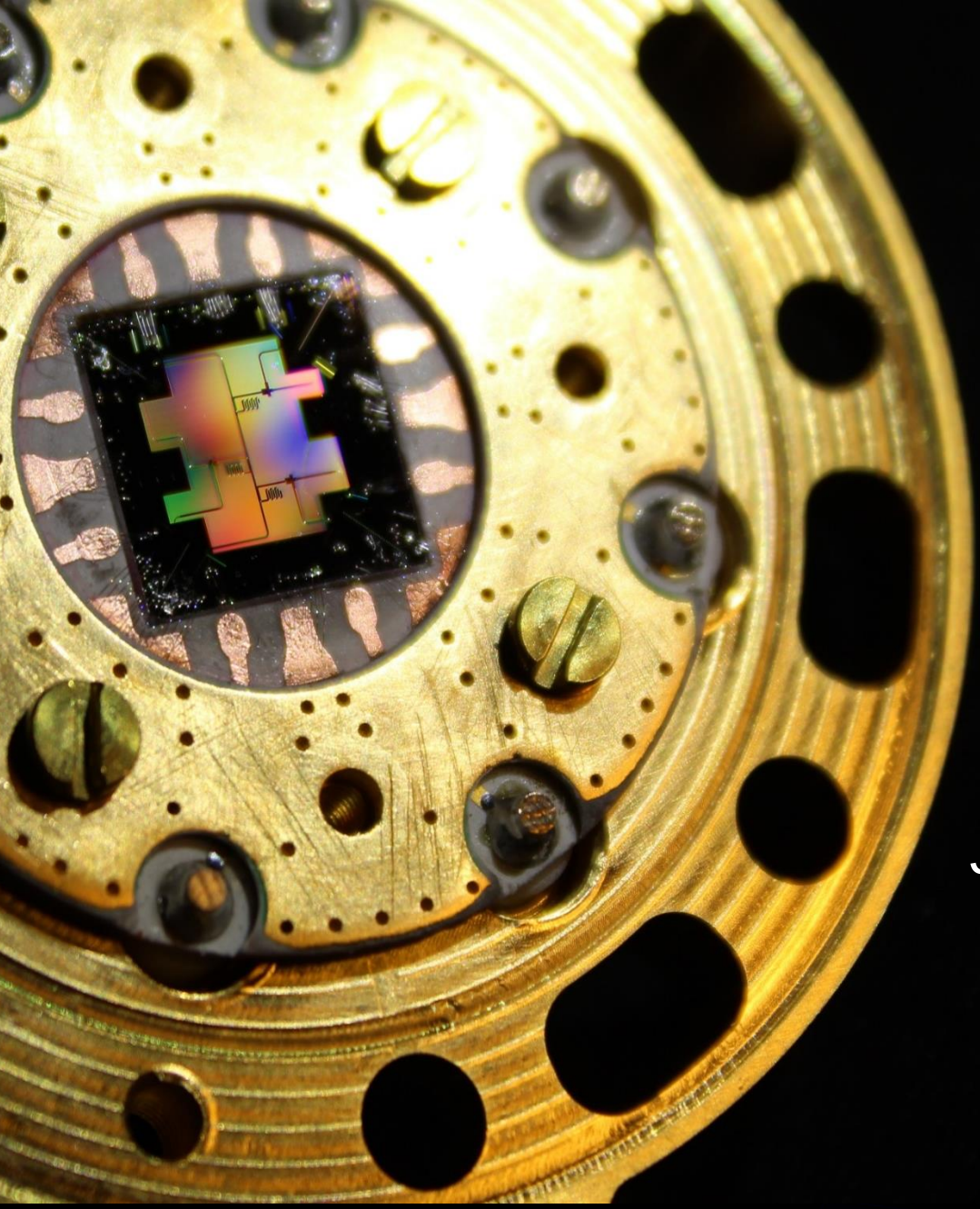


Quantum Computing

Mikko Möttönen

VTT Technical Research Centre of Finland

Joint **Professor of Quantum Technology** at

Aalto University and

VTT

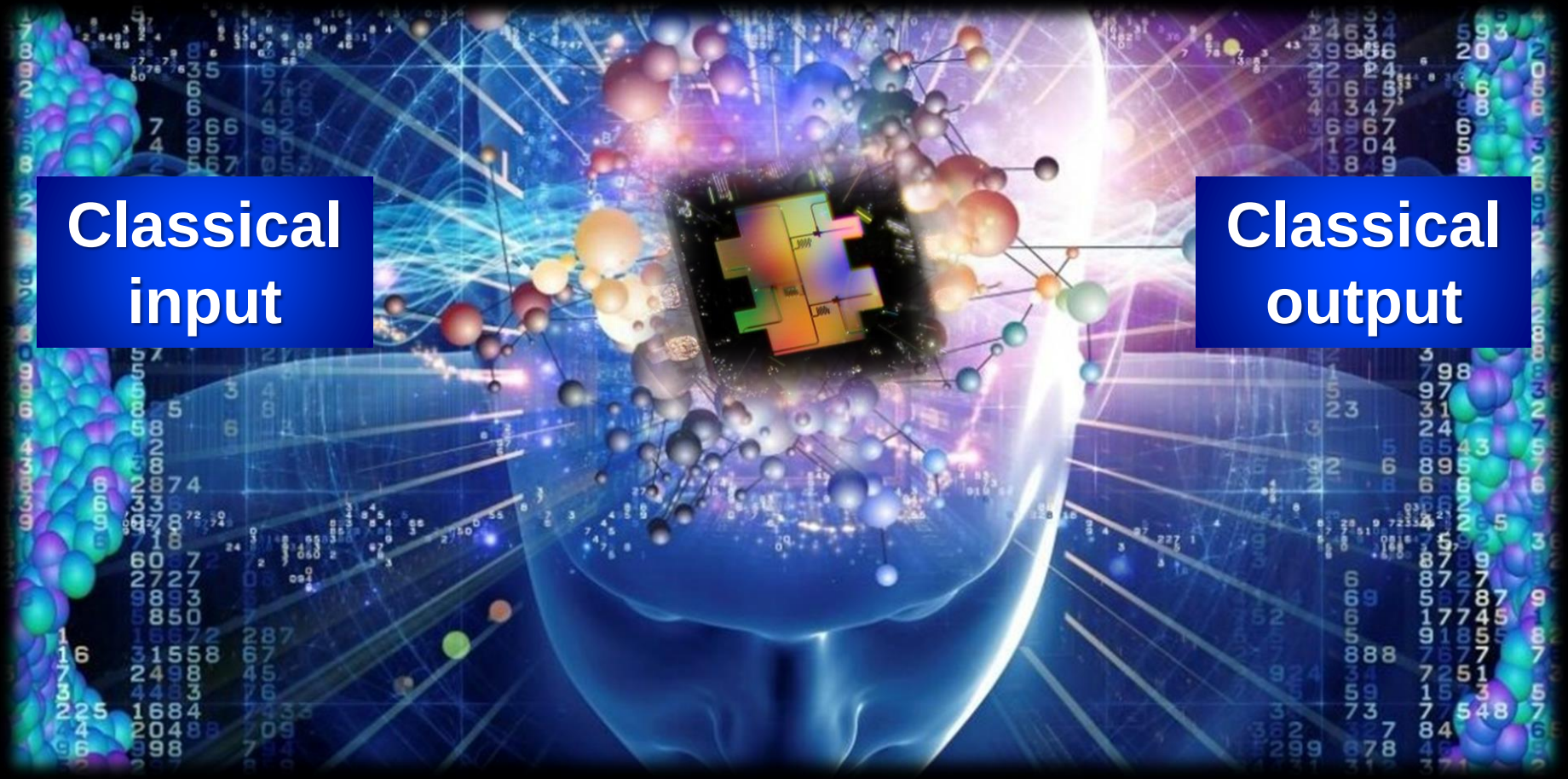
Aalto University School of Science

VTT

Figure credit: Jan Goetz

QCD Labs

Quantum computing



