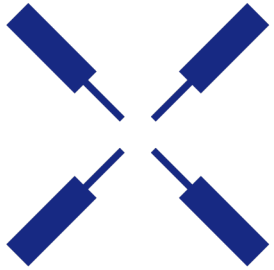

Zurich
Instruments

Supporting Quantum Advantage from the Classical Side

Sadik Hafizovic
CEO

March 27th, 2023

Zurich Instruments

Company profile

- Founded in 2008, 150+ people, 20+ nations
- Headquarters in Zurich, Switzerland
- Offices in China, USA, Germany, Korea, France, Japan
- Partners in Taiwan, India, Australia
- Part of Rohde & Schwarz since 2021
- Rohde & Schwarz in New Delhi, Bengaluru, Mumbai, Hyderabad

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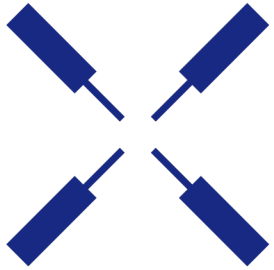
Rohde & Schwarz India Pvt. Ltd.

Zurich Instruments



Zurich
Instruments

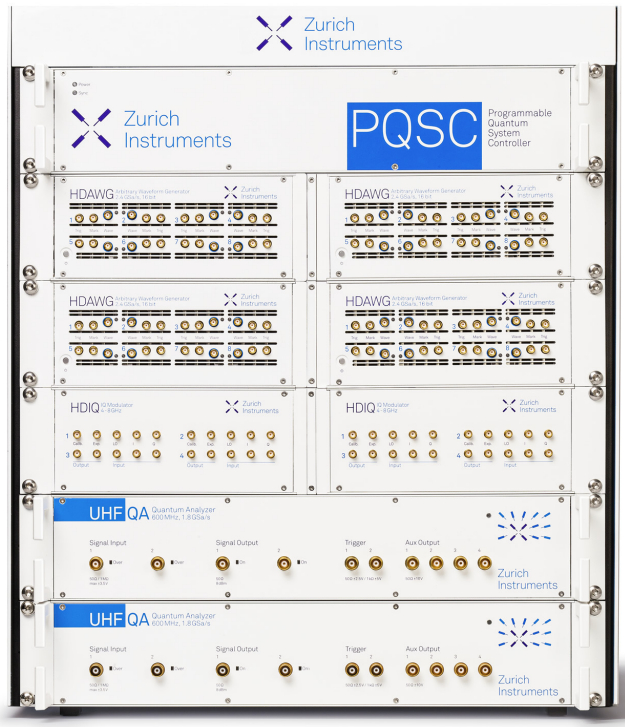
Quantum Mission

Help build the quantum computer and be the leading Quantum Computing Control System provider.

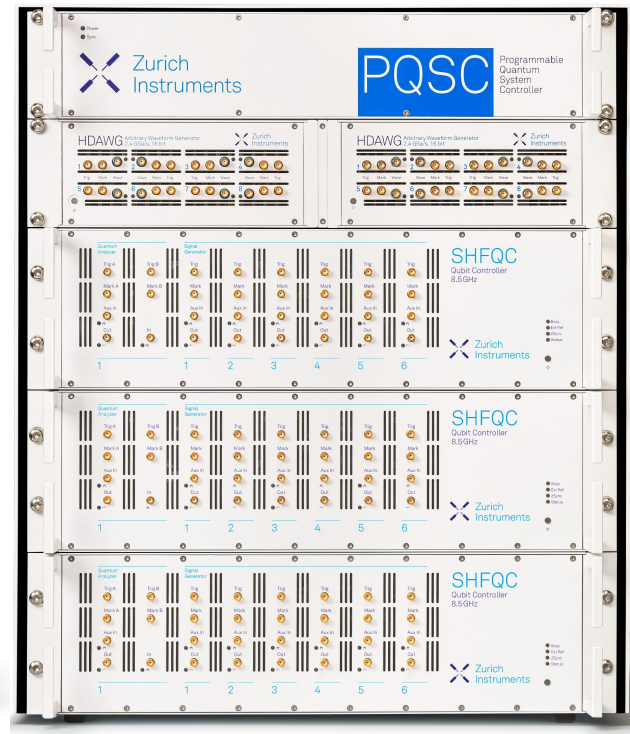
Quantum Computing Control System (QCCS) Roadmap

