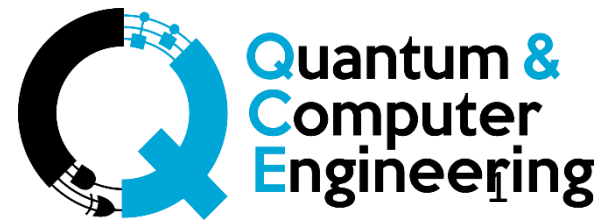


Cryo-CMOS for Quantum Computing and more...

Fabio Sebastiano

f.sebastiano@tudelft.nl

Delft University of Technology



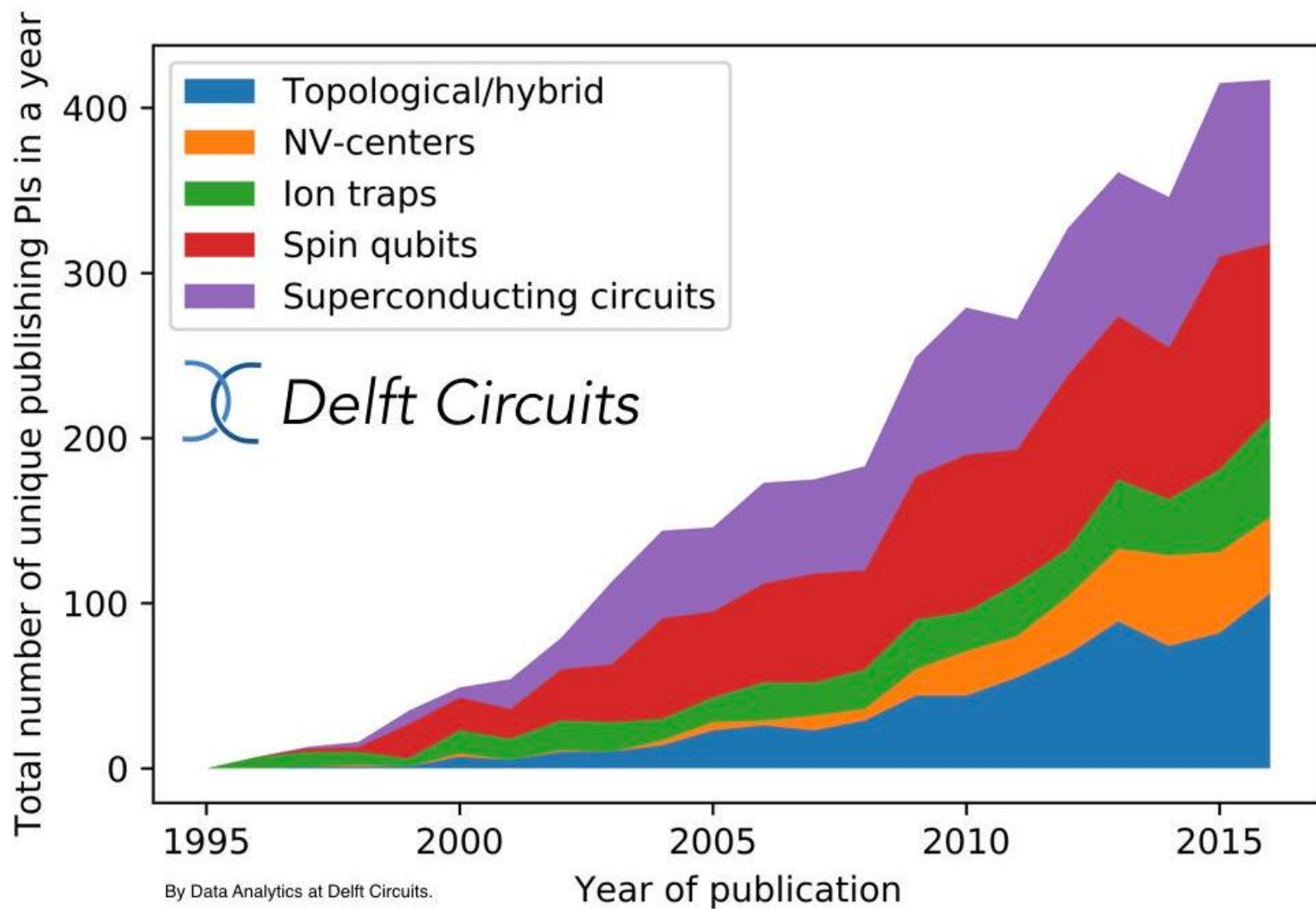


quantum computing will



The
Co

38



The Quantum *Industrial* Hype



TE News Startups Mobile Gadgets Enterprise Social Trending Apple Google Face

Google AI quantum computing

Google Partners With UCSB To Build Quantum Processors For Artificial Intelligence

Rigetti Computing Takes Small Step Toward Cloud Services In Big Leap For Quantum Computing **rigetti** **Forbes**



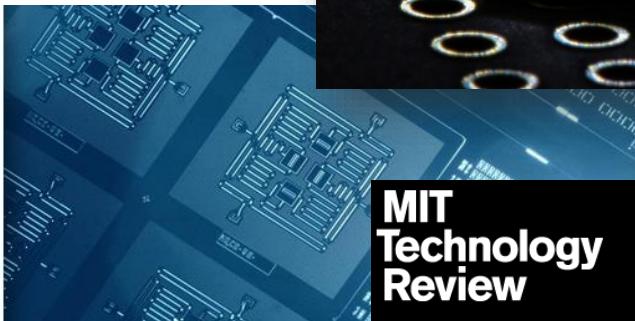
Microsoft

Microsoft
@ Redmond, Delft

Honeywell

Goodbye Moore's Law! Intel invests \$50 million into quantum partnership **FORTUNE**

