

Towards accessible, European hybrid quantum-HPC compute systems

Semicon Europa 2024

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Director Semicon & Quantum, TNO,
Member of supervisory board, QuantumDeltaNL,
Member of SAB, Quantum Flagship.





We are TNO

Mission: Creating impactful innovations for the sustainable wellbeing and prosperity of society

4,500 professionals

- Dutch national RTO,
- Established by law and started in 1932,
- Independent of direct public and private interest.
- Supporting companies to innovate,
- Supporting government in policy making,
- Designated tasks, e.g., Defence National Lab.



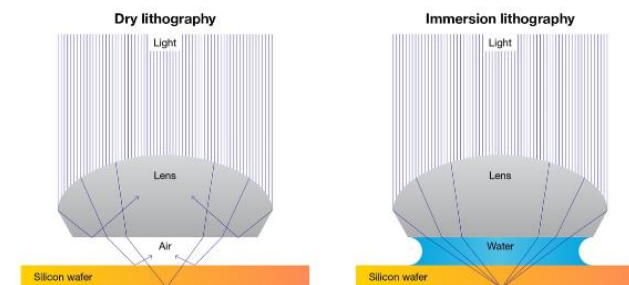
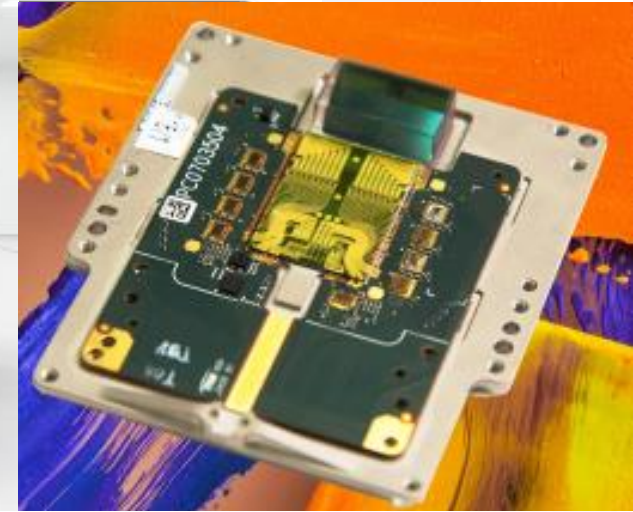


TNO Semicon partners

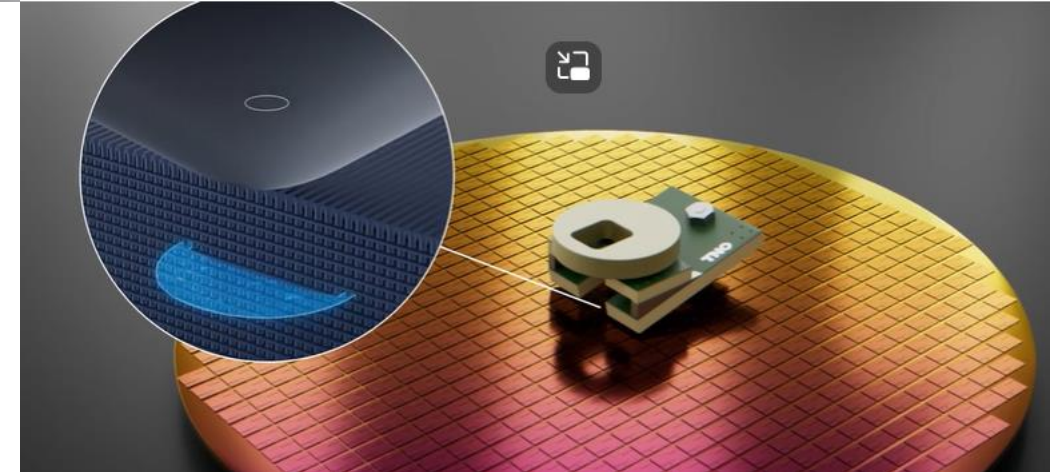




TNO Semicon



Immersion DUV systems differ from dry systems, with the former containing a layer of water between the lens and wafer.



