



EUROPE IS GETTING READY: EUROHPC-QCS

A European infrastructure: quantum computing and simulation as a service

28 FEBRUARY 2024 | TOMMASO CALARCO | MOBILE WORLD CONGRESS, BARCELONA



THE EU QUANTUM FLAGSHIP



Consolidate and **expand**
European **scientific**
leadership and **excellence** in
quantum research

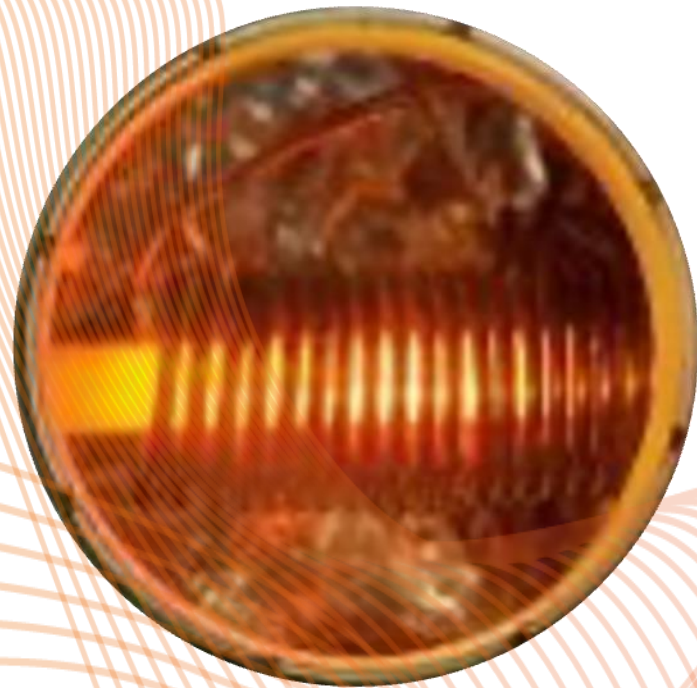


Kick-start a **competitive**
European industry in
quantum technologies and
position Europe as a **leader** in
the future global industrial
landscape

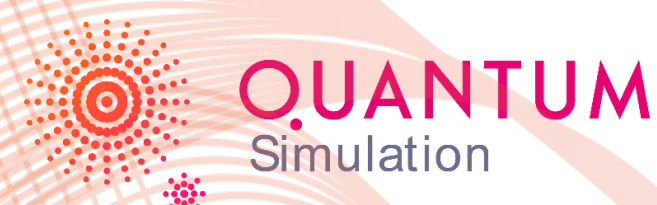


Make **Europe** a **dynamic** and
attractive region for
innovative **research, business**
and **investments** in quantum
technologies

QUANTUM TECHNOLOGIES: EU FLAGSHIP RESULTS



For a secure digital society and a quantum enabled internet



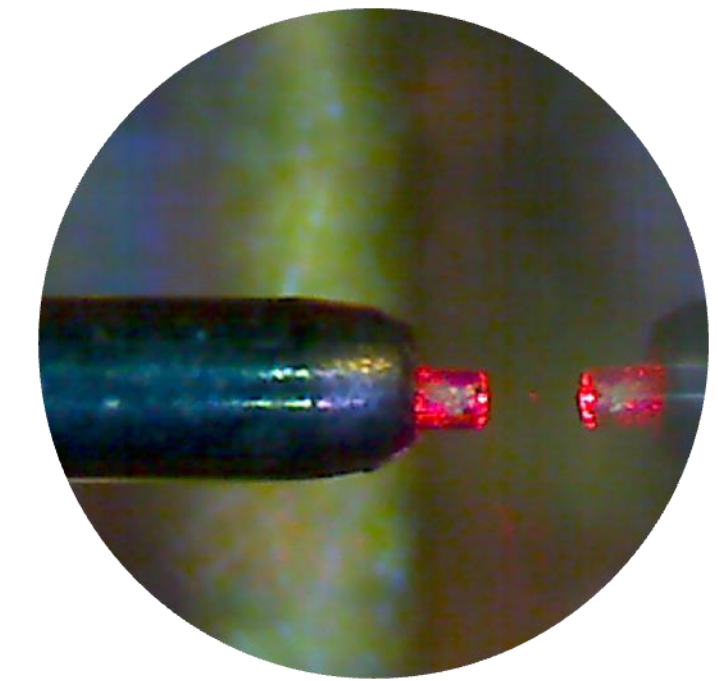
Simulating complex systems for advanced design and development



Bringing accuracy and performance to unprecedented levels



Computing power to overcome currently unsolvable problems



Addressing foundational challenges for development of quantum technologies

- ✓ **World-leading advances** in cont. variable QKD
- ✓ High efficiency and **multiplexed quantum memories**
- ✓ Development of advanced systems' components

- ✓ Next gen atomic-based programmable Quantum Simulators
- ✓ **Practical quantum advantage**
- ✓ **Pan-European hybrid HPC/quantum infrastructure** (100 qubit analogue sims at FZJ and GENCI)

- ✓ **Diamond quantum sensors** (automotive, medical imaging)
- ✓ First **quantum sensors in space**
- ✓ New MEMS-based quantum sensors
- ✓ Next gen integrated/compact **optical quantum clocks**

- ✓ 50 qubit **trapped-ions Quantum Computer** (with low power consumption at 1.5KW) deployed and online
- ✓ **25 superconducting qubit device** with 99% 2-qubit gate fidelity built

- ✓ **World record** tuneability of **photon emitters**
- ✓ New single photon detectors
- ✓ High-fidelity quantum gates with microwave-driven ions
- ✓ Compact **entangled photon-based light sources**
- ✓ Detection and control of single rare earth ions

From Flagship to Fleet



Bring quantum technologies from the lab to the market and consolidate European scientific leadership in quantum research

- FUNDAMENTAL R&D
- TECHNOLOGY SUPPLY

Work Programme 2021-22
DESTINATION

DIGITAL AND EMERGING TECHNOLOGIES FOR COMPETITIVENESS AND FIT FOR THE GREEN DEAL

RESEARCH BASED
HORIZON EUROPE

ADVANCED DIGITAL SKILLS



Develop short term training courses and Master programmes in key capacity areas



EUROPEAN QUANTUM TECHNOLOGIES FUNDING OPPORTUNITIES

QT Fund
FINANCING THE GROWTH AND BUILDING A SUSTAINABLE EUROPEAN QUANTUM INDUSTRY

INFRASTRUCTURES & INDUSTRY
DIGITAL EUROPE

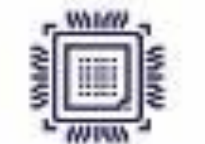
QUANTUM COMMUNICATION INFRASTRUCTURE (EuroQCI)



Build and deploy in the next decade a certified secure pan-European end-to-end QCI for cybersecurity services

- QKD INFRASTRUCTURE
- TESTING OF CROSS-BORDER QCI LINKS

QUANTUM COMPUTING INFRASTRUCTURE (EuroHPC)



Build and deploy an infrastructure for big data, artificial intelligence, high performance computing, among others

- QT/HPC HYBRID
- QUANTUM SIMULATION/COMPUTATION

QUANTUM COMPUTATION & SIMULATION INFRASTRUCTURE

Classical quantum
simulation hardware in HPC

Quantum computation and
simulation hardware (ion traps,
super-/semi-conducting qubits,
spin qubits, photonic circuits,
neutral atoms)