IBM Shows Off
Computing Ch

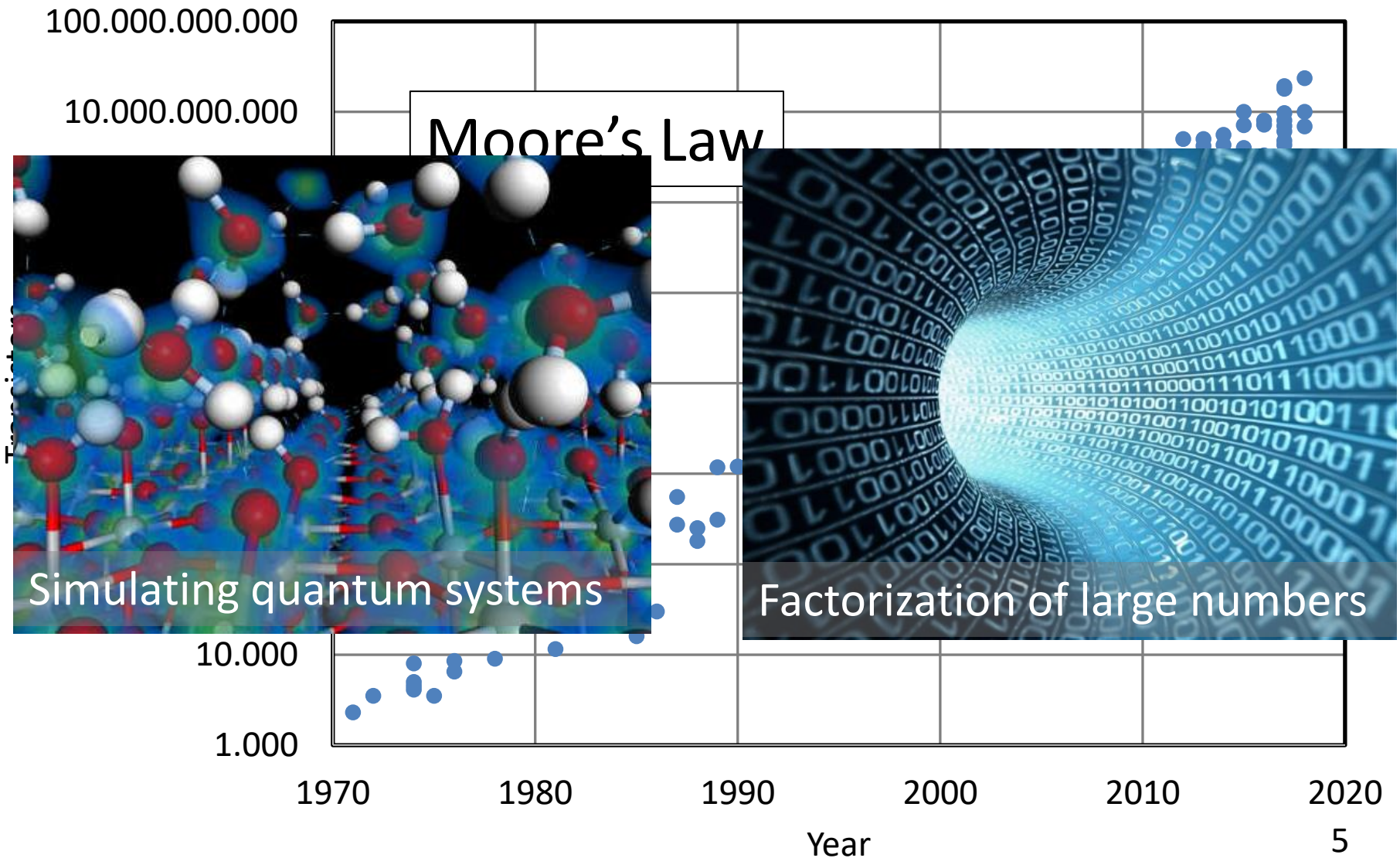


MIT
Technology
Review



TU Delft

The Future of Computing

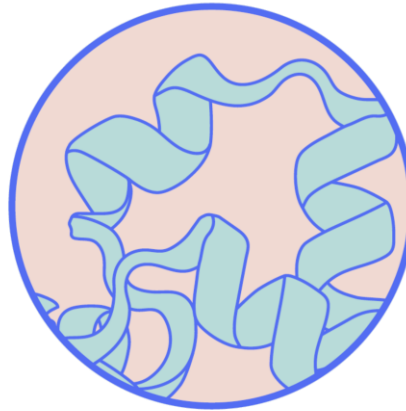


Why quantum computers?