Pre QCCS

QCCS Gen 1



QCCS Gen 2



2014 2016 2018 2020 2022 2023

← Full compatibility and future-proof investment →

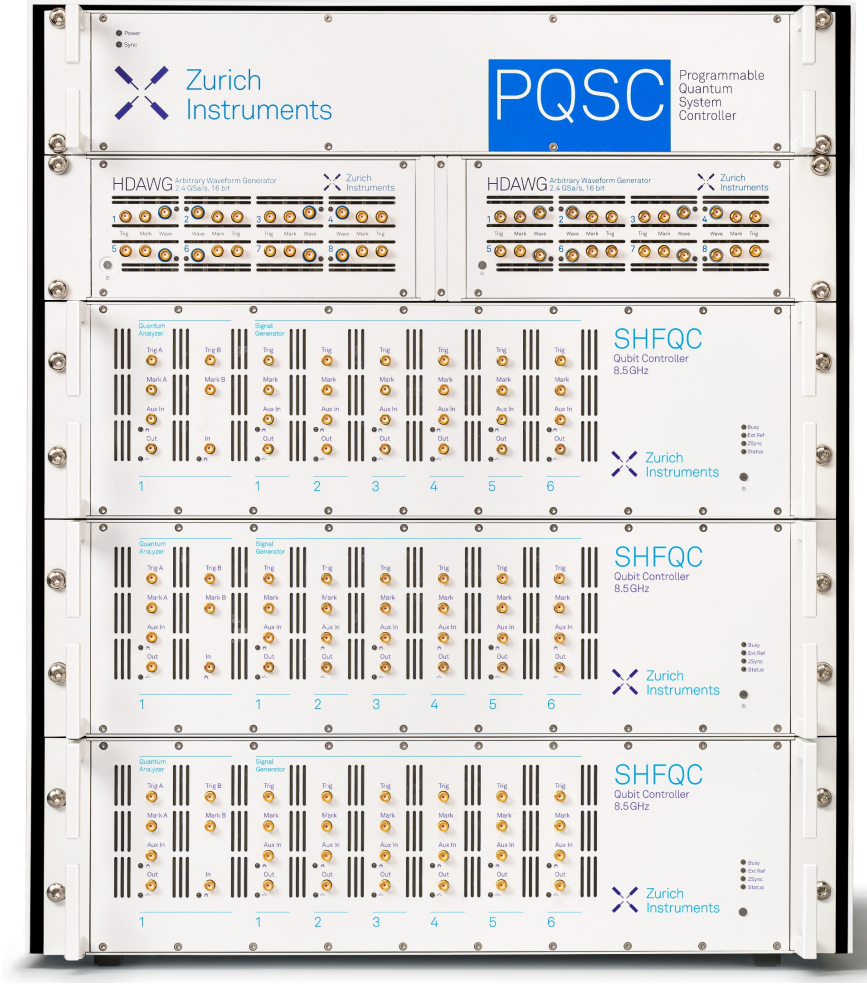
Gen 2 Quantum Computing Control System (QCCS)

Gen 2 Hardware improvements

- No mixer calibration
- Lower drift & latency
- Higher fidelities
- Accelerated execution

LabOne Q

- Intuitive programming that abstracts away control hardware
- Supports full power of the underlying control hardware



Latest addition: SHFPPC Parametric Pump Controller

What is it

- Operates up to 4 parametric amplifiers
- The world's first off-the-shelf solution

Benefits

- Higher readout fidelity and speed: keep amps in optimal working point
- Stability: Automatic monitoring and tuning
- UX: Fast automatic tune-up and re-optimization
- → An innovation that accelerates progress in quantum advantage

