Action D.5.4

Materials and devices nanofabrication for quantum technologies

Progetto di Eccellenza DFA

Frontiere Quantistiche

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Quantum Frontiers

Action D.5.4: LaTeQ lab infrastructures (Budget: 350 k€)

OR2: New Materials and Models at the Quantum Frontier

Development of novel quantum materials and devices:

- Single-photon sources
- Novel qubits
- Metasurfaces and metalenses for entangled photons
- Quantum imaging

Applications:

- Quantum Communication, Sensing, Computation

Quantum Frontiers

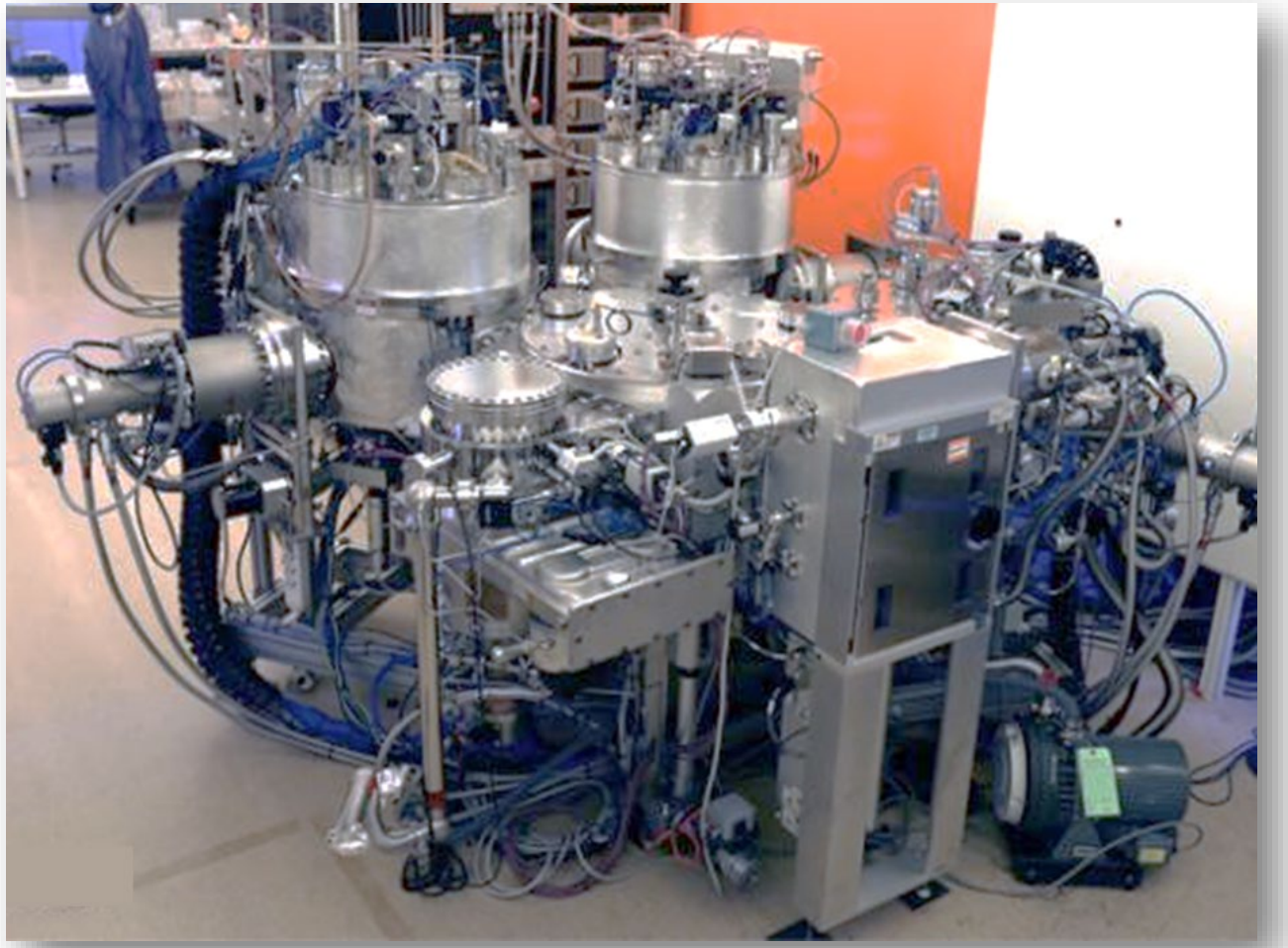
Action D.5.4: LaTeQ lab infrastructures (Budget: 350 k€)

Adopted criteria

- Suitability to achieve the objectives of OR2 of Quantum Frontiers
- Transversal use for a large community at DFA
- Respect of the allocated budget
- Possibility to be upgraded through future funding

