INTO THE COLD

CHILLING AT THE JÜLICH SUPERCOMPUTING CENTRE

DEC 2024 I DR. DAVID RABANUS

Mitglied der Helmholtz-Gemeinschaft

JÜLICH Forschungszentrum
Wandel gestalten

NEEDS TO FREEZE

For computing:

Quantum computers or annealers → Isolation from ambient conditions → Increased lifetime of quantum states → More complex operations possible

For supporting tech:

Supporting, ancillary electronics circuits → I/O, supply voltages, microwave pulse trains → Proximity to quantum chips within cryostat → Higher integration density for improved scaling

FROSTY COMPUTING FRONTIERS

Roles of, and activites at, the JSC-CryoLab: Operation of research quantum computers

- **CQC project. A public-private partnership for the *integration exercise*.**
- **JUSPARK. The turn-key system by IQM, for *research and young talent training***
- **EPIQ, a development partnership for an *ion-trap* quantum computer**
- **ARQUE-5: spin-based quantum computer based on *electrons in silicon***

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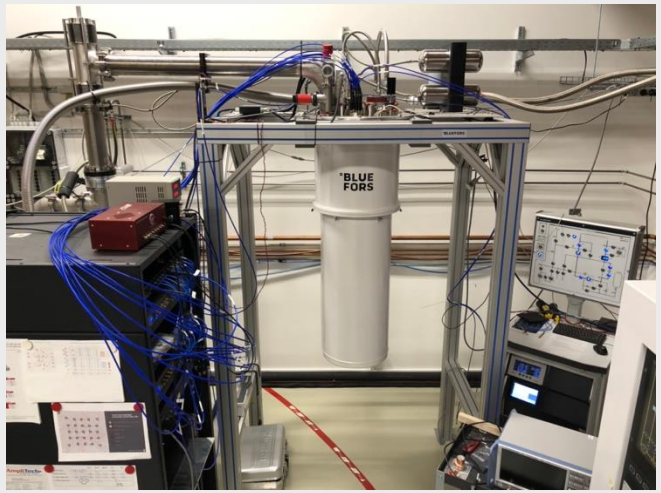
Roles of, and activites at, the JSC-CryoLab: Operation of research quantum computers

CQC project. A public-private partnership for the *integration exercise.*

- CQC has built a component-based superconducting quantum computer ("System"), deeply integrated directly into an HPC environment ("Hybrid").
- Part of the exercise: sourcing components exclusively in Europe.
- **Since OCT 2023**



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  - A quantum computer with 5 superconducting qubits and tunable couplers. An affordable platform for training and research. Access to all hardware components and possible exchange of components for research purposes including read-out electronics.

  - Access to all software layers, including the Microwave pulse library.
  - Upgrade option to 20 Qubits – reuse of the cryostat and part of the control electronics.

  Since SEP 2024

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EPIQ, a development partnership for an *ion-trap* quantum computer

A quantum computer by eleQtron, based on
- trapped,
- laser-cooled,
- microwave-controlled
- Ytterbium ions, with
- up to 32 qubits and
- full all-to-all connectivity.

Coming in 2025

Mitglie

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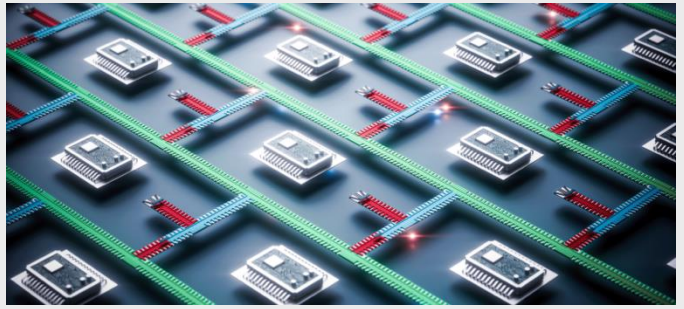
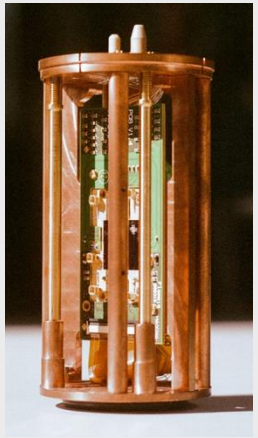
  A quantum computer by ARQUE Systems, with
  - qubits made from electron spins,
  - in a Si/Ge heterostructure,
  - with unique electron shuttling concept:

  A novel spin-bus-platform.

