Condensed Matter Physics Laboratory 999DF

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Objectives of the course

Study of molecular systems, nanostructures (quantum dots, quantum wells, ...) and/or atomic vapors by means of spectroscopic techniques of radiation and/or electron scattering.

Theoretical background

Born-Oppenheimer approximation; electron-photon and atom-photon interaction in semi-classical approximation in 1st order perturbation theory; optical transitions and momentum conservation; electron scattering theory; vibrational spectra of molecules; electronic excitations.

Working principles of instruments used in the laboratory: laser, cryostat, interferential filters, thermocouples, monochromators, photodiodes, photomultipliers, lock-in amplifiers, vacuum equipment (pumps, gauges, etc.), electron energy analyzer; electronic noise; risk assessment in laboratory activities.
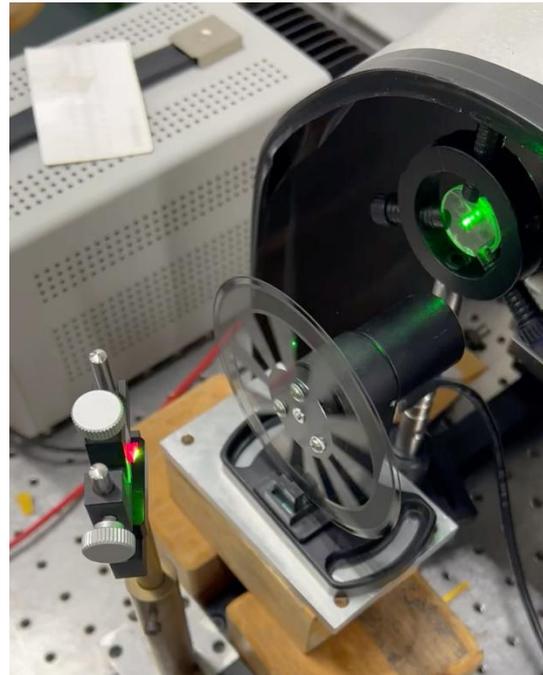
Possible practical activities

Characterization, calibration and measurement of the instrumental response function of a photomultiplier and/or of an electron energy analyzer; assembly and test of experimental setups for photoluminescence or laser absorption measurements; analysis and minimization of noise in signal detection; acquisition of electron energy loss spectra; acquisition of photoluminescence spectra; spectral analysis; error evaluation in measured spectra; writing of a laboratory report on the performed activities and interpretation of the acquired experimental results.

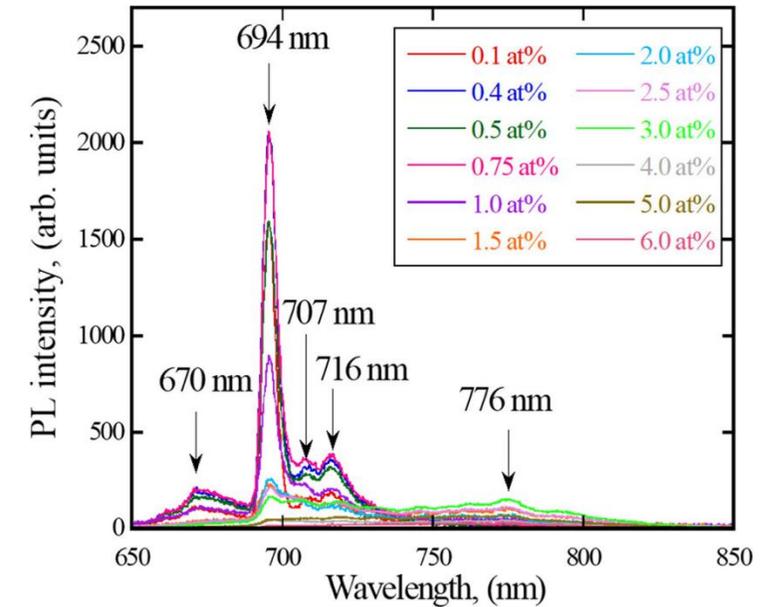# Objectives of the course

Some examples:

Ultra-high vacuum systems

Photoluminescence

Data acquisition and analysis

Didactical methods

Theoretical lectures (~20 hours) and practical lab activities (~52 hours, in ~4-5 hour sessions). Students will be divided in groups of max 3 people for the practical activities.

Examination methods

Written report (one per group) on the laboratory activities performed by the group: experimental methods, results, data analysis and discussion (~20-30 pages in total).

Oral exam on the contents of the report and on the fundamental aspects of the techniques used in the lab.

Prerequisites

Basic knowledge of measurement techniques, data analysis and error propagation; basic knowledge of quantum mechanics and condensed matter physics.

**Roberto Costantini & Alberto Morgante**

Research interests:

- **2D materials** and hybrid organic/inorganic **heterostructures**
- X-ray and laser based photoemission
- Time-resolved spectroscopies
- Electronic properties and **ultrafast charge transfer dynamics**

ANCHOR-SUNDYN laboratory

ISTITUTO OFFICINA DEI MATERIALI

Elettra Sincrotrone Trieste

Research group

Alberto Morgante (UniTS)

Martina Dell'Angela (CNR-IOM)

Albano Cossaro (UniTS – DSCF)

Luca Floreano (CNR-IOM)

Luca Schio (CNR-IOM)

Cesare Grazioli (CNR-IOM)

PhD students

Davide Piva

Giacomo Agnesod

Simone Micheloni
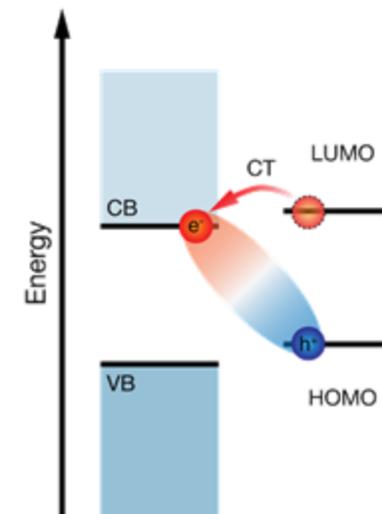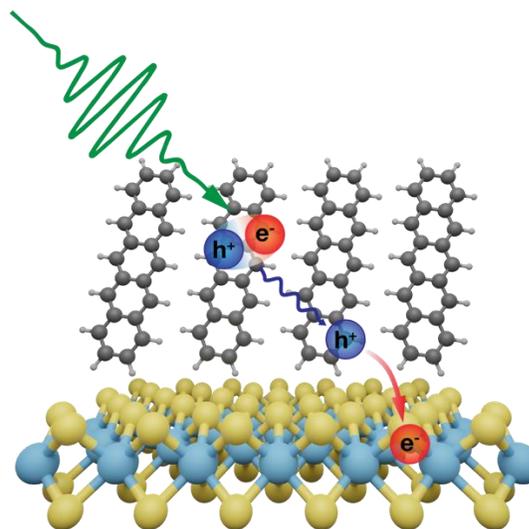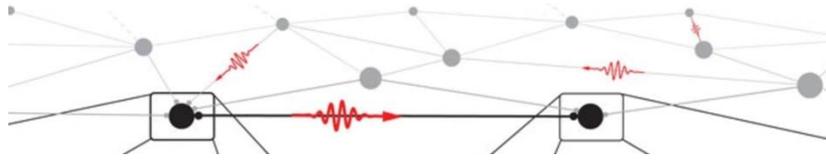
Ritter et al Nature (2012)
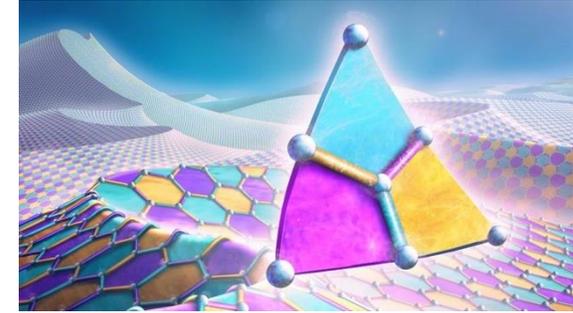
Nill et al, Science (2014)

Communication

Computing

Quantum information processing

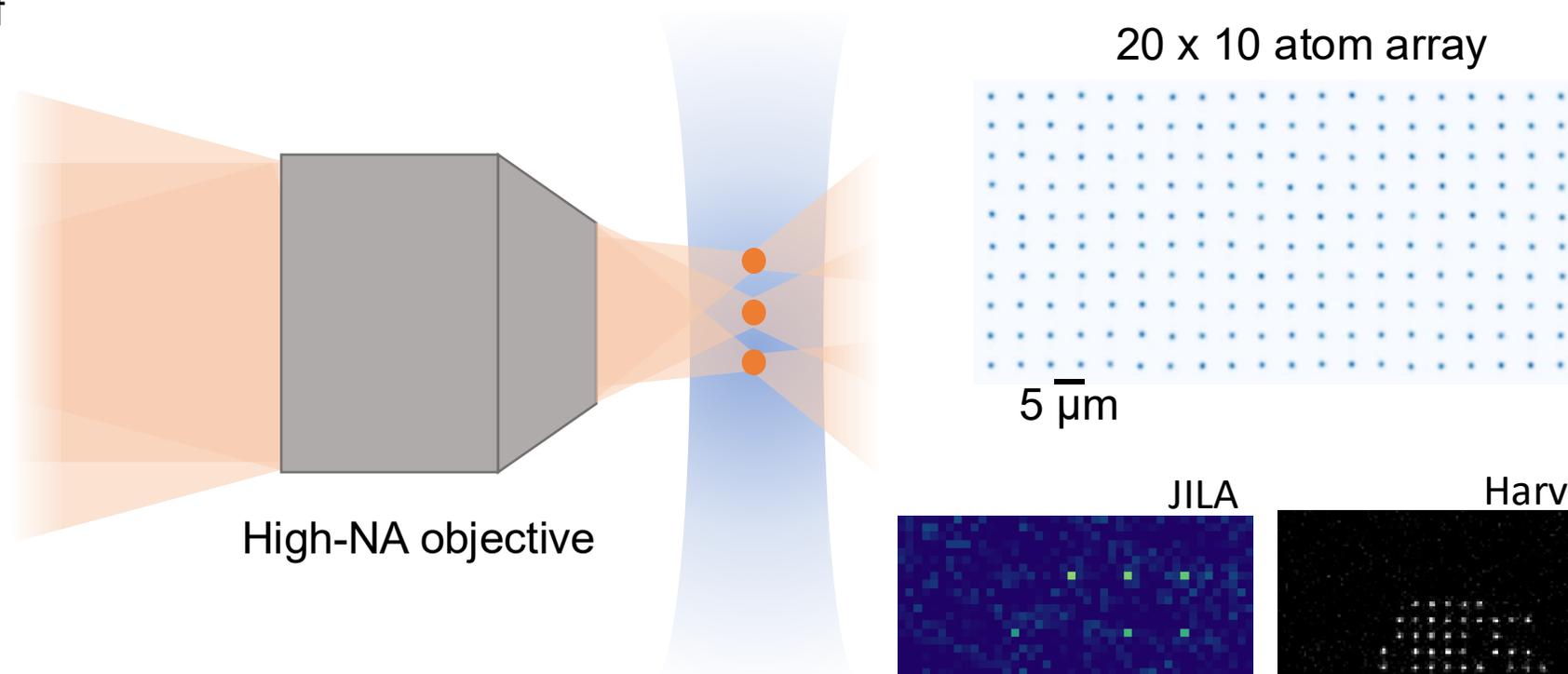**Metrology**

Simulation
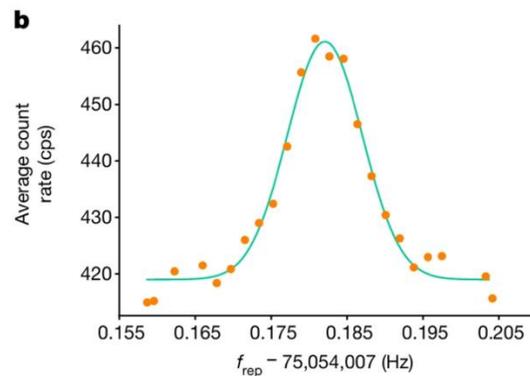
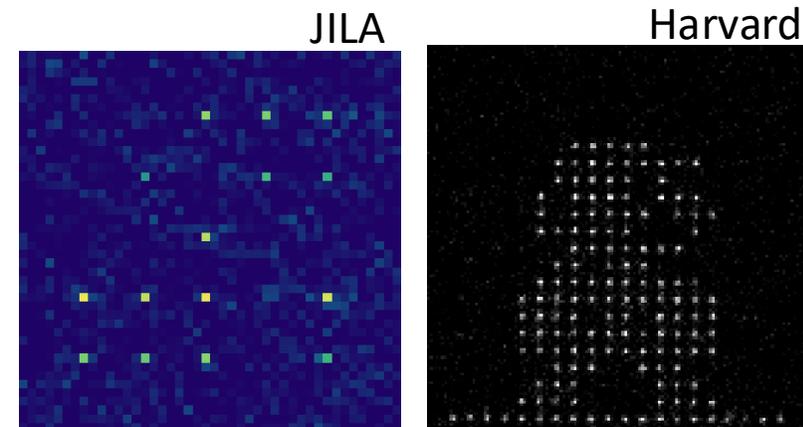Zhang et al Nature (2024)
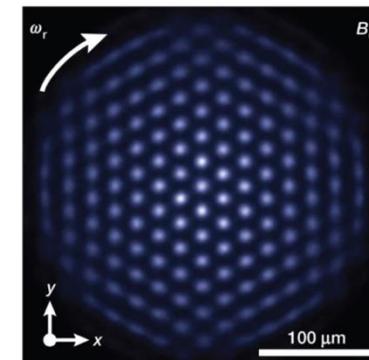
Britton et al Nature (2012)

QC with optical tweezers
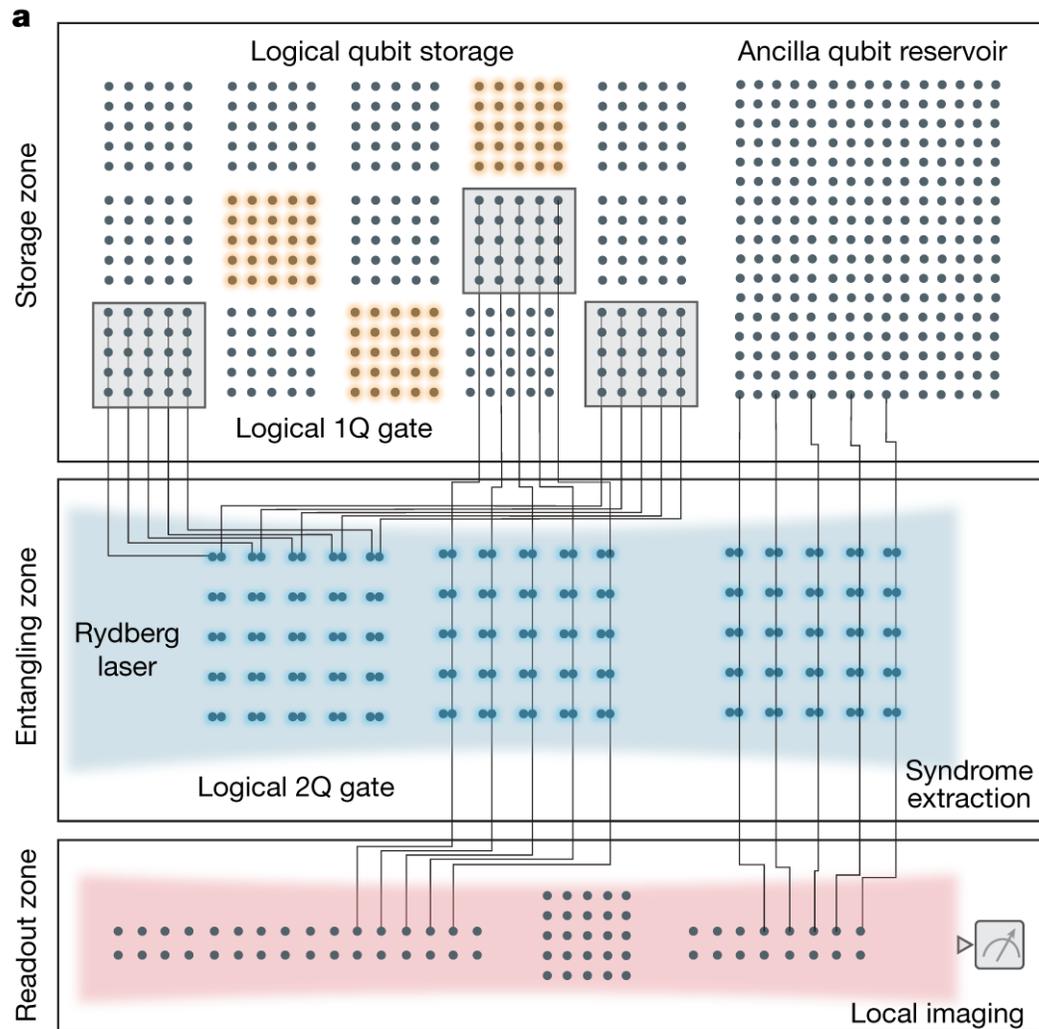
Atoms are trapped by virtue of light-matter interaction

Laser beams are used to manipulate atoms and for fluorescence detection
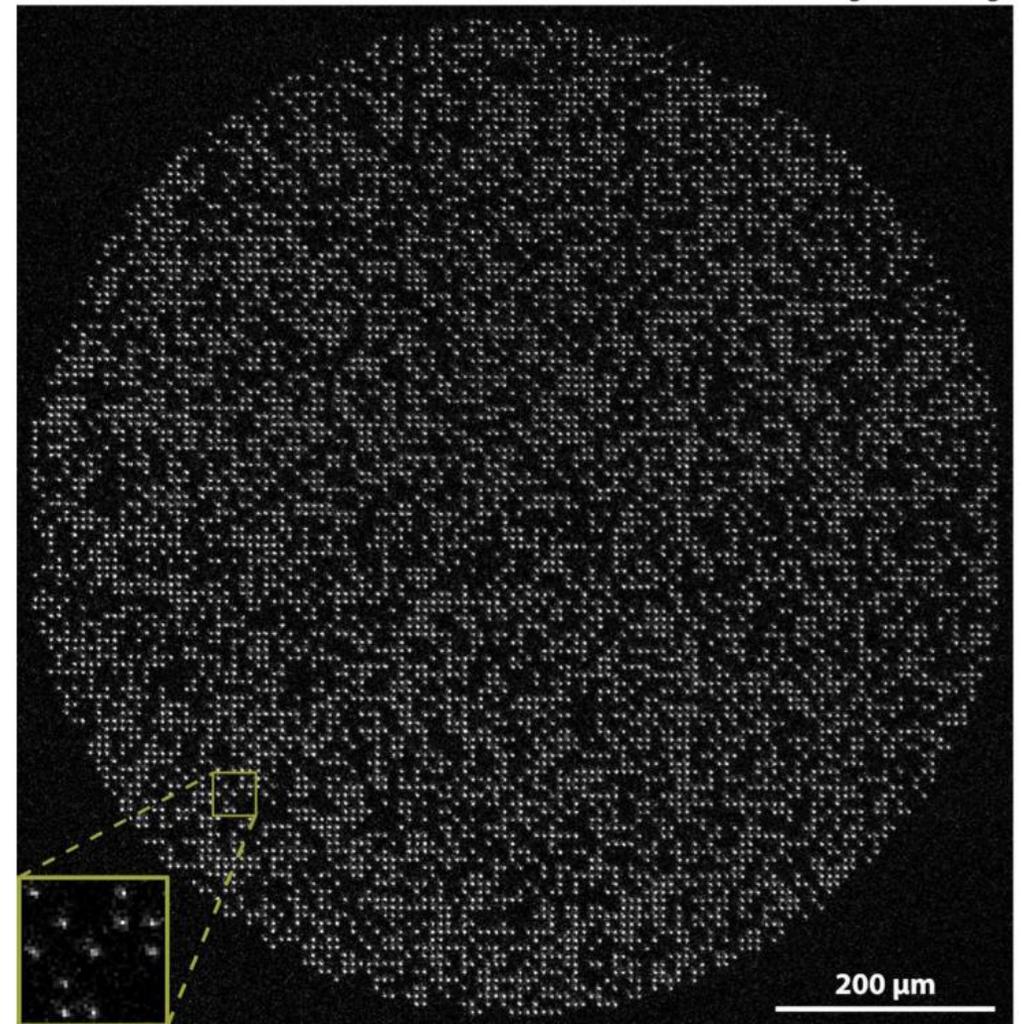
20 x 10 atom array

5 µm

High-NA objective

JILA

Harvard

Pioneering technology from Grangier group

State of the art architectures

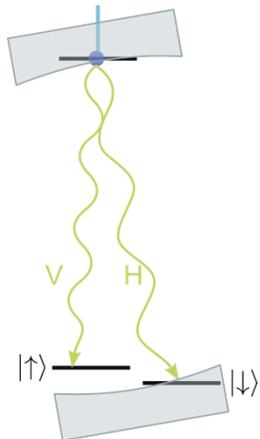Bluvstein et al., Nature 626, 58-65 (2024)

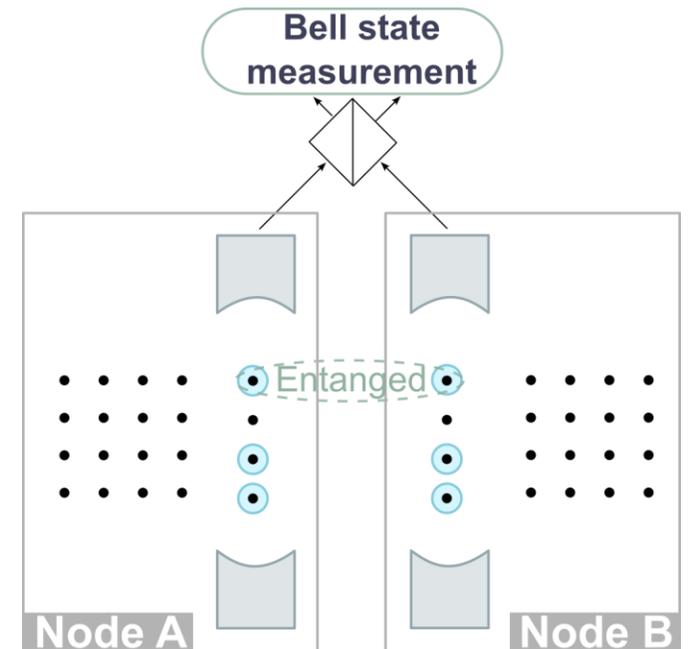Manetsch et al., ArXiv 2403.12021

Scaling up: modular architecture
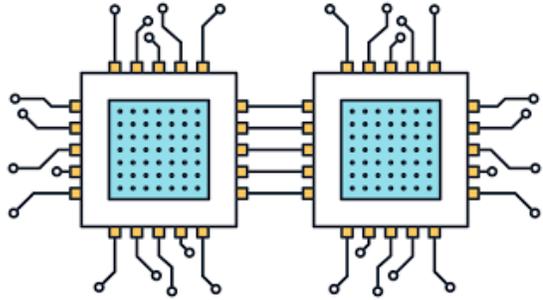
Similar approach to classical parallel computing: small computing modules connected to each other.
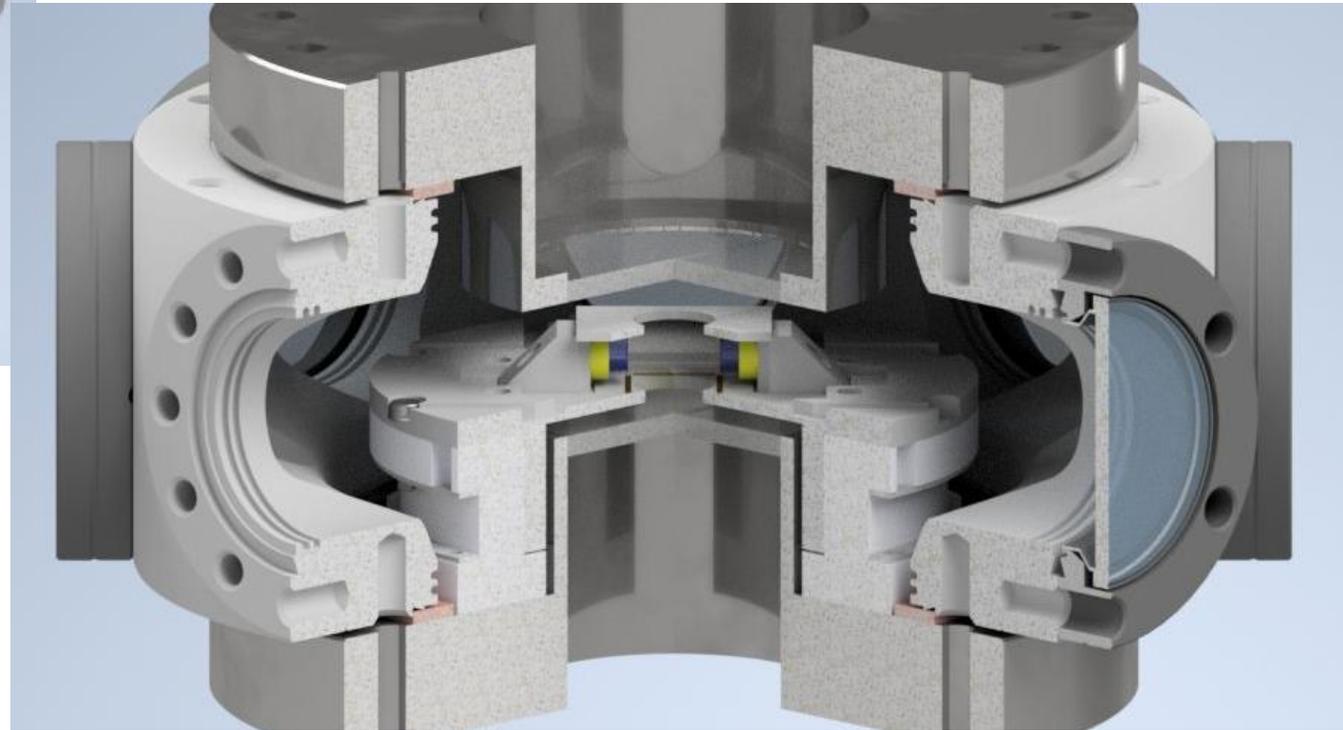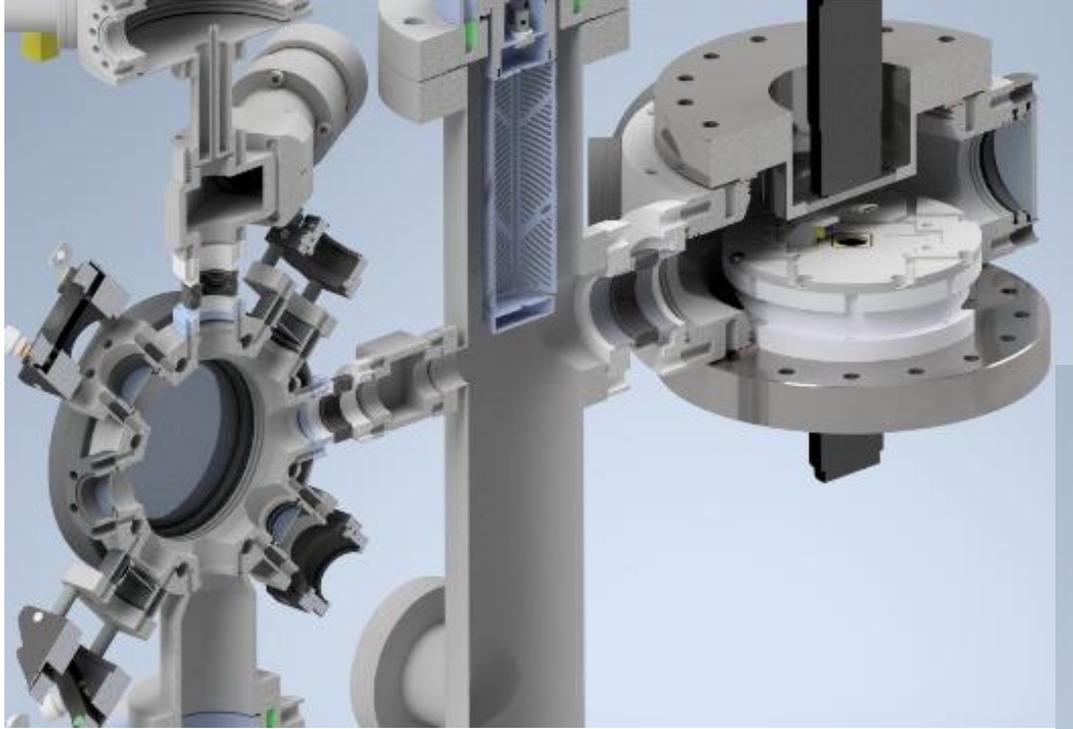
Remote entanglement

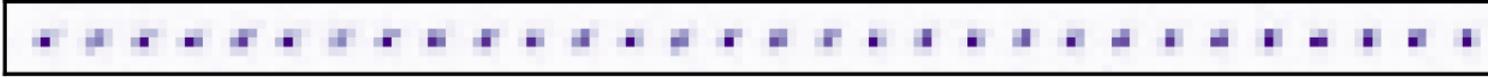Qubits in each processor are entangled with photons.

Photons interfere and are measured to swap entanglement leaving qubits in two different chambers entangled
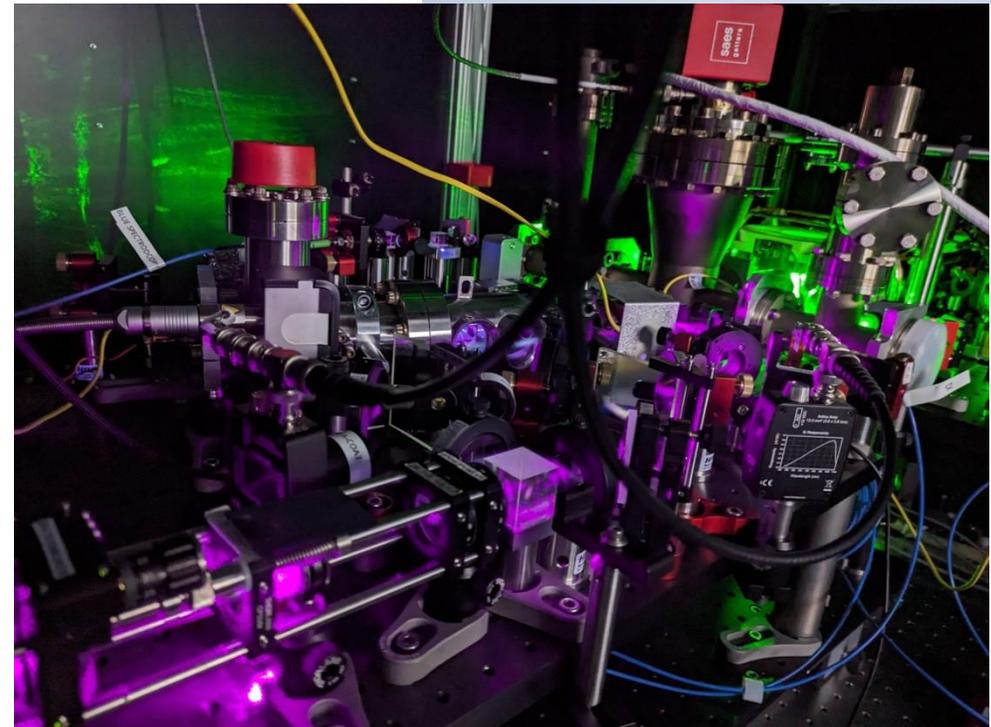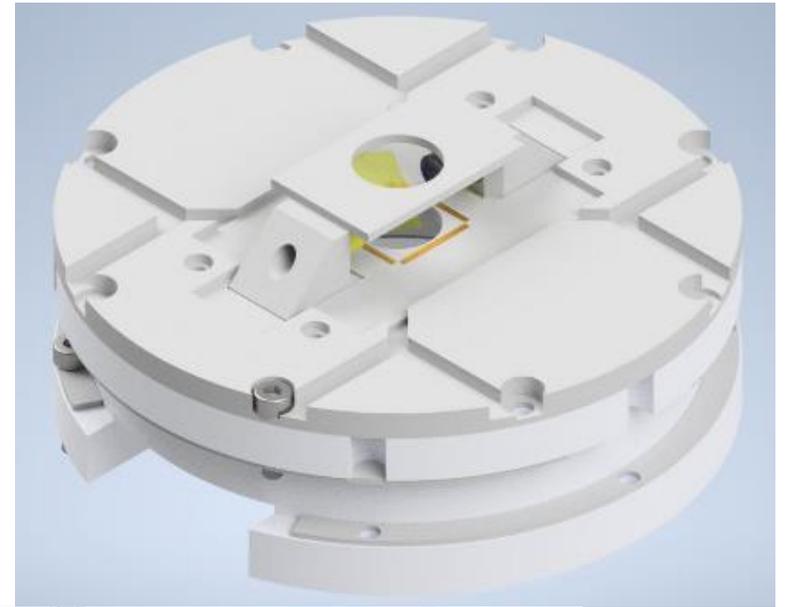
Scaling up: modular architecture @ UNITS

Conclusions

❖ Necessary ingredients to build a quantum computer

❖ Trapping single atoms

❖ Basic operations with atoms in tweezers

❖ How to scale atomic systems: modular architectures

ArQuS Lab

Omar Abdel Karim

Riccardo Forti

Thank you for the attention!