Credit: Jan Goetz/Aalto University

Molecular thoughts, credit: Agsandrew

Aalto University School of Science

VTT

QCD Labs

Quantum bit = Qubit

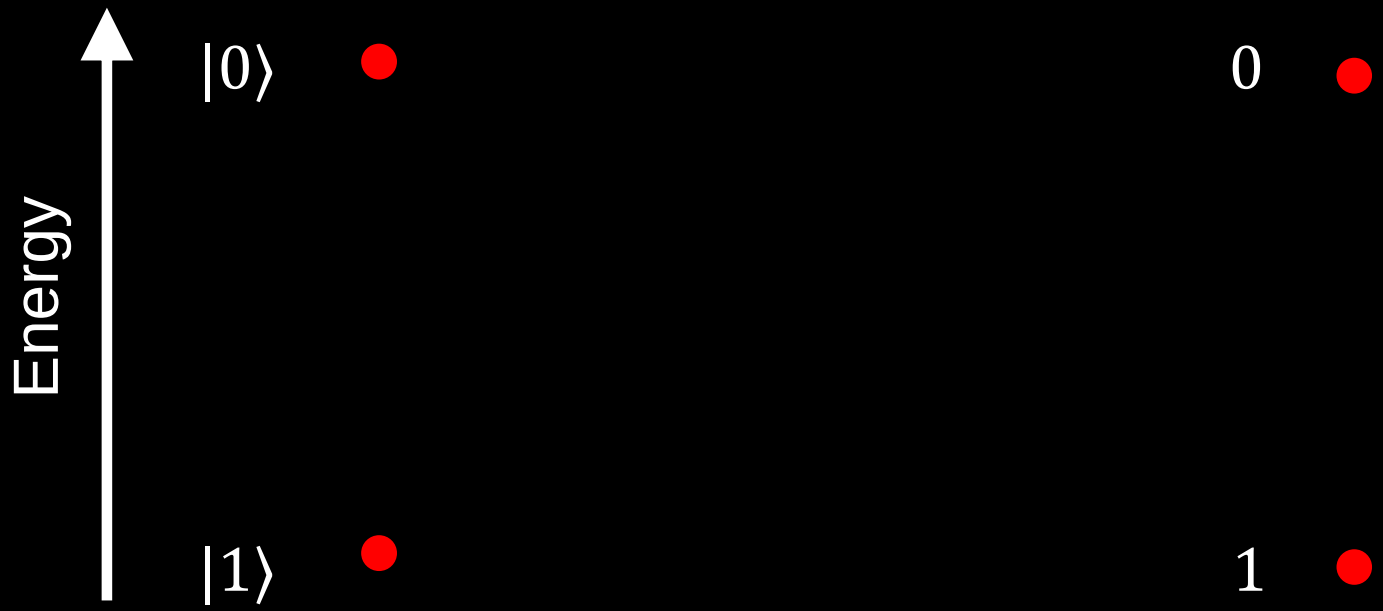
https://vttblog.com/2019/05/23/quantum-technology-what-is-that/

Single qubit

- Two energy (eigen)states

Single bit (classical)

