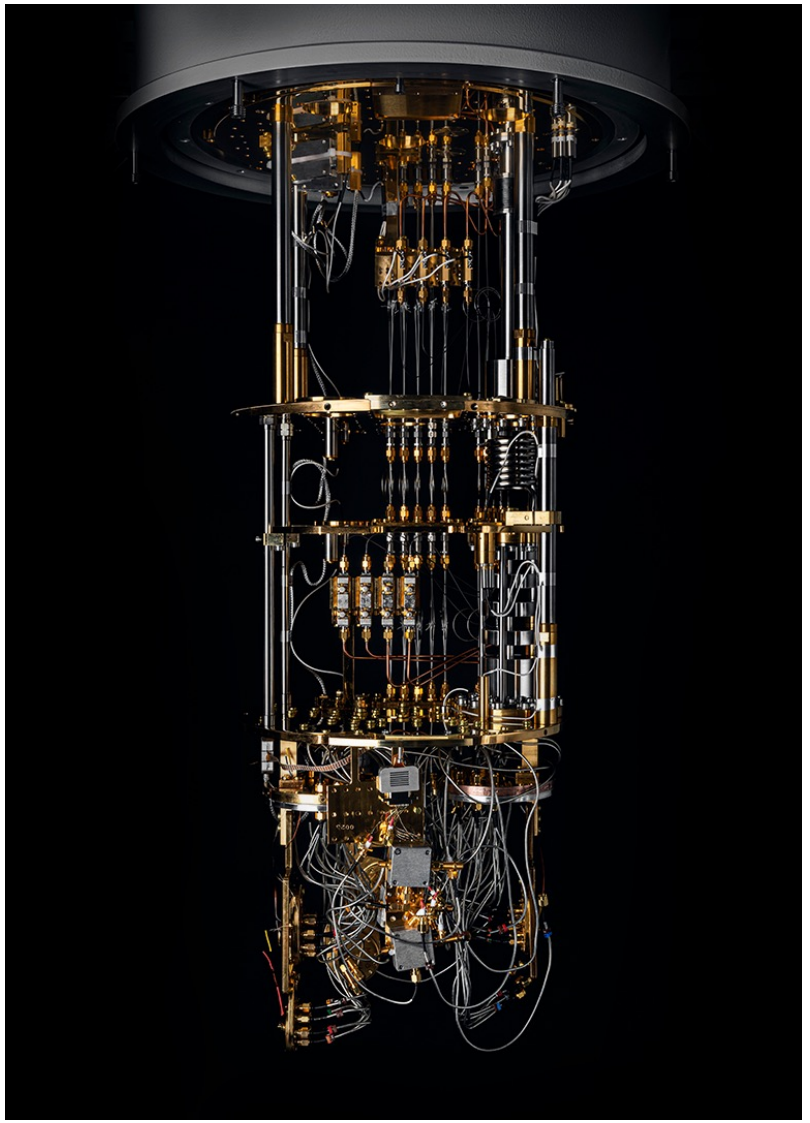
Bringing quantum acceleration to HPC



Dr. Peter Eder

Head of Partnerships, IQM Quantum Computers

peter.eder@meetiqm.com

Company intro

IQM builds and delivers quantum computers

180+ experts

90 PhDs

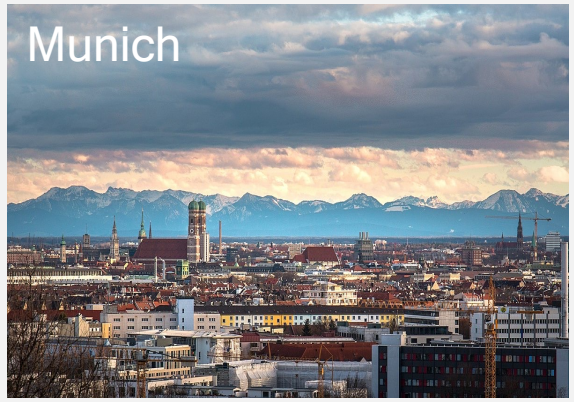
34 nationalities

>100 M€ investment

On-premises & full access

2 systems sold

1 delivered

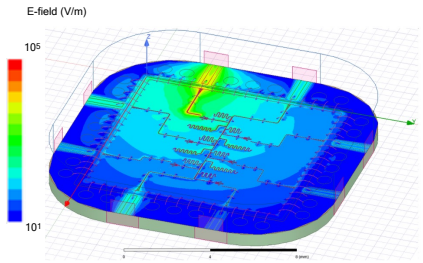


A business strategy to accelerate innovation

Building full-stack systems and delivering them to on-premises to customers
Re-invest the revenue to critical parts of the value chain

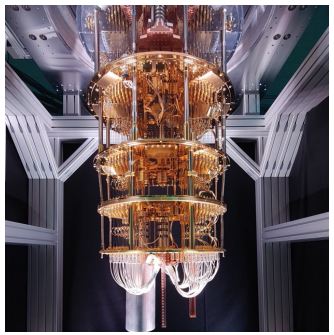
IQM´s strategic value chain:

1) Design of QC chipsets

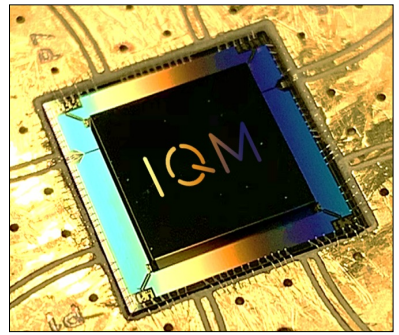


2) Production of QC chipsets**

3) System & HPC integration



4) innovative quantum ASICs



Covering the whole value stack allows for unique hardware-software Co-Design
>50 patent families filed for strategic QC components & implementations to ensure FTO

Accelerated innovation and production cycle

** Strong public support: Europe is start a European Chips Act from the EUR 120bn which was set aside for the semiconductor supply chain as part of Europe's EUR 800bn Covid recovery plan.