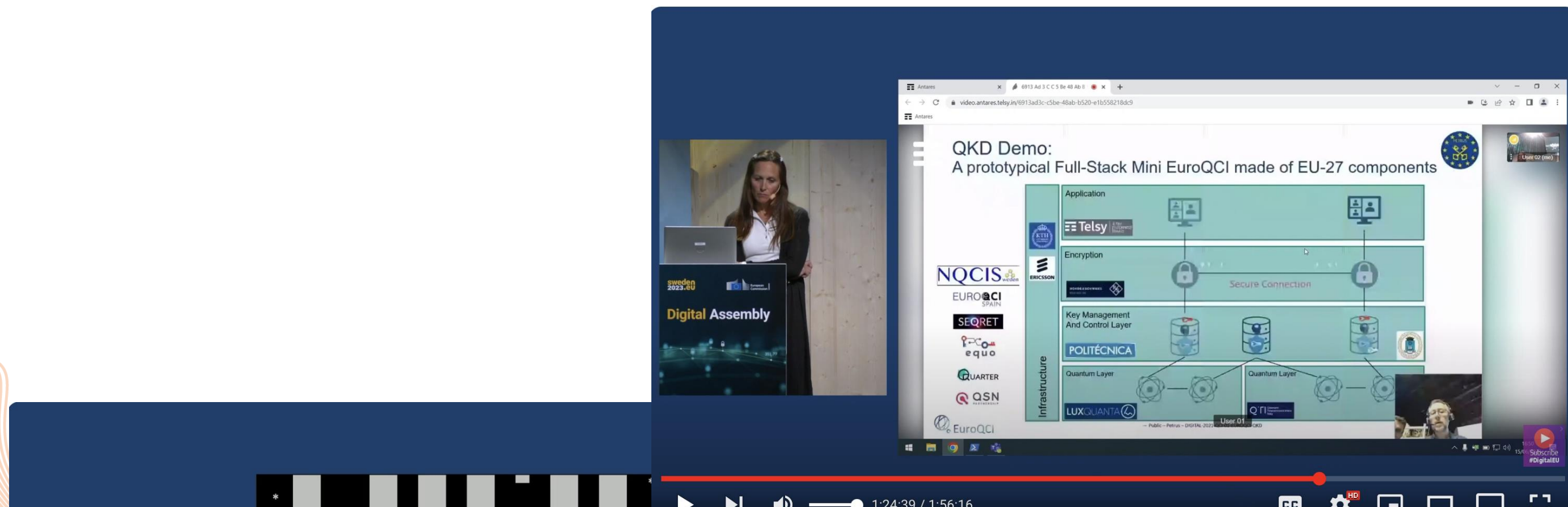
Quantum testbed facilities
for hardware developers

Quantum application
database
(verification/validation,
algorithms, apps)

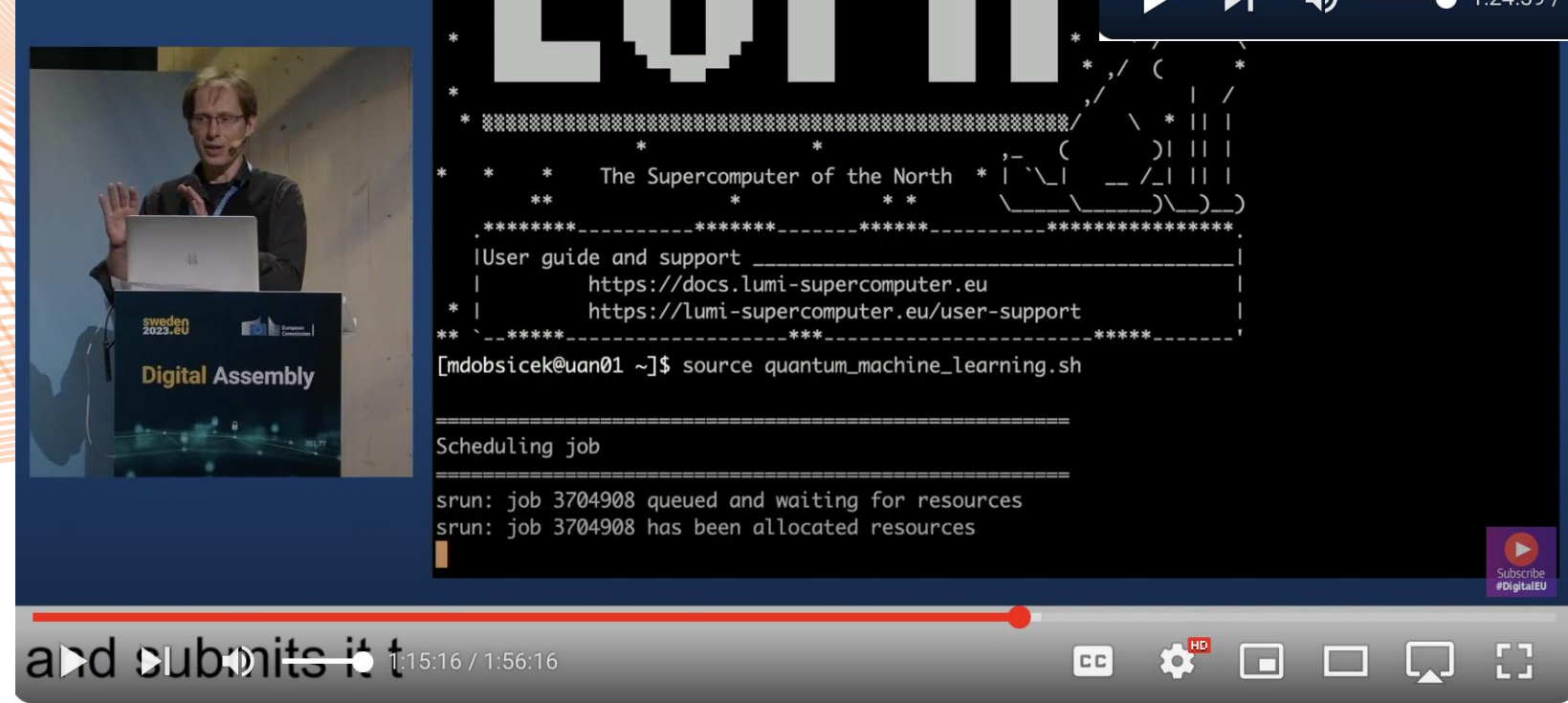
2023 Digital Assembly QT demonstrators



download here!



The screenshot shows a video player interface. The main content is a presentation slide titled "QKD Demo: A prototypical Full-Stack Mini EuroQCI made of EU-27 components". The slide features a central diagram with layers: Application (Telsy), Encryption (Secure Connection), Key Management And Control Layer, and Quantum Layer (POLITECNICA, LUX QUANTUM). Logos for NQCIS, EUROQCI, SEQRET, EQUO, QUARTER, QSN, and EuroQCI are visible on the left. A small video inset shows a woman presenting.



The screenshot shows a video player interface. The main content is a terminal window with the following text:

```
*****  
* The Supercomputer of the North *  
*****  
|User guide and support  
|https://docs.lumi-supercomputer.eu  
|https://lumi-supercomputer.eu/user-support  
*|  
*****  
[mobsicek@uan01 ~]$ source quantum_machine_learning.sh  
  
Scheduling job  
srun: job 3704908 queued and waiting for resources  
srun: job 3704908 has been allocated resources
```



The screenshot shows a video player interface. The main content is a photograph of a white cylindrical device labeled "exail ABSOLUTE QUANTUM GRAVIMETER". The device is on a stand in a dark room. A video inset shows a person's hands.