Support Quantum Advantage from the Classical Side

Capabilities

- Bring-up and characterization performance + flexibility

Few qubits

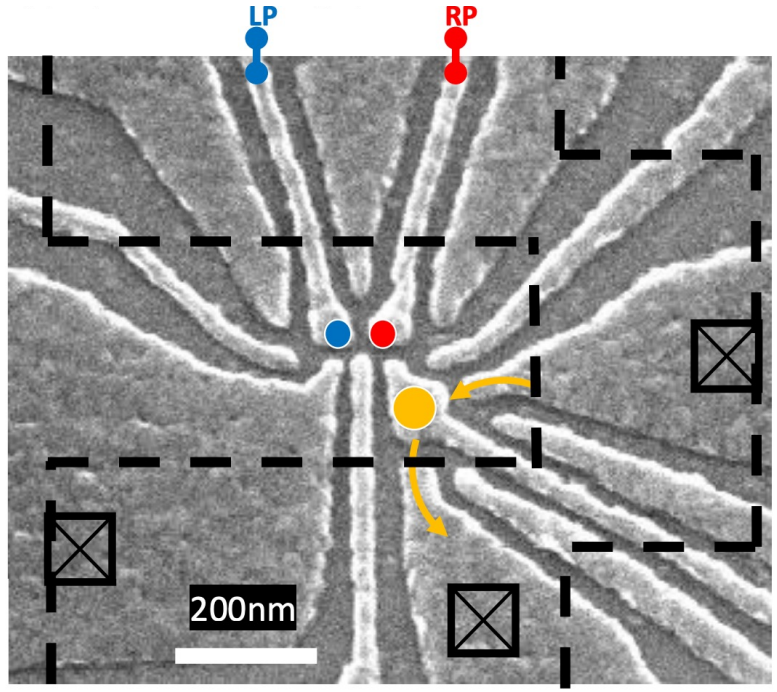


Photo credit: Quantum Inspire

Qubits made by advanced semiconductor manufacturing

A.M.J. Zwerver[1], T. Krähenmann[1], T.F. Watson[2], L. Lampert[2], H.C. George[2], R. Pillarisetty[2], S.A. Bojarski[2], P. Amin[2], S.V. Amitonov[1], J.M. Boter[1], R. Caudillo[2], D. Corras-Serrano[2], J.P. Dehollain[1], G. Droulers[1], E.M. Henry[2], R. Kotlyar[2], M. Lodari[1], F. Luthi[2], D.J. Michalak[2], B.K. Mueller[2], S. Neyens[2], J. Roberts[2], N. Samkharadze[1], G. Zheng[1], O.K. Zietz[2], G. Scappucci[1], M. Veldhorst[1], L.M.K. Vandersypen[1,*], J.S. Clarke[2,*]

(Dated: February 1, 2021)

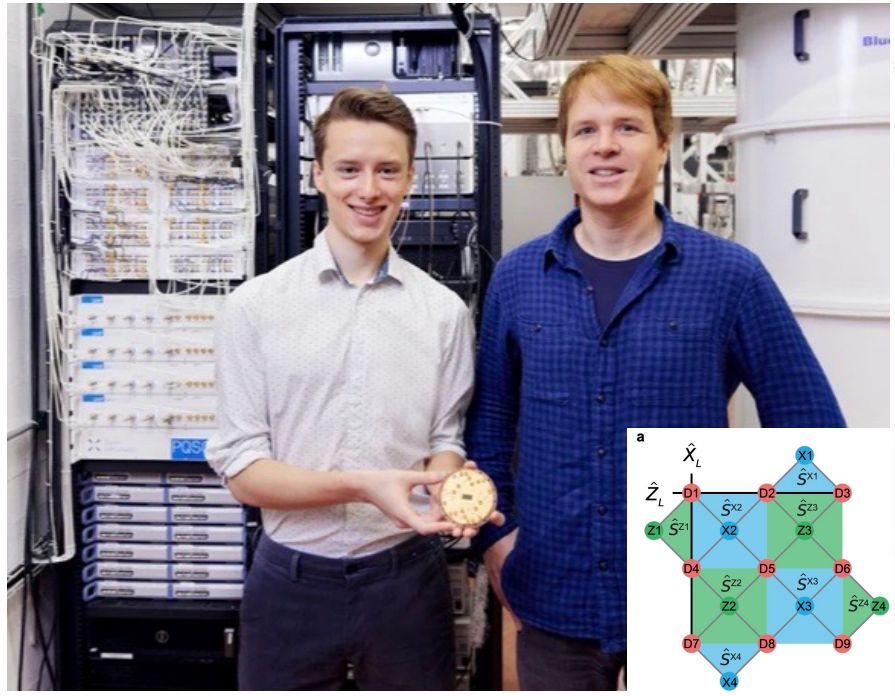
Support Quantum Advantage from the Classical Side

Capabilities

- Bring-up and characterization performance + flexibility
- Feedback
- Quantum Error Correction

Few qubits

20-200 qubits, Surface 17, 49



Nathan Lacroix, Sebatian Krinner, et al.
Quantum Device Lab, ETH Zurich, Switzerland

Support Quantum Advantage from the Classical Side

Capabilities

- Bring-up and characterization performance + flexibility
- Feedback
- Quantum Error Correction
- Tileable and distributed control
- HPC connectivity