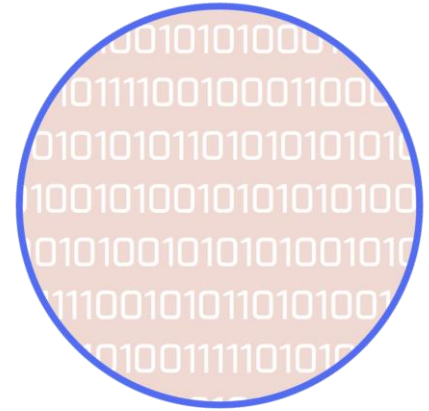
Encryption/decryption



Protein folding



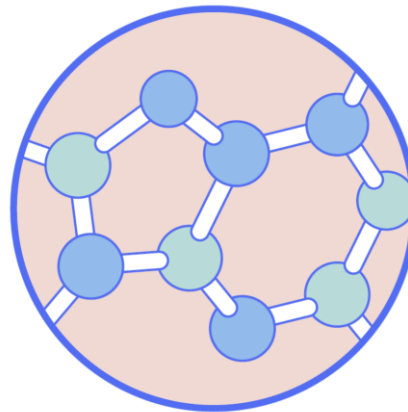
Big data



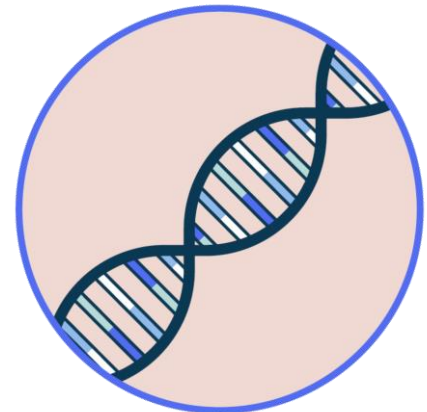
Drug synthesis



