C12

Building scalable and ultra-coherent quantum computers with carbon nanotubes

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SUMMARY

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01

C12 in a nutshell

Founded in 2020

Paris-based quantum hardware startup

Technology from the Ecole Normale Supérieure in Paris

24 employees

$10m Seed round in June 2021

First application-specific chips for quantum chemistry & optimization developed within consortiums

360 CAPITAL

bpifrance DIGITAL VENTURE

BNP PARIBAS DÉVELOPPEMENT

02

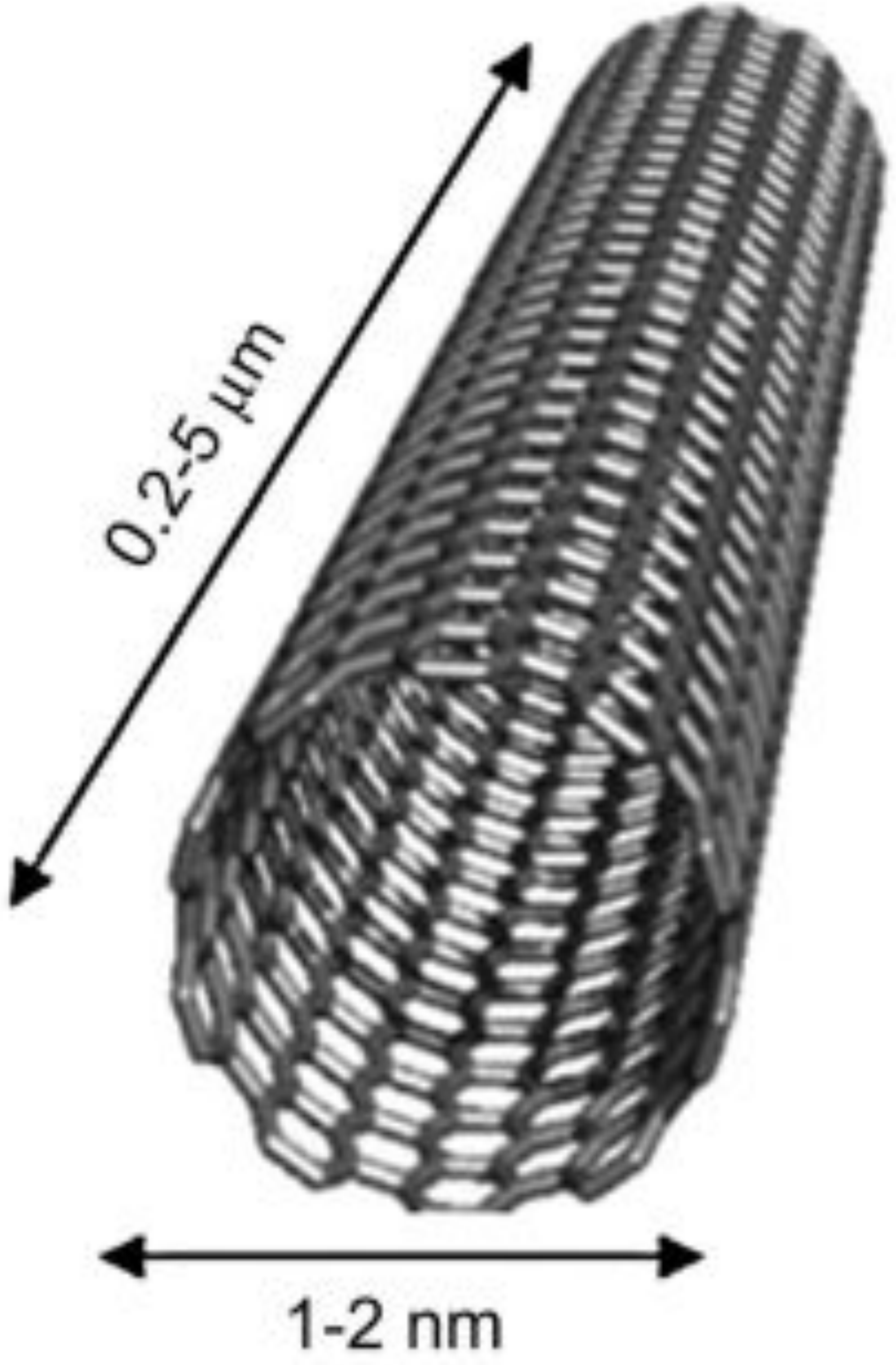
Our vision

Errors come from defects in the qubit material

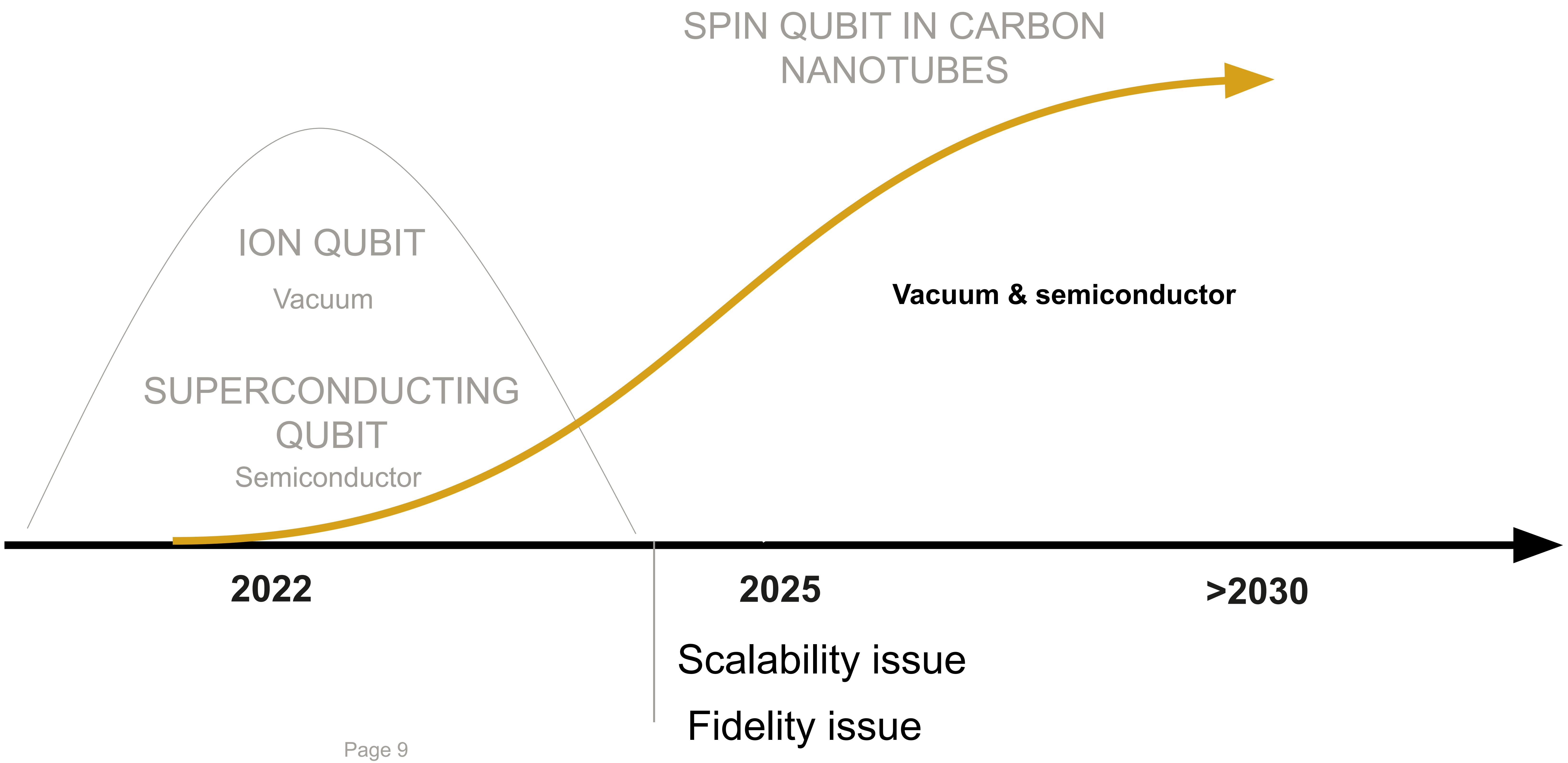
“A roadmap in 10 years, based on a solid-state qubit, relies on breakthroughs in material science.”

Chris Monroe, IonQ co-founder and chief scientist

We are transforming Carbon Nanotubes into “quantum transistors”



Carbon Nanotubes have the potential to process quantum information with high fidelity and at large scale



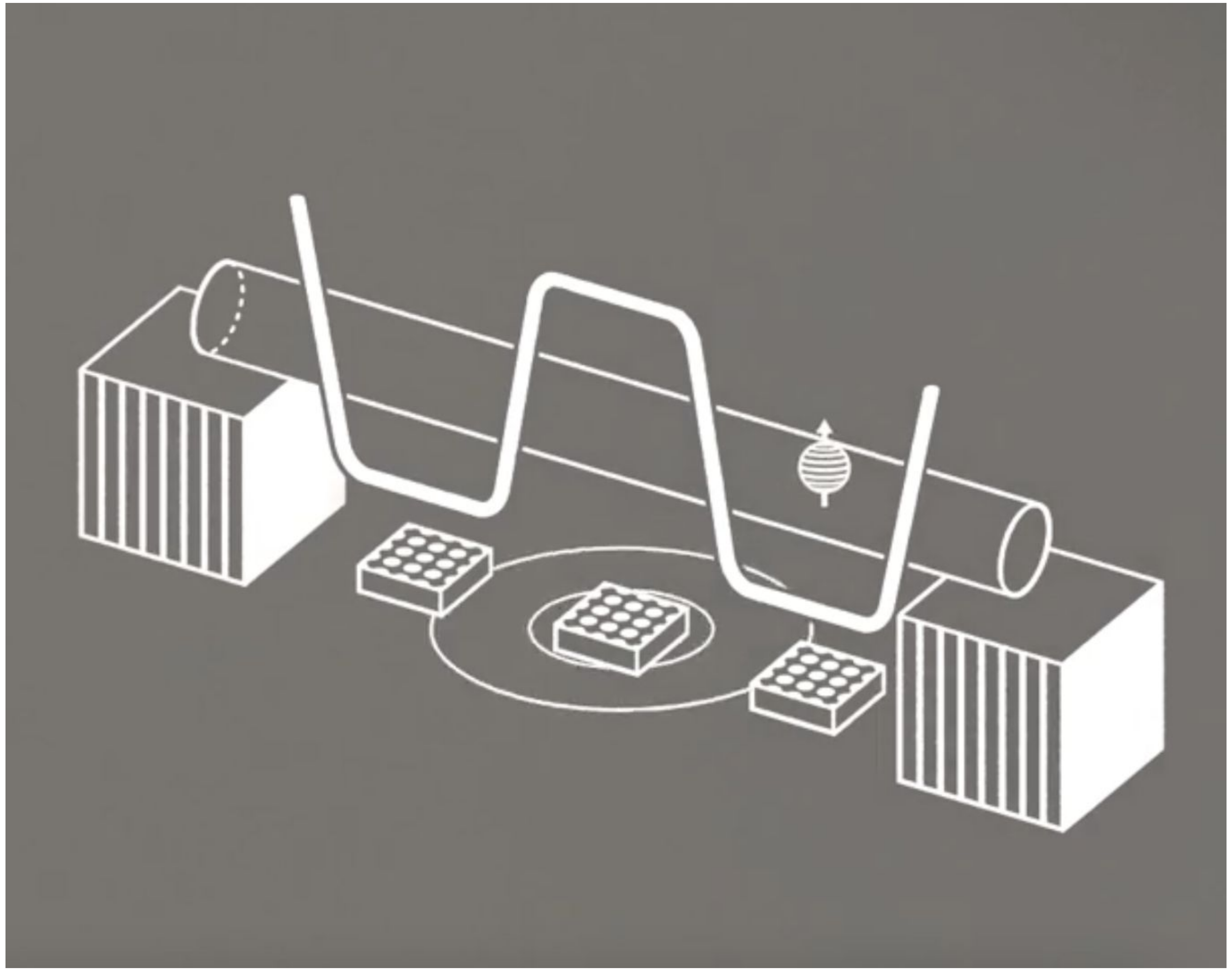
C12's qubit is a spin qubit hosted in a single carbon nanotube