First quantum computer in thriving Finnish Quantum Ecosystem now operational

With this milestone, VTT and IQM take a step closer to making quantum computers manufacturable, scalable and more accessible for the world.

ESPOO, Finland (November 30th, 2021) Today, VTT Technical Research Centre of Finland announced that the country's first operational 5-qubit quantum computer is up and running. Together with the quantum computing hardware startup IQM, VTT has taken its first steps to enable the building of quantum computers that will be both scalable and easier to manufacture, allowing more companies to begin their quantum computing journey.

The incredible computing performance of quantum computers makes it possible to solve problems that are beyond the capabilities of modern high-performance computers. In the future, quantum computers will be used, for instance, to accurately model viruses and drugs or used to design materials that are challenging to design with today's technology.

Product plans

MARKETS & CUSTOMERS

- National labs & research centers
- Private HPCs & HPC suppliers
- Enterprises with HPC needs

IQM PRODUCT LINES

- "IQM research"
- "HPC Integration"
- "Quantum ASICs"

Tactic → **Plans** → **Strategy**

- Distribution channels
- Software stack: In-house & partnering
- Universal approach for processor
- Application-specific approach for processor

Product-market fit

- On-prem vs cloud
- Use cases
- Technology Readiness Level (TRL) of IQM
- Market sizes

Distribution Channels	On-prem	Off-prem
Rented	Rent/Lease	Cloud
Owned	Classic sales	Co-Location

IQM

Strategy

today 2030

FOUNDATION

Commercialize early quantum computers for research and education

to create ecosystems and to build technological and business capabilities required for quantum advantage

ADVANTAGE

Enable special-purpose quantum advantage for key customers

to kickstart the spread of useful quantum computing and accelerate its benefits through co-design

DISRUPTION

Provide full quantum advantage for everyone

to advance the world to a new technological era with quantum computing

COLLABORATION **TRUST** **AMBITION**

We build world-leading quantum computers for the wellbeing of humankind, now and for the future

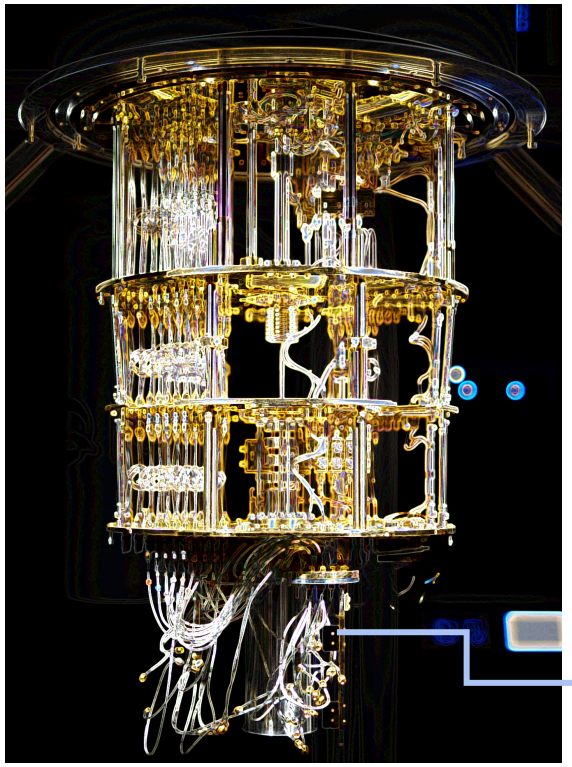
Our tech

How does a Quantum Computer look like?

- ✓ Cryogenic environment: 20mK (temperature in open space 2.7K)
- ✓ Shielded from environment
- ✓ Vacuum

- ➢ Let us look inside!

How does a Quantum Computer look like?