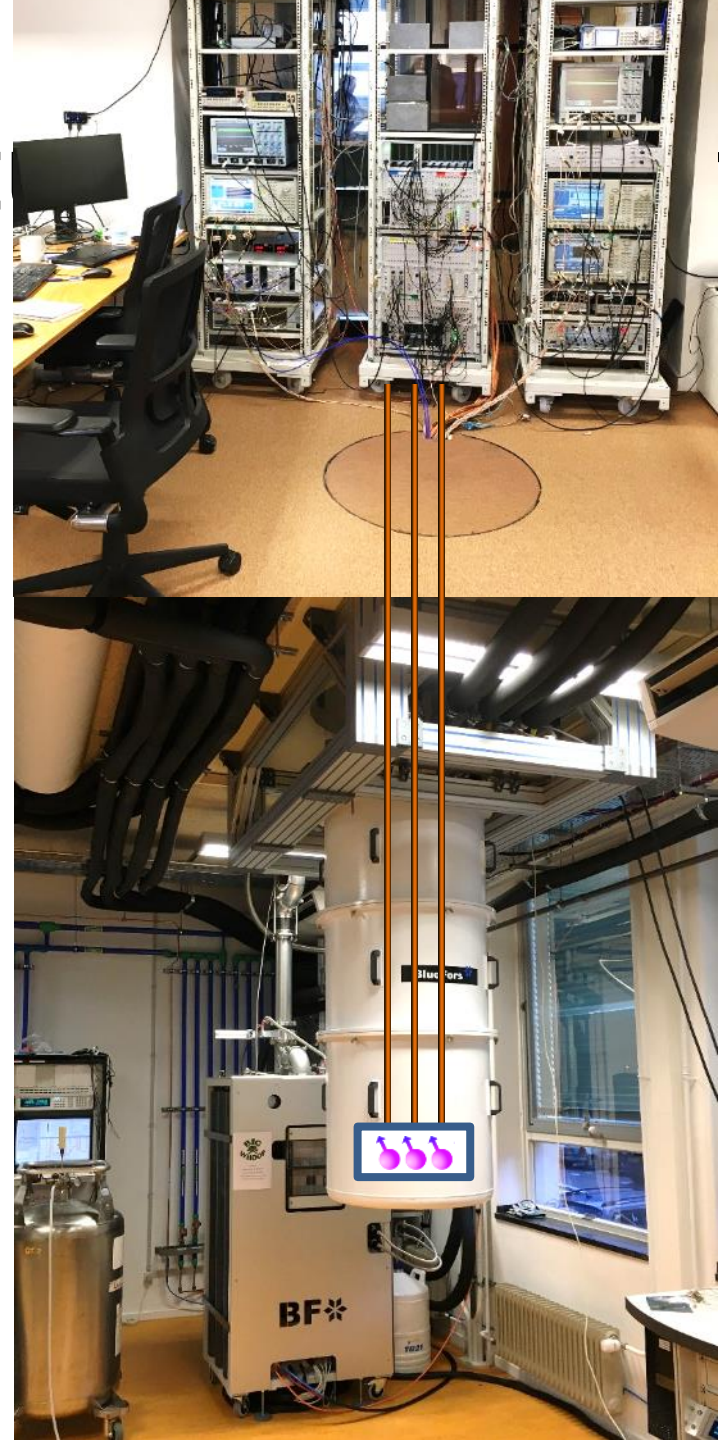
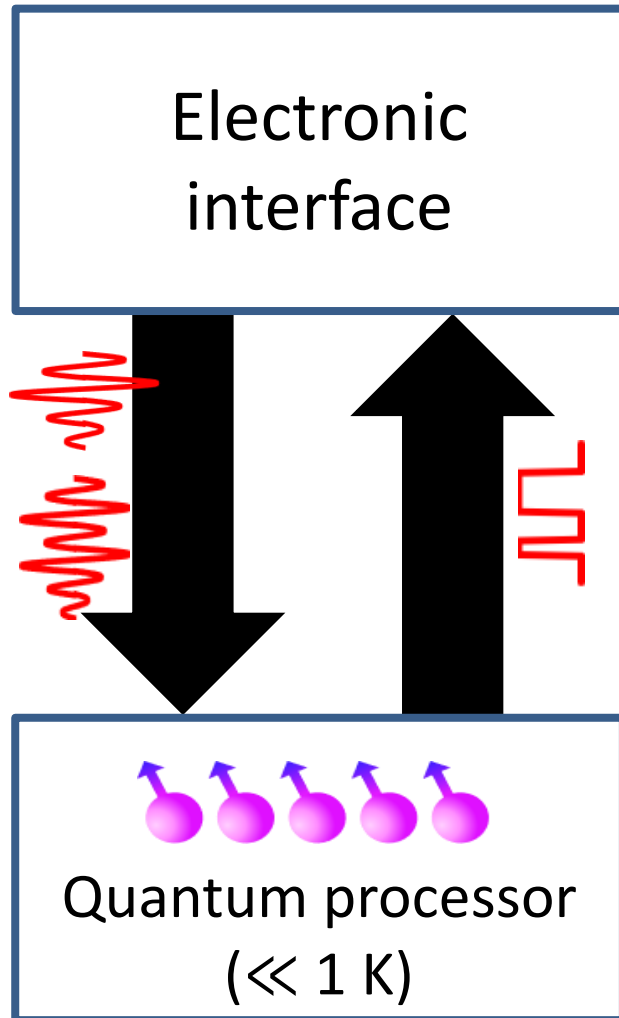
Molecule simulation



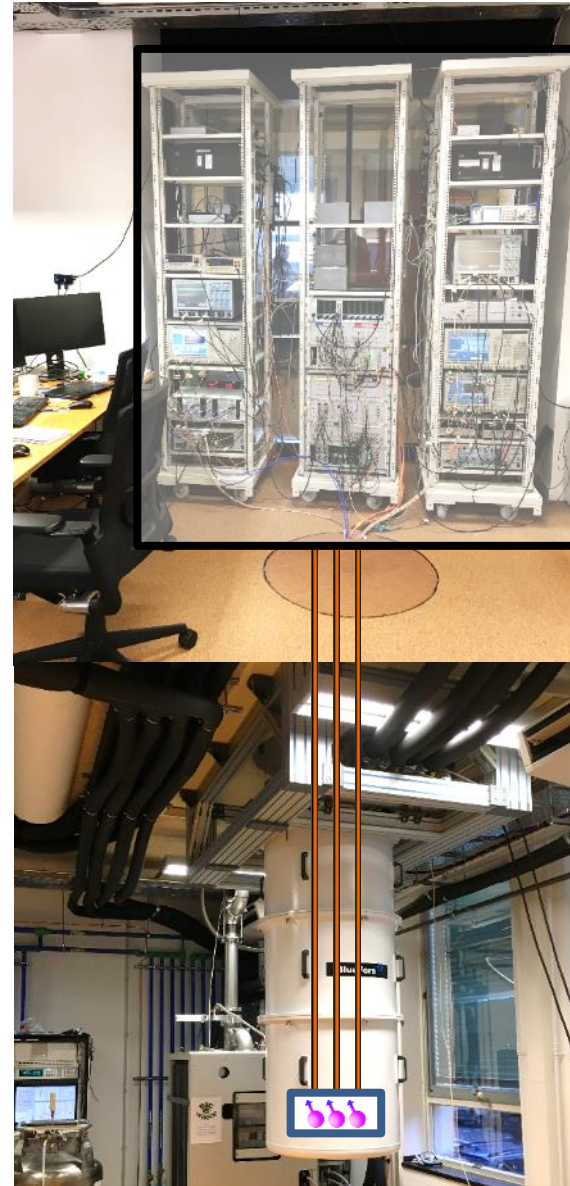
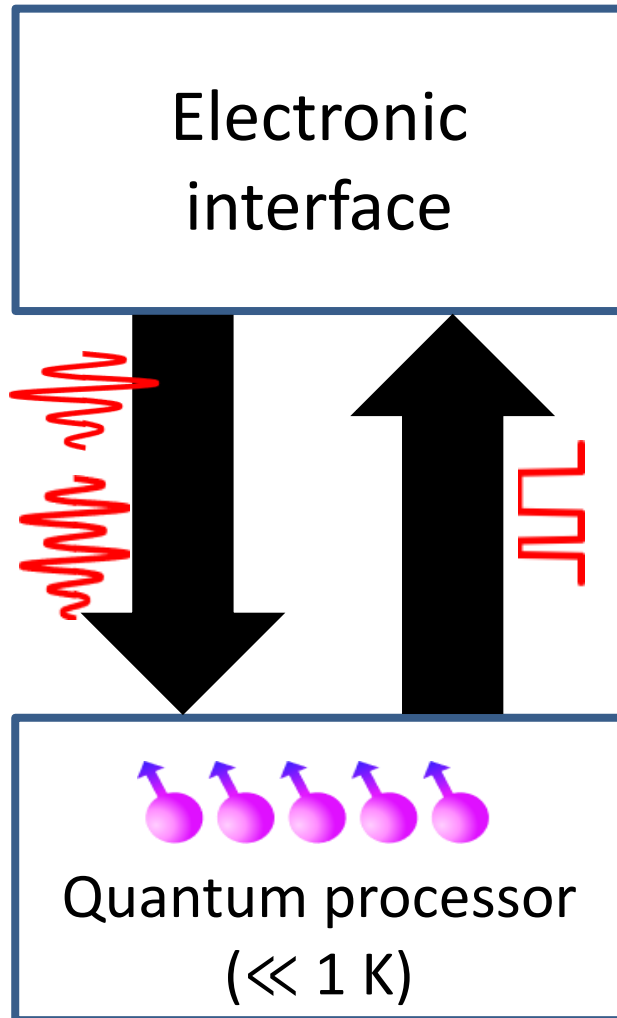
DNA analysis