Multi-chamber system for PVD

Cluster system for multiple deposition techniques based on Physical Vapour Deposition (PVD)

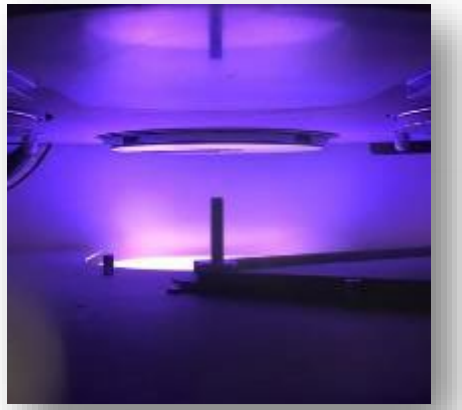


Magnetron Sputtering Chamber:

- 4 sources (RF and DC)
- Heatable substrate (< 800°C)
- Reactive sputtering
- Gate valves
- 4 inch samples
- Substrate bias (plasma cleaning or biased growth)

E-beam Evaporation Chamber

Multi-chamber system for PVD

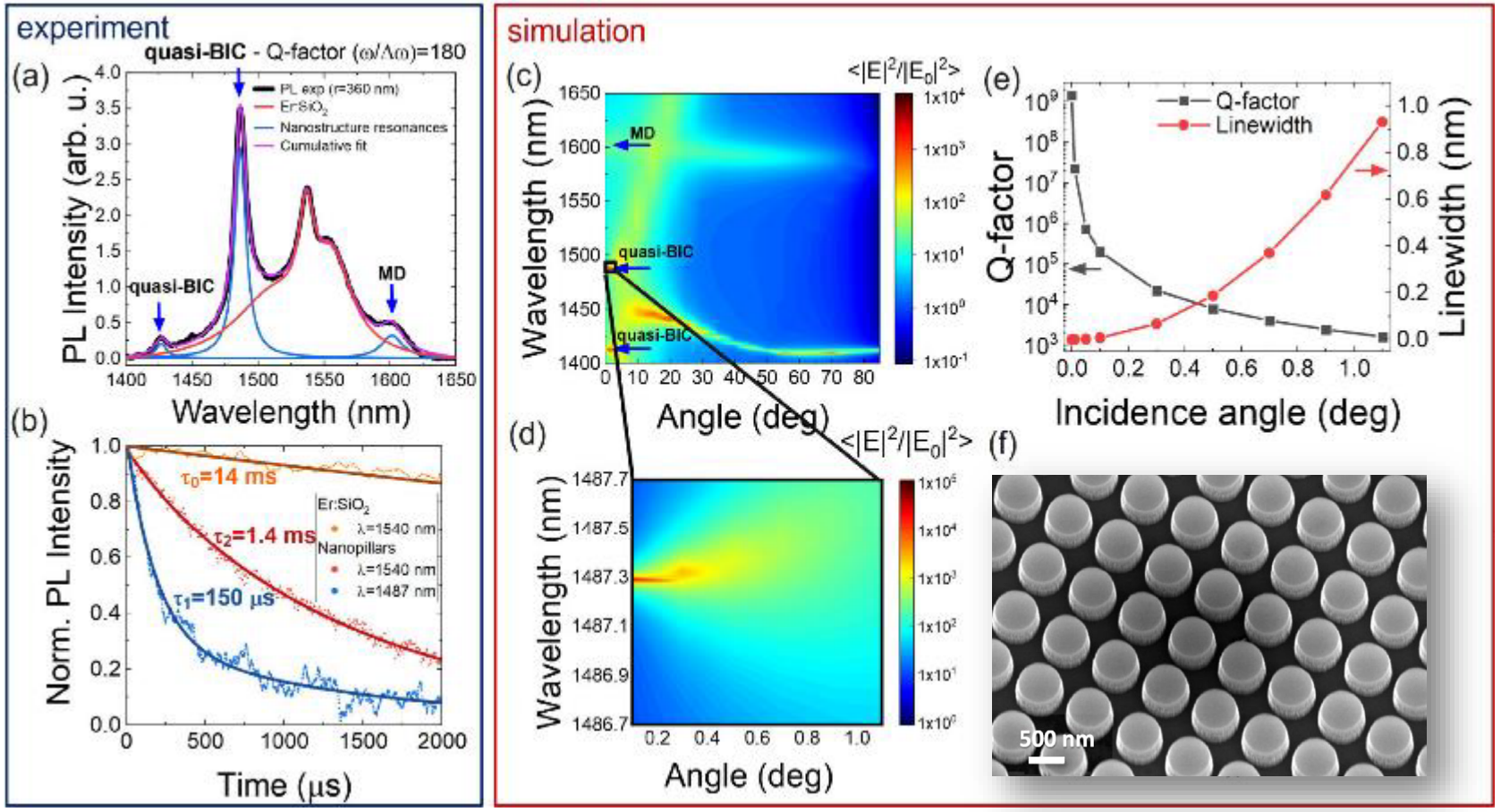


- Modular design
- Multi-process system:
  (co-)sputtering and evaporation
- Sample transfer without vacuum breaking (low contaminations)
- Installation:
  DFA Ground Floor
  Room 32 (21 m^2) or
  Room 15 (14 m^2)

