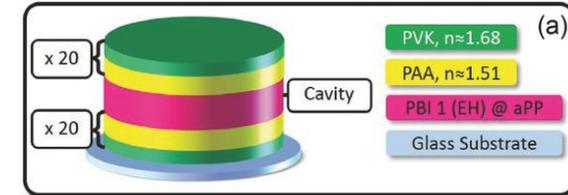
Nanoscale, 2025, 17, 26855



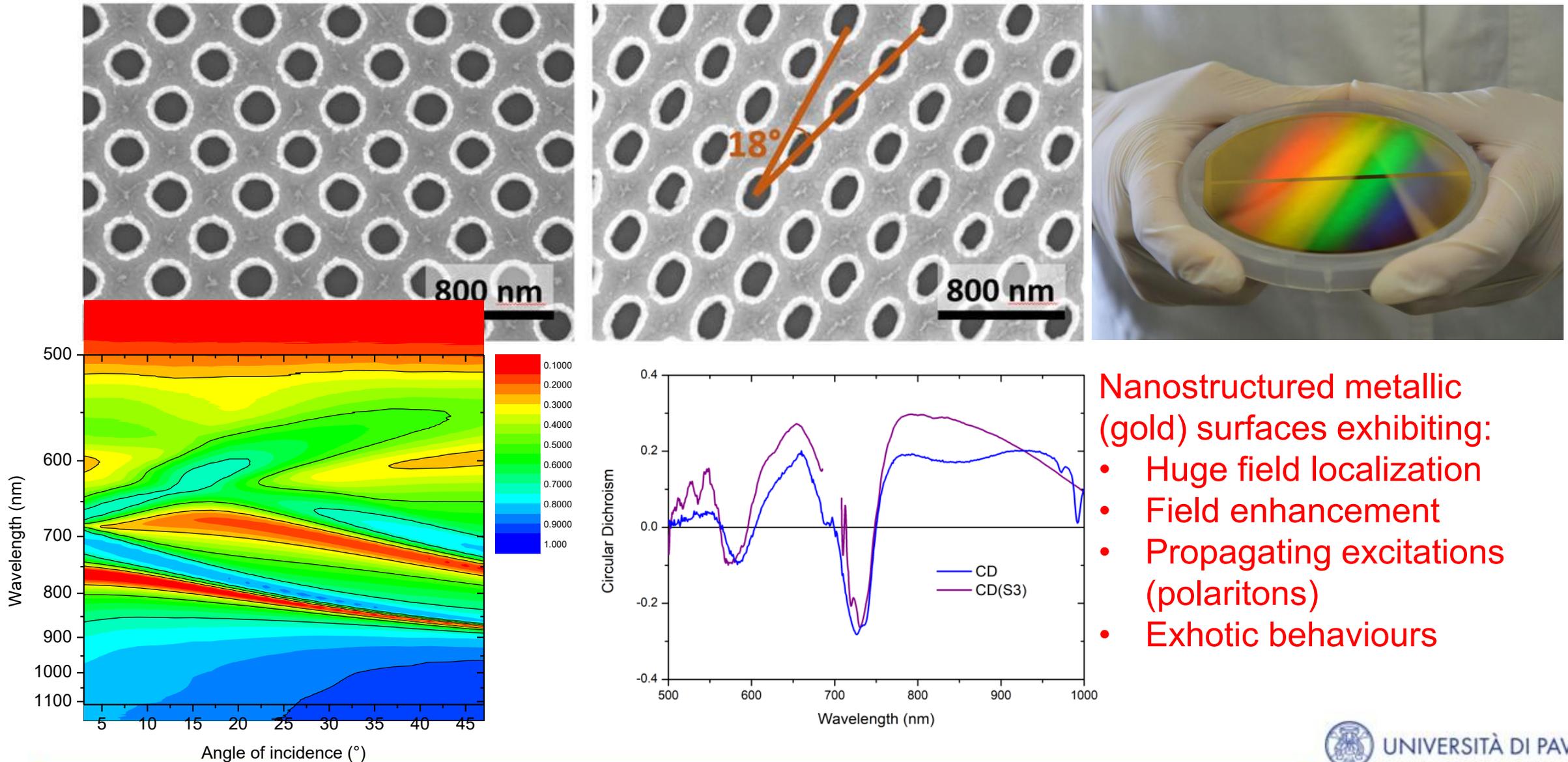
Raman Intensity (a.u.)
600
500
400
300
200
100
400