Jülich **UN**ified Infrastructure for **Q**uantum computing

QC user facility for **science** and **industry** · **Unified portal** for access to QC devices · Development of algorithms · Modular **quantum-HPC hybrid** computing · **Training** and **user support**

Analog quantum computer



D:WAVE Advantage

The Quantum Computing Company™

Quantum annealer (2021)

- **5640** super-conducting qubits (Pegasus graph)
- Temperature: 15mK
- Combinatorial optimization



PASQAL Fresnel

Quantum simulator (2024)

- **100** neutral rubidium atoms (2D & 3D array)
- Atoms trapped and controlled through laser pulses
- Quantum chemistry

Digital quantum computer



10 qubit fully HPC-embedded demonstration system



Cloud-Zugang 2024

54 qubit digital-analog hybrid system



European project building a **1000** qubit device led by FZJ

Quantum emulator

JUQCS

Jülich Quantum Computer Simulator

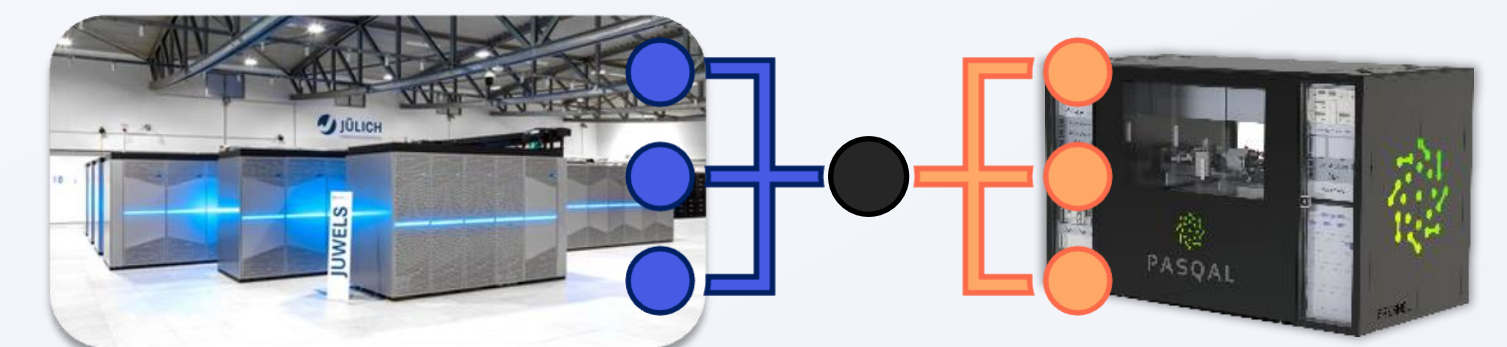
Massively parallel emulator of gate-based quantum computers (**43** qubits on JUWELS)