App: single-photon sources

T. Cesca,
B. Kalinic
G. Mattei
(NSG)

Er^{3+}@ telecom wavelengths (1.5 microns): high Q-factor nanocavities



Bound States in the Continuum (**BIC**) Modes

- 10^9 Q-factor
- Sub-nm linewidth
- High Purcell factors

Sputtering:
Er, SiO_2, Al_2O_3, Si

evaporation:
Cr (lift-off and EBL)

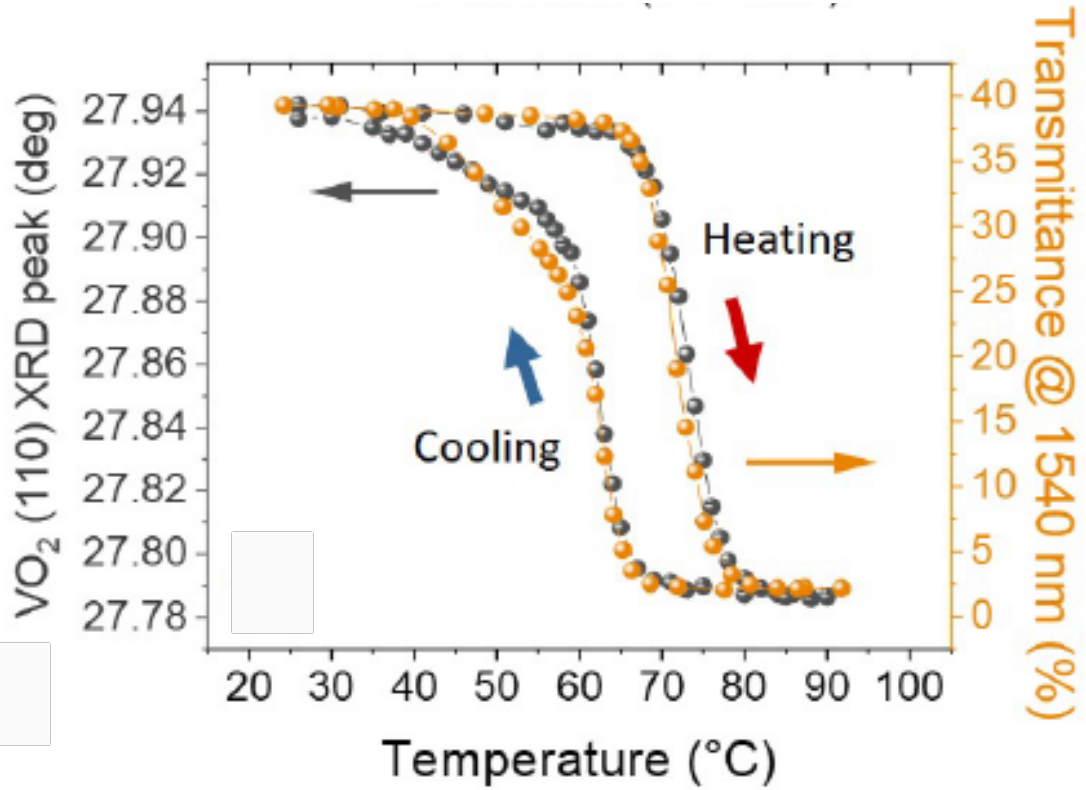
RIE: patterning

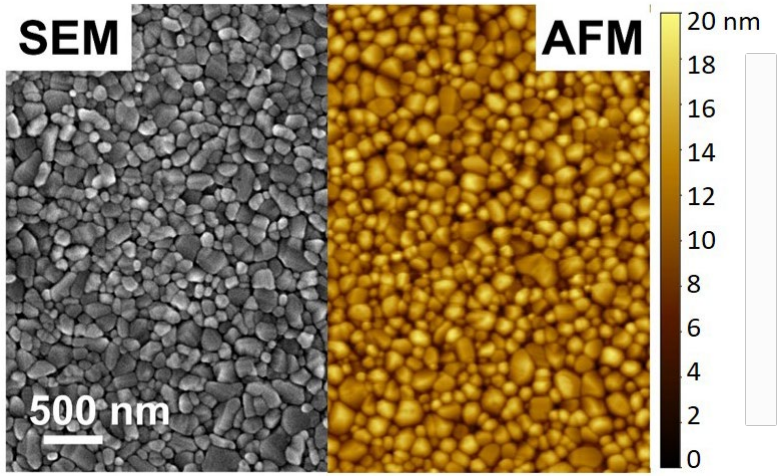
B. Kalinic, et al, *Quasi-BIC Modes in All-Dielectric Slotted Nanoantennas for Enhanced Er^{3+} Emission*, ACS Photonics (**2023**)