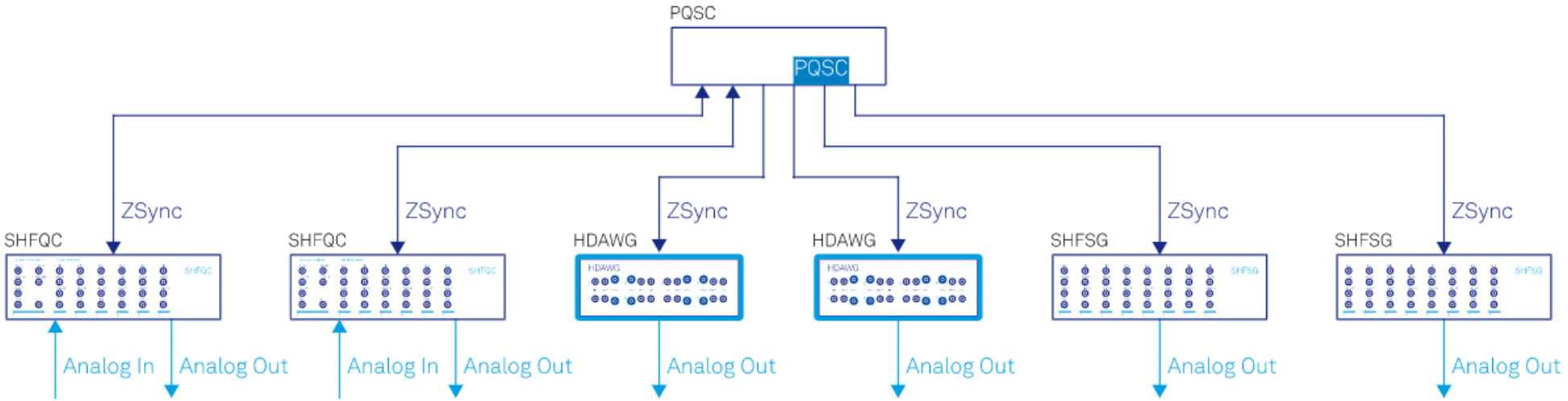
Few qubits

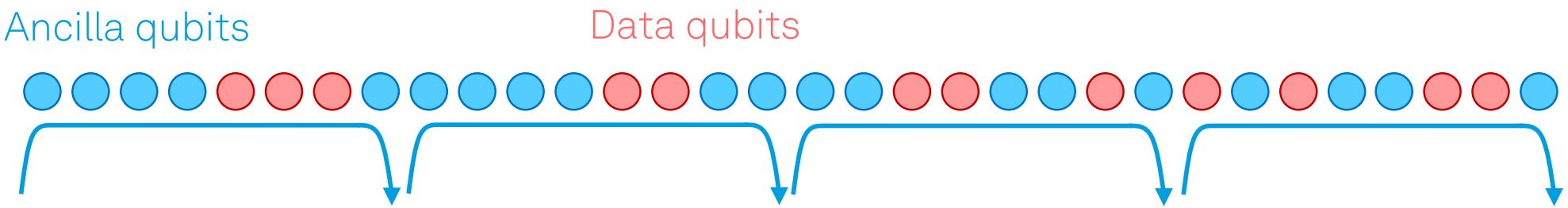
20-200 qubits, Surface 17, 49

1000 qubits

Photo reference: doi: 10.1126/science.abe8122

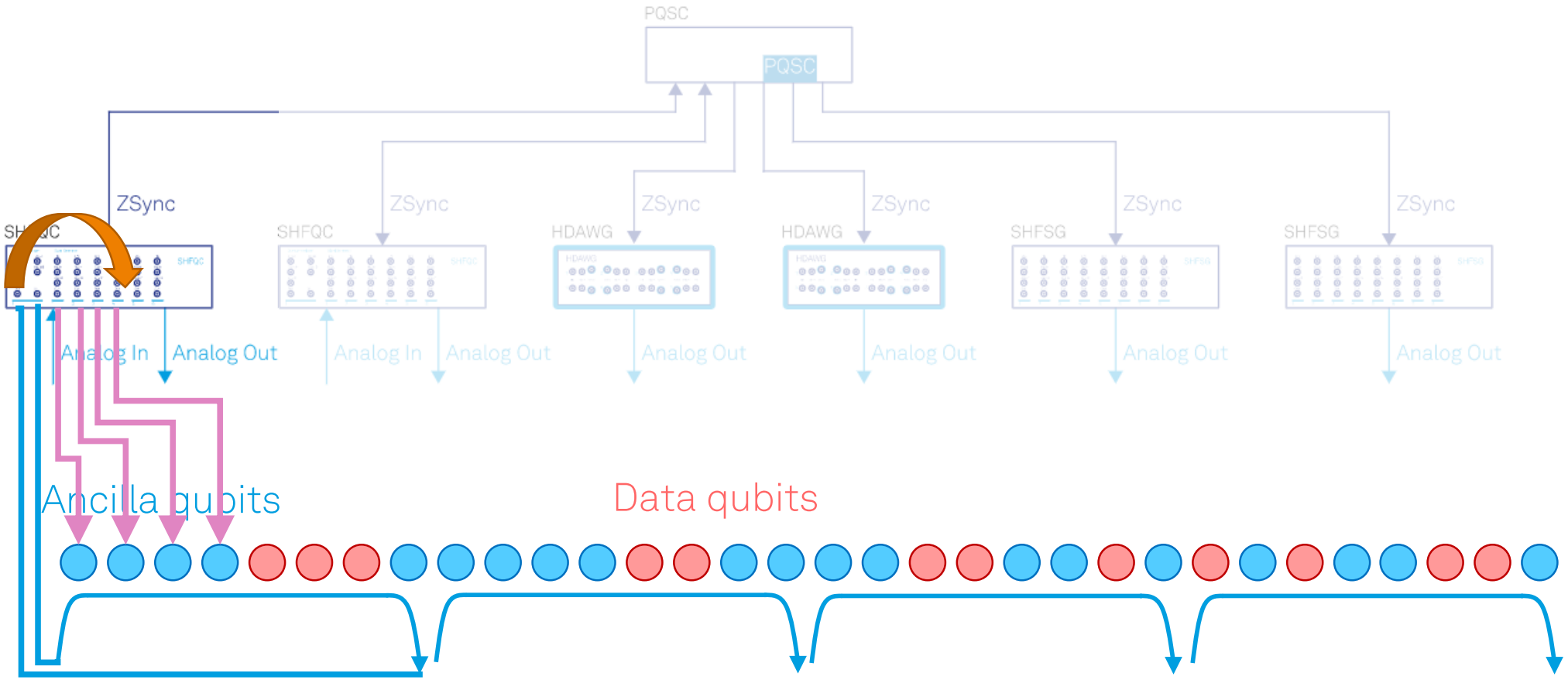
QCCS Architecture





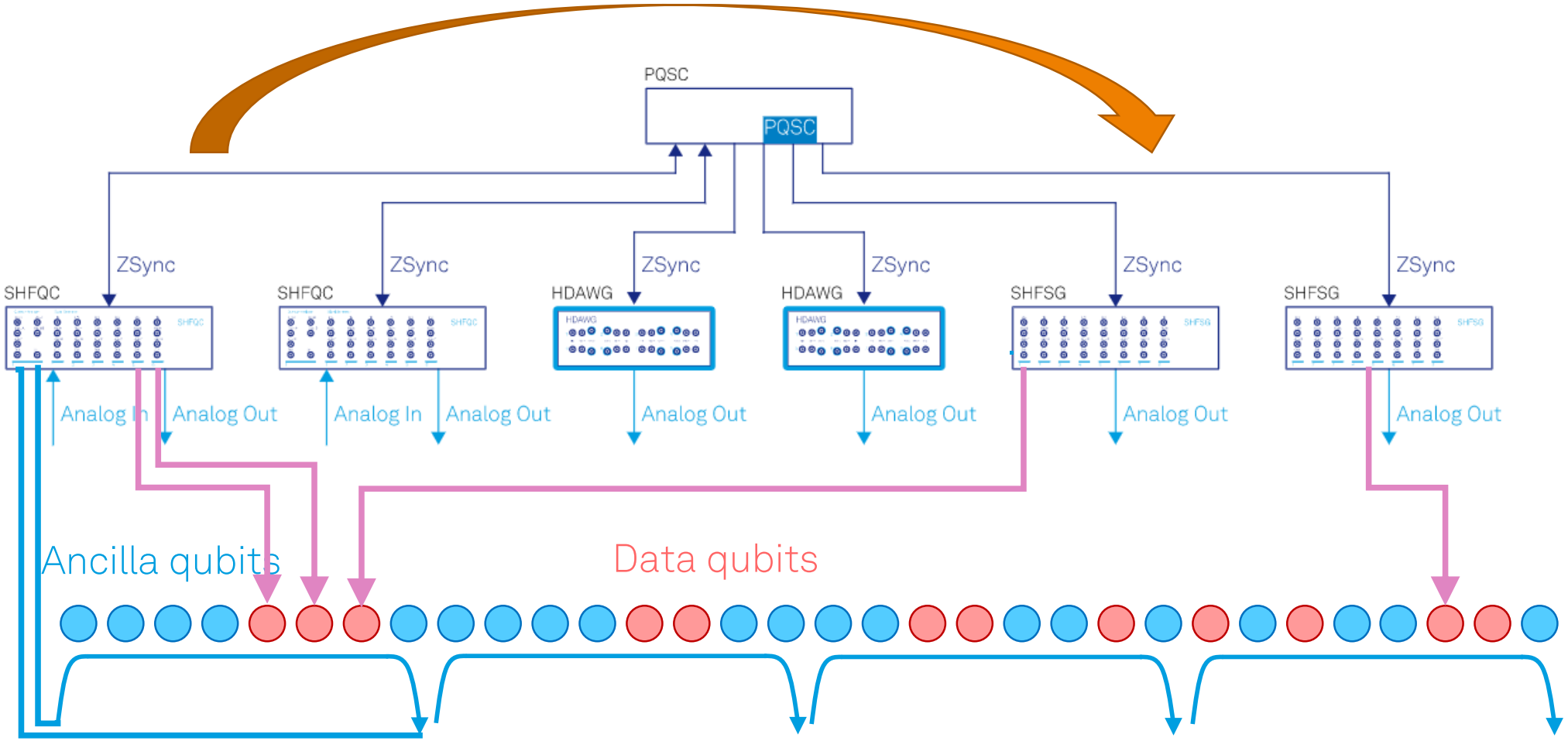
QCCS Architecture

Local feedback on the fastest path: <300 ns



QCCS Architecture

Global feedback: typ. 500 to 1,000 ns



People make the Difference

Support with Outstanding Application Know-How

More than 25 PhD-level physicists in M&S!

A company by scientists for scientists

Zurich Instruments Collaboration Projects

USA

→ Build a stabilized qubit
(Andreas Wallraff,
Leo diCarlo)

Switzerland

Innosuisse → Quantum error correction
(Andreas Wallraff)