A real-life quantum



A real **How to scale up?** inter



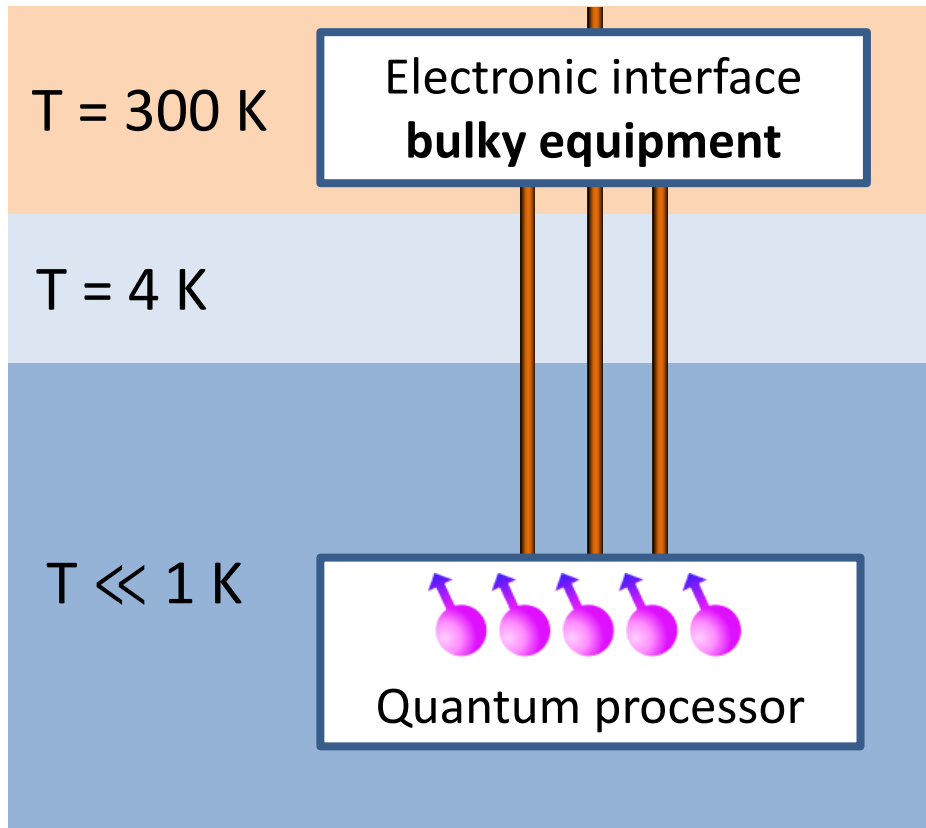
The most powerful quantum computer

- Google's QC with 53 superconducting qubits
- Demonstrated *quantum supremacy*



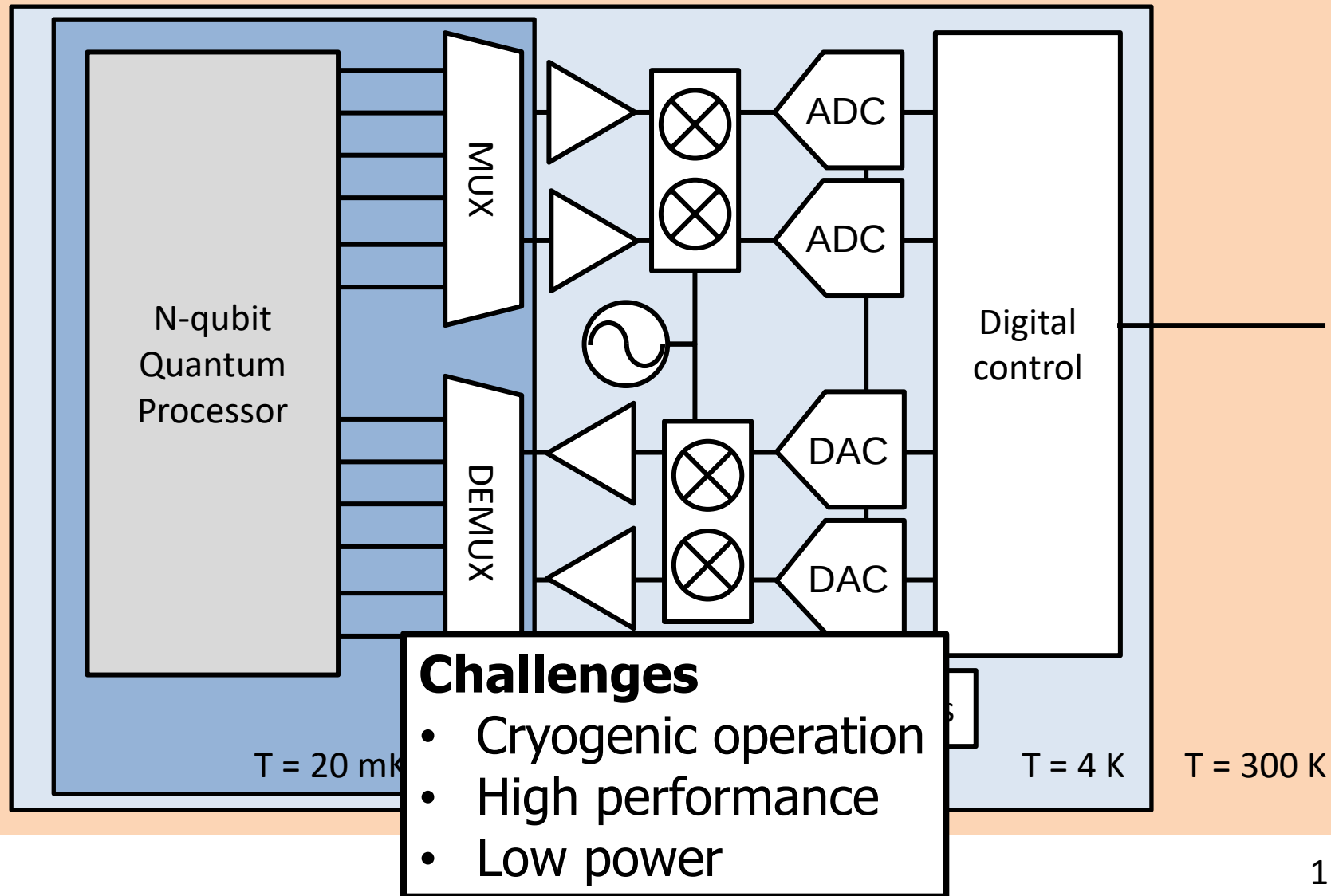
Towards a scalable controller

State of the art



Cryogenic and integrated electronic interface
for **large-scale** quantum computers

A Scalable QC with cryo-CMOS



The group



A cryo-CMOS Interface

Qubits
specs

Best IP award @
DATE 2017
[PRAppl. 2019]

N-qubit
Quantum
Processor

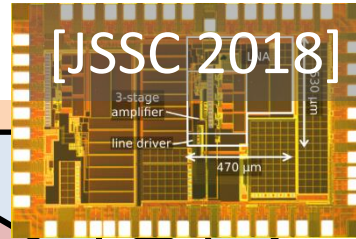
[ISSCC 2020]

DEMU

Pov

[ISSCC 2020]

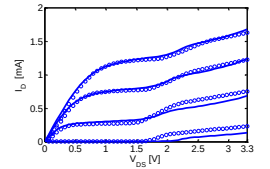
[JSSC 2018]



ADC

ADC

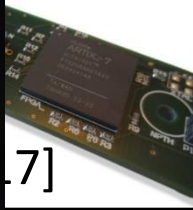
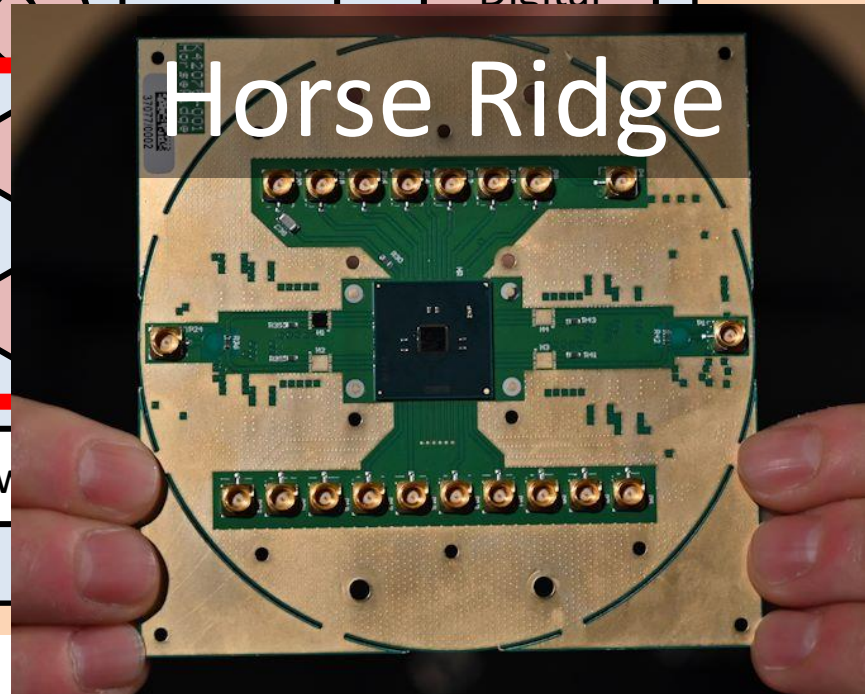
Cryo-CMOS
models



[JEDS 2018]

Digital

Horse Ridge

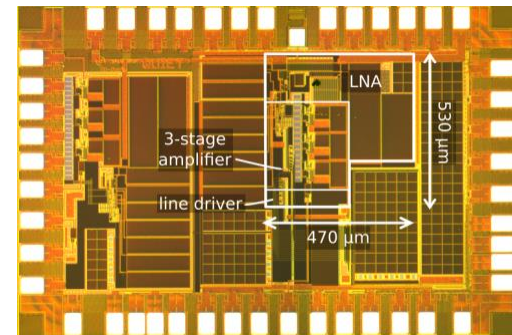


[7]