Atos

Quantum learning machine

Simulator of gate-based QC with up to **31** qubits

<HPC|S>



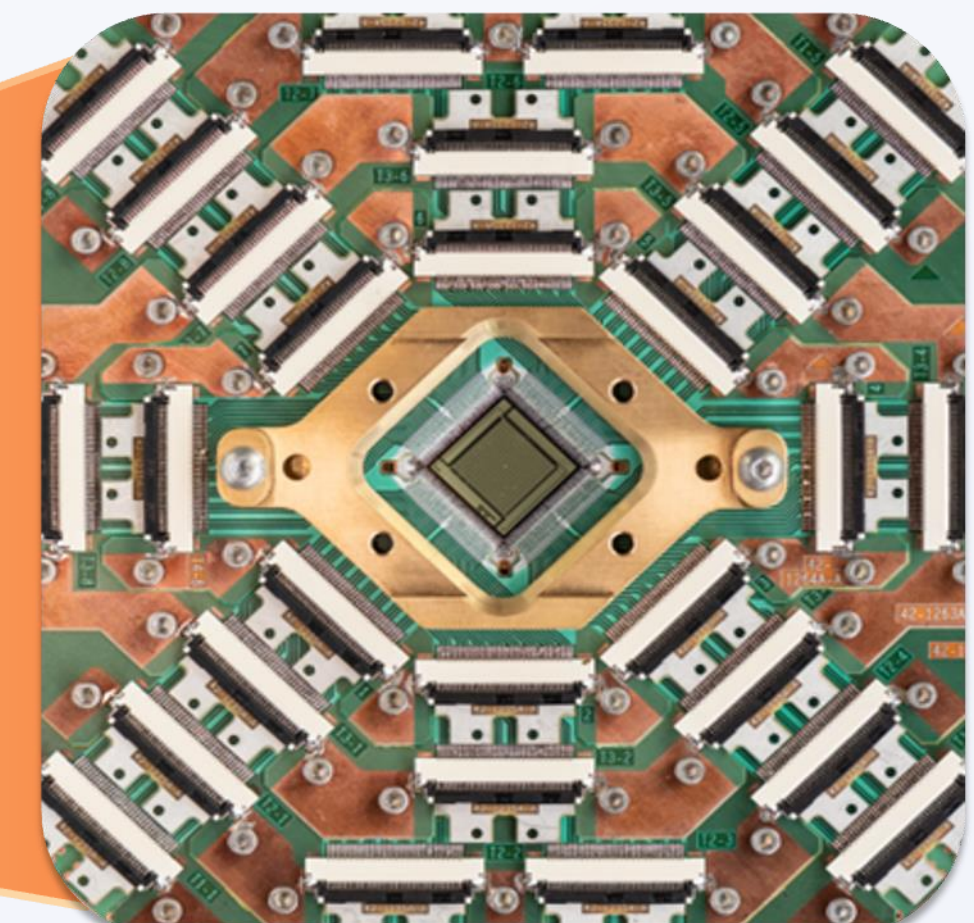
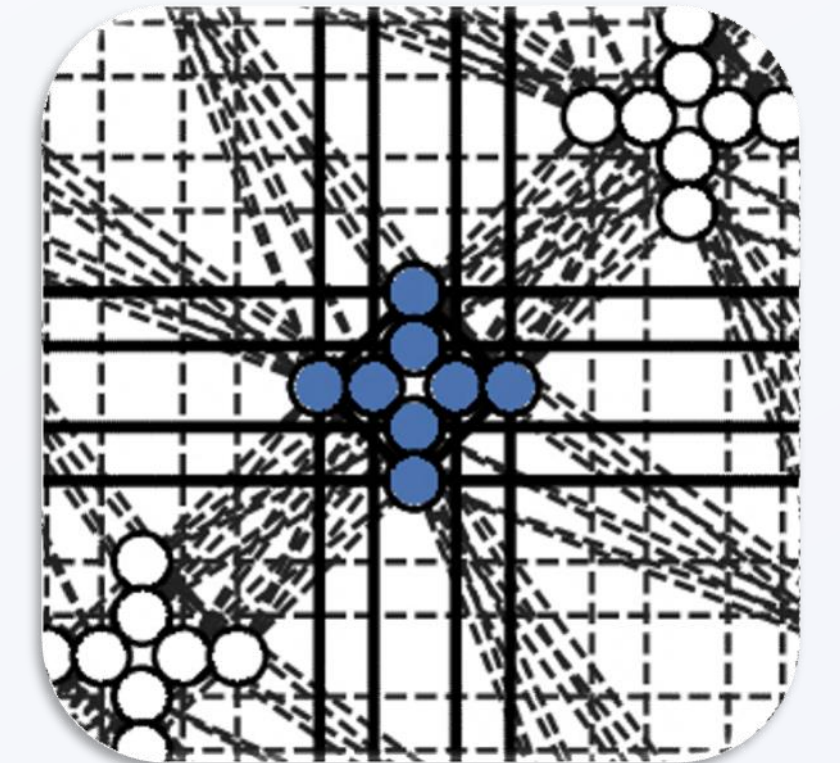
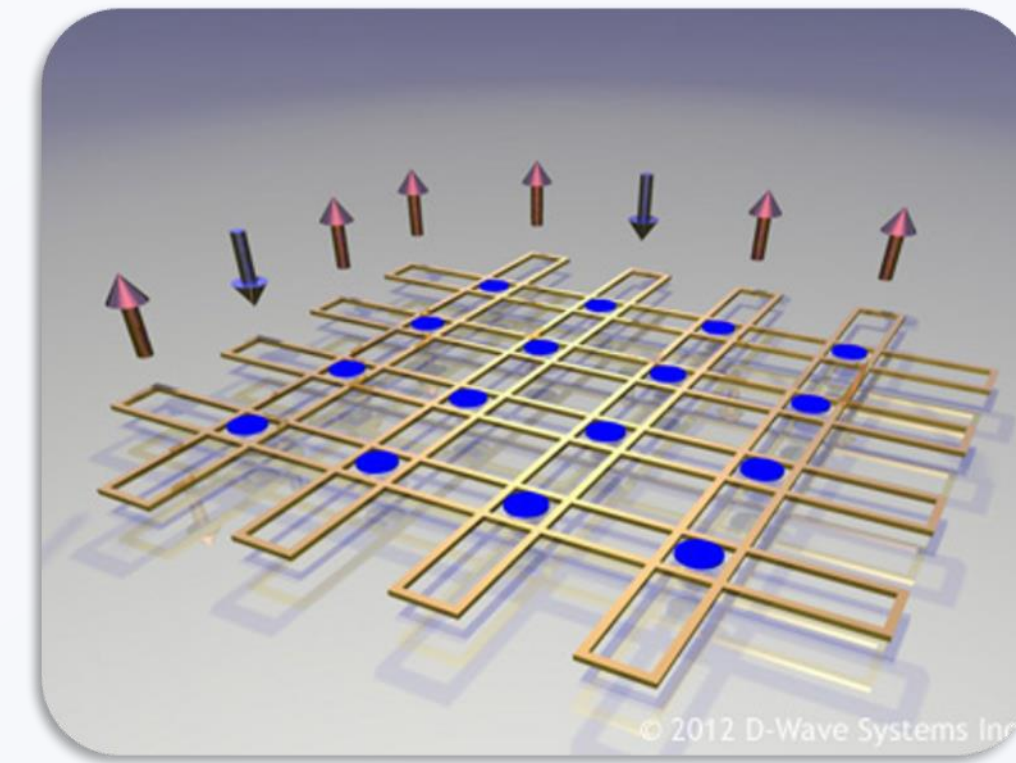
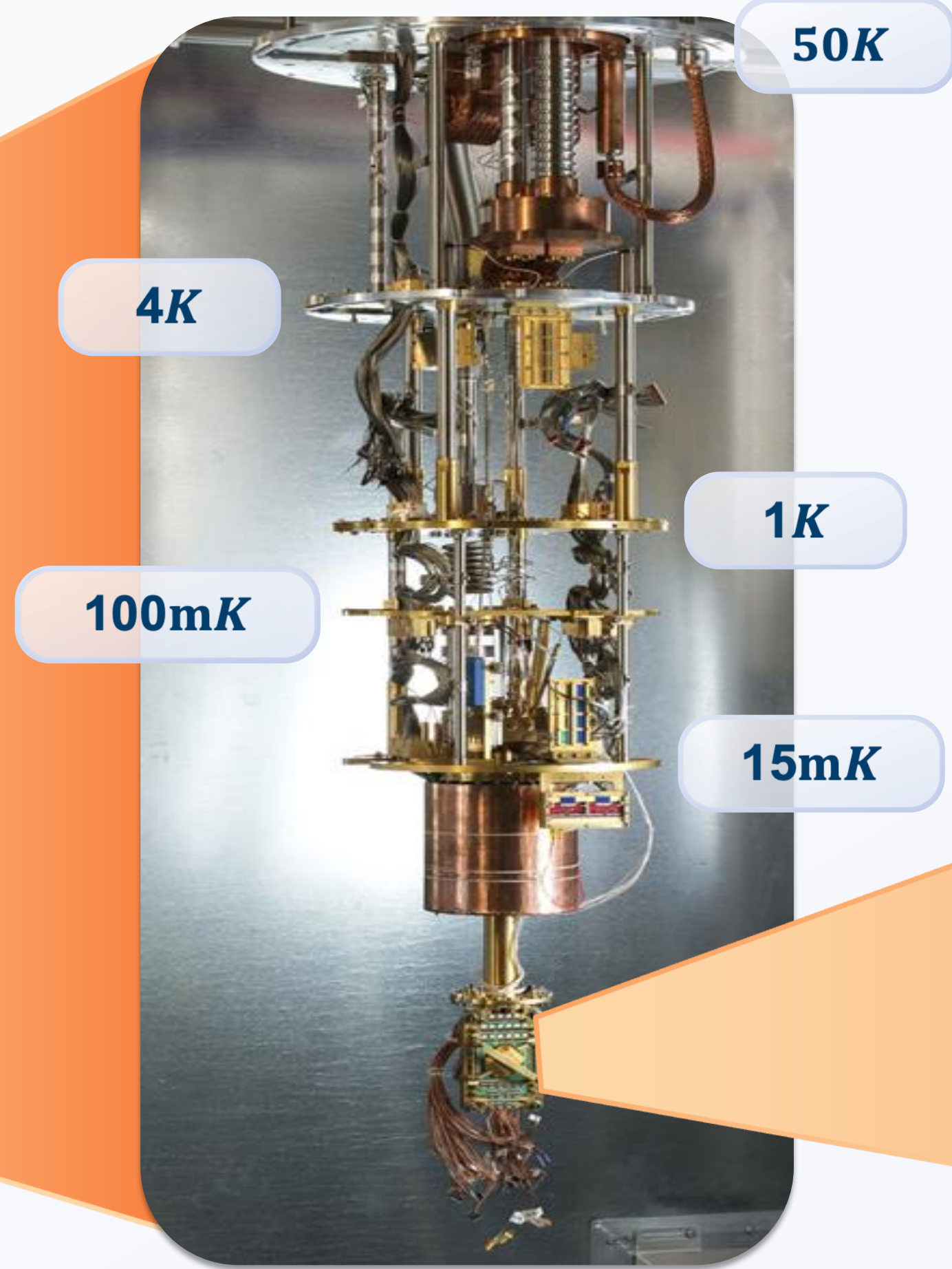
Cooling system