2-4 K

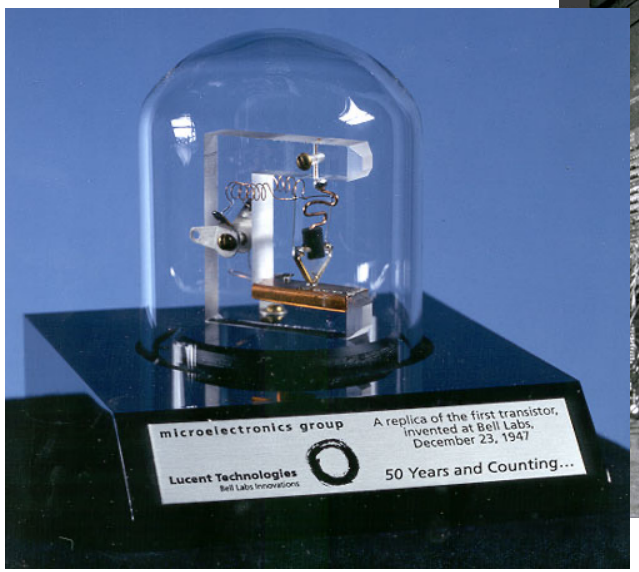
800 mK

100 mK

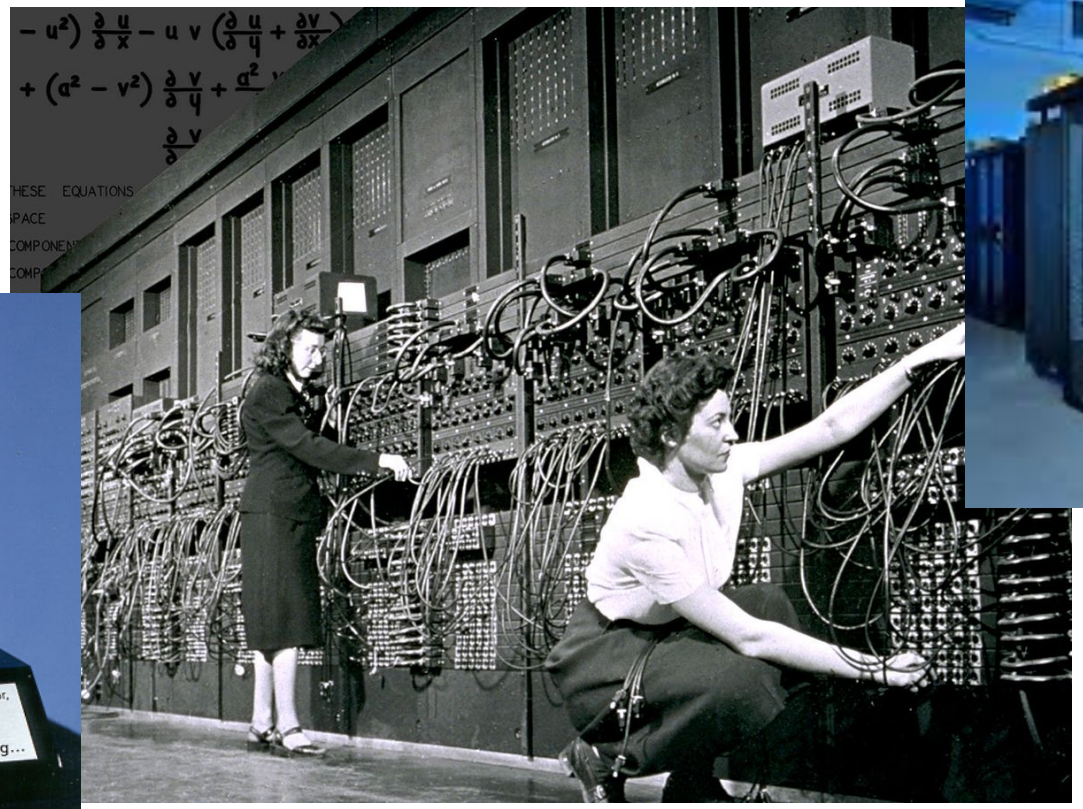
15-20 mK

Quantum processor sits inside a shield that protects it from EM radiation

Don’t forget about history



First Transistor (1948)



TRADIC (1954)

SUPERMuc at LRZ (2020)

Strategic advantage: private quantum foundry in Europe

Drivers:

Quantum processors are too complex for public or university cleanrooms.

Low availability, chip shortage

AUTOS APRIL 9, 2021 / 7:52 PM / UPDATED 2 DAYS AGO

White House convening summit with top execs on chip shortage

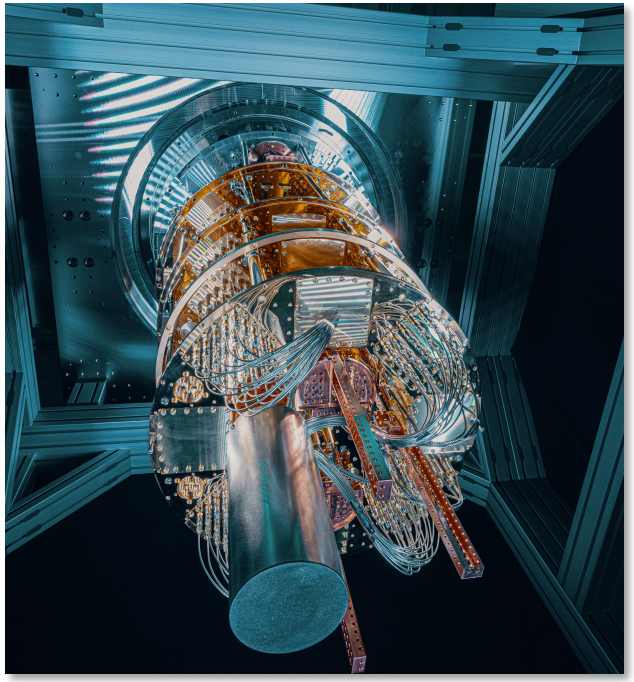
By David Shepardson 3 MIN READ

WASHINGTON (Reuters) -Almost 20 major companies worried about a global semiconductor chip shortage that has roiled the automotive industry will send senior executives to a White House summit Monday, a senior official said on Friday.