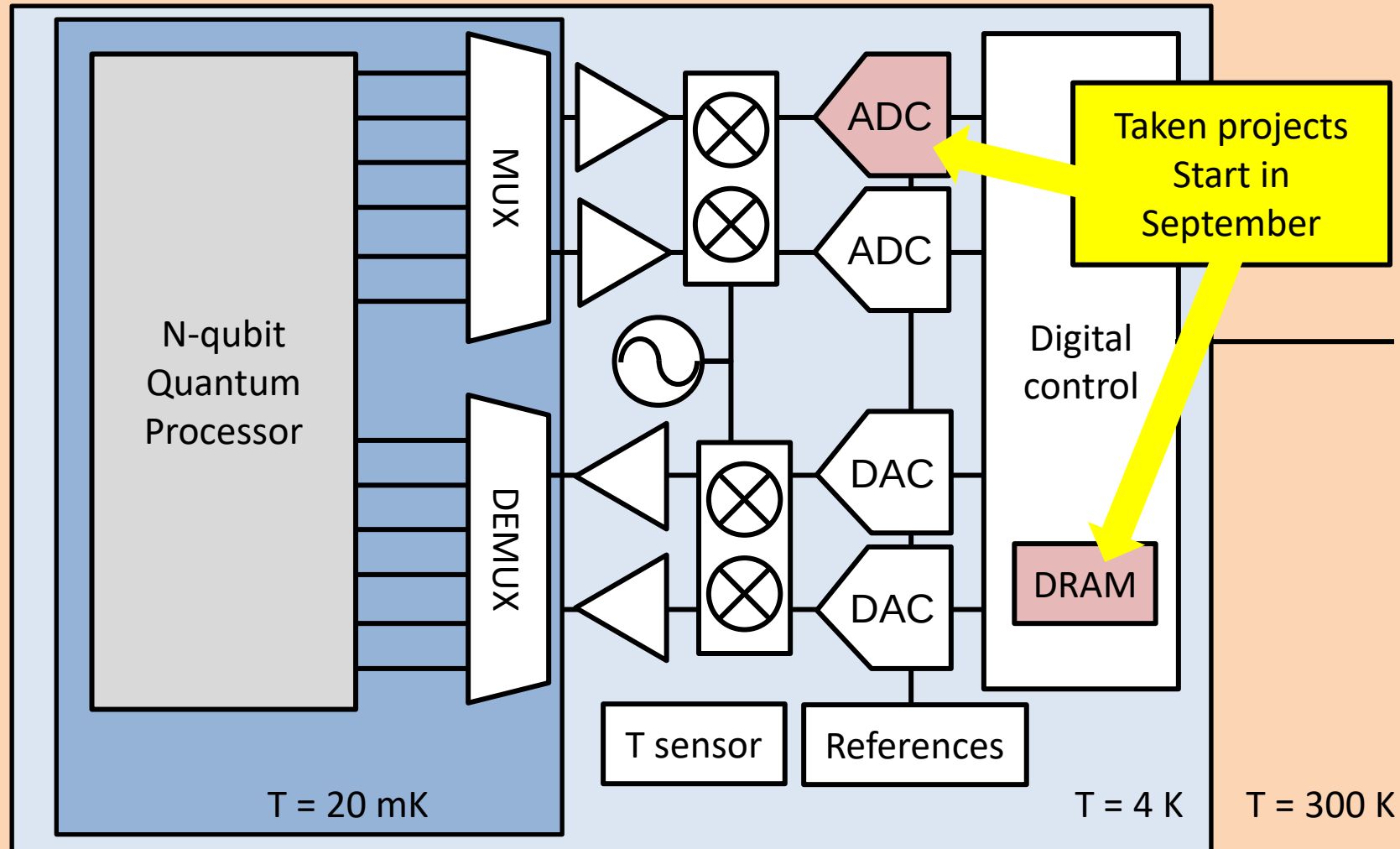
0 K

Cryo-CMOS project overview

- Project examples:
 - Cryo-CMOS temperature sensor
 - SiGe BiCMOS readout for Superconducting Nanowire Single-Photon Detectors (SNSPD)
 - Noise in cryogenic CMOS transistors
 - Cryo-CMOS high-speed DAC
- Each project includes:
 - System analysis and choice of best architecture
 - Circuit design in 40-nm CMOS
 - Layout of test chip
 - Tape-out
 - Chip characterization

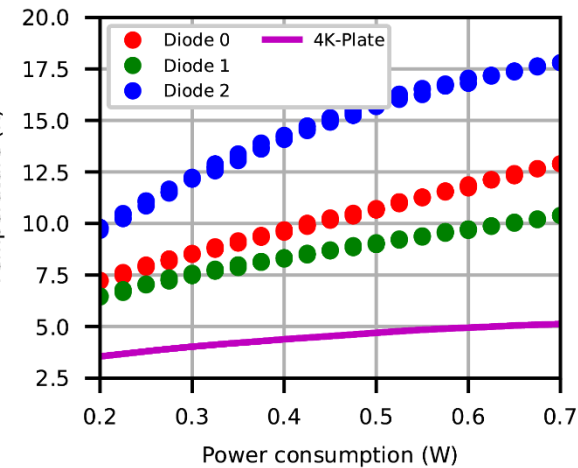
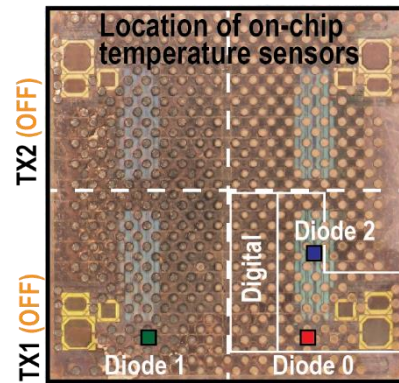


MSc thesis projects

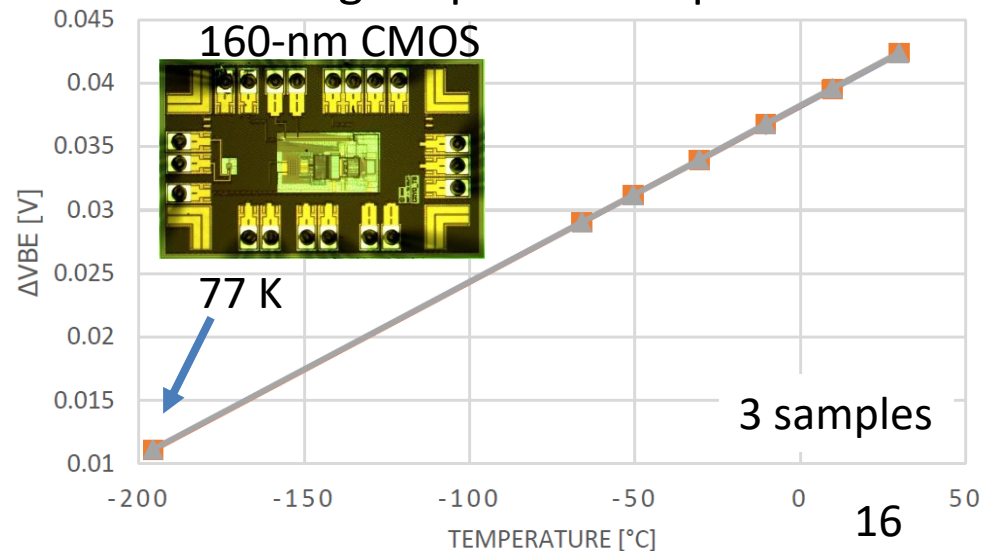


Cryo-CMOS Temperature Sensor

- Self-heating is problematic at 4 K
- How to sense on-chip temperature?
- Objective:
 - Develop a temperature-to-digital converter at 4 K
 - Use 40-nm CMOS