  Coming in 2025





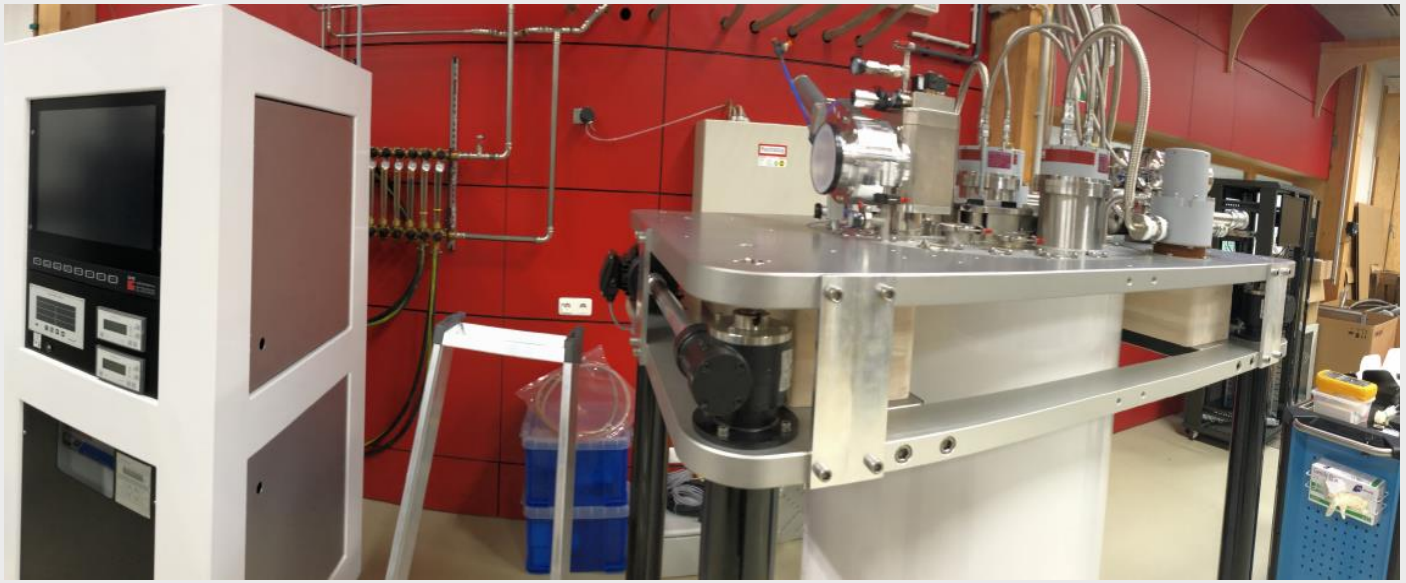
SCHOOLING FOR COOLING

GCC, the German Course of Cryogenics Cryostat: versatile for *training, testing, development*

A cryogenics format for young talent, aiming at stakeholders of the whole value chain:

- apprentices,
- vocational trainees,
- students of engineering and sciences
- corporate lifelong learners

Since OCT 2023



WHAT NEXT? ANYONE ELSE IN FOR A CHILL?

WHAT NEXT? ANYONE ELSE IN FOR A CHILL?

(You bet!)

COOLER, FASTER, BETTER

Overclocking? Extra cooling?

Cooling+Overclocking processing units

- yields only marginal improvements
- increases power consumption disproportionately

Unless you get to cryogenic temperatures

- and reach temperatures low enough for superconduction (SC).

COOLER, FASTER, BETTER

Overclocking? Extra cooling?

Cooling+Overclocking processing units

- yields only marginal improvements < 20%
- increases power consumption disproportionately

Unless you get to cryogenic temperatures

- and reach temperatures low enough for superconduction (SC).
- ...and somebody figured out how to make a supercond. transistor!

SPOILER ALERT!

Somebody did figure out how to make a superconducting transistor!