Efficient IP generation

Advantages:

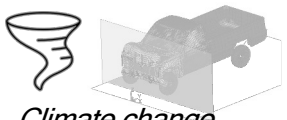
- Accelerates design & production cycle
- Guarantees production stability
- Know-how generation and possibility for foundry service
- Reinforces the in-house developed quantum design automation



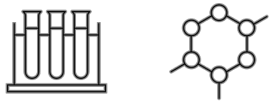
HPC integration

Why HPC & quantum?

HPC centres solve the challenges of tomorrow …



Climate change
& crash simulations



Drug discovery, simulations
& molecular dynamics

$$\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2} + f(t,x)$$

Finance, PDEs
& optimization problems

HPC tasks have a large overlap with quantum solutions
Quantum computing will augment a growing USD 40 Billion* market.

76% of global HPC centers will use quantum computing by 2023***

Painpoints to be solved:

- ↳ HPC centers must scale their computing power to stay competitive, creating a strong innovation pressure
- ↳ Next generation HPC hardware gives only incremental improvement, yet being too bulky & too energy comsumptive
- ↳ Quantum computers offer exponential computing power for HPC centers but are hardly available

Vision: IQM quantum computer in an HPC center

* https://www.hpcwire.com/2019/06/18/at-isc-for-the-hpc-industry-these-are-the-good-old-days/
** https://www.nextplatform.com/2021/07/16/hpc-at-the-heart-of-tsmcs-growth/
*** https://www.meetiqm.com/technology/iqm-atos-state-of-quantum-research-2021/

Quantum acceleration

QUANTUM COMPUTING:

New computing paradigm using quantum bits (qubits) as computation elements.

Promise of up-to **exponential** scaling improvements.

HYBRID QUANTUM-CLASSICAL ALGORITHMS:

QC are good at specific tasks.

These tasks are part of larger, **complex computations**.

HPC workflow **offloads** relevant tasks to **quantum accelerators**.

CONCLUSION:

QC needs to be **integrated** to HPC systems.

Development needs to start **now** to increase benefits when **quantum advantage** is available.

Challenges

MINDSET CHANGE:

New paradigm – back to algorithmic drawing board.

USER AWARENESS & ENGAGEMENT:

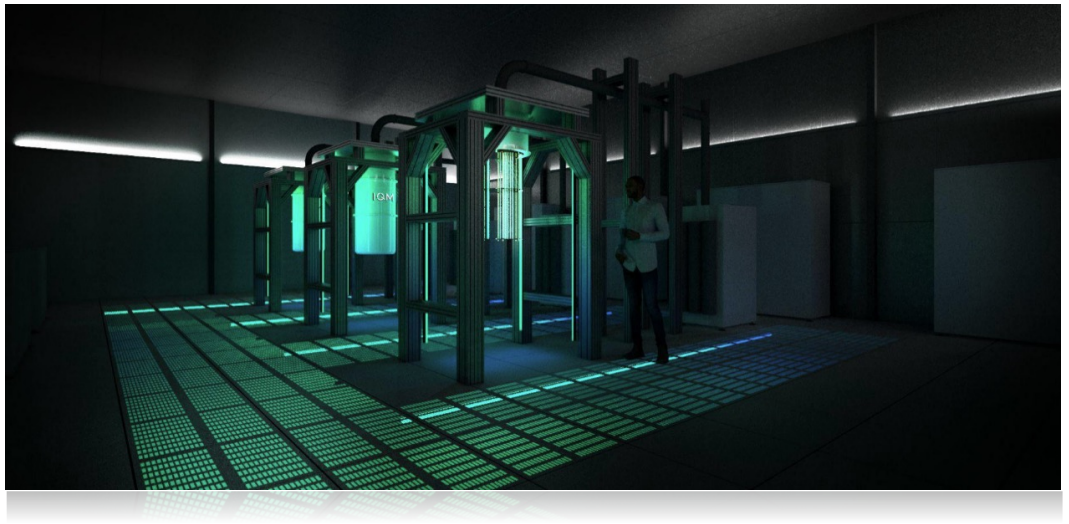
Simplified user interface.
Strong educational support.
Single programming environment.

DEPLOYMENT MODEL:

On-premises v. remote v. deep integration.

RESOURCE MANAGEMENT:

Communication protocols.
Scheduling for jobs with stochastic runtimes.
Management of an increasing number of QCs.
Different QCs can have very different specs and be good for specific classes of applications.