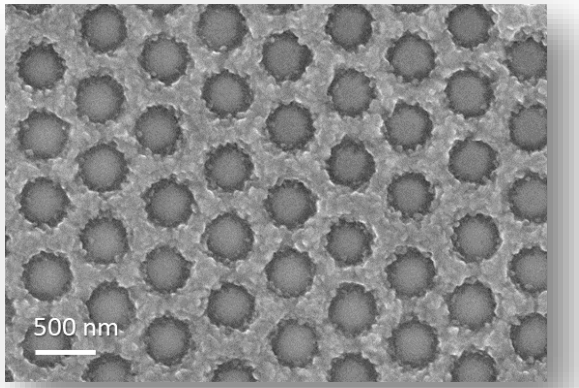
App: single-photon sources

T. Cesca,
B. Kalinic
G. Mattei
(NSG)

Er^{3+}@ telecom wavelengths (1.5 microns):
ultrafast active optical control







Sputtering (hot stage):
Er, SiO_2, VO_2

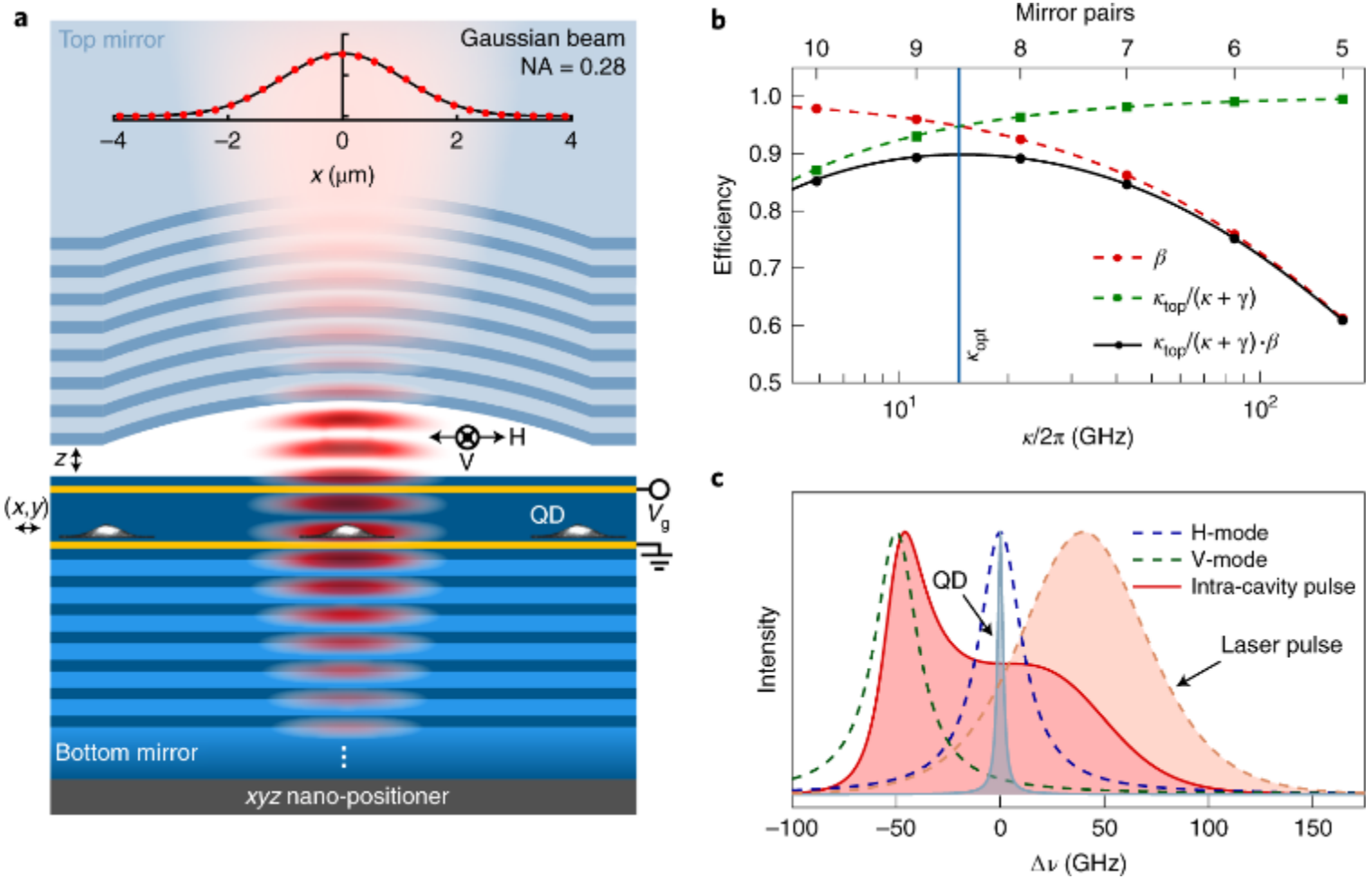
evaporation:
Cr (lift-off and EBL)

