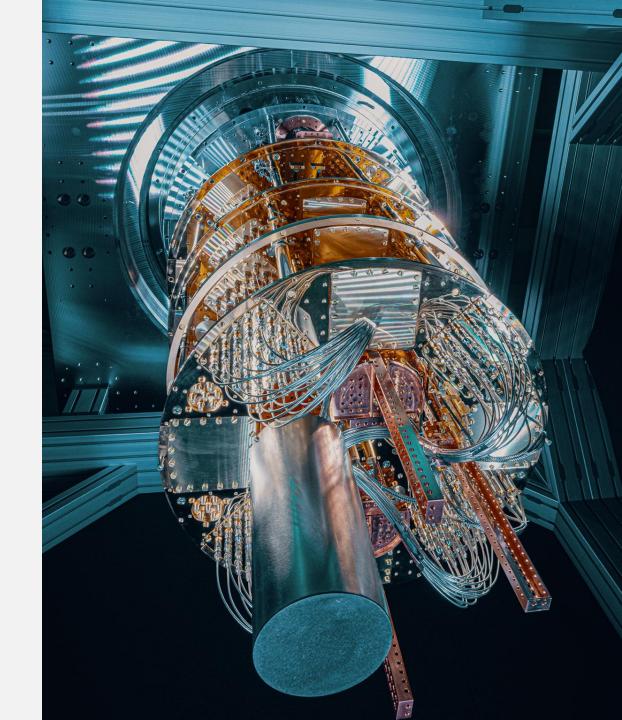
Scaling challenges of quantum computing - IQM approach

TQCI seminar 2024

Hermanni Heimonen Head of Product







Social

How do we educate more experts?

Ecosystem

 How do we avoid painting ourselves into a corner?

Algorithms

 What are the key requirements when implementing algorithms on hardware?

Hardware

This is what you all expect me to talk about

IQM Spark[™]

Start Your Quantum Journey

For universities and research labs

Our **5-qubit** superconducting quantum computer, brings **affordable** and **easy access** to quantum computing with custom learning experiences for future scientists, developers, and innovators.





	2022	2023	2024	2025	2026	2027	2028	2030	2031	2033+
	Foundation				Quantum Utility			Quantum Advantage		
Simulation \$28bn value in 2030	Short to medium-sized molecular simulations (e.g., H2O, LIH, BeH2) and simulations of Ising and fermion models Proof of concept: simulation of battery electrolytes				Medium size molecular simulations and new quantum materials for battery optimization and carbon capture			Drug discovery, catalyst and fertilizers design, carbon capture Development of novel quantum materials, battery materials and energy storage		
Optimization \$18bn value in 2030	System benchmarking, noise characterisation		Proof of concept: power plant maintenance scheduling, Product portfolio optimization, train scheduling			Medium size problems: portfolio optimization, traveling salesperson and graph coloring problems			Advanced logistics and routing, energy grid Glob optimization, risk management, infrastructure and planning, telecom and data center enermanagement	
Quantum Machine Learning \$26bn value in 2030		Proof of concept: p fraud detection	predicting chemical reaction behaviour,		Anomaly detection, feature selection, quantum data encoding, drug discovery, image generation			Bio data generation for training, drug-discovery, personalized medicine, complex market dynamics modelling, optimizing trading strategies, smart cities and autonomous systems		
Software Platform		d-alone	Loose HPC integration	HPC integration guidebook	Tight HPC integration Realtime encoding		Realtime encoding	of QLDPC code		
	algorithm execution Pulse-level access Open architecture and programming fr				nd programming framewo	rk for developers and p	partners			
Processor Layout		\Diamond		\$						
	NISQ			QEC Demonstrators			Fault Tolerance			
Performance	99.8%	99.8%	99.9% Two-qubit gate fidelity	99.92%	99.94%	10 -6	10 -6	10 ⁻⁷ Logical error rate	10 ⁻⁸	10 ⁻⁹
Qubit Crystal Topology	5	20	54	150	300 160+2	1k	5k	40k	100k	1M
count Star Topology			6	24 46	150		JA.	400	100%	JIVI
Logical qubits	Logical qubits Testbeds for 1-2 logical qubits						60-180	240-720	600-1800	2400-7200