0. Ultra-pure carbon nanotube, connected between electrical contacts, suspended above an array of gate electrodes

1. Gate electrodes to trap a single electron in a double quantum dot

2. Magnetic gate electrode to entangle the electronic spin with the charge dipole in the double quantum dot

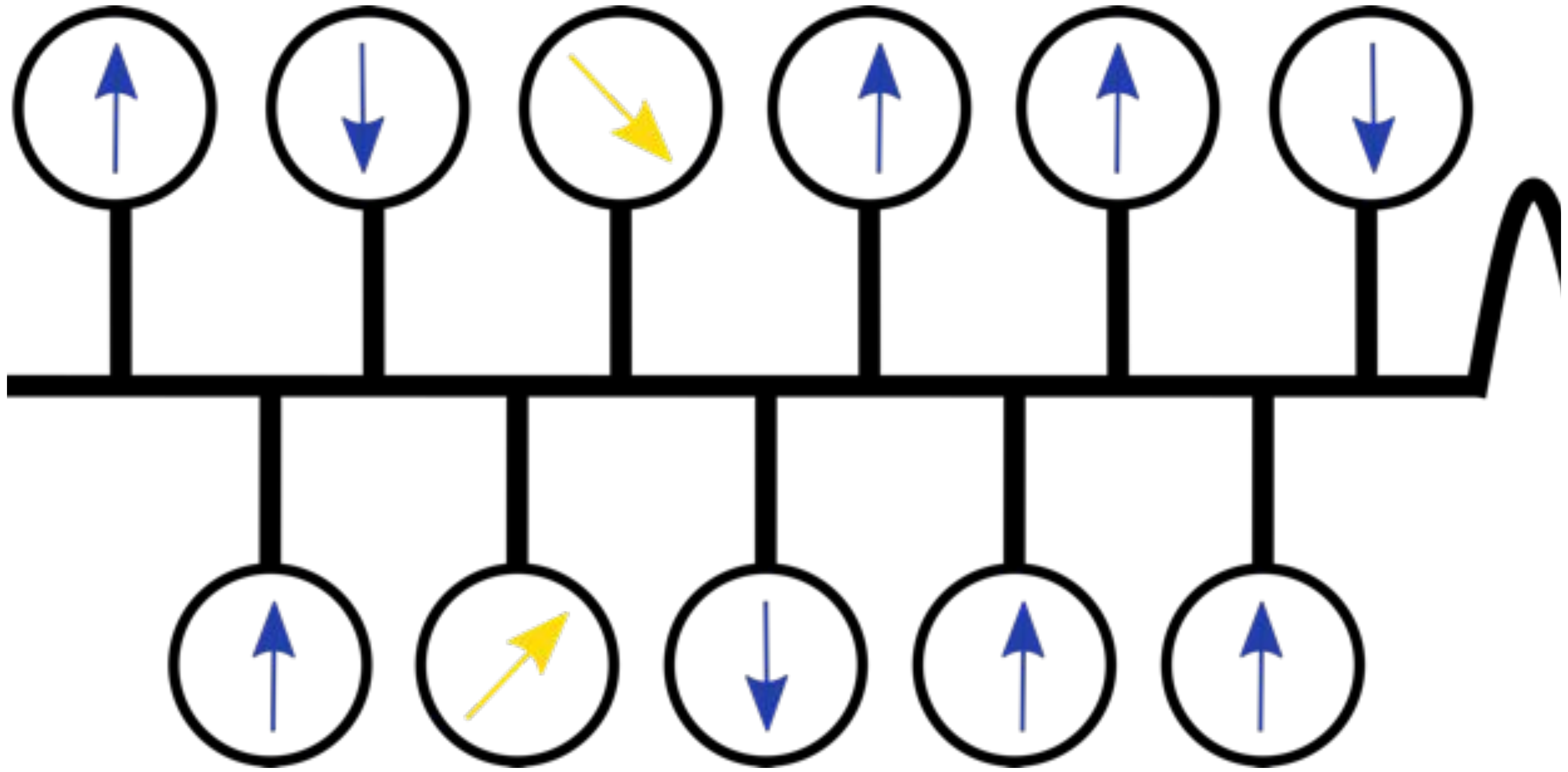
3. Spin qubit addressed through the resonator via microwave pulses



In C12's chip layout, spin qubits are coupled to a unique microwave superconducting resonator