B. Kalinic, et al., "*Active modulation of the Er^{3+} emission lifetime by VO_2 phase-change thin films*" ACS Photonics (**2023**)

App: single-photon sources

T. Cesca,
B. Kalinic
G. Mattei
(NSG)

Er^{3+}@ telecom wavelengths (1.5 microns):
Tunable cavities



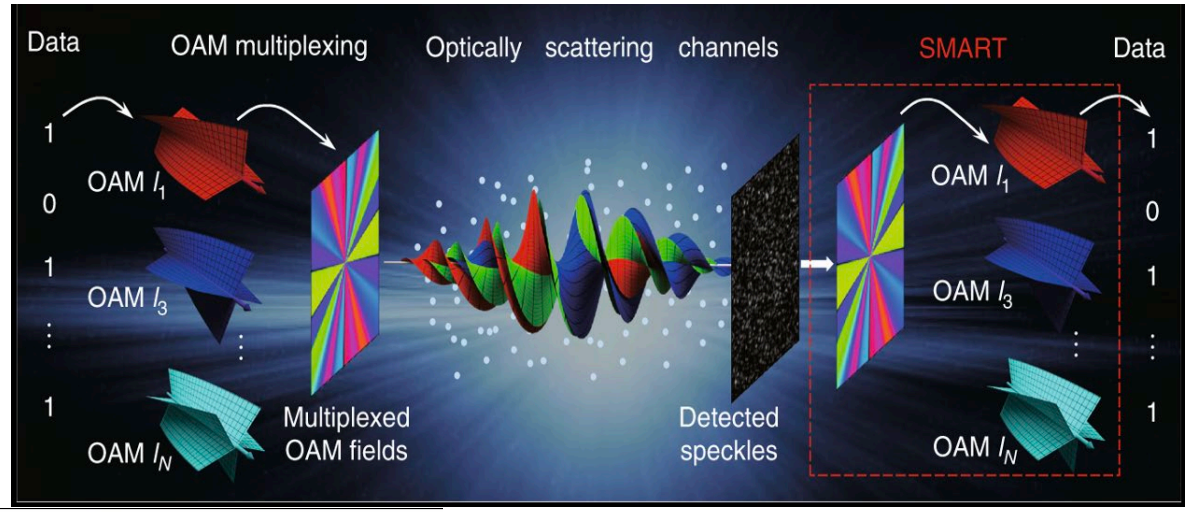
Sputtering:
Er, SiO_2, Si,
Bragg Mirror

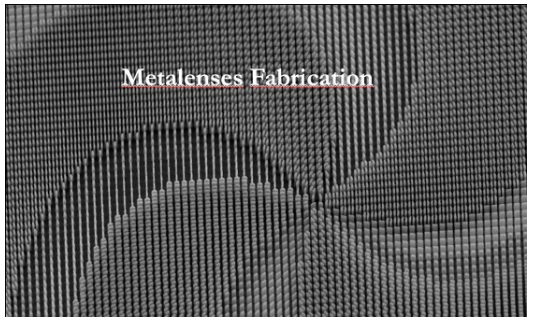
evaporation:
Bragg Mirror

N. Tomm et al., *A Bright and Fast Source of Coherent Single Photons*, Nat. Nanotechnol. 16, 399 (**2021**)

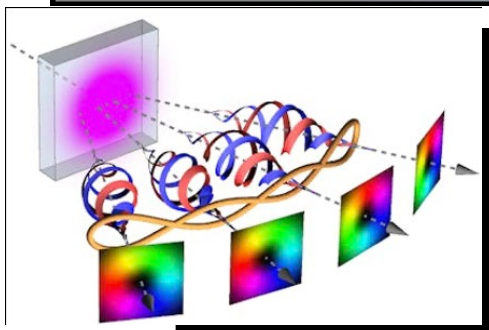
App: multistate quantum entanglement

F. Romanato, G. Ruffato

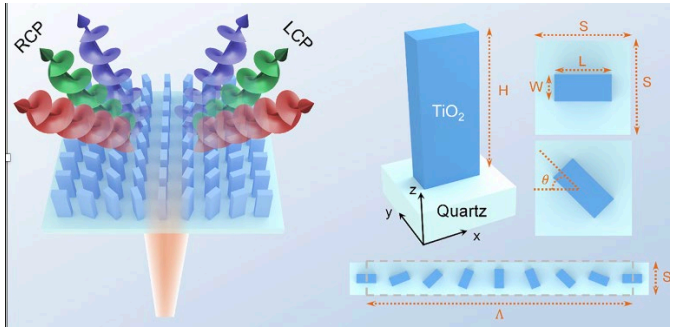




- Meta-lens can generate entangled photons for secure quantum communication QKD