Germany

MUNIQC-SC
Quantum Computing Demonstrator
Superconducting Qubits

Munich Quantum Valley

→ Control 100 qubits

QSOLID

→ Scaling and HPC

Europe

SuperQuLAN

→ Entangle 2 fridges over 30 m

OpenSuperQPlus

→ Scaling of superconducting QCs

ModQC

→ Multi-QPU quantum computers

Netherlands

Quantum Inspire

→ A quantum computer on the web

Quantum Economy: Accelerating quantum startups

IQM

European Startup

- Roadmap to ~150 qubits
- HPC connectivity
- Error correction

Image reference: https://www.meetiqm.com

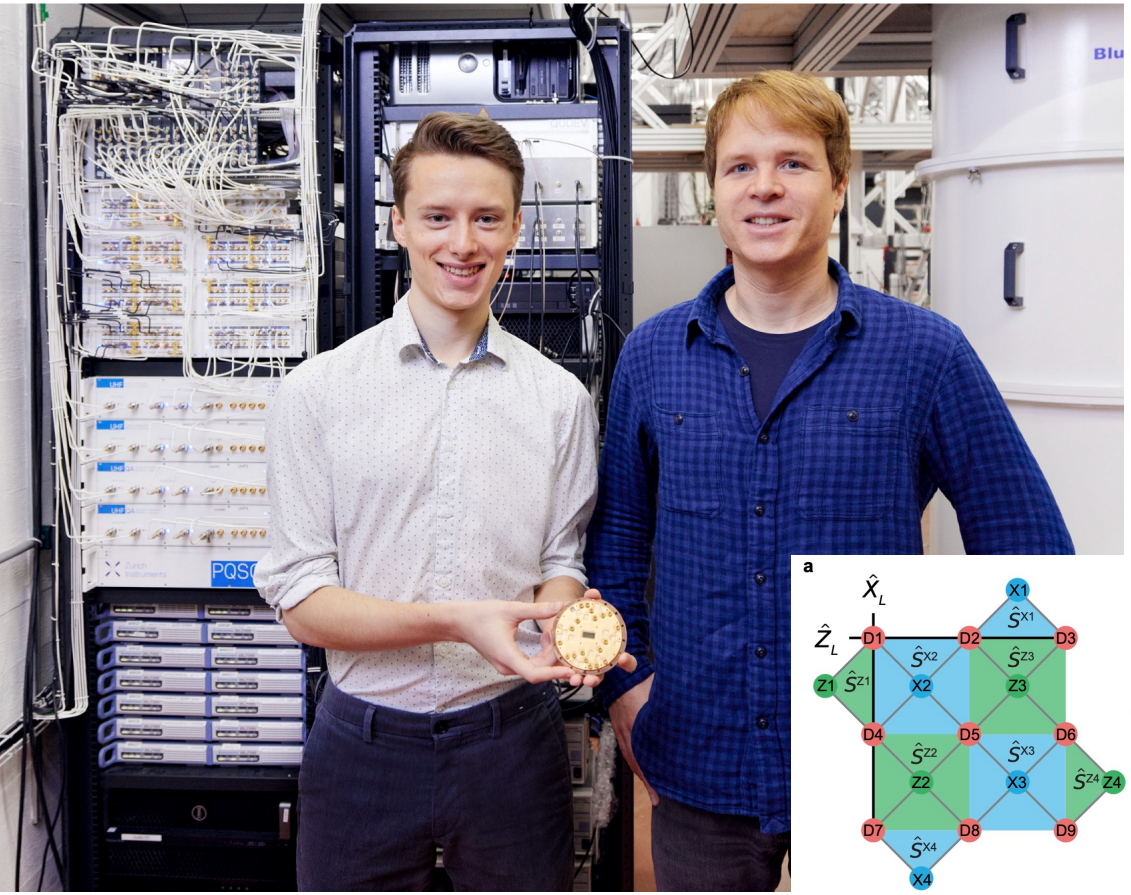
ATLANTIC QUANTUM

US Startup

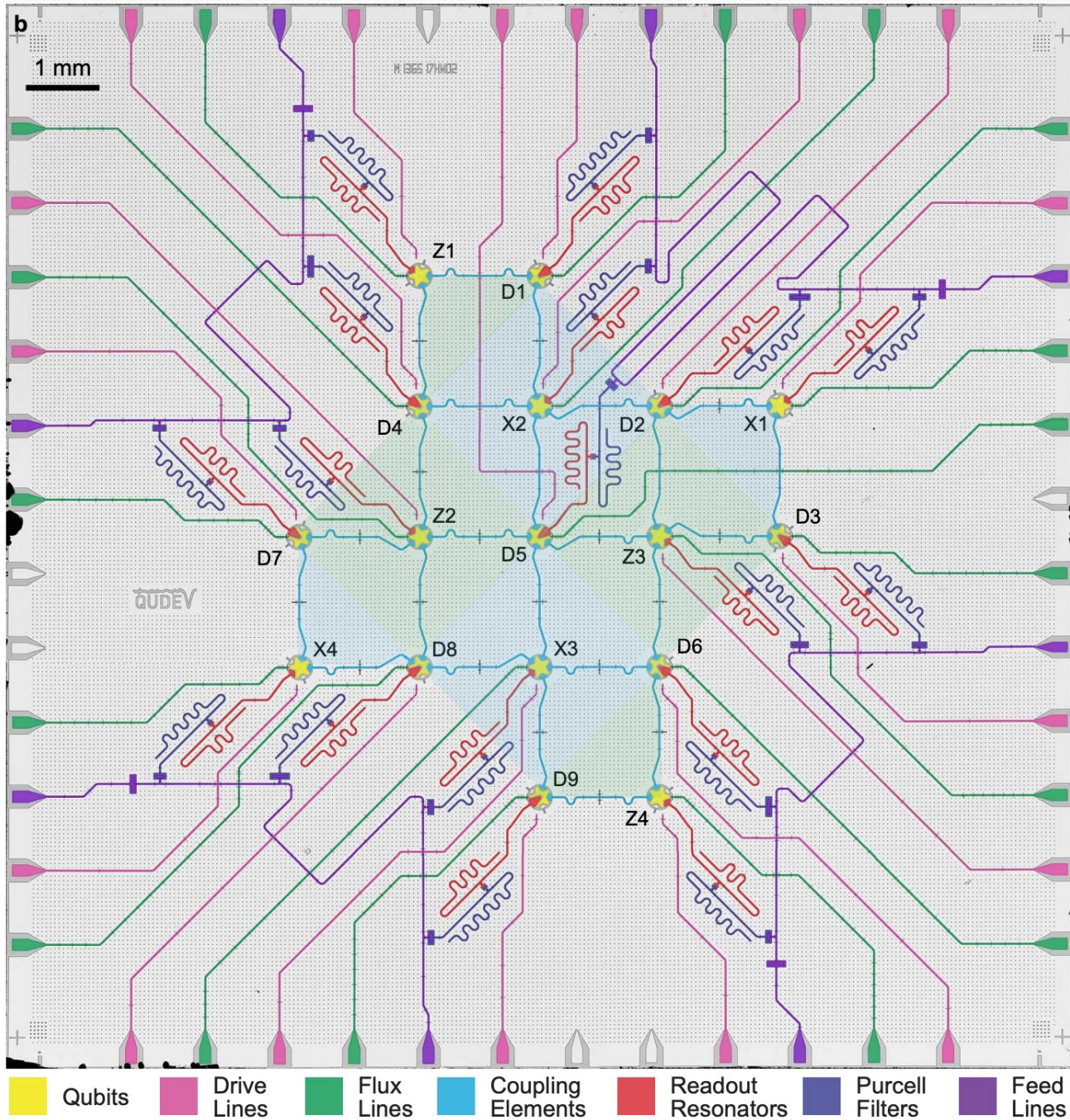
- MIT spin-off on Fluxoniums
- Reduced capital requirement + speed-up
- Compatibility to global software ecosystem