Ref: Scaling NbTiN-based ac-powered Josephson digital to 400M devices/cm2 (arXiv:2303.16792v2)

NEXT STATION:

Fast superconducting computing (digital)

- Imagine 50-100 GHz clock rates (30 GHz published)
- Think of scalar CPU applications:

  Molecular dynamics

  Matrix multiplications

  (...)
- Imagine this integrated as module into our HPC environment.
- SC transistors resilient to high energy radiation: space applications?

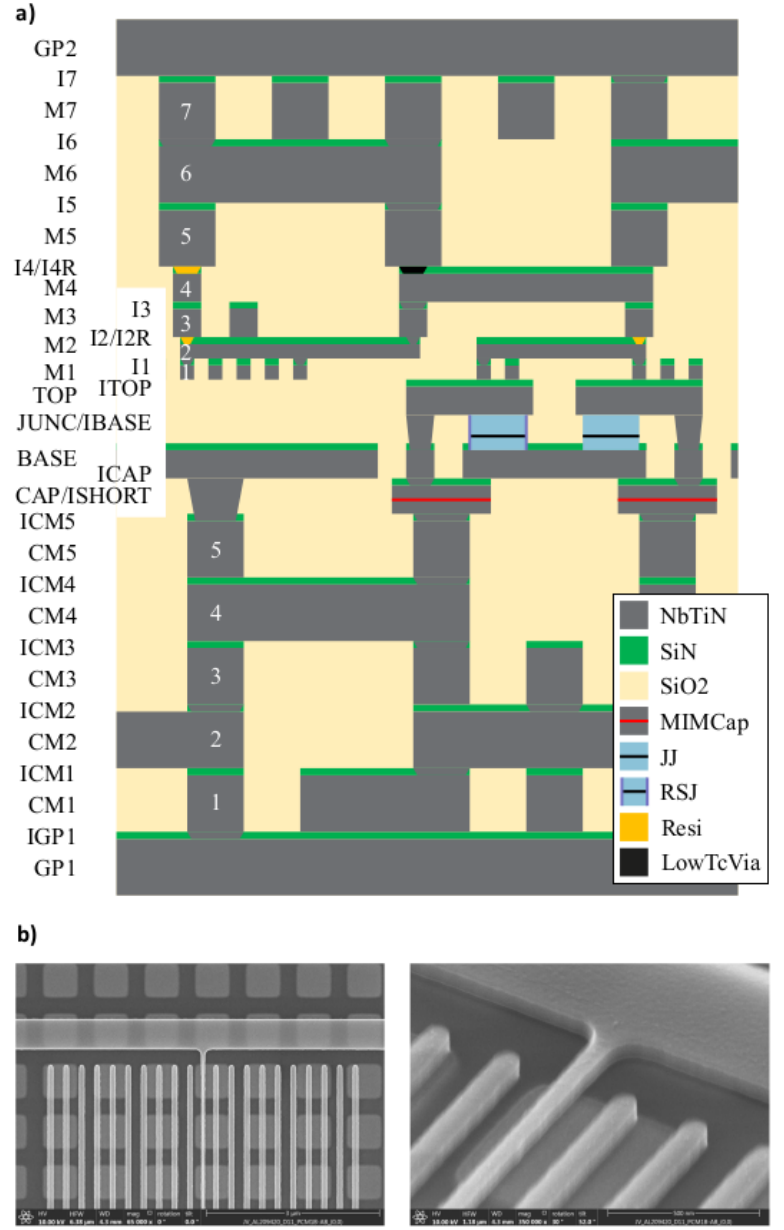


FIG. 1. Fabrication stack. a) The proposed fabrication stack has 16 metal with power distribution layers on the bottom, tunable capacitor and JJ at the center, and wireup layers on top. b) SEM images of two metal layers with 50 nm critical dimension.

OUTLOOK

For fast superconducting computing (digital)

- Systems engineering towards higher TRLs, with modularity in mind
- Ancillary components and subsystems (I/O, memory, bus architecture)
- Thermal design and verification
- Integration testing
- Compiler development

THAT’S WHAT WE’RE DOING:

Chilling at the Jülich Supercomputing Centre

Thanks for your attention.