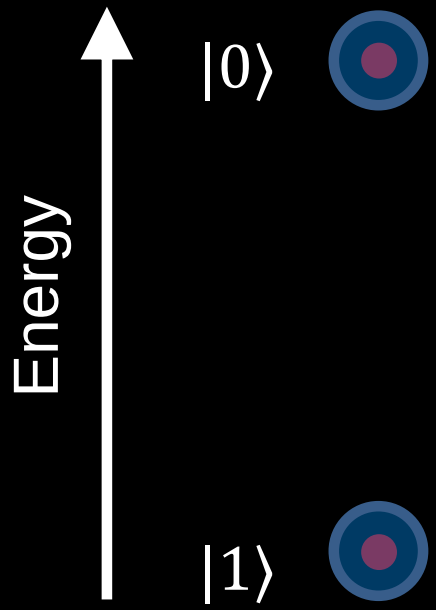
- Continuum of energy states



Quantum bit = Qubit

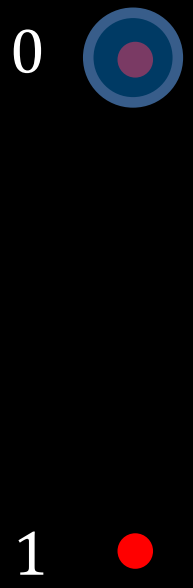
Single qubit

- Two energy (eigen)states



Single bit (classical)