- Multistate entanglement will be determined by using the optical setup for entangled photon detection
- Entangled photon microscopy will be developed using ghost photons



- Meta-atoms made of Si/glass or TiO_2 can be deposited by sputtering and nanostructured using metal evaporation

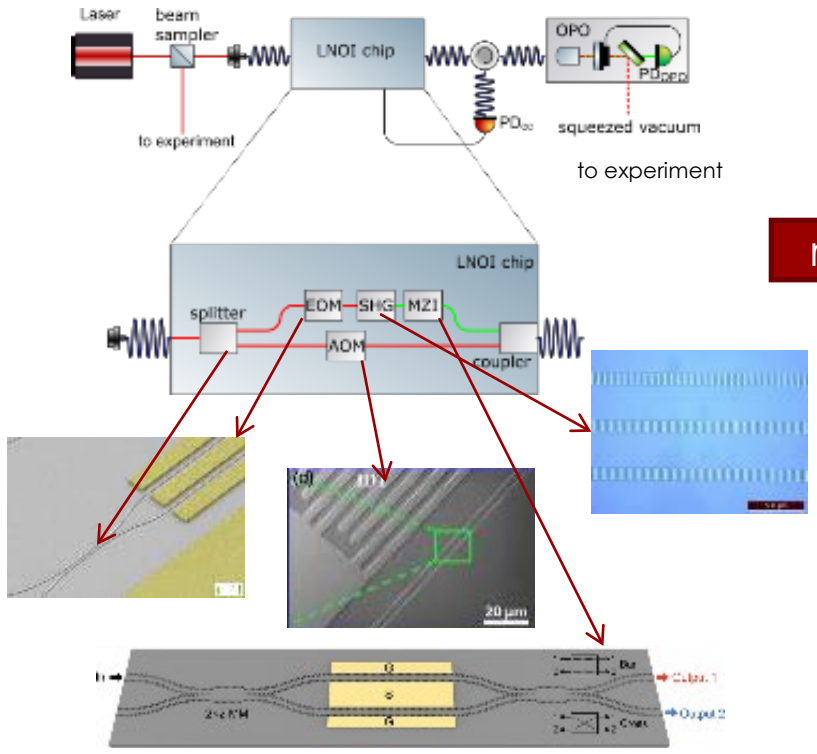


App: hybrid squeezed vacuum source

M. Bazzan,
J.-P. Zendri

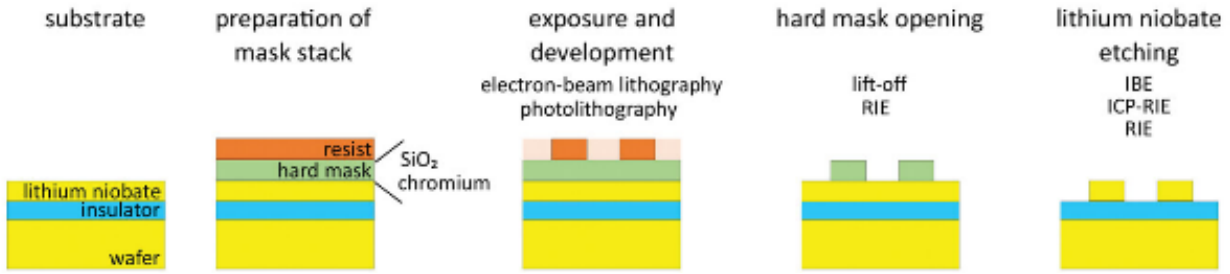
Fabrication of **integrated optical chips** for the generation and preparation of optical signals to be fed to a quantum vacuum squeezing source

- Idea: **integrated squeezed vacuum source** where all the beam preparation operations are pre-performed on an optical chip.
- Interesting experiments in **fundamental physics** and **precision measurements** (see presentation by J.-P- Zendri)