76% of HPC Centers to adopt quantum technologies by 2023

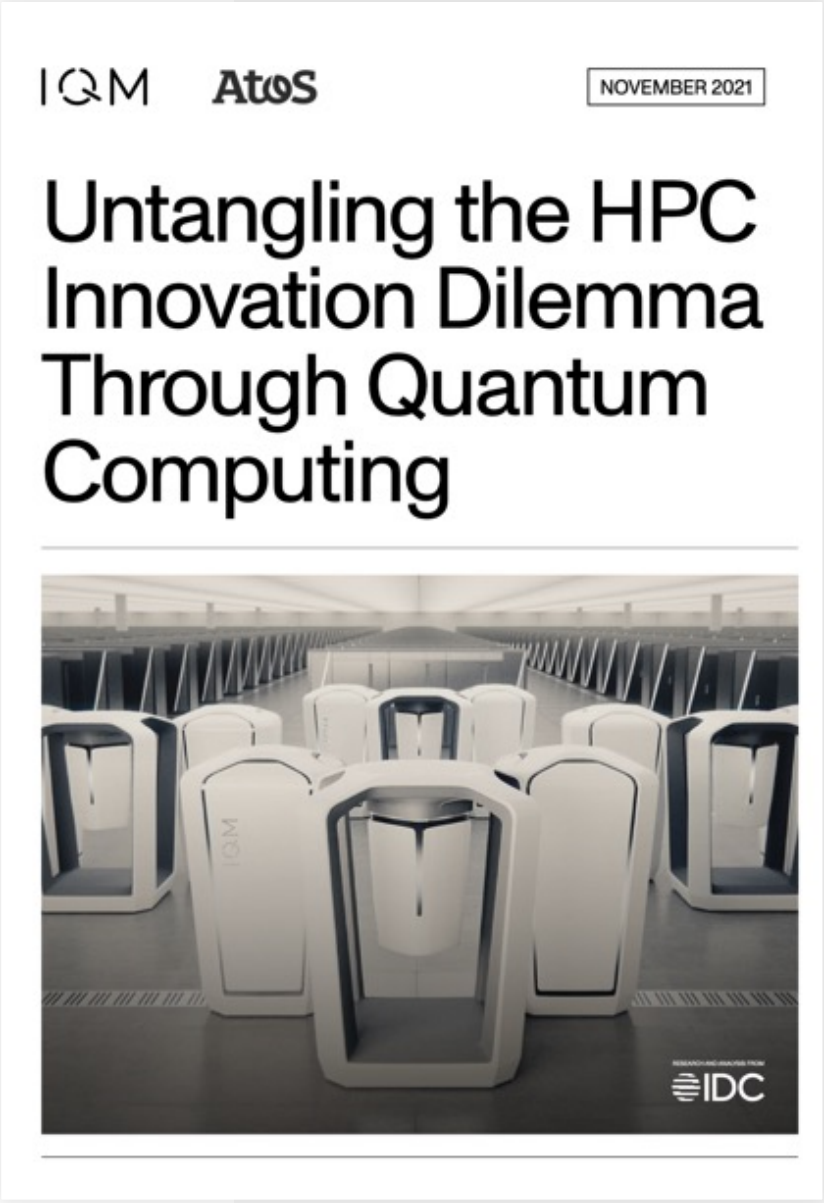
IQM, as the global leader in on-premises quantum computers, is well equipped to seize the HPC opportunity. Study findings:

- HPC centres face an increasing pressure to radically innovate their infrastructure, that is currently characterized with long time to output, low energy efficiency, and high capex requirements

- **110 HPC centres** worldwide, in our latest research list quantum computing as one of the solutions to address their innovation challenge

- **76%** of the HPC Centers globally will adopt quantum technologies by 2023. Study revealed that one third of the HPC centres have already begun experimentations

- **71%** of the HPC centers will adopt on-premises infrastructure by 2026, due to the notable benefits of on-premises solutions, such as high bandwidth, low latency, and broad availability



On-premise systems

First sale of a quantum accelerator to HPC

20-qubit accelerator to be delivered by mid-2024

IQM won the public tender arranged by BMBF to build the world's first quantum accelerator to HPC.

Project includes integration of simulation software components (HQS) and hardware (Atos QLM) as well as use-case evaluation.

The 45M EUR project will provide on-site solutions for quantum computing in conjunction with supercomputers which is essential for the development of cutting-edge high-tech solutions from Europe.

2022	2023	2024
INTEGRATION DESIGNS READY	20-QUBIT QUANTUM ACCELERATOR	FINAL ON-SITE ACCEPTANCE

Fast Lane to Quantum Advantage

IQM Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften MAY 2022

Bringing quantum acceleration to supercomputers

MARTIN RUEFENACHT[1], BRUNO G. TAKETANI[2], PASI LÄHTEENMÄKI[3], VILLE BERGHOLM[3], DIETER KRANZLMÜLLER[1], LAURA SCHULZ[1], AND MARTIN SCHULZ[1,4]

[1] *Leibniz Supercomputing Centre, Garching near München, Germany*
[2] *IQM, Nymphenburgerstr. 86, 80636 Munich, Germany*
[3] *IQM, Keilaranta 19, 02150 Espoo, Finland*
[4] *Technical University of Munich, Garching near München, Germany*

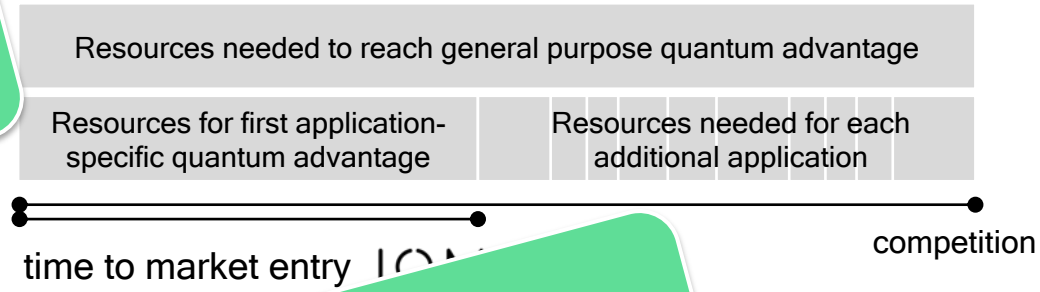
How to unlock industry applications?