25kW power consumption

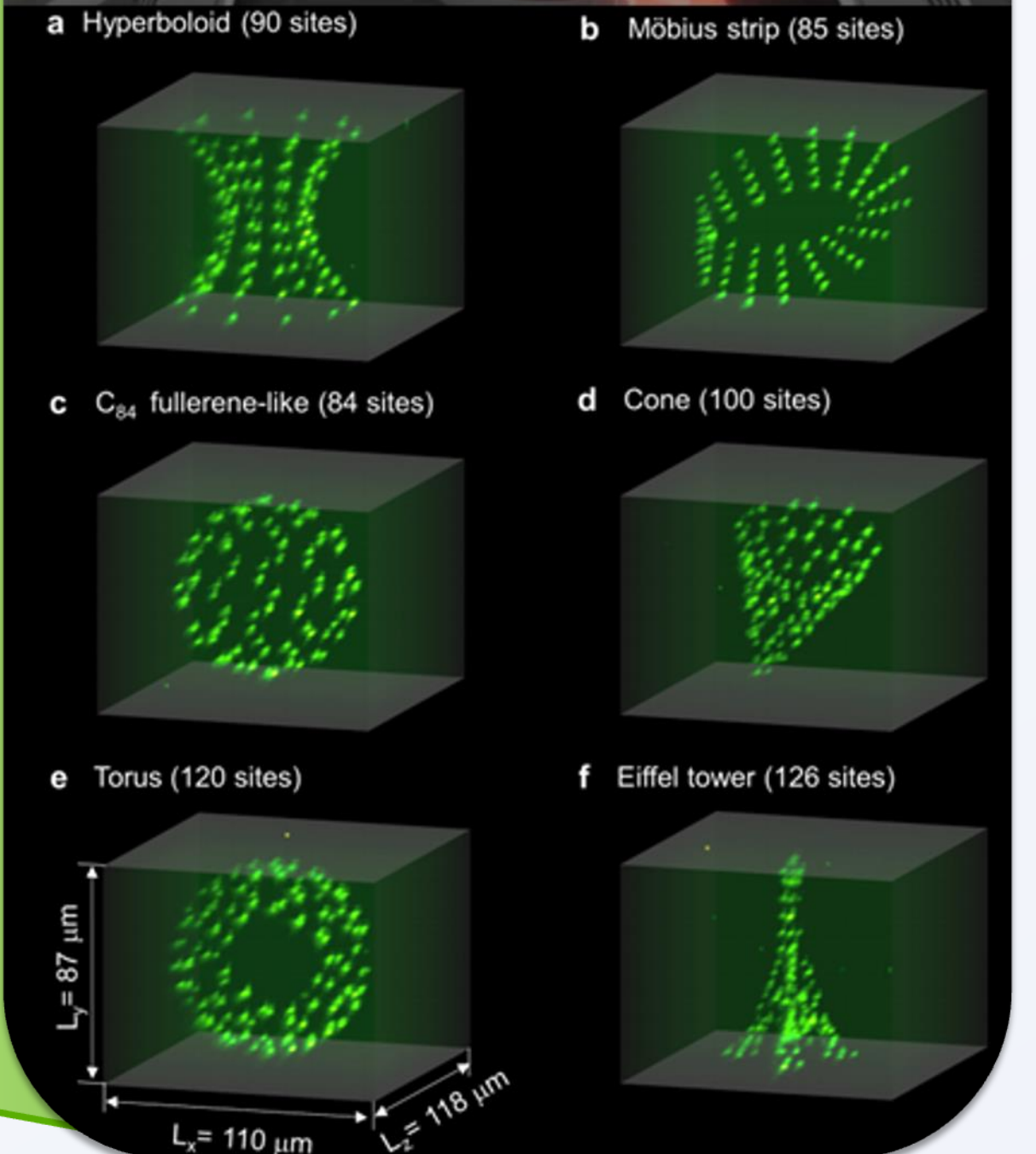
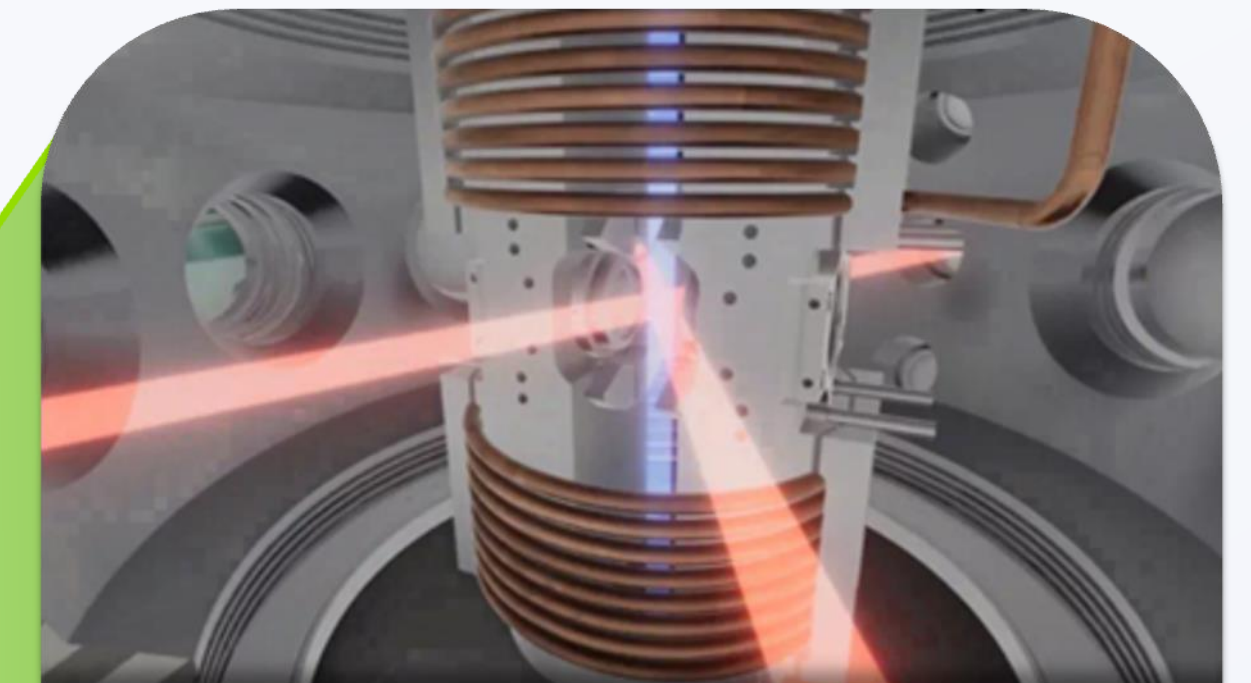