Control & readout via the superconducting resonator

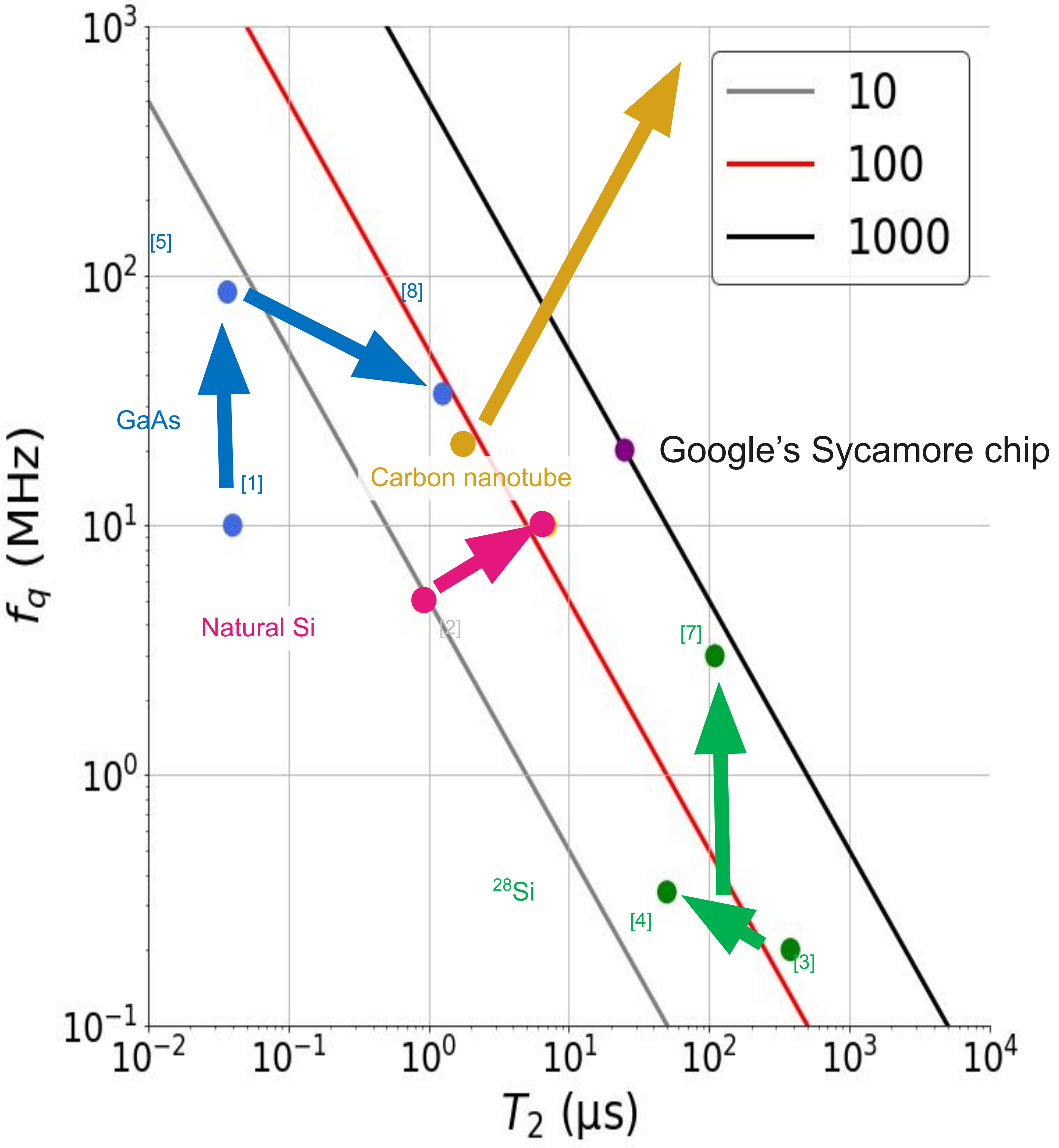
Two qubit gates performed via a virtual photon exchange with the resonator and spin-spin coupling between two qubits