- Continuum of energy states



Quantum bit = Qubit

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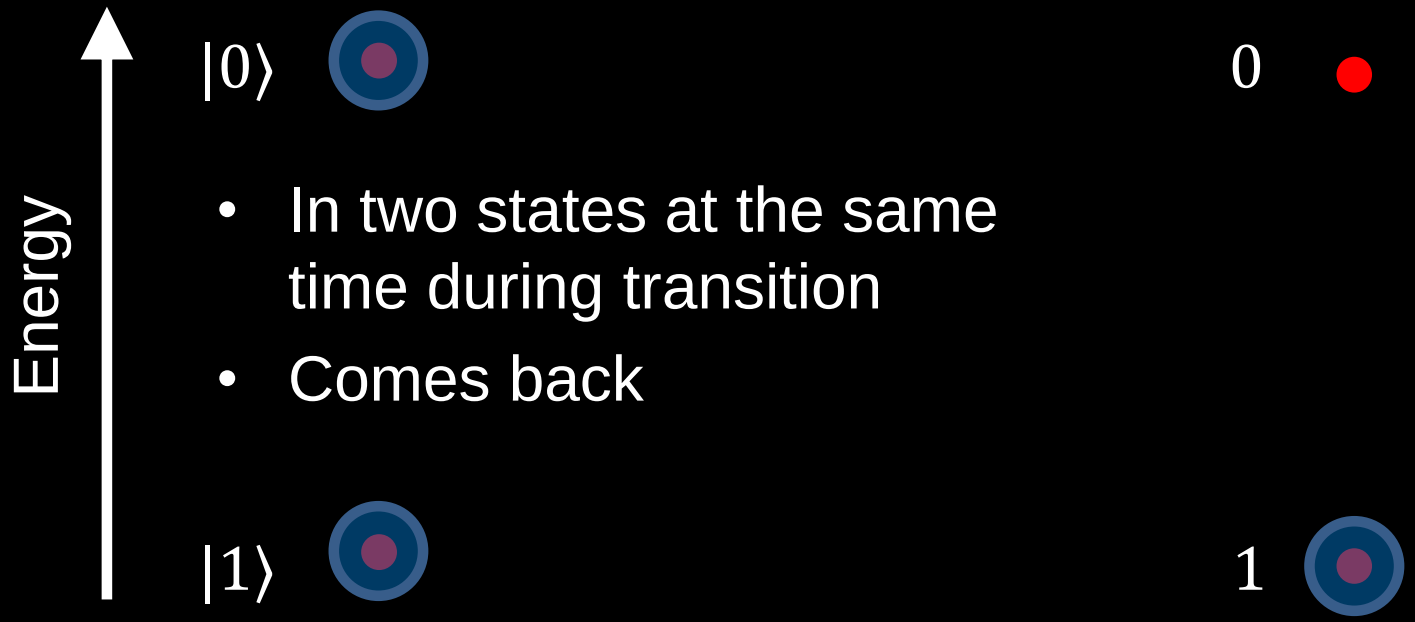
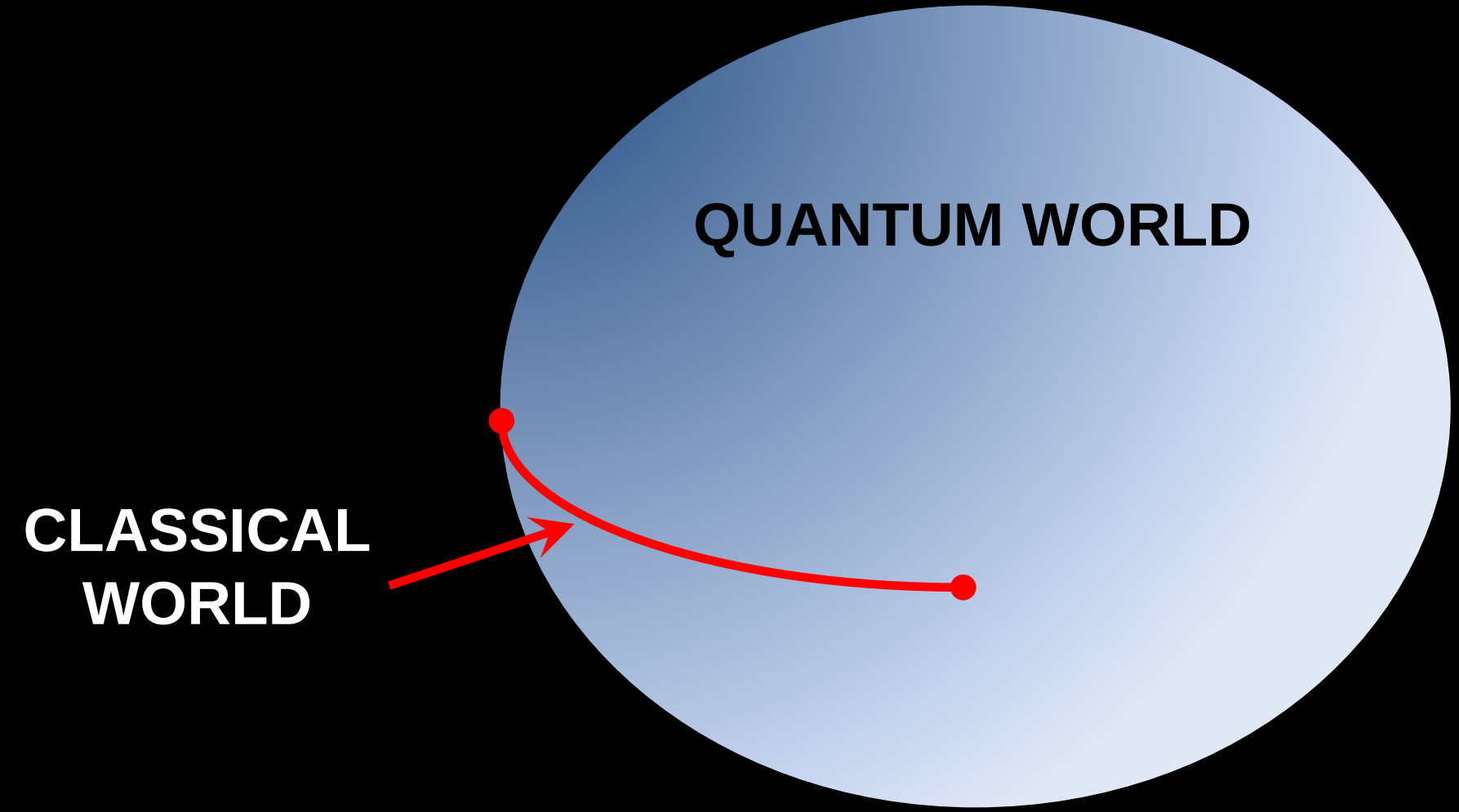
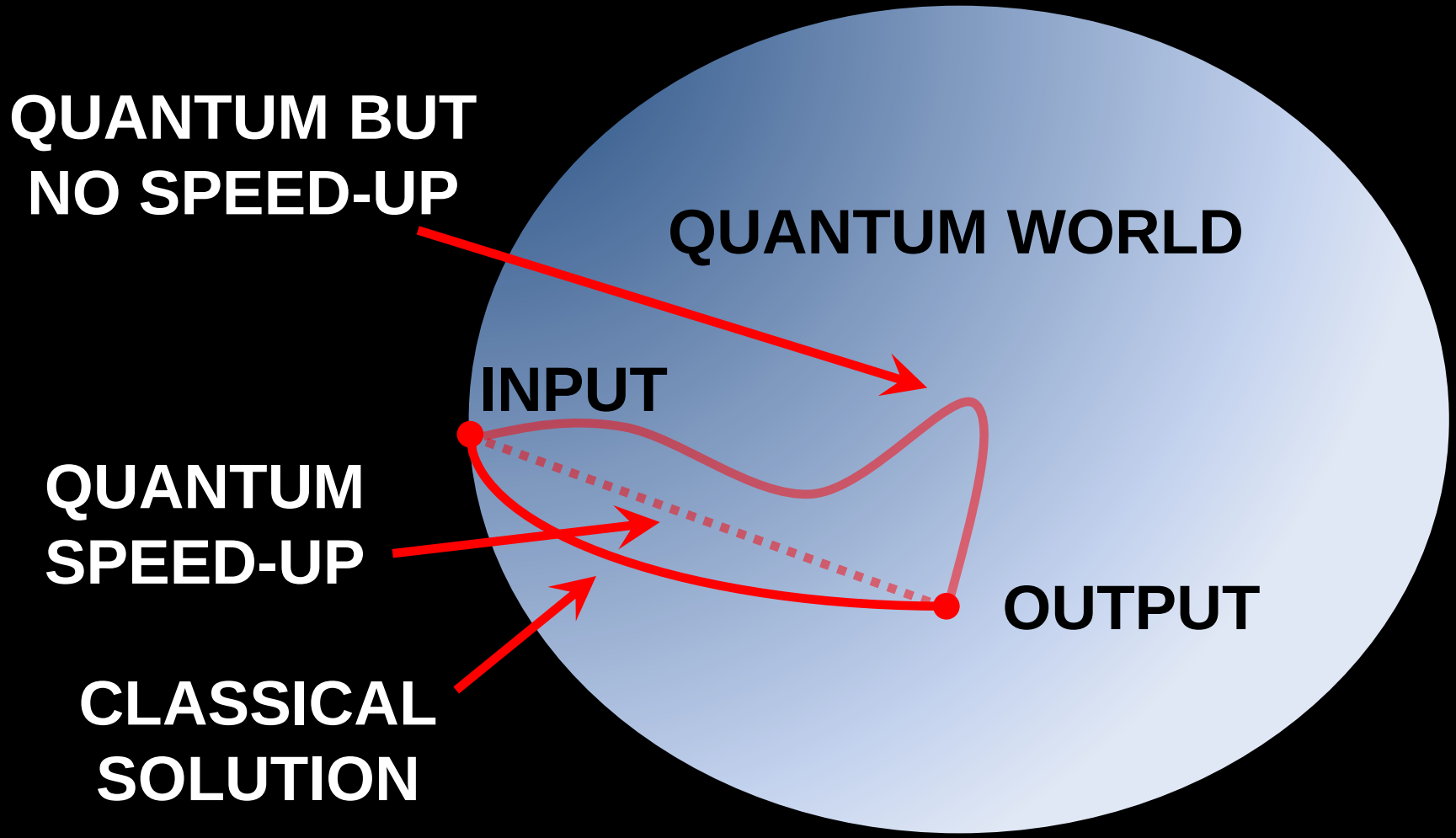