First-to-market in selected applications using a fast lane to quantum advantage

IQM approach

- hardware efficie
  (QuASIC

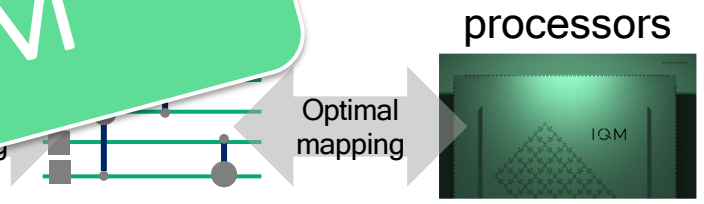
Q-Exa



Reasonin

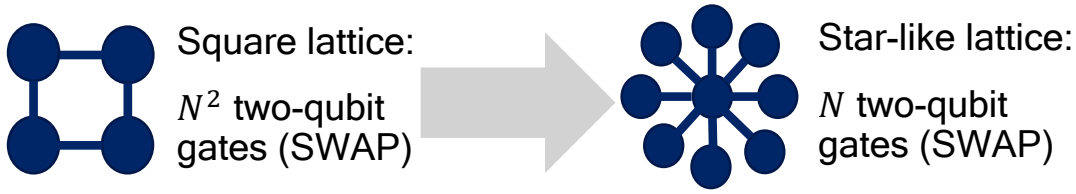
- Fast Lane t quantum advantage for each application
  - Less qubits required compared to general-purpose approach
  - Fewer gates required compared to general-purpose a
  - Required specs will be reached sooner in IQM´s R&D r
- Faster time to market for industry applications

TAQO-PAM



Example

- Adopted chip geometry to reduce hardware overhead
- Algorithm for improving NMR imaging:
  → Better gate efficiency by using a star-like chip geometry



Thank you for tuning in!

www.meetiqm.com

WE ARE HIRING!