Image reference: https://www.atlantic-quantum.com

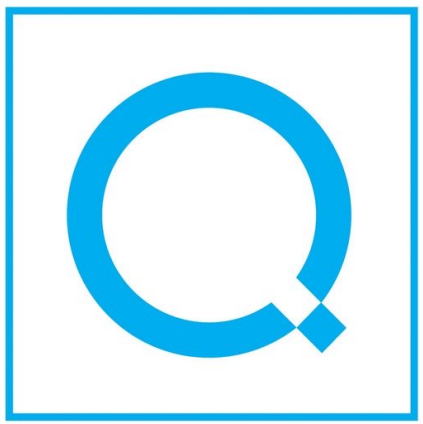
Surface 17



Nathan Lacroix, Sebastian Krinner, et al.
Quantum Device Lab at ETH Zurich, Switzerland



Source: *Nature* **605,** 669–674 (2022);
https://doi.org/10.1038/s41586-022-04566-8



LabOneQ

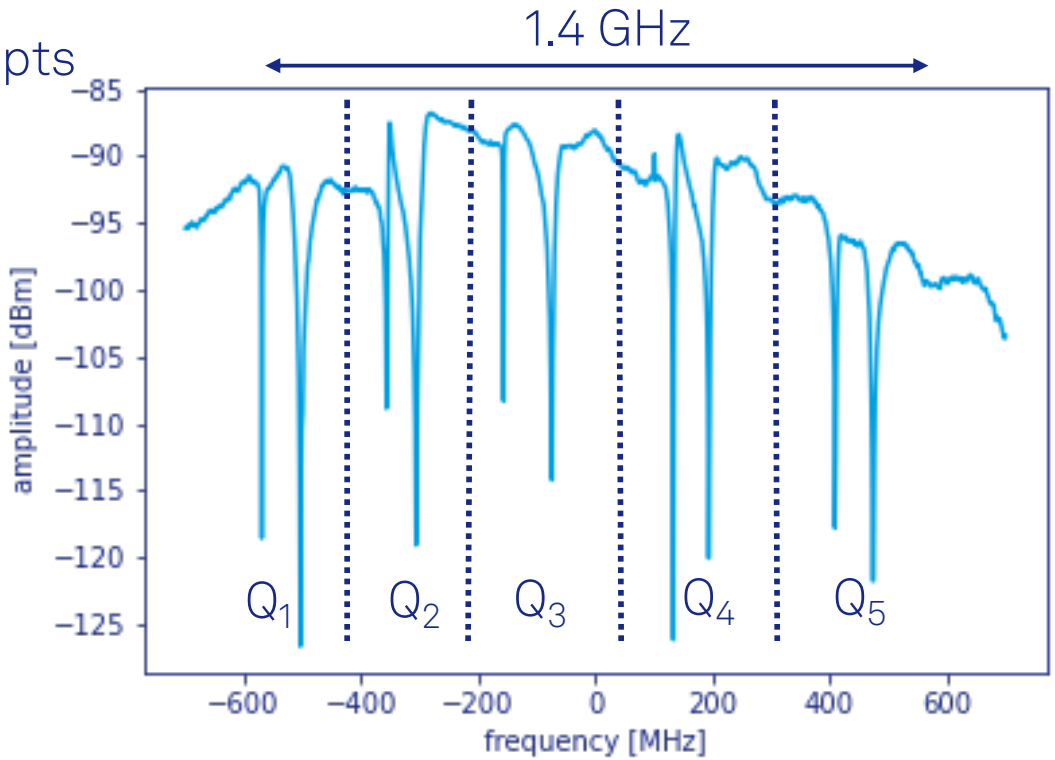
Reality Check: Resonator Spectroscopy in Seconds

Measurements at the speed limit

```
frequency_sweep = LinearSweepParameter(
    start=-0.7e9, stop=0.7e9, count=1000
)
with exp.acquire_loop_rt(
    acquisition_type=spectroscopy, count=1,
):
    with exp.sweep(parameter=frequency_sweep):
        exp.acquire(signal="acquire",
                    handle="res_spec",
                    length=10e-3
                    )
```

1000 pts

10 ms



Optimal operation of instruments

LabOne Q exploits real-time loops for optimal duty cycle

Duty cycle 95%