- In two states at the same time during transition
- Comes back

Classical vs. Quantum



Quantum speed-up

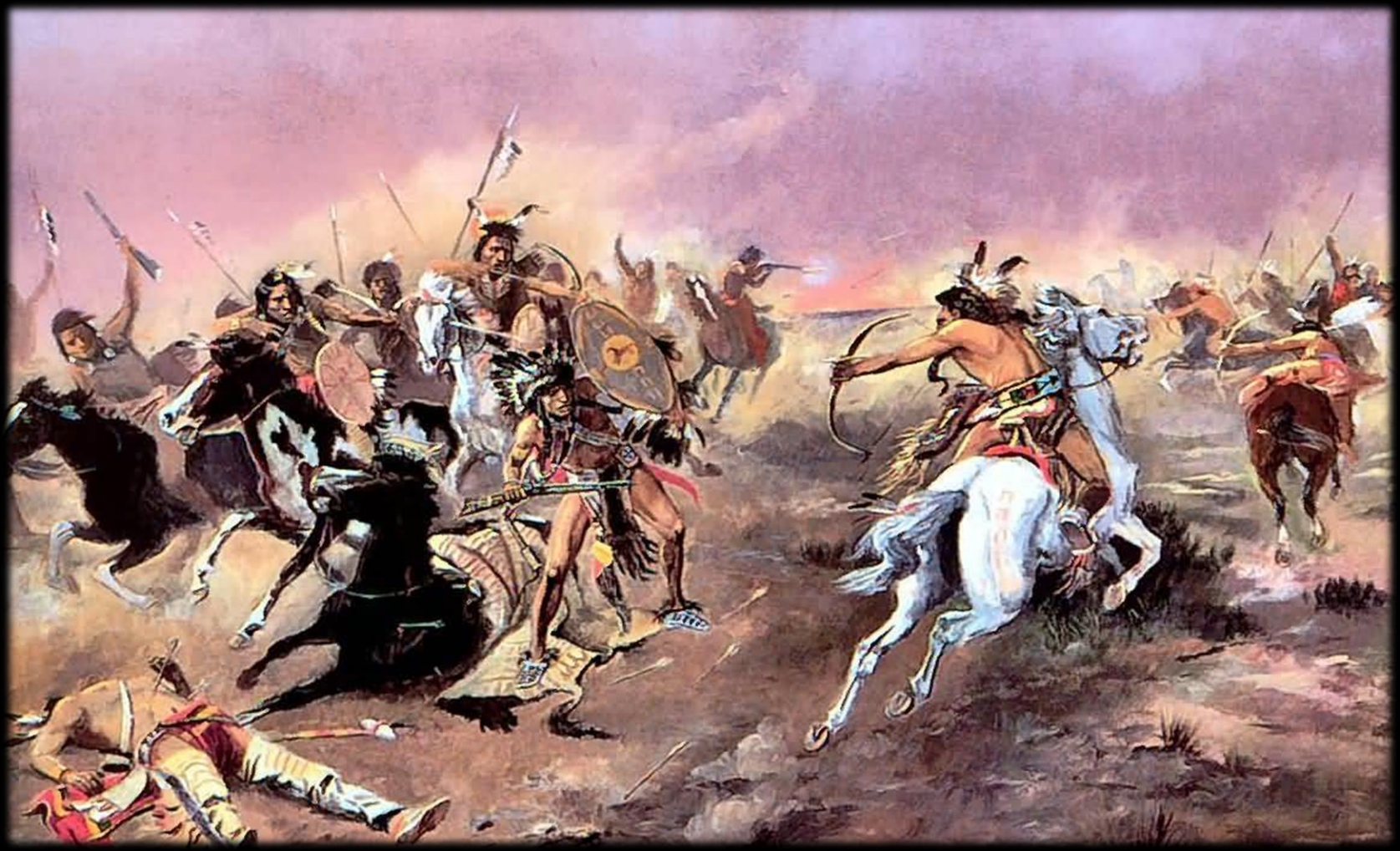


Is quantum speed-up necessary for quantum computers to be useful?