Exploring the possibility to reveal nanoplastics

All-Polymer Photonic Microcavities Doped with J-Aggregates

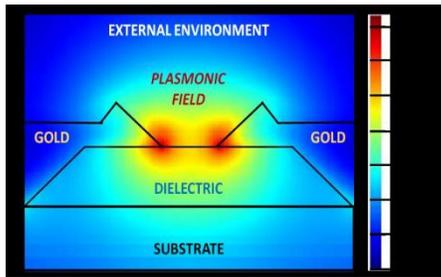


Plasmonic Surfaces



- Nanostructured metallic (gold) surfaces exhibiting:
- Huge field localization
 - Field enhancement
 - Propagating excitations (polaritons)
 - Exhotic behaviours

Plasmonic Surfaces



Field enhancement
Structural control
Photonic design

Fundamental research:

- Extraordinary transmittance
- Induced chirality
- BIC (Bound In Continuum) states

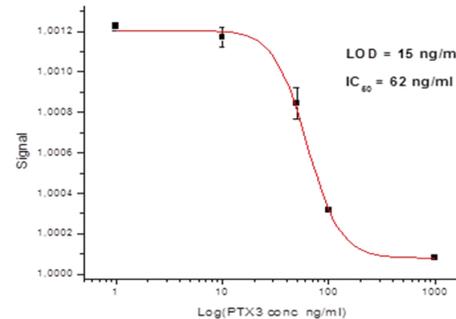
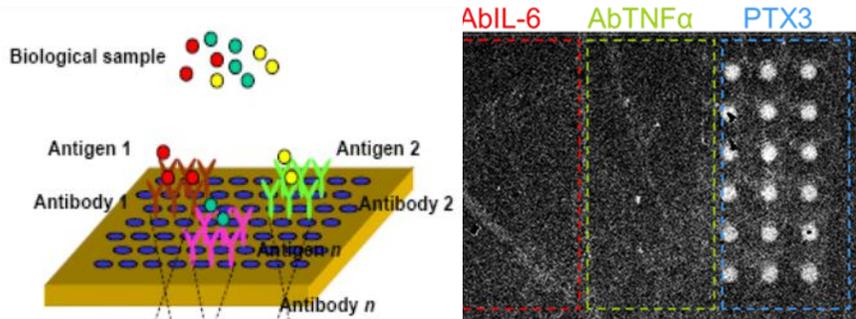
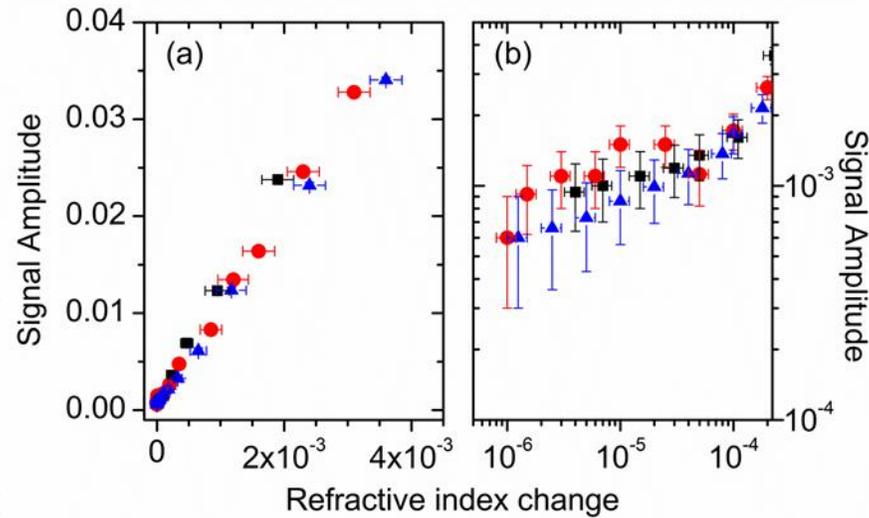
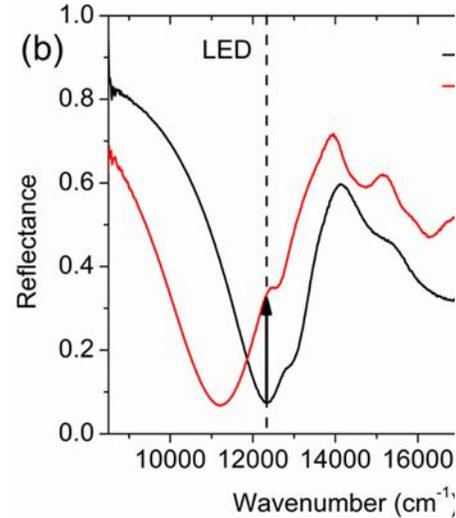
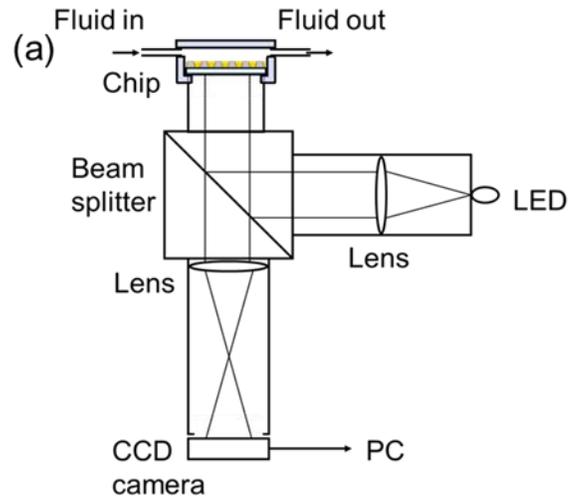
Applied research:

- Molecule detection
- Development of new sensing methods and devices
- Implementation in: agri-food

bio-medical
pharma
environment



Plasmonic Surfaces



- Sensitivity on 10^{-6} refractive index changes
- Fast and simple optical detection
- Multiplexing capabilities
- No need of complex sample treatment

Interdisciplinary connections with chemistry, biology, electronics, informatics, statistic and AI, ...

Multidisciplinary InterDept. Research Centers

MADE Research Center for Advanced Materials & Devices

Strong interaction with research groups from 5 UniPV departments: Chemistry, Physics, III Engineering, Civil Engineering and Architecture, Pharmaceutical Sciences.

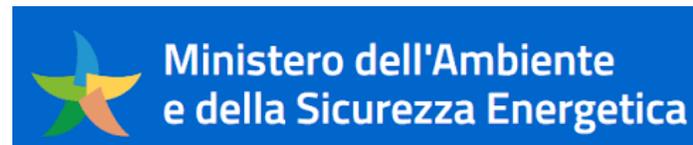
- fosters research collaborations and the effective use of human and technological resources
- carries out materials design, synthesis, study, and characterization activities in the following research fields: New technologies, methods for synthesis and characterization of materials, **Electronics and Photonics**, Energy and Environment, **Soft matter**, **Biomaterials**, **Materials for nanomedicine**, **Functional micro- and nanomaterials**

CISRIC Research Center for Cultural Heritage conservation

Research interaction with research groups from 10 UniPV departments

- interdisciplinary studies and research related to the conservation of assets of historical, artistic, cultural interest
- diagnostic procedures to study creation procedures, conservation issues and deterioration prevention

**Funding:
agencies
& third parties**



Contacts:
pietro.galinetto@unipv.it
maddalena.patrinii@unipv.it

Plasmonic Surfaces and Sensors

Our Network



Contacts: Francesco Floris
francesco.floris@unipv.it