Bruno G. Taketani

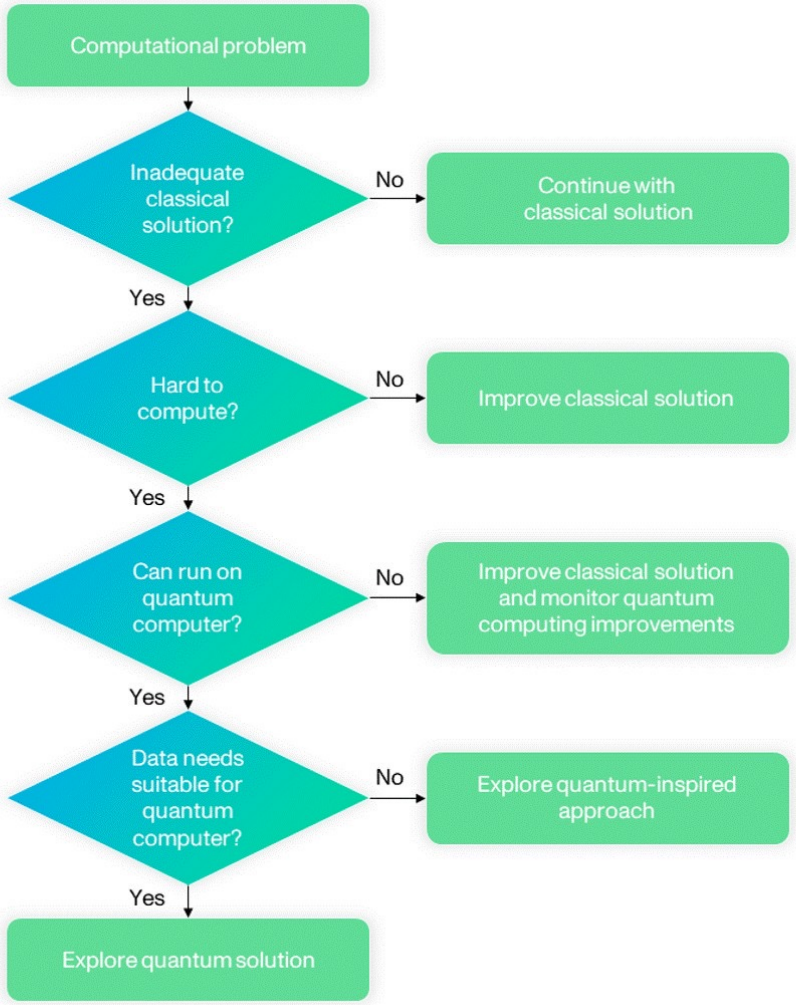
HPC Integration Lead

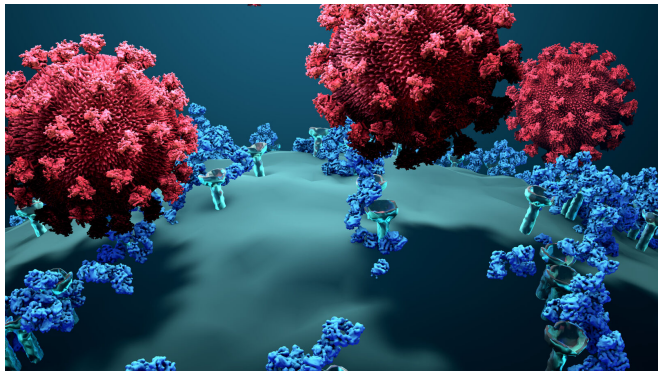
bruno.taketani@meetiqm.com

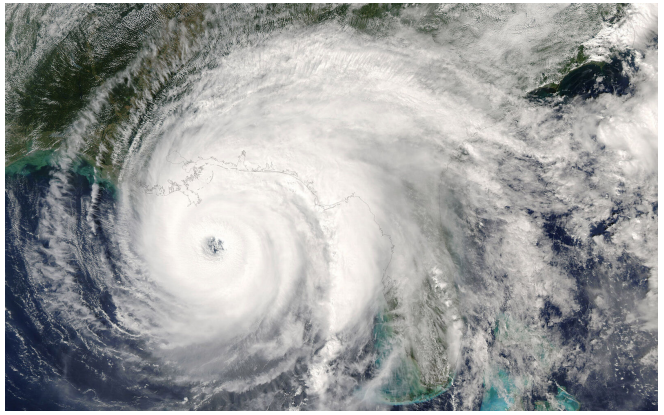
www.meetiqm.com

Backup

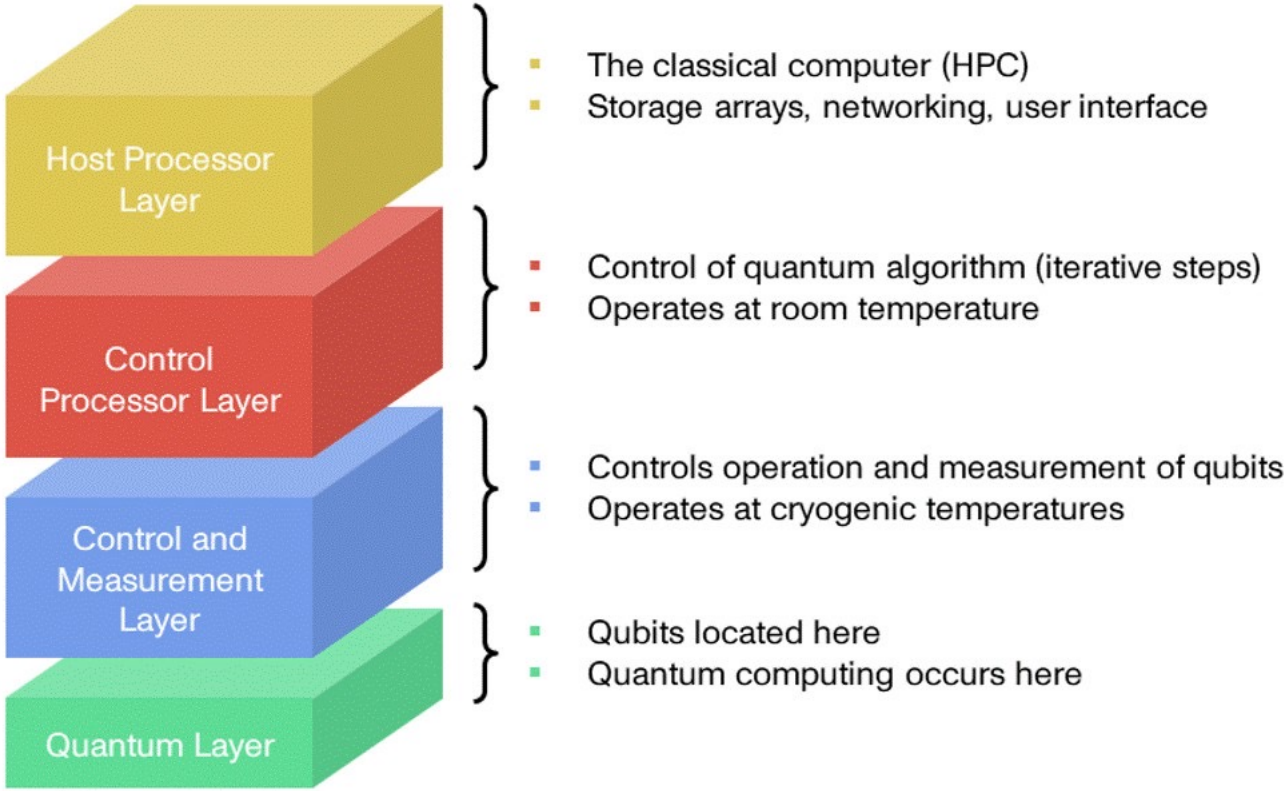
When to utilize quantum?