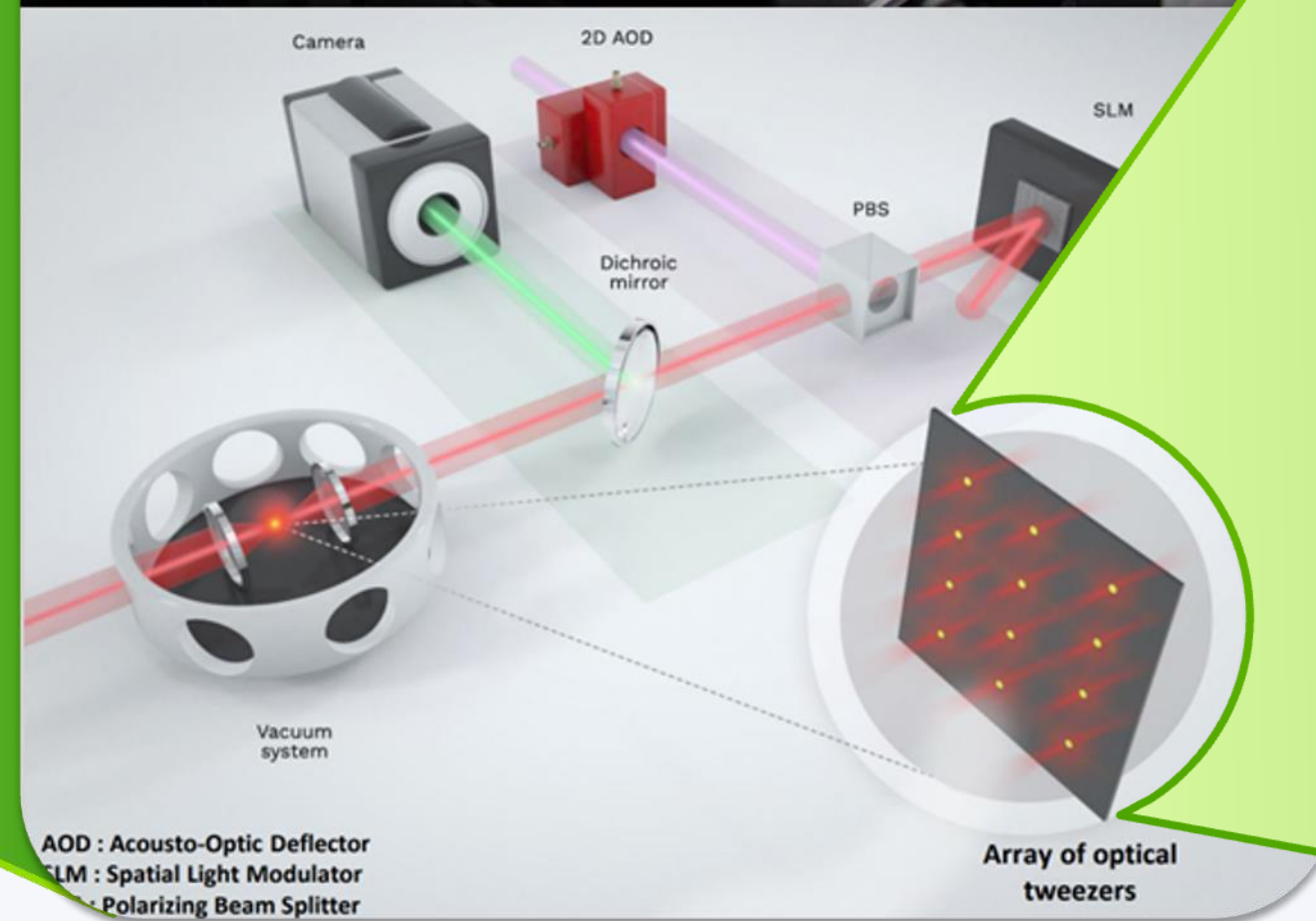
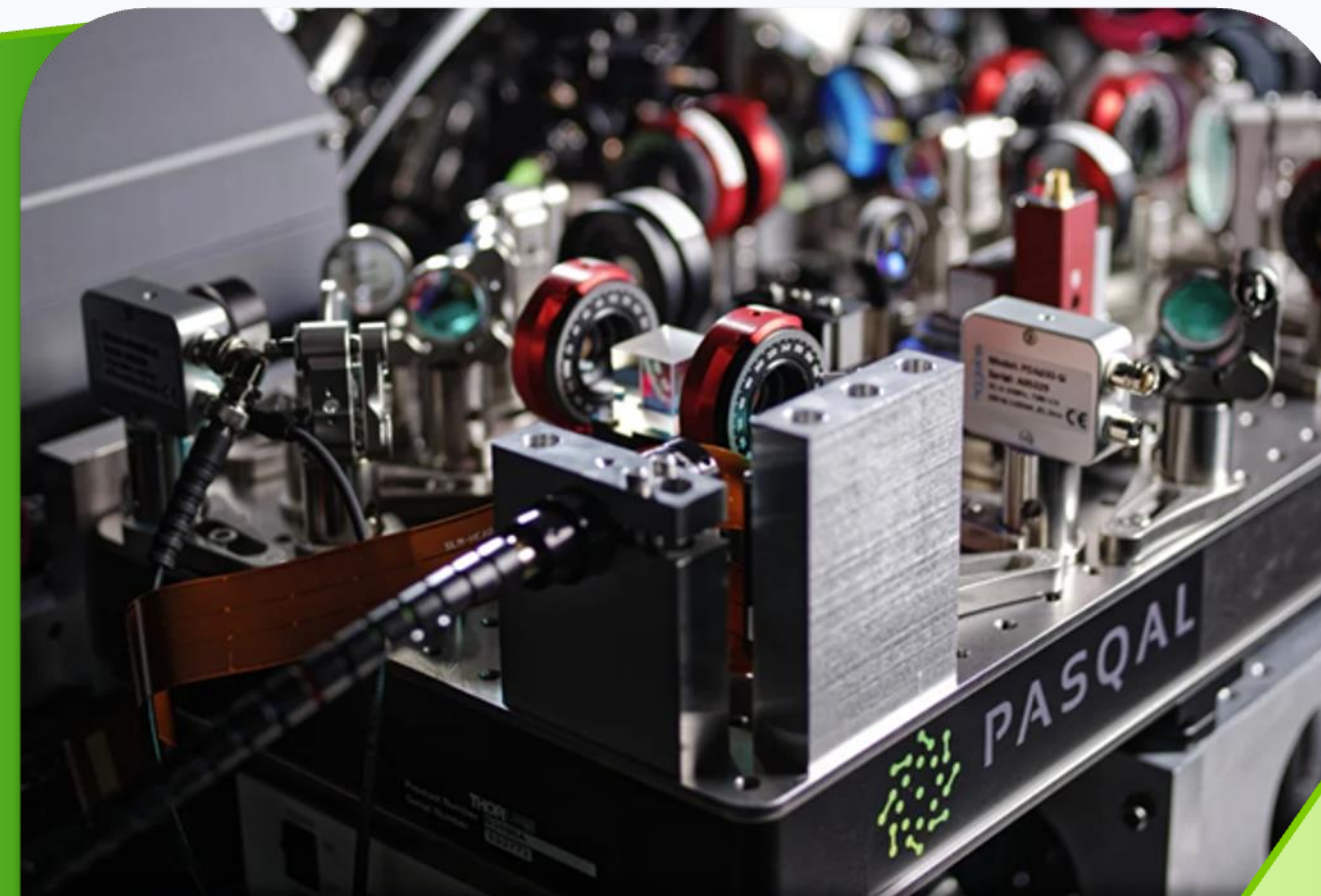
Quantum Processing Unit