Quantum advantage:

faster, cheaper, more accurate

Quantum supremacy



[Charles M. Russell: For Supremacy (1895)]

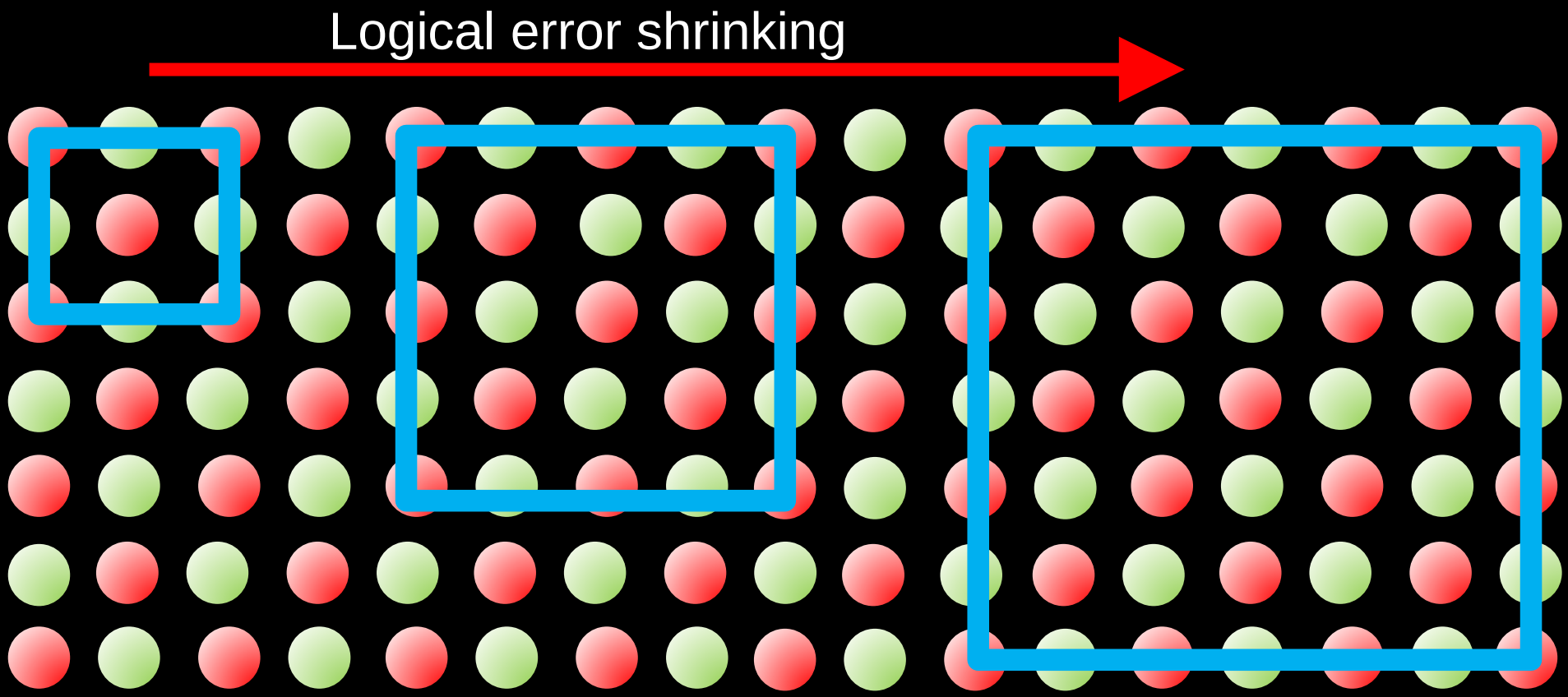
Quantum supremacy

- Google/NASA
- Quantum computers faster in a reasonable computational task than any classical computer
- Does not need to be useful
- How to check?

[Charles M. Russell: For Supremacy (1895)]

Quantum error correction

- Many physical qubits = logical qubit

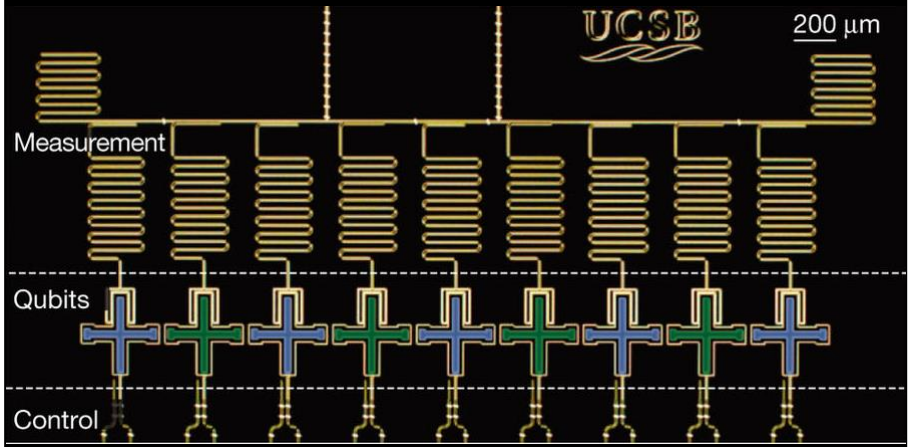


[A. G. Fowler et al., Phys. Rev. A 86, 032324 (2012)]