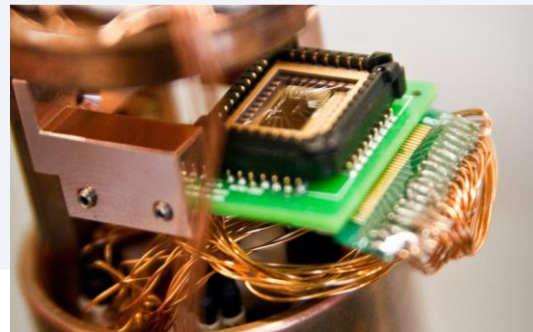
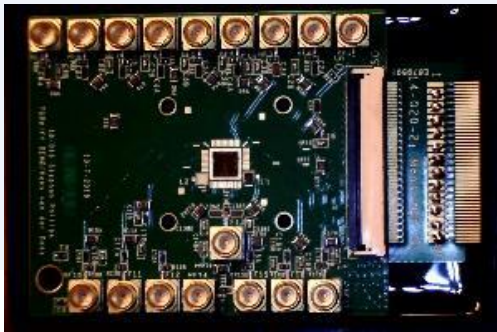
Quantum computing

- Exploiting superposition & entanglement:

$$\Psi = \alpha \left| \begin{array}{c} \uparrow \\ \bullet \end{array} \right\rangle + \beta \left| \begin{array}{c} \downarrow \\ \bullet \end{array} \right\rangle$$

$$|\Psi\rangle = \frac{1}{\sqrt{2}} \left| \begin{array}{cc} \uparrow & \downarrow \\ \bullet & \bullet \end{array} \right\rangle + \frac{1}{\sqrt{2}} \left| \begin{array}{cc} \downarrow & \uparrow \\ \bullet & \bullet \end{array} \right\rangle$$

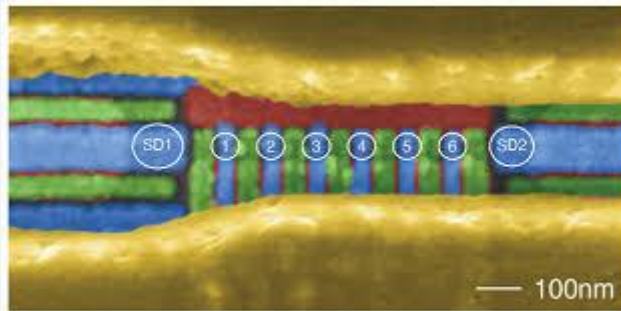
- Each additional quantum bit doubles the number of states
 - Exponential vs linear scaling (Moore's law).