03

Advantages of the tech

1. A qubit with a very high quality factor

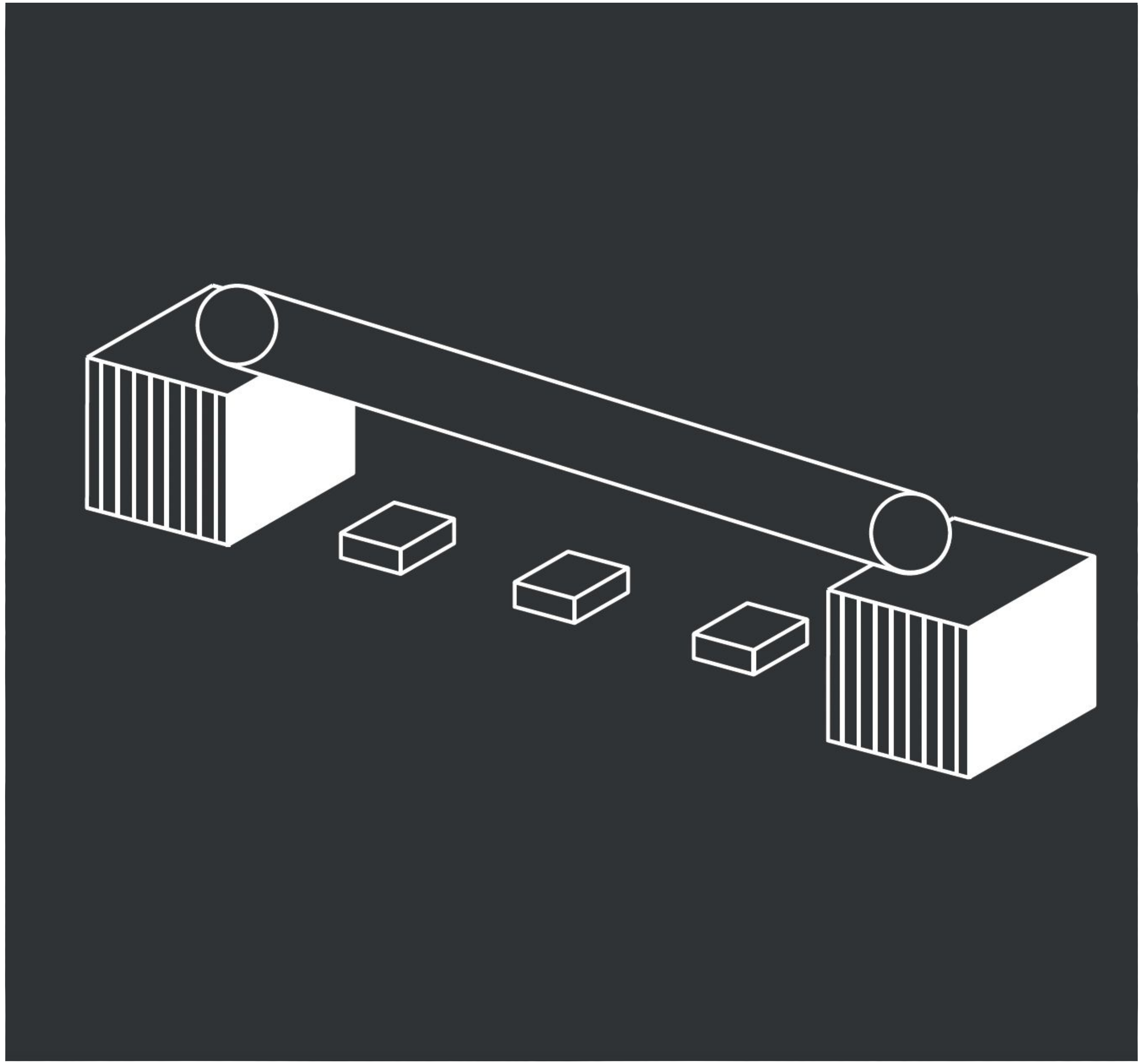


Long coherence time

Fast coupling

[1] F.H.L. Koppens *et al.*, Nature **442**, 766 (2006).
[2] E. Kawakami *et al.*, Nat. Nanotechnol. **9**, 666 (2014).
[3] M. Veldhorst *et al.*, Nat. Nanotechnol. **9,** 981 (2014).
[4] M. Veldhorst *et al.*, Nature **526**, 410 (2015).
[5] J. Yoneda *et al.*, PRL **113**, 267601 (2014).
[6] K. Takeda *et al.*, Sci. Adv. 2, e1600694 (2016).
[7] J. Yoneda *et al.*, Nat. Nanotechnol. 13, 102 (2018).
[8] T. Nakajima *et al.*, Phys. Rev. X 10, 011060 (2020)
[9] T. Cubaynes *et al*, npj, Quantum Information, (2019) 5:47

Spin qubit in a ultra-pure material

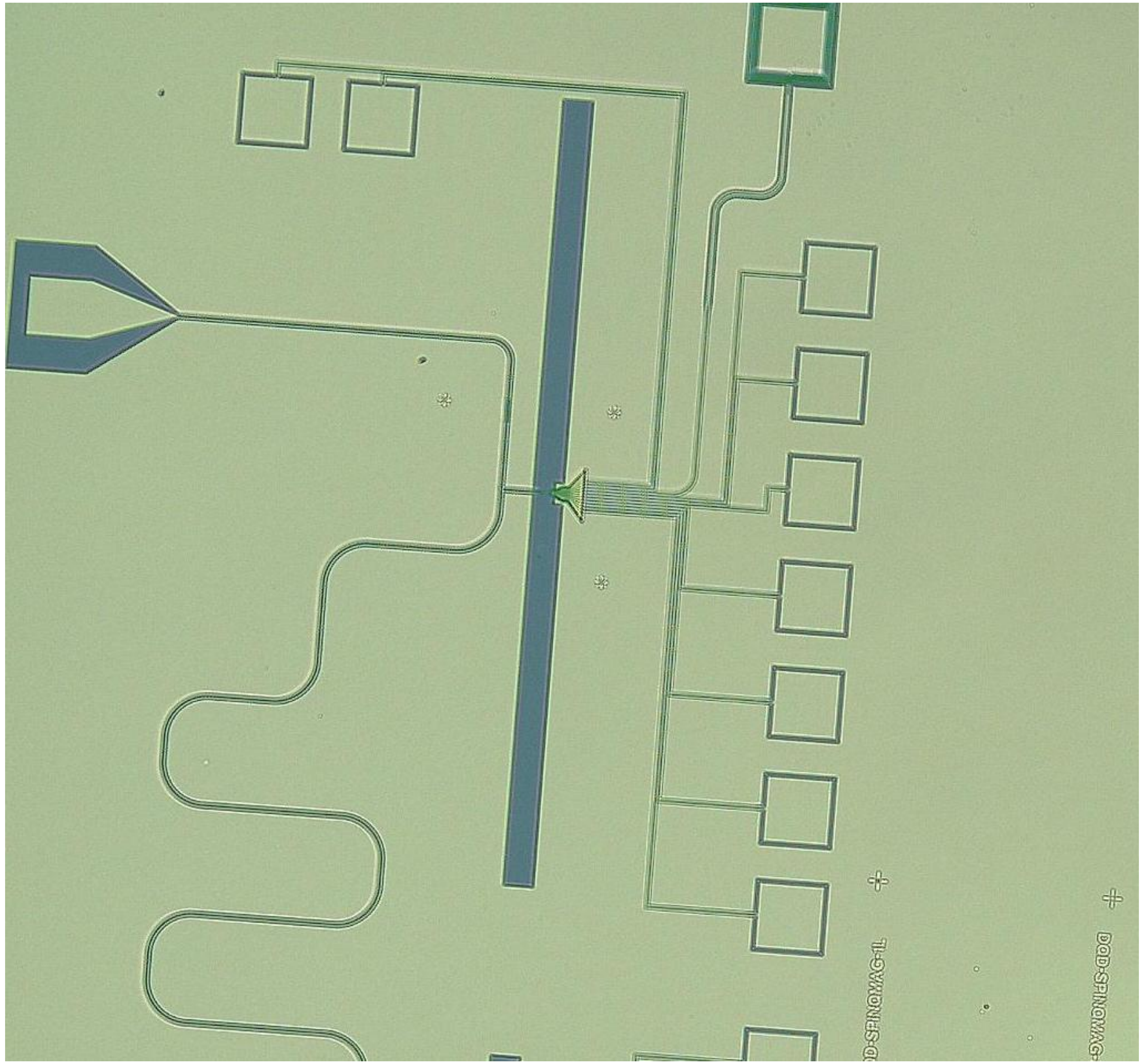


Less than 0.5 nuclear spin per dot

Vacuum isolation (oxide-free)