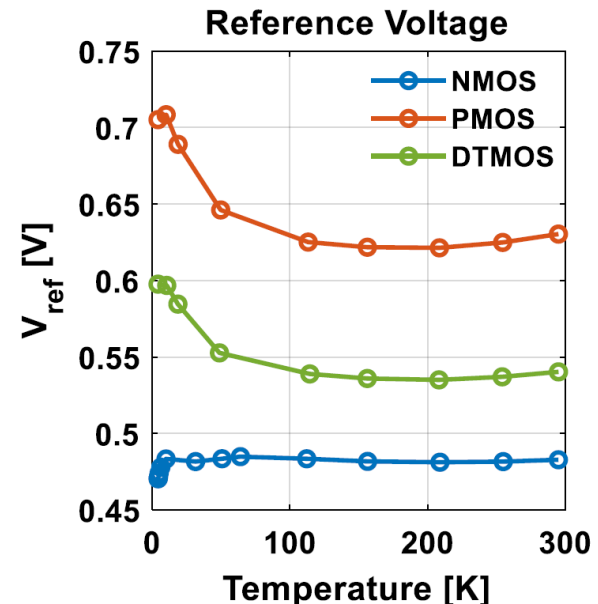
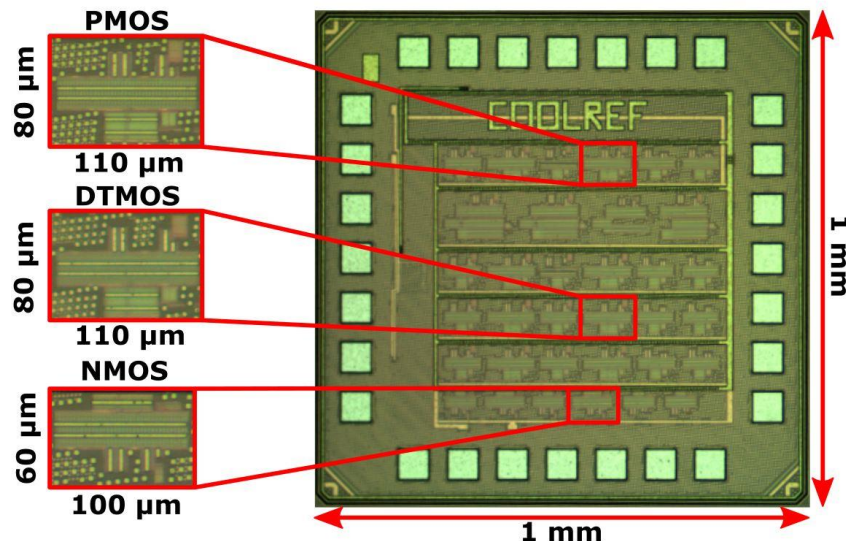


Analog output vs. temperature



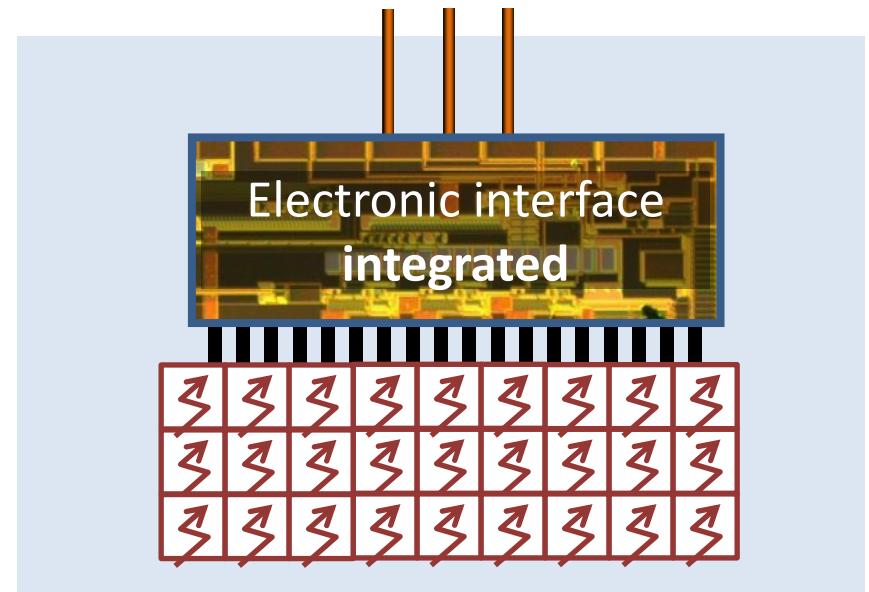
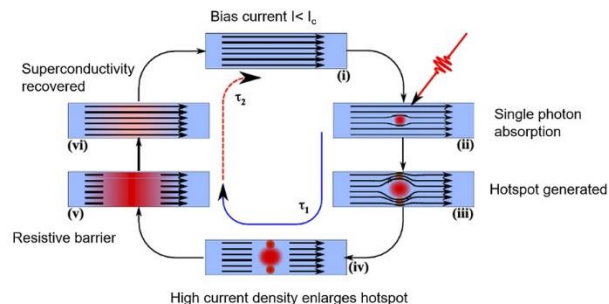
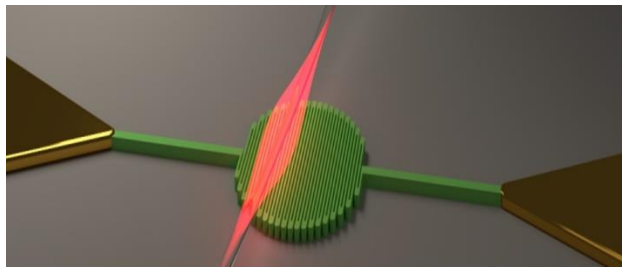
Cryo-CMOS Voltage Reference

- Voltage references needed in any SoC
 - DAC, ADC, LDO,...
- Objective:
 - Design an accurate voltage reference at 4 K
 - Use Intel 22-nm FinFET process

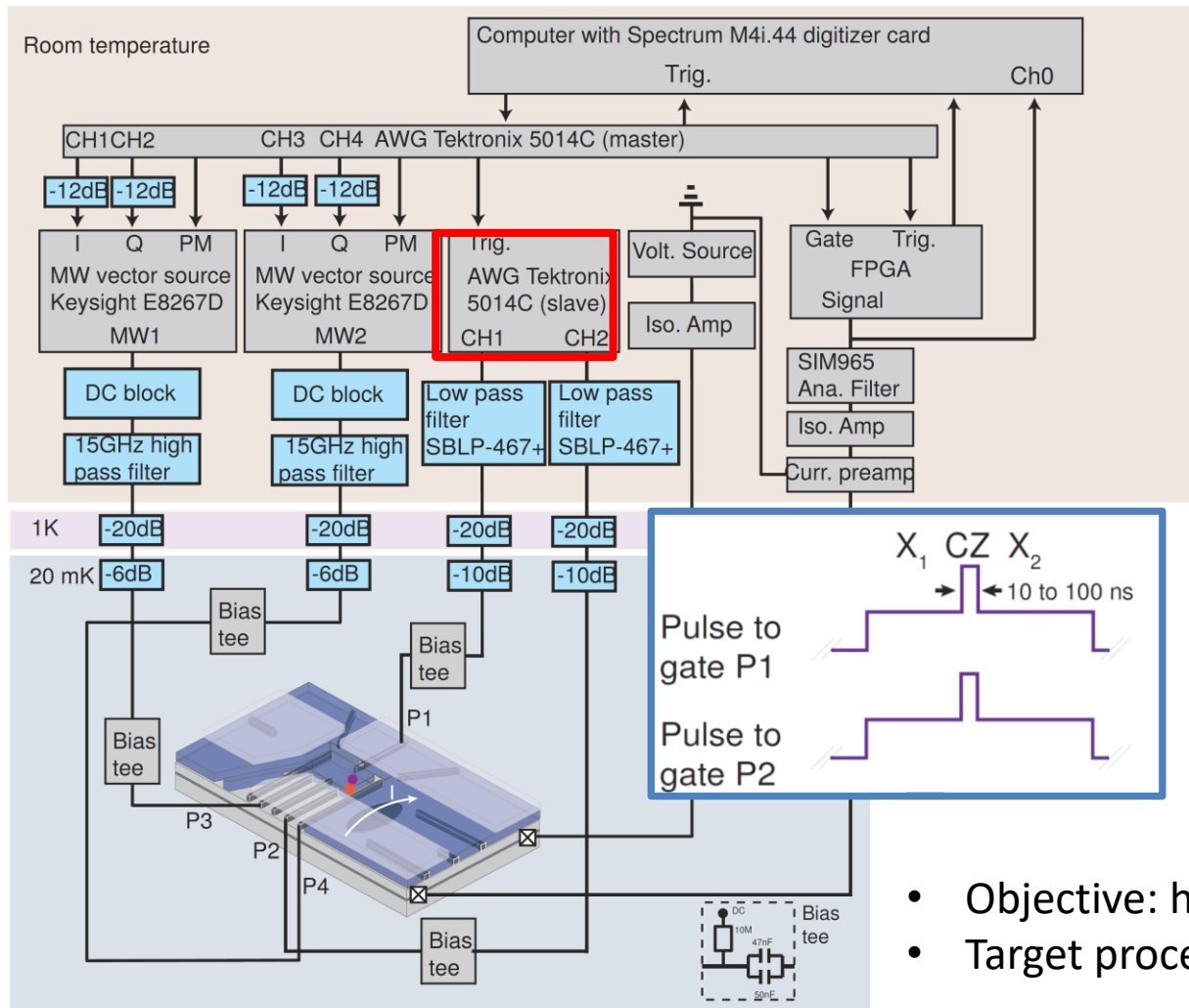


Cryo-CMOS Readout for SNSPDs

- Superconducting Nanowire Single-Photon Detectors (SNSPD)
 - Extremely accurate sensors (sensitivity, jitter)
 - But work only at cryogenics
- Objective: develop a cryo-CMOS readout
- Target process: 130-nm SiGe BiCMOS



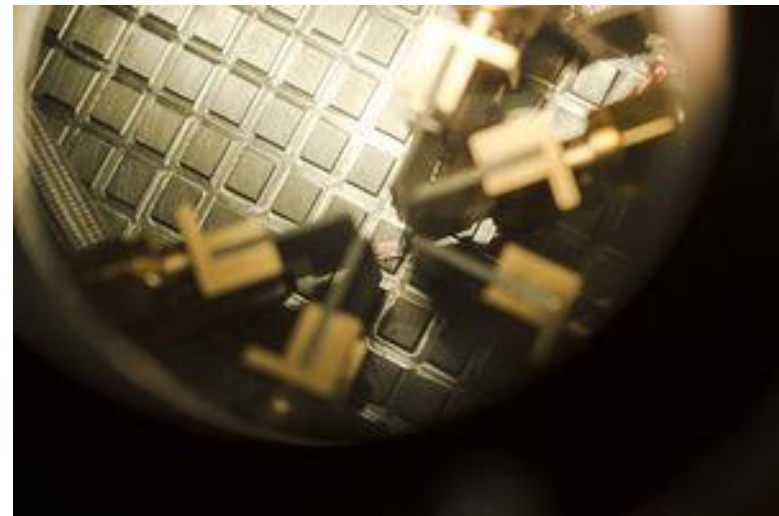
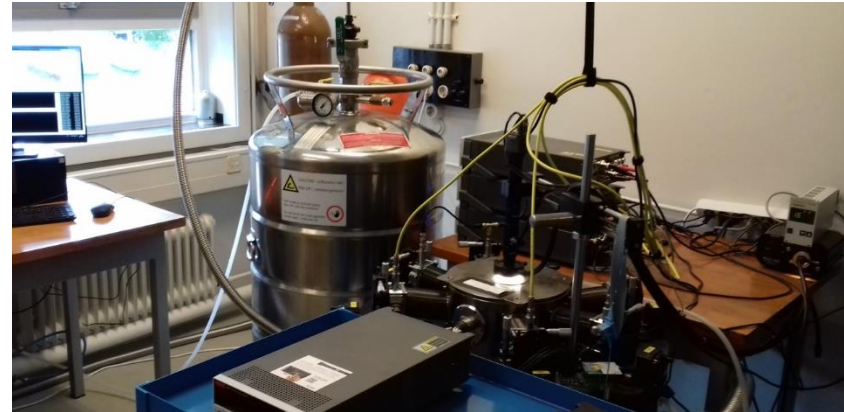
Cryo-CMOS high-speed DAC



- Objective: high-speed DAC for 2-qubit gates
- Target process: Intel 22-nm FinFET CMOS

Device Characterization projects

- CMOS is well known...
- ... but not **cryo**-CMOS
- Need to characterize and model:
 - Self-heating
 - Noise (flicker and thermal)
 - RF behaviour
- Involve:
 - Chip design with test structures
 - Test and characterization
 - Build physical model



CALL/MAIL ME FOR ANY QUESTION!
F.SEBASTIANO@TUDELFT.NL