World's first integrated academic & applied R&D center

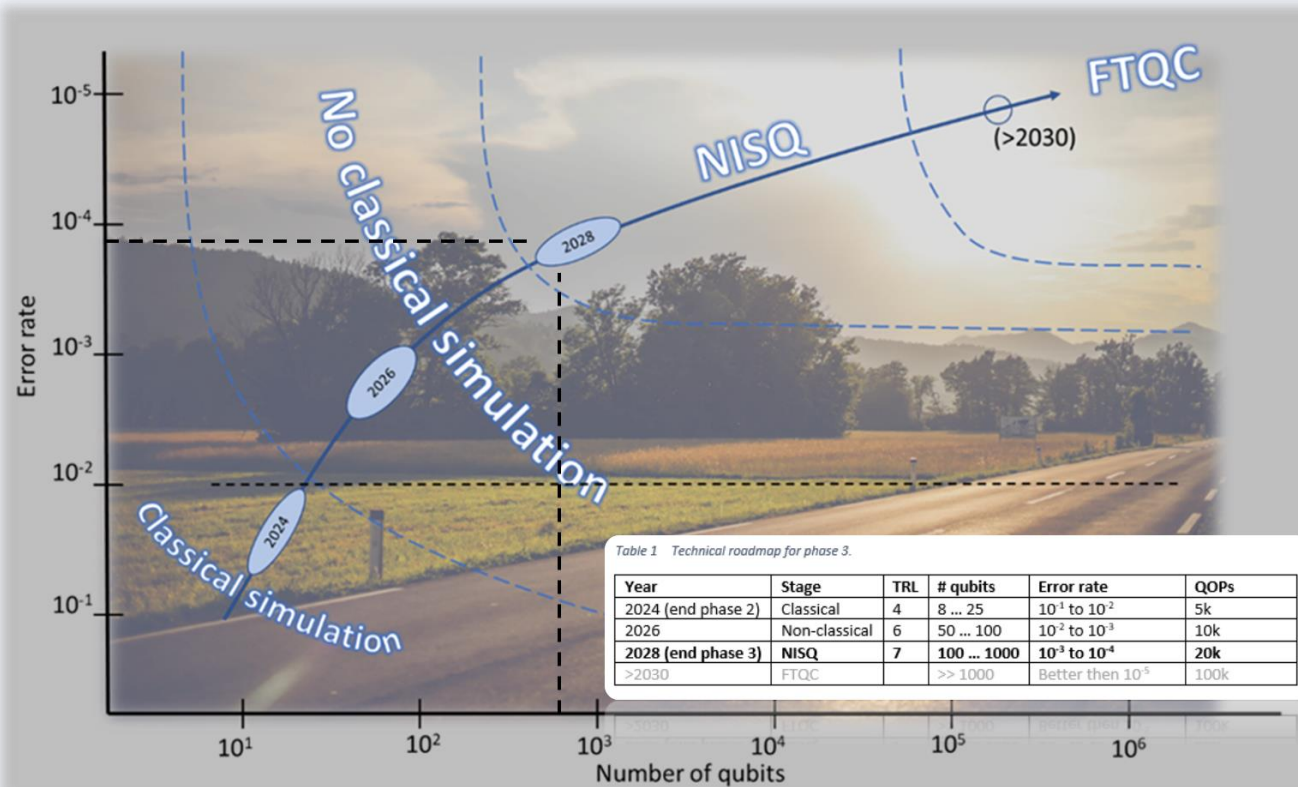
- Started in 2014,
- TNO + TU Delft,
- 250+ people.
- Scientific Director Prof. Dr. Lieven Vandersypen.



QuTech

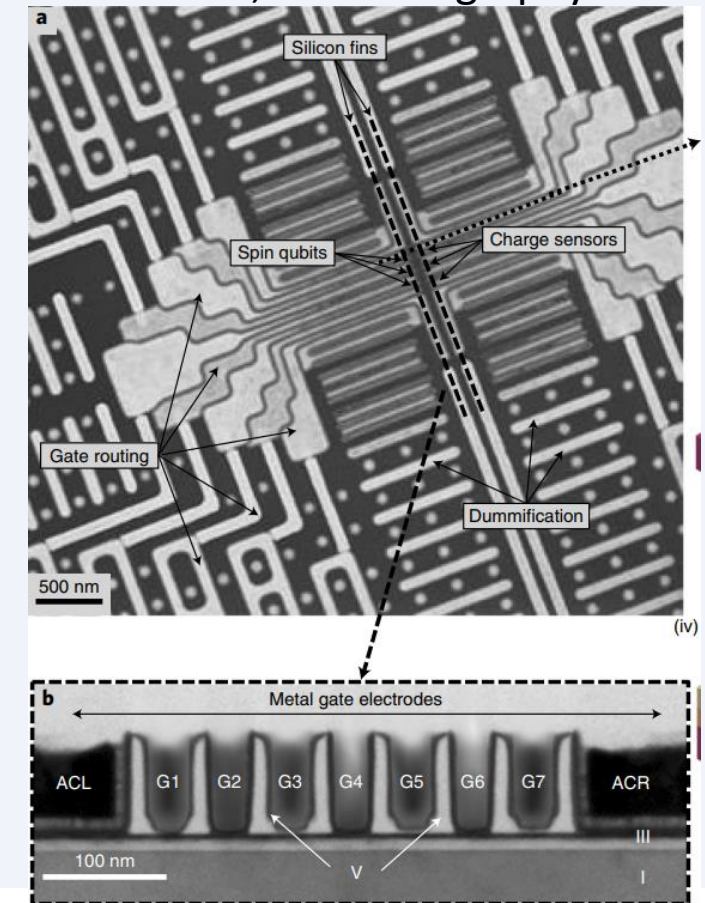


Scalability?