Control of confined phononic modes

Fast coupling



Microwave on-chip control

2-qubit gate duration – c. 500 ns

1-qubit gate duration – c. 80 ns

2. A unique solid-state architecture

All-to-all connectivity

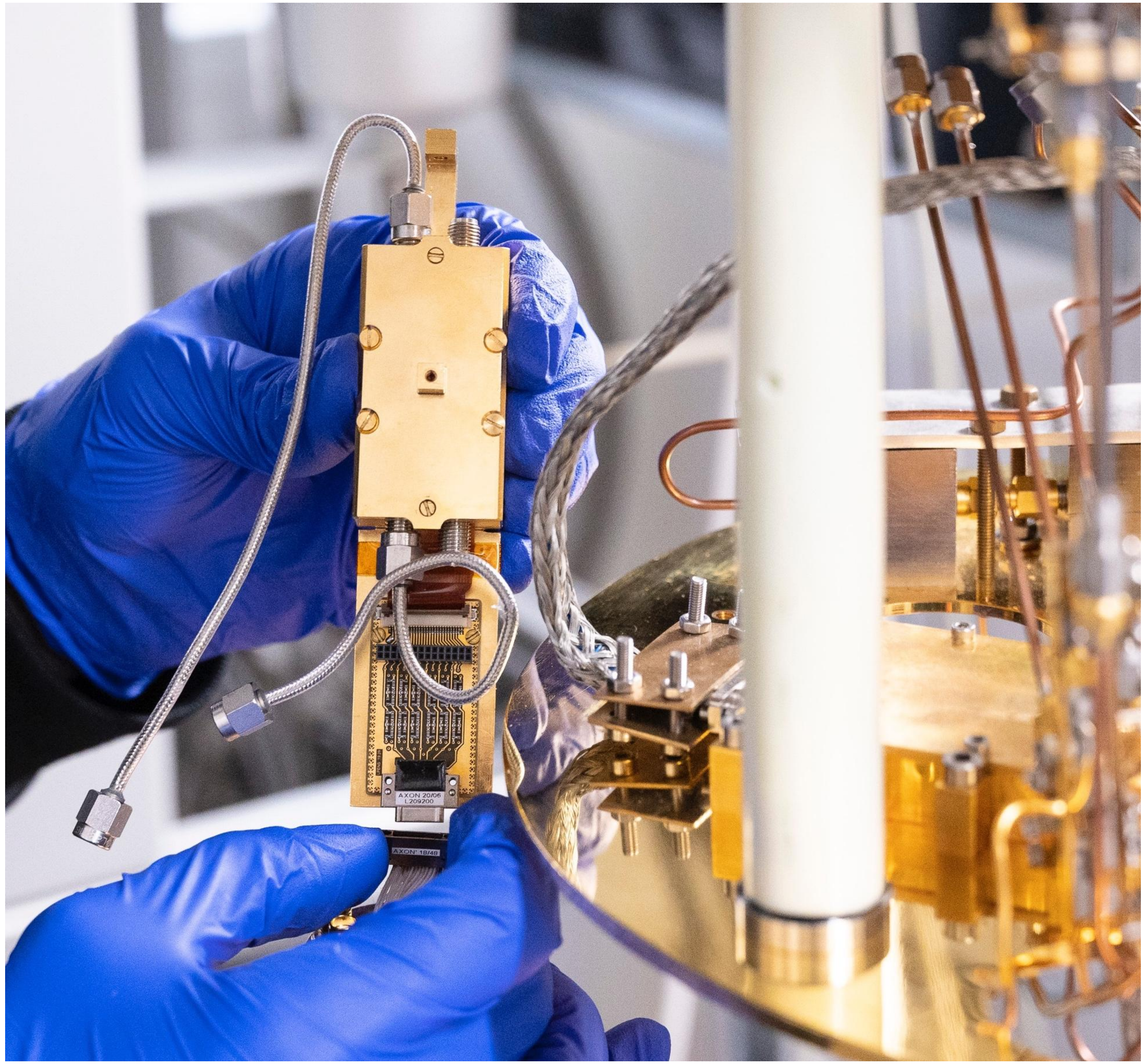
Exponentially tunable spin-photon coupling

3. Scalable quantum computing

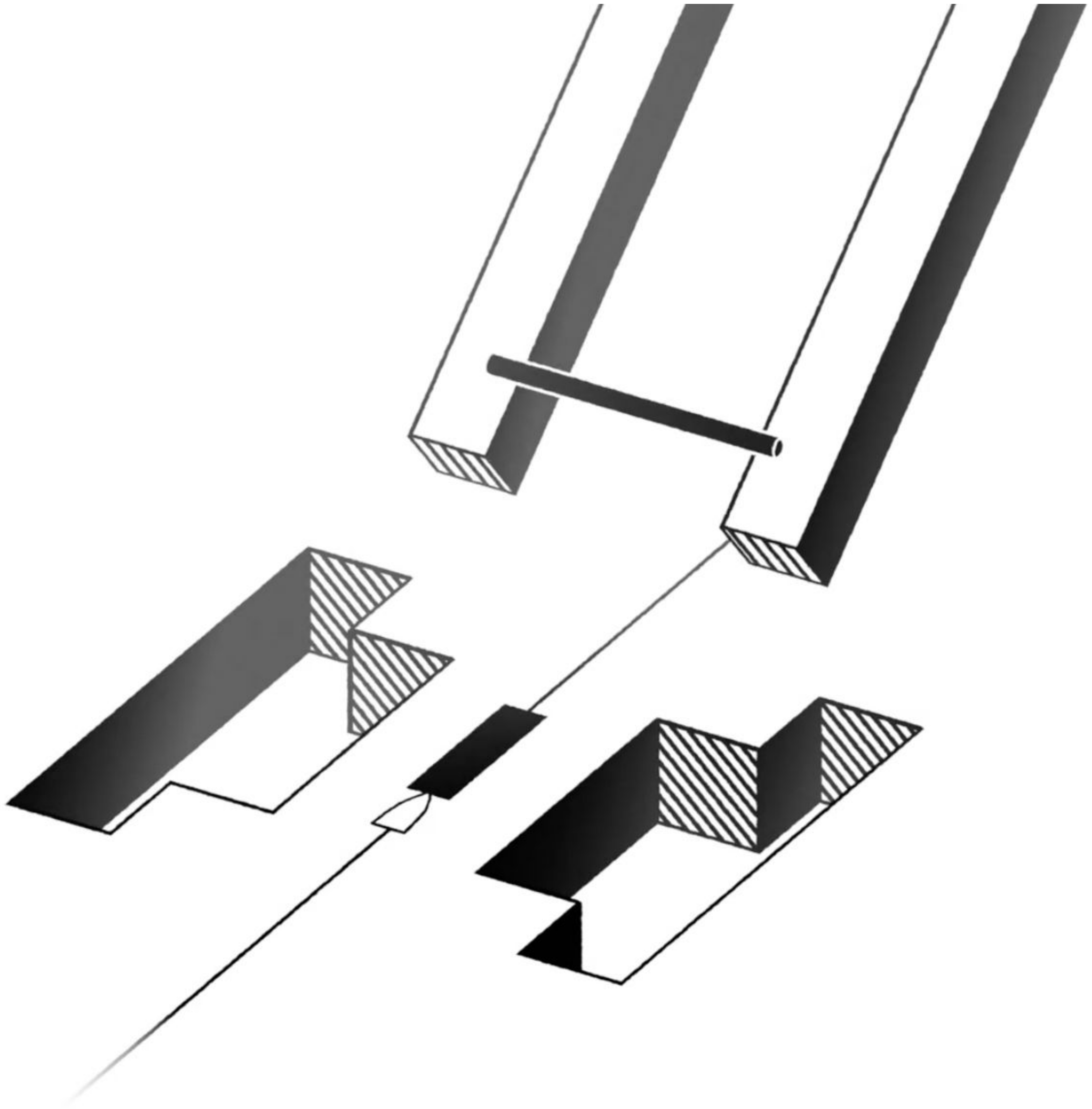
Semiconductor integration & high qubit density