From linear chains to 2D arrays

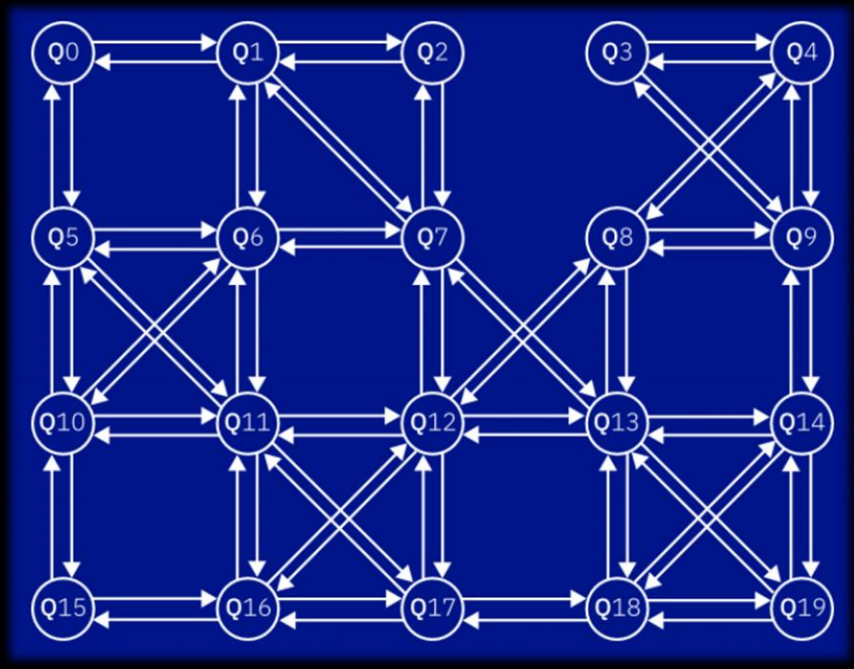
Quantum error correction in a 9-qubit linear array

[J. Kelly et al., Nature **519**, 66 (2015)]

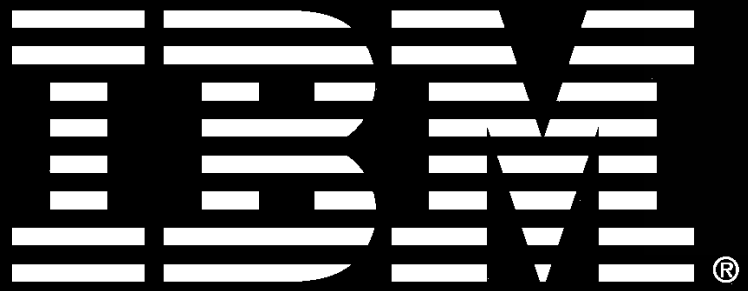


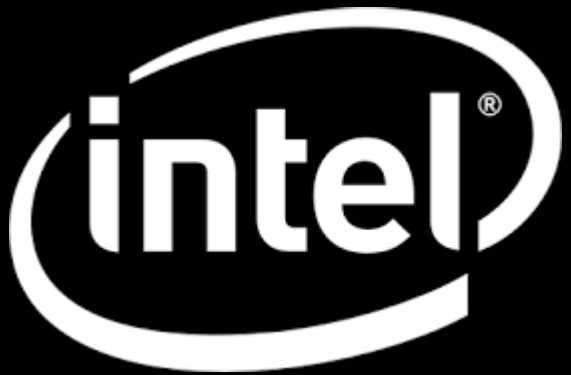
4×5 array in online use

[IBM Quantum Experience website]



Some major players





CoE in Quantum Technology

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Prof. Christian Flindt
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QCD Labs

Quantum Computing and Devices (QCD)