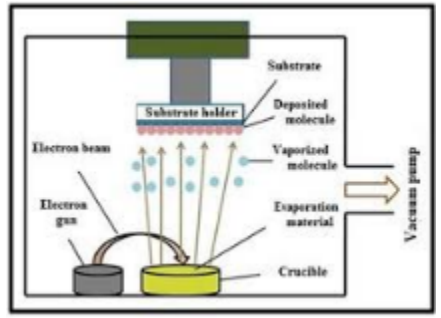


realization

The different functionalities can be obtained on a **LiNbO3-on-Insulator** wafer by a common fabrication procedure:

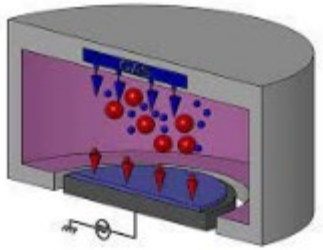


e-beam evaporation



Optical lithography

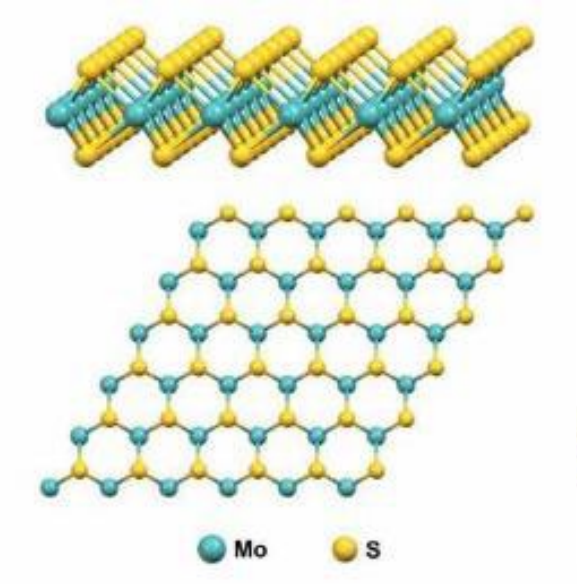
Reactive ion etching

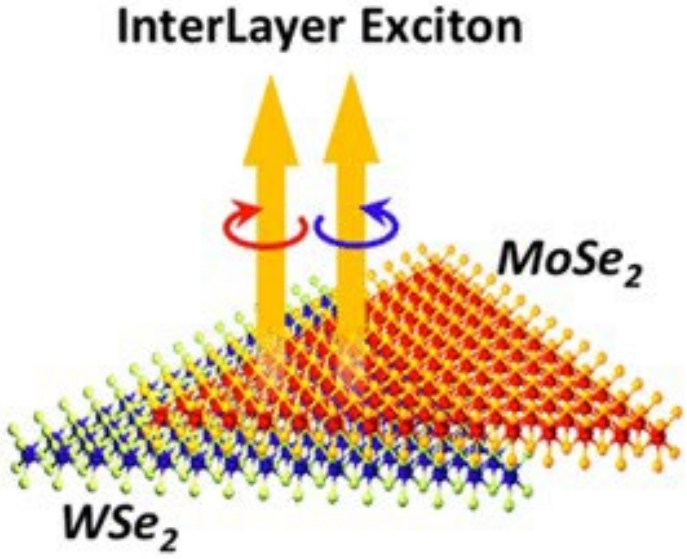


App: single-photon sources

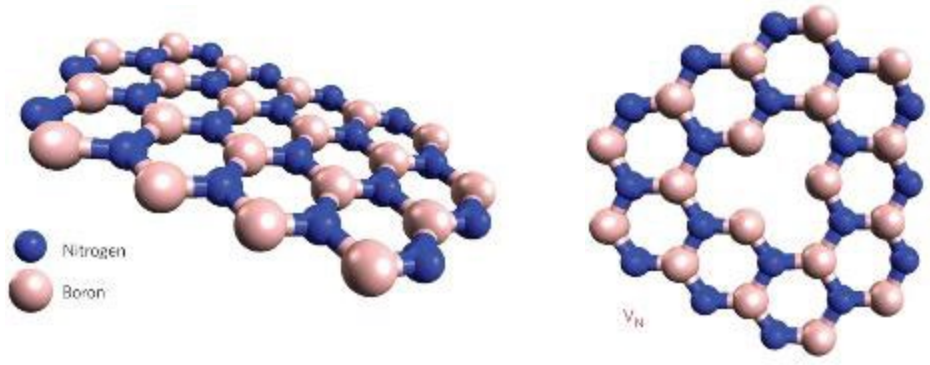
M. Merano

Monolayer TMDC and heterostructures





Nitrogen Vacancy in monolayer BN



Among the different methods for 2D growth, sputtering is getting attention due to its simplicity, reliability, large area growth possibility and repeatability.