Qubit pre-selection

Quantum error correction



Electrically Gated Semiconductor Qubits



Patented nano-assembly process

Small qubit footprint
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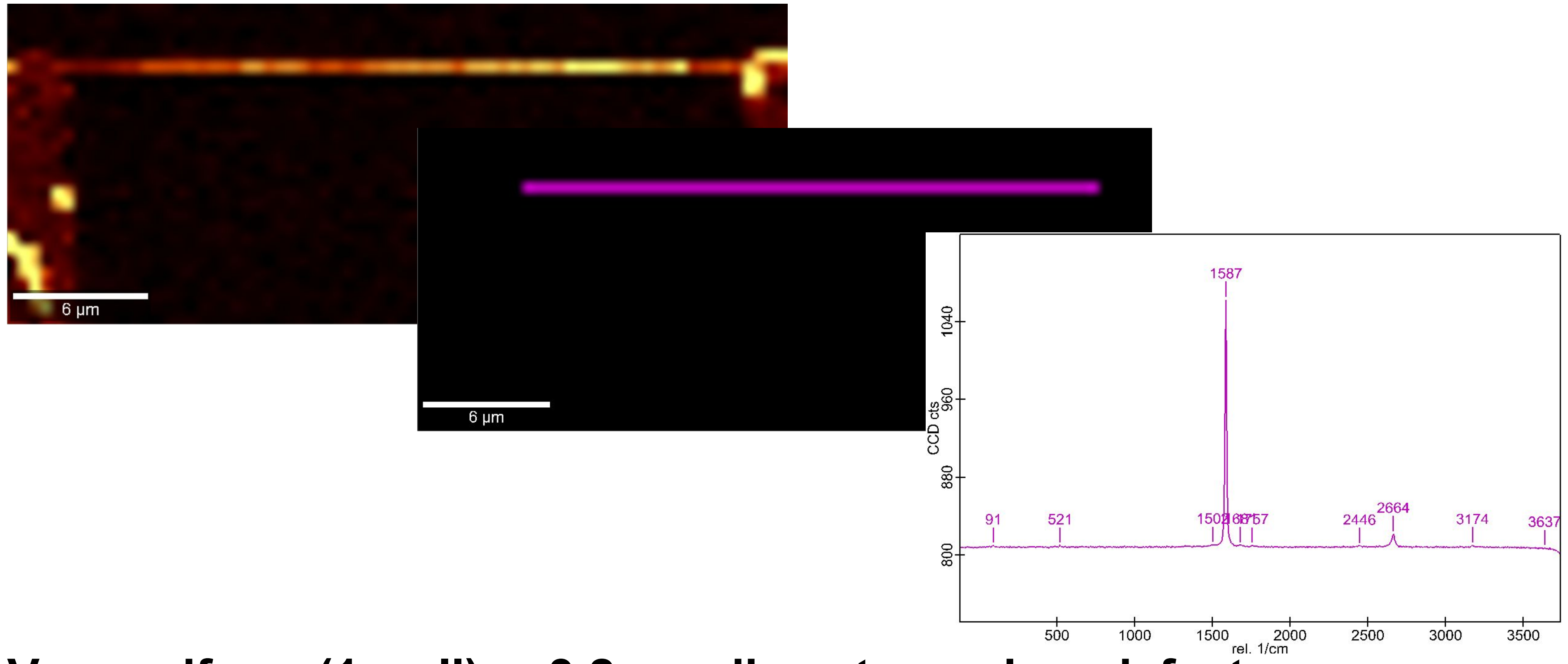
Use of fabrication methods similar to classical electronics