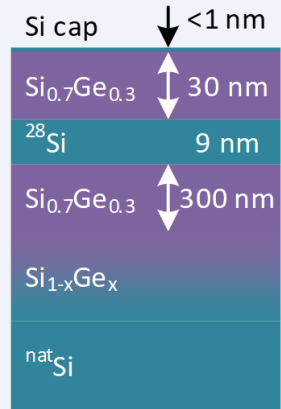


Intel – TU Delft – TNO collaboration:

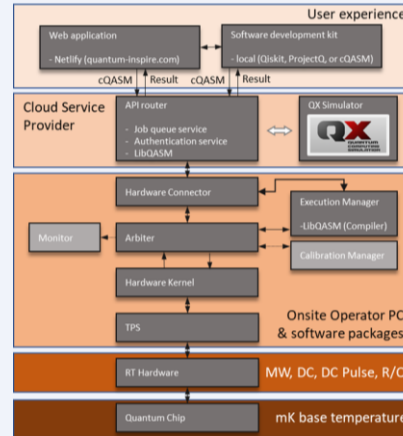
Then world's first spin qubits from 300mm fab, EUV lithography.



TNO/QuTech built Europe's first quantum computer



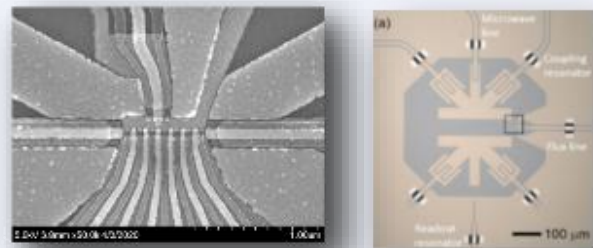
Materials: G. Scappucci



System Architecture & QX Simulator



GUI & electronics



Spin & superconducting qubit devices

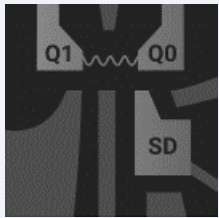


Connection to HPC's of SURF & Hardware

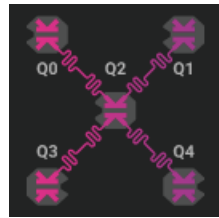




Quantum Inspire

SURF*Available now*

Spin-2
2 qubits



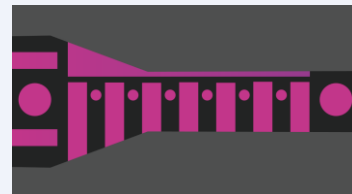
Transmon-5
5 qubits



QX emulator
34 qubits



2024
(selected beta users)



Spin-6
6 qubits

Give it a spin!

Quantum Inspire - By QuTech

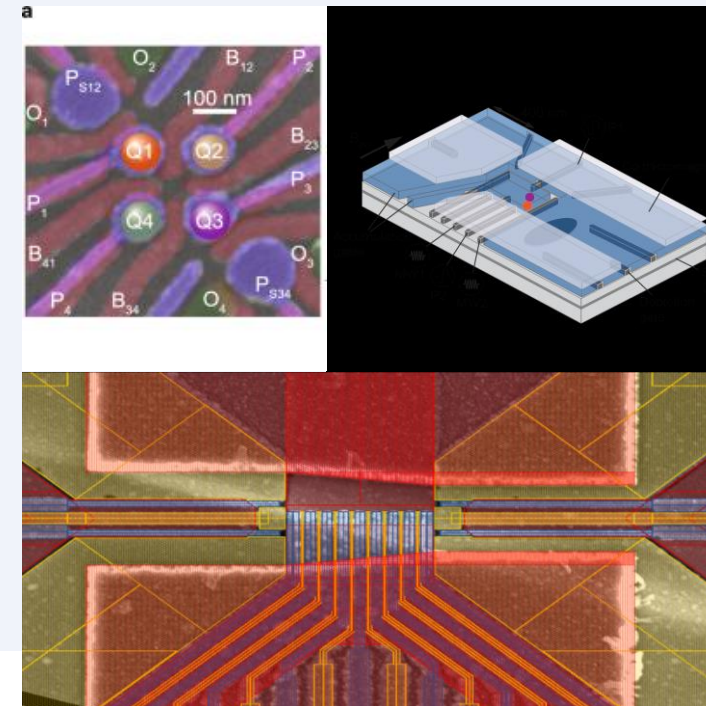
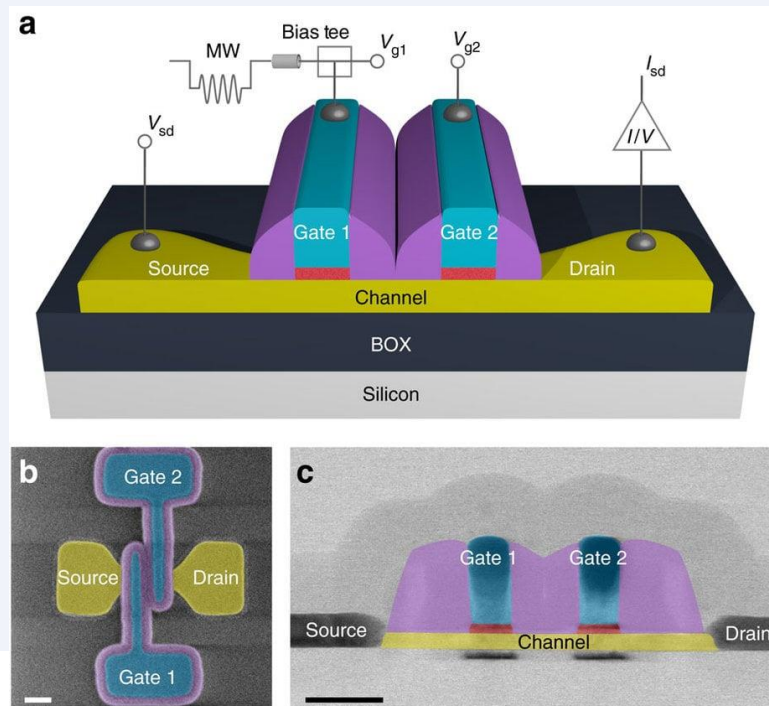