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QCD Labs

6.5.2019

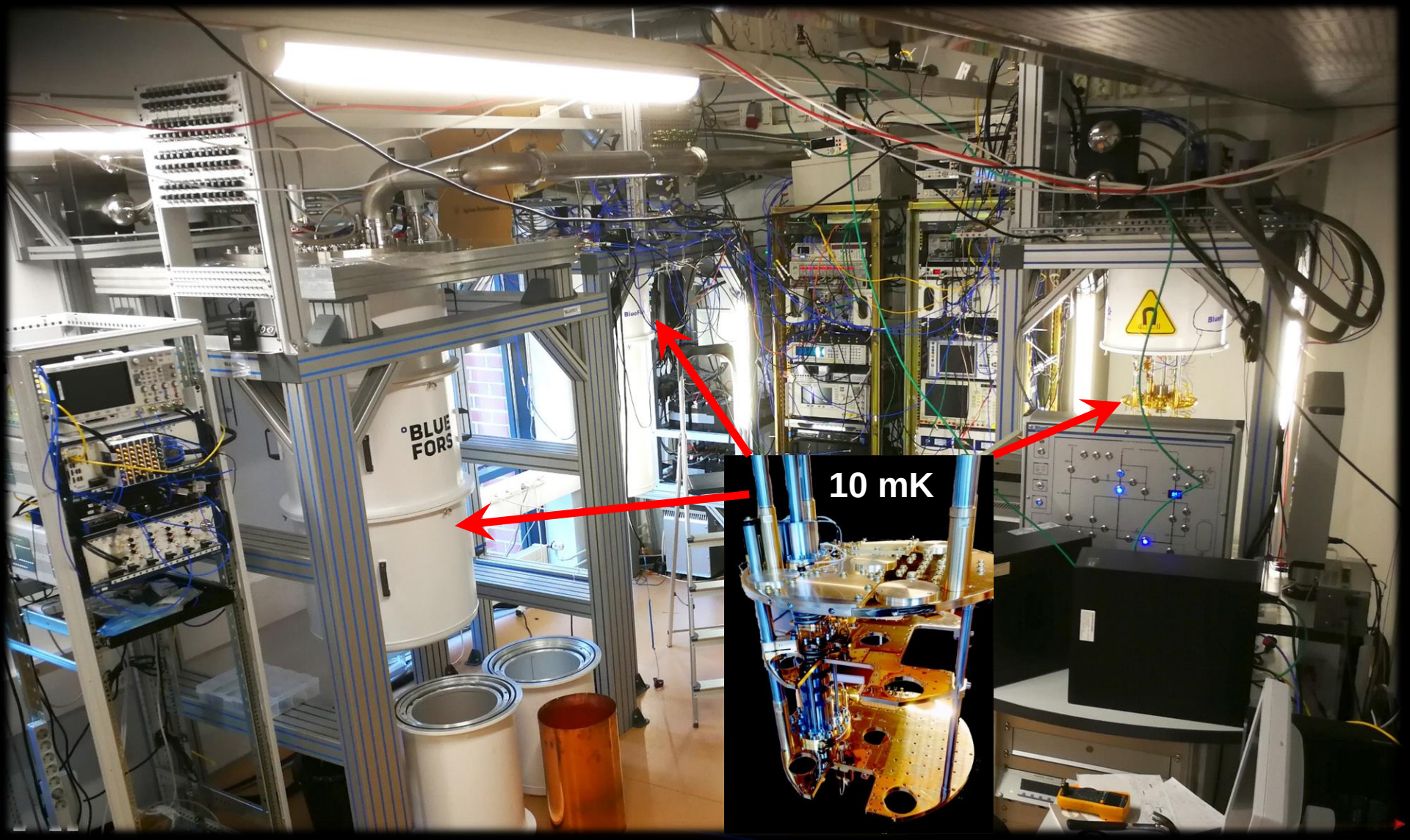

Figure credit: Heikka Valja

Some local results

Dissipation engineering

- QCR = Component to reset quantum circuits

[M. Silveri et al. Nat. Phys. **15**, 533 (2019)]

Qubit readout

- Multi channel readout

[J. Ikonen et al., PRL **122**, 080503 (2019)]

Thanks!

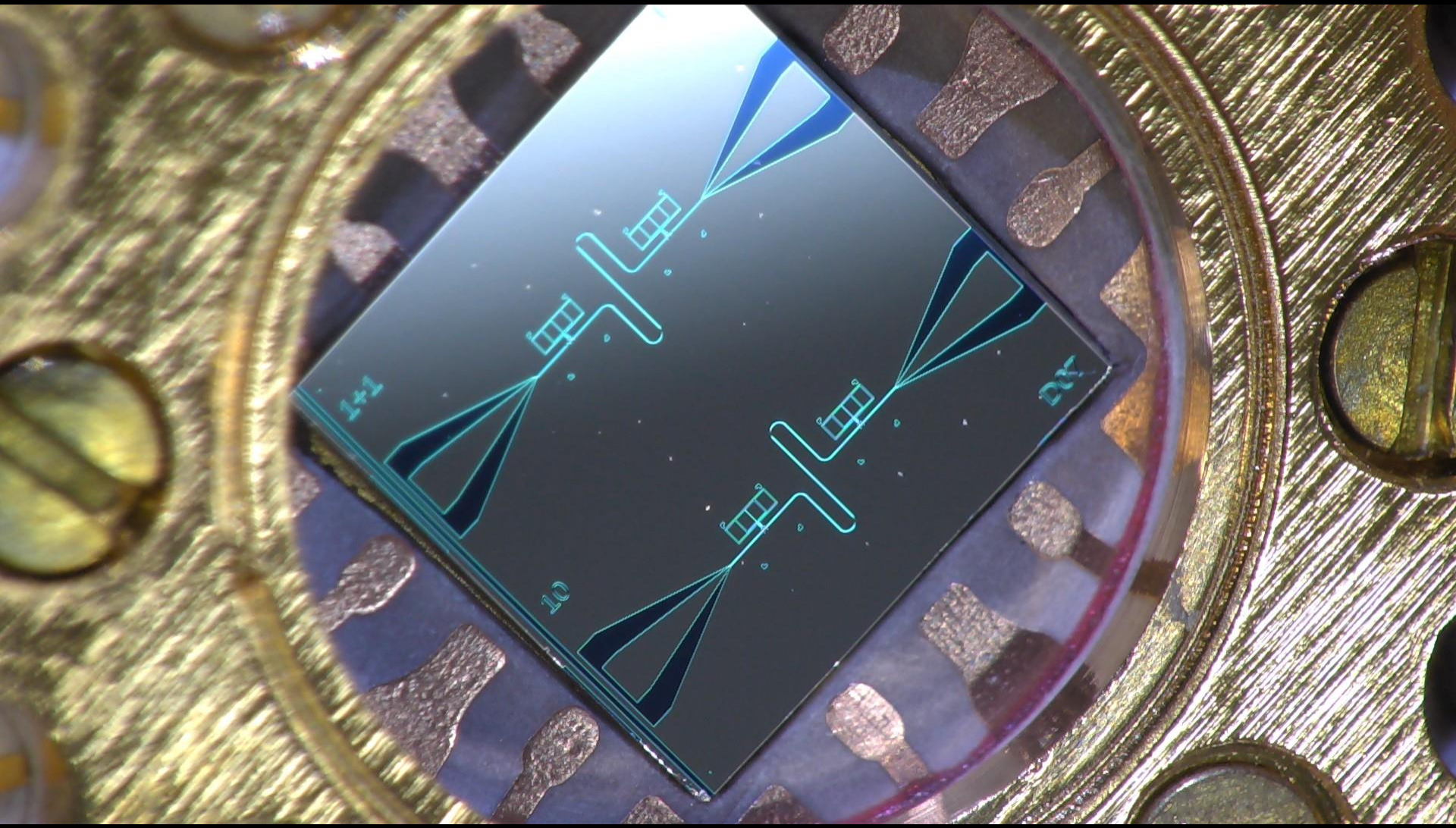

Figure credit: Kuan Yen Tan

THANKS!