Qubit pre-selection

Raman spectroscopy

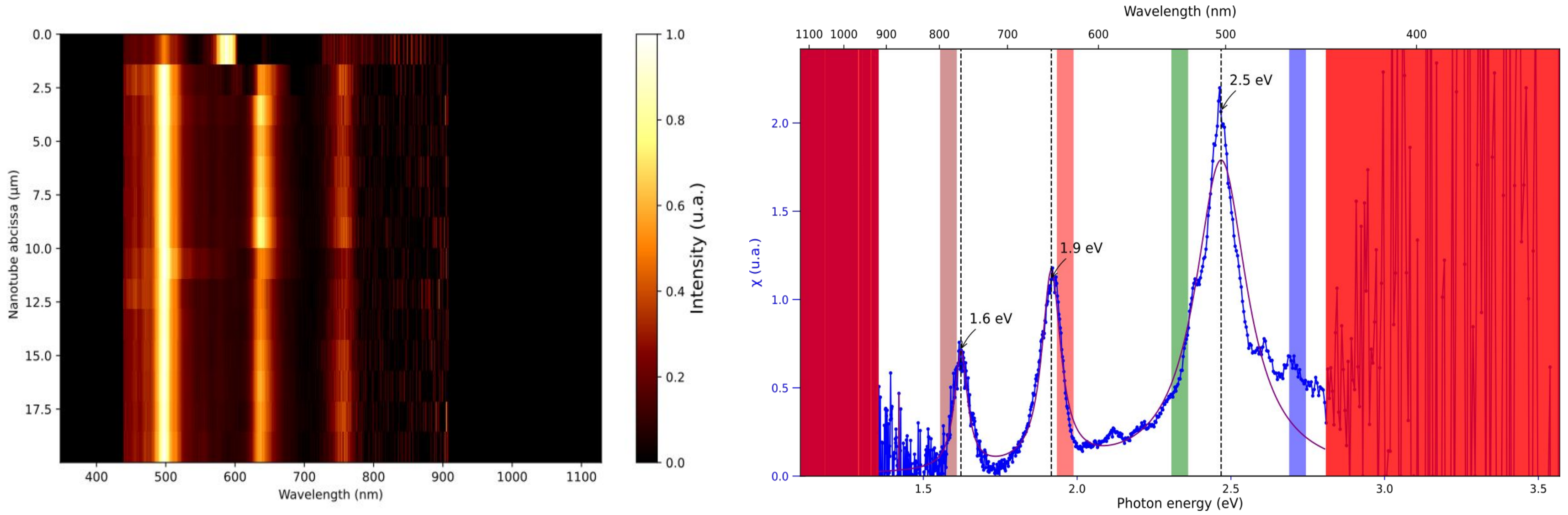


Very uniform (1 wall) c. 3.2 nm diameter and no defect

Non-invasive method

Machine learning assisted selection

Rayleigh spectroscopy



C12 carbon nanotube uniform over c. 20um

04

Challenges & outlook

C12

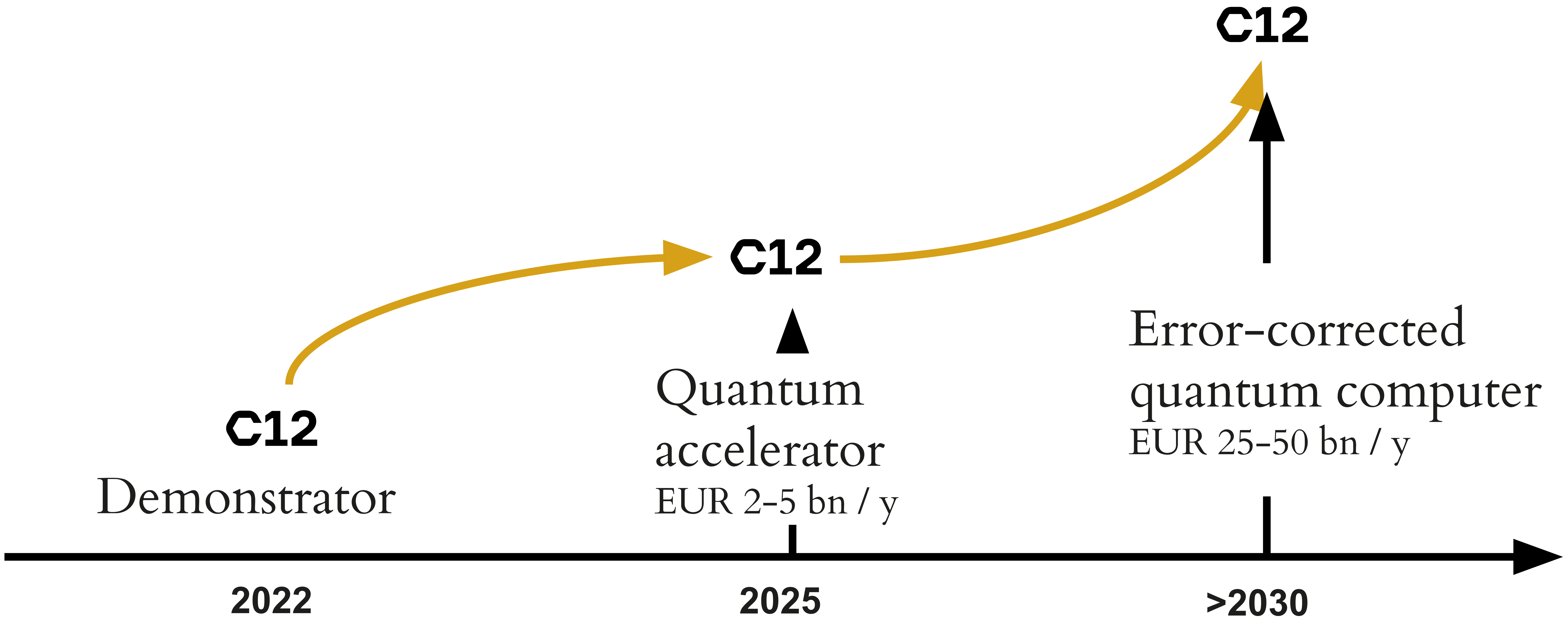
Carbon nanotube spin qubit is a promising quantum computing platform but still early-stage tech

ULTRA-PURE MATERIAL

MULTI-QUBIT CHIP LAYOUT

SOFTWARE INTEGRATION

C12's processor is a prime candidate for Noisy Intermediate-Scale Quantum applications



BCG analysis

We are developing first two application-specific chips with partners

Quantum Chemistry

Hydrogen conversion

Quantum algorithm: Variational Quantum Eigensolver

2-year project

Quantum optimization solver

Graph-based combinatorial problems

Quantum algorithm: Quantum Approximate Optimization Algorithm

3-year project

Air Liquide

To be announced

Atos

Artelys OPTIMIZATION SOLUTIONS

C12

Leading the next materials leap in quantum computing

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