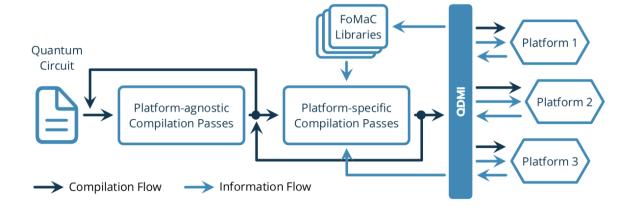


QDMI — Quantum Device Management Interface



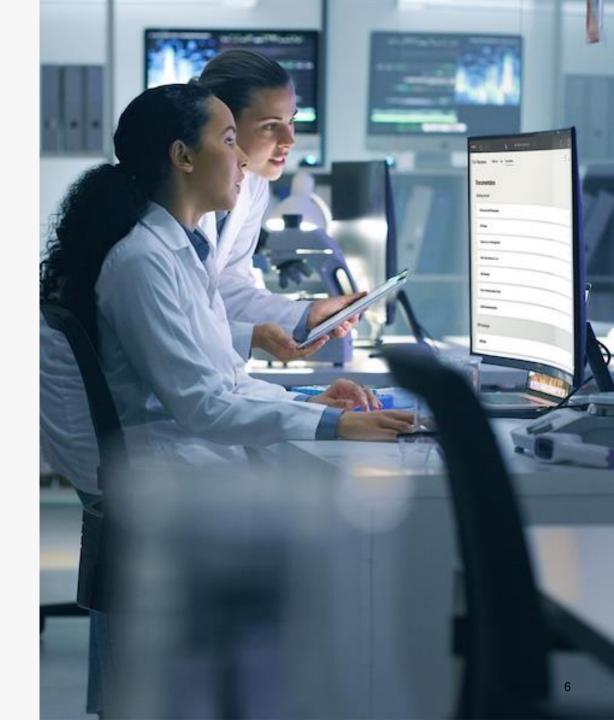
The Quantum Device Management Interface (QDMI) is the central part of the Munich Quantum Software Stack (MQSS)—a sophisticated software stack to connect end users to the wide range of possible quantum devices. It enables the submission to and the control of gate-based quantum systems and enables software tools to automatically retrieve and adapt to changing physical characteristics and constraints of different platforms. QDMI strives to connect the software and hardware developers, mediating between their competing interests, bridging between technologies, and eventually providing corresponding figures of merits and constraints to be considered. QDMI is therefore the method of choice for integrating new platforms into the MQSS and for software tools to query information from these platforms. QDMI is provided as a collection of C header files to allow fast integration into an HPC environment.





Algorithms

- In our (and most player's) roadmap we transition from NISQ to FTQC.
 - But this is not a binary choice!
 - There will be a smooth transition
 - How will EM and partial QEC interplay?
 - Tradeoff: Speed vs fidelity
 - Resource theories missing
- Quantum algorithms must be integrated into hybrid workflows (probably with HPC) without abstracting too far

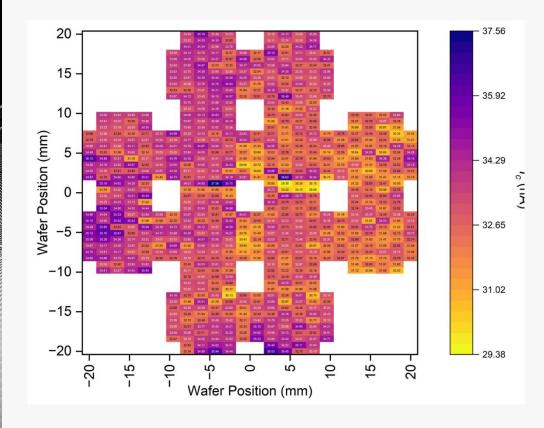


Hardware challenges

- We strongly agree with the previous speakers
- Electronics scaling
 - Current providers go to 1000qb range
 - They can maybe push this to 10 000qb
 - At that range the price will start to overtake all the other components
 - And the reliability needs to be increased dramatically. We cannot have broken control electronics!
 - The electronics also need to be integrated with QEC decoder logic!
- Long-distance couplings for qLDPC codes
 - 3D integration with qubit connections across layers needs to be developed
 - IQM Star making use of computational resonators gives is some basic building blocks
 - IQM Star and IQM Crystal merger for FTQC
- Error rates
 - We see that transmon technology can bring us comfortably into the 99.9%-99.99% fidelity range

Hardware challenges

- Josephson Junction uniformity
 - Even with 100% yield, we will need high enough uniformity
 - The industry will need to learn from semiconductor industry trilayer process
 - IQM has F1 pilot line fabrication facility in operation - Next gen fabrication facility needs to be develop: yield, repeatability, throughput



Let's start your quantum journey together!



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Got questions?

Just contact us!



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