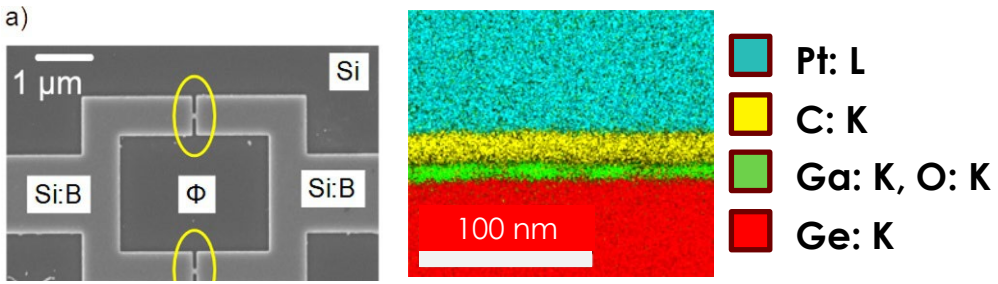
Sputtering: MoS_2 , $MoSe_2$, WSe_2

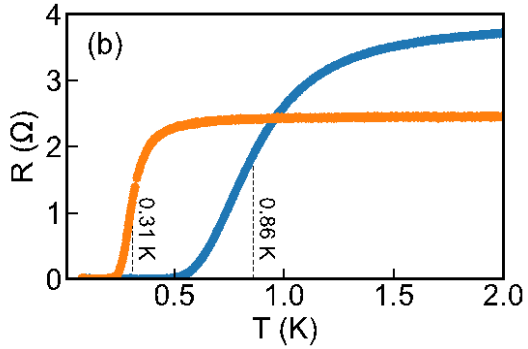
App: synthesis of quantum materials

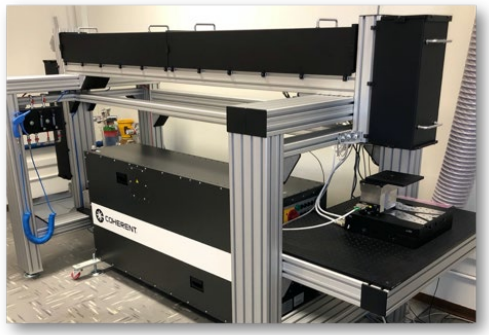
E. Napolitani,[12]
D. De Salvador,
E. Di Russo,
F. Sgarbossa

Deposition of nano-layers by sputtering and e-beam evaporation followed by Pulsed Laser Processing

Superconducting hyperdoped Ge or Si for solid-state SQUID qubit fabrication

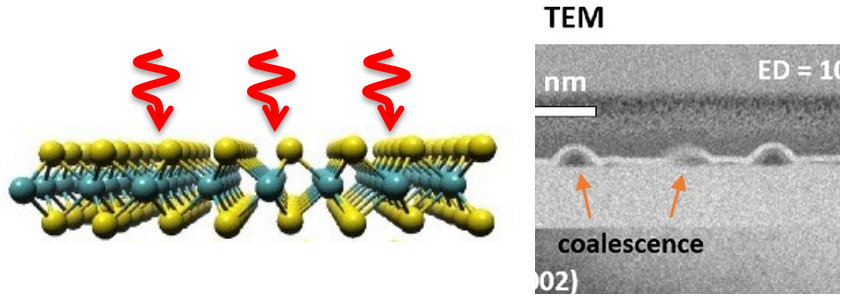


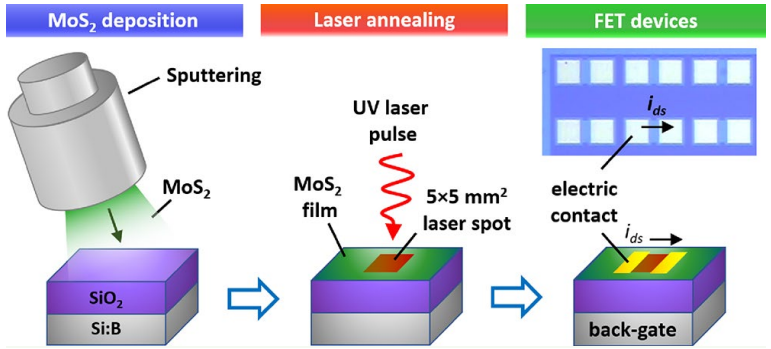




Laser Processing Laboratory @DFA

Synthesis and processing of TMD 2D materials for nanoelectronics and quantum photonics





Sputtering: Si, B, Ga, Ge, MoS_2

…in summary: Action D.5.4 @ LaTeQ

- The proposed system for LaTeQ Lab is very versatile and can be used for different quantum materials synthesis and processing.
- Future expansions and implementations con be considered to extend the range of applications.
- Together with the optical systems that will be acquired within the project (Action D.5.5, presentation by T. Cesca) it provides **a shared facility for the synthesis and advanced characterization of materials and devices for quantum optics.**

Sputtering/evaporation multichamber system