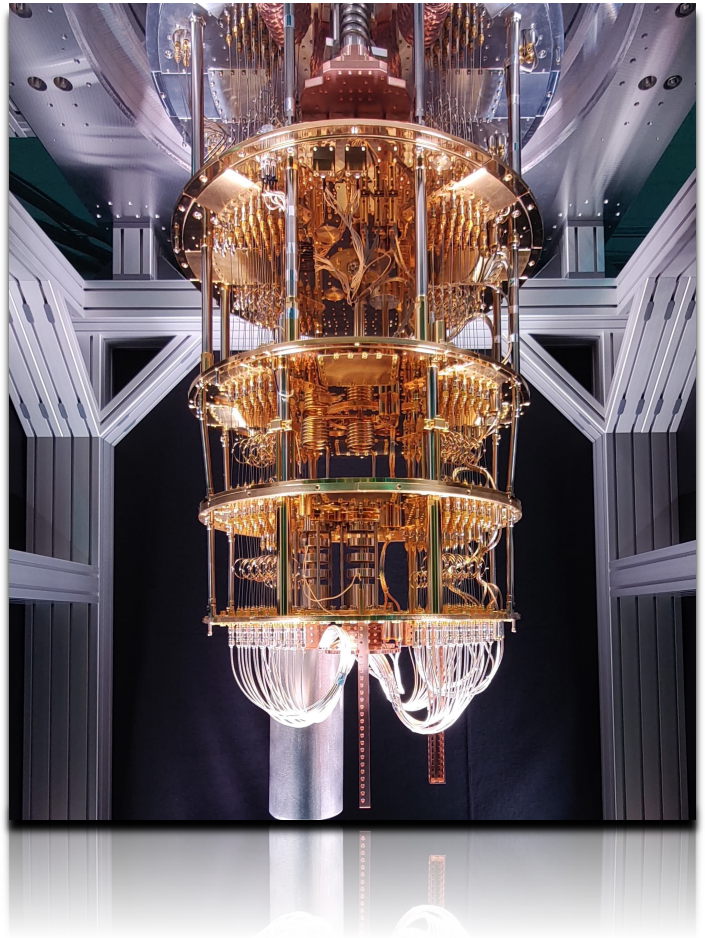




How to implement the quantum computing system

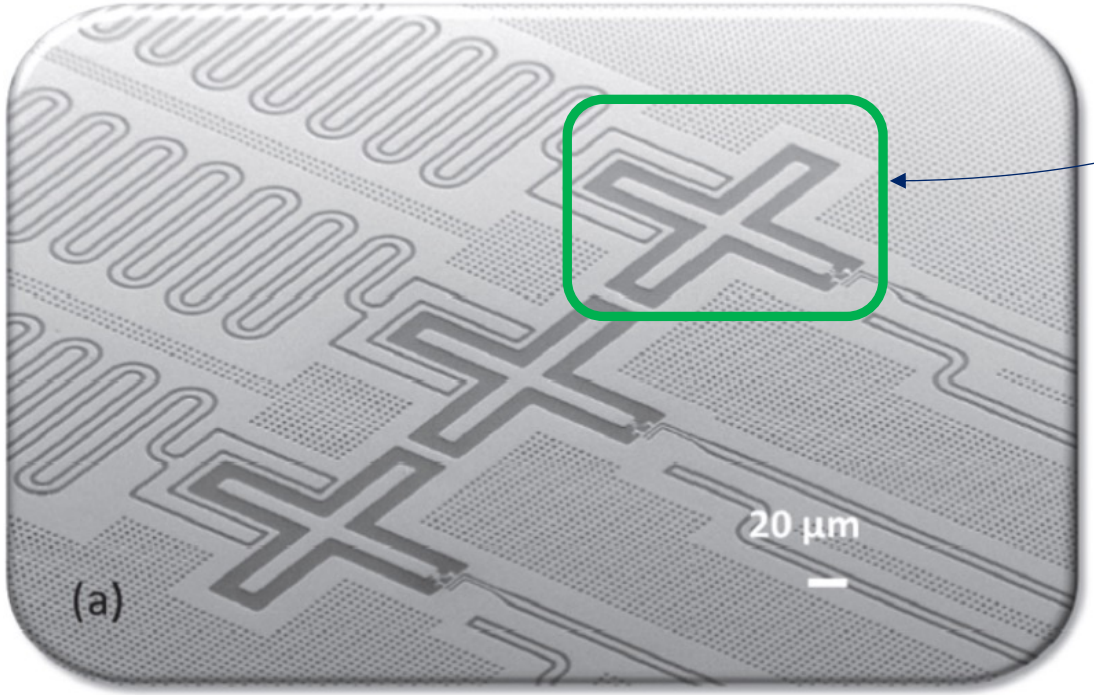


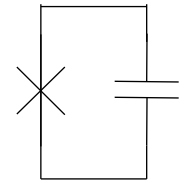
IQM QUANTUM COMPUTER



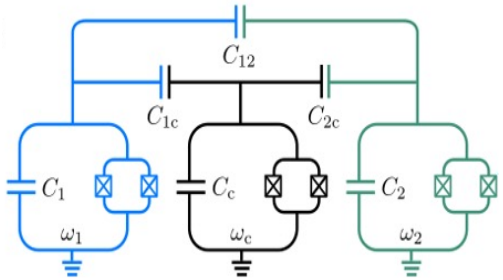
Superconducting qubits as ICs

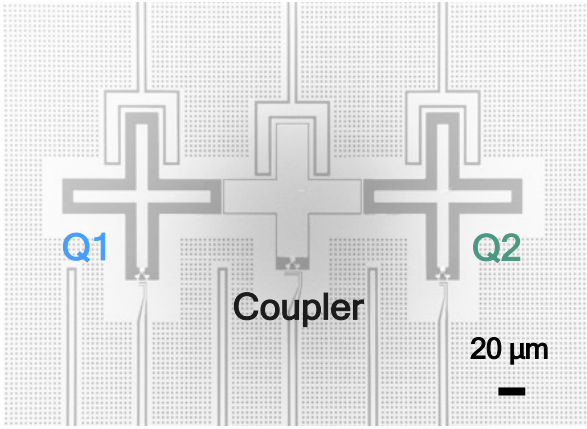
- **Physical implementation of qubits as superconducting integrated circuits**





Josephson junction X is the nonlinear inductance (A transmon qubit)





Two-qubit gate with a third qubit as flux-tunable coupler