<https://www.quantum-inspire.com>



Scaling (EU projects)

- QLSI2: material platforms by CEA-Leti (FD-SOI) and QuTech (Si/SiGe) for 8 qubits and beyond,
- OpenSuperQPLUS (lead Juelich), connecting European 100-superconducting qubits.



EuroQCS: European Quantum Computing & Simulation Infrastructure

QC



HPC



- 8 sites, different qubit material platforms,
- 20 to 100's of qubits, installed from 2025 on.

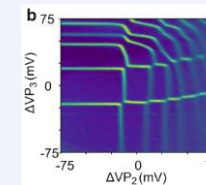
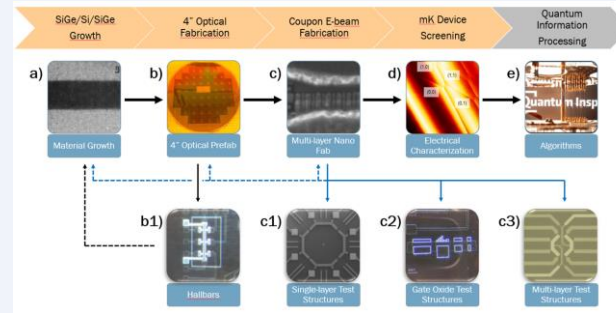
Scaling!

- TNO's QITT: Europe's first quantum testing lab, easy access for SME,
- TNO and VTT lead consortium of European RTO's for pilot line nano-fabrication and testing sites: Qu-Test and Qu-Pilot,
- Spin-off creation, from TNO and TU Delft alone:
- Support private companies



Challenges & synergies with Semicon

- Semicon inspired process flows,
- Metrology & equipment
 - E.g. in ARCTIC, 36 partners, TNO integrates a new 1K, high throughput quantum dot characterization system,
- Tuning & calibration
 - Search for good point in a $2N+1$, path dependent gate-voltage space,
- Application development!



Thank you for your attention



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- QuTech www.qutech.nl
- QDNL www.quantumdelta.nl
- Quantum Flagship www.qt.eu
- TNO Youtube playlist https://www.youtube.com/playlist?list=PLgRS0eU7ETjplNwg0uU9NPiEzQU_iVPhQ
- TNO Semicon film <https://youtu.be/AX31JEwN174>
- EBL2 <https://www.tno.nl/en/focus-areas/industry/semiconductor-equipment/tno-international-centre-for-contamination-control-iccc/eb12-euv-exposure-and-analysis-facility/>



The value chain in more detail