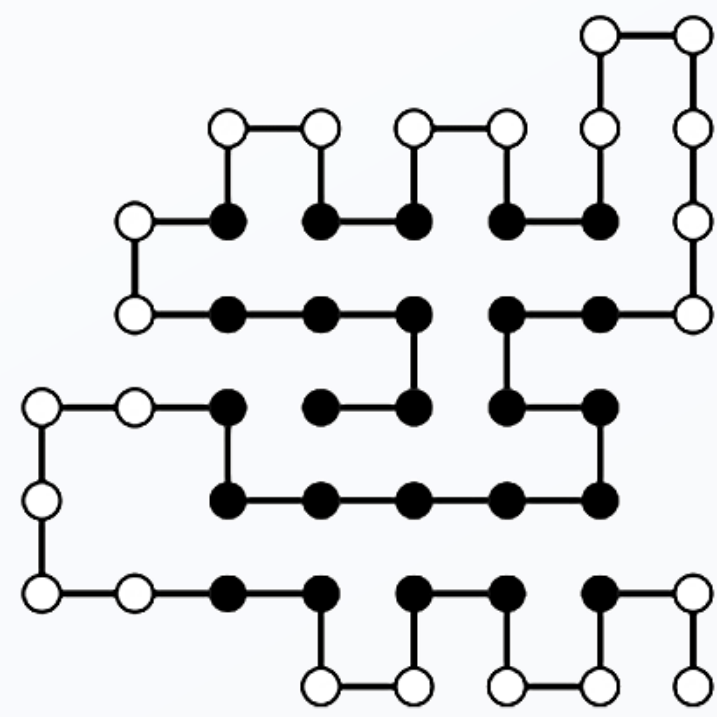
5640 super-conducting qubits

Pegasus topology with 40.484 couplers



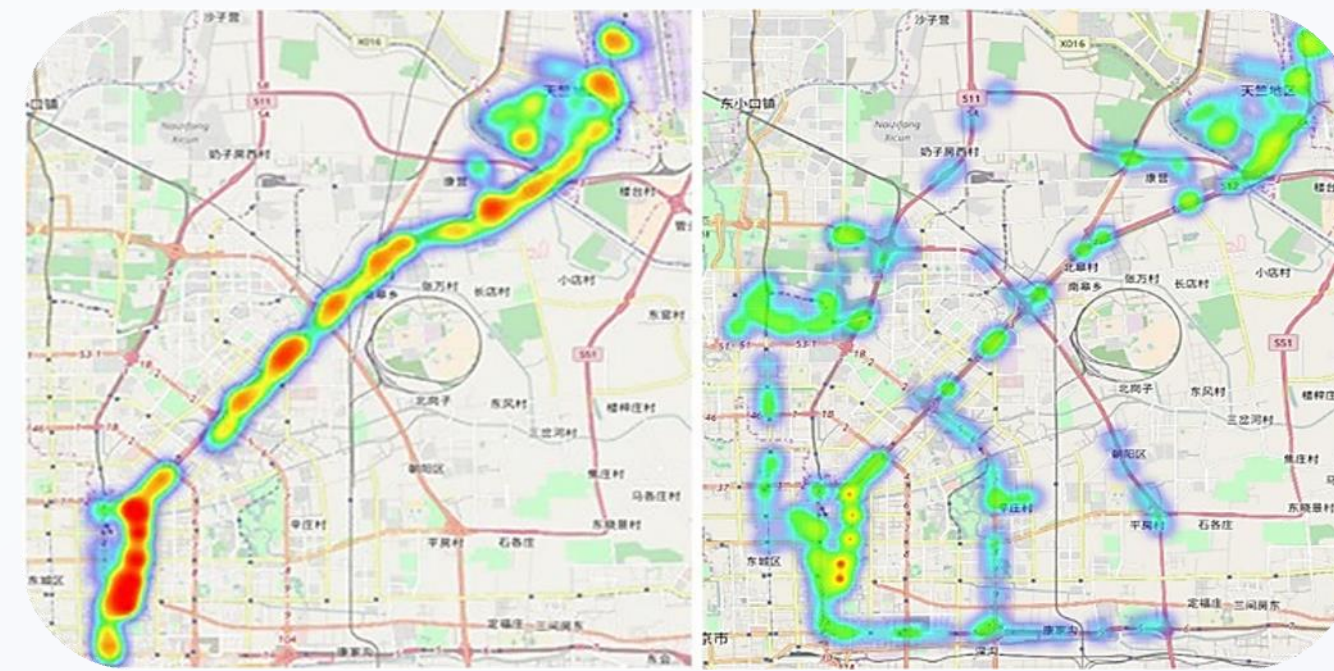
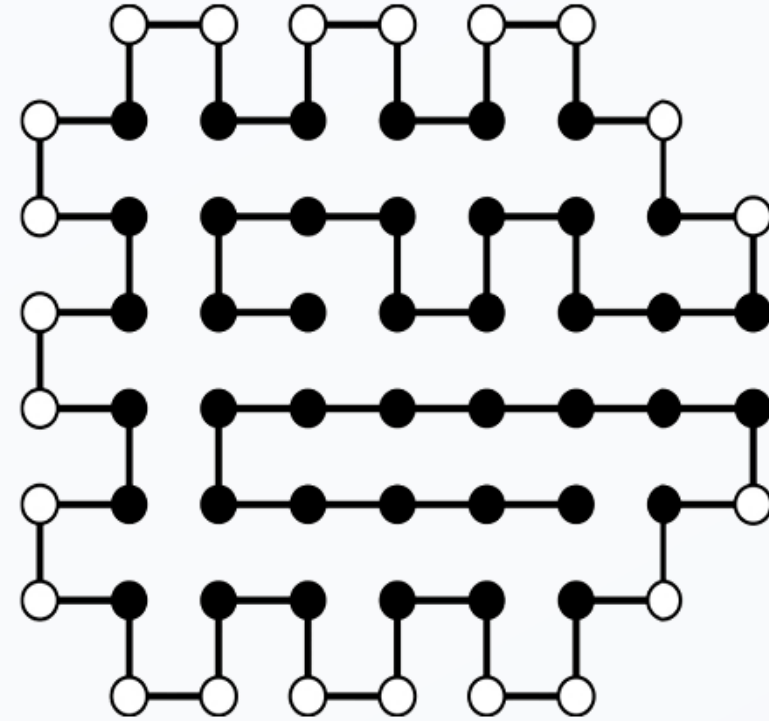
100 Rydberg atoms
tapped in a 3D lattice





Protein folding

<https://doi.org/10.1103/PhysRevResearch.4.043013>



Traffic optimization

<https://doi.org/10.3389/fict.2017.00029>



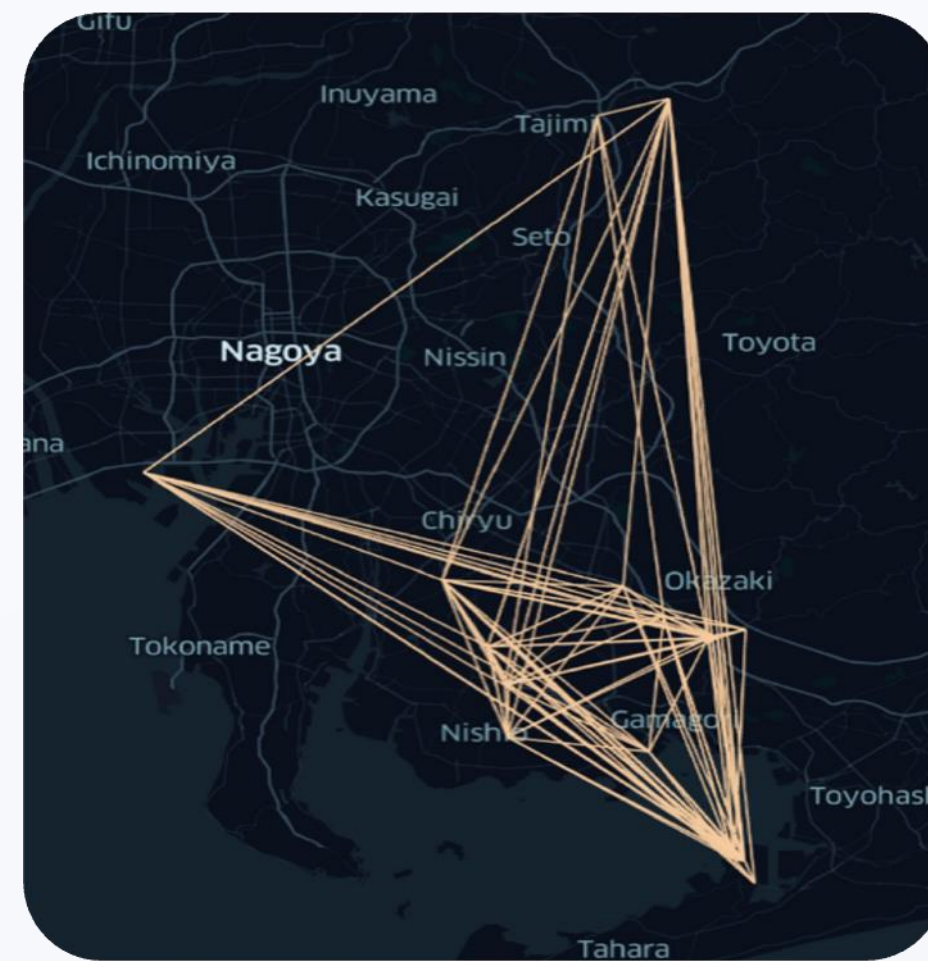
Aircraft scheduling

<https://doi.org/10.1103/PhysRevApplied.14.034009>

Tomato	Paprika	Cucumber	Zucchini	Lettuce	Carrot	Onion	Raddish	Oregano	Basil	Thyme	Parsley	Chives	Rosemary	Sage	Dill	Coriander	Mint
-1	-1	1	0	-1	-1	-1	0	-1	-1	0	-1	-1	0	0	0	-1	-1
-1	-1	0	0	-1	0	0	-1	-1	0	0	0	0	0	0	0	0	0
-1	1	-1	0	-1	-1	0	0	0	0	-1	0	0	0	0	0	-1	0
-1	0	0	-1	0	0	0	0	0	0	-1	0	0	0	0	0	0	0
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-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0
-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0

Garden optimization

<https://doi.org/10.1007/s11128-021-03226-6>



Supply chain logistics

<https://doi.org/10.1038/s41598-023-31765-8>

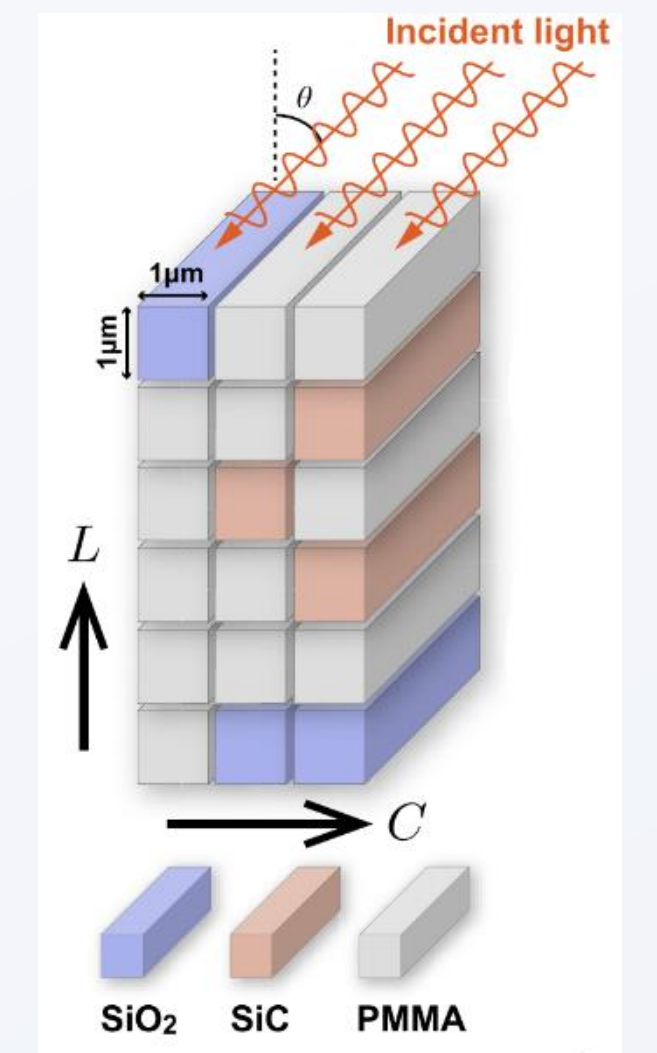
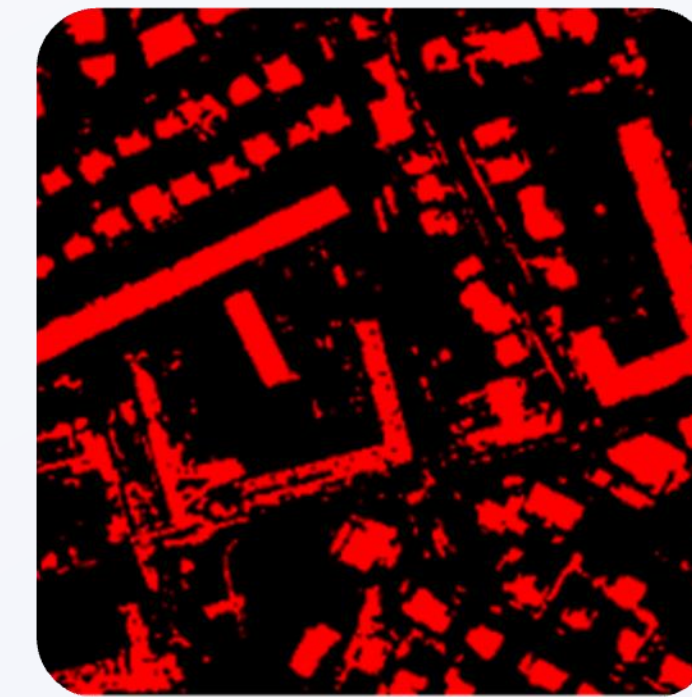
Applications on the D:WAVE Advantage

The Quantum Computing Company™



Machine learning

<https://doi.org/10.48550/arXiv.2303.11705>



Material design

<https://doi.org/10.1103/PhysRevResearch.2.013319>

Signatories of the **QUANTUM DECLARATION**

Cyprus, Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Italy, Romania, Slovakia, Slovenia, Spain and Sweden recognise the strategic importance of quantum technologies for the scientific and industrial competitiveness of the EU and commit to collaborating on the development of a world-class quantum technology ecosystem across Europe, with the ultimate aim of making Europe the 'quantum valley' of the world, the leading region globally for quantum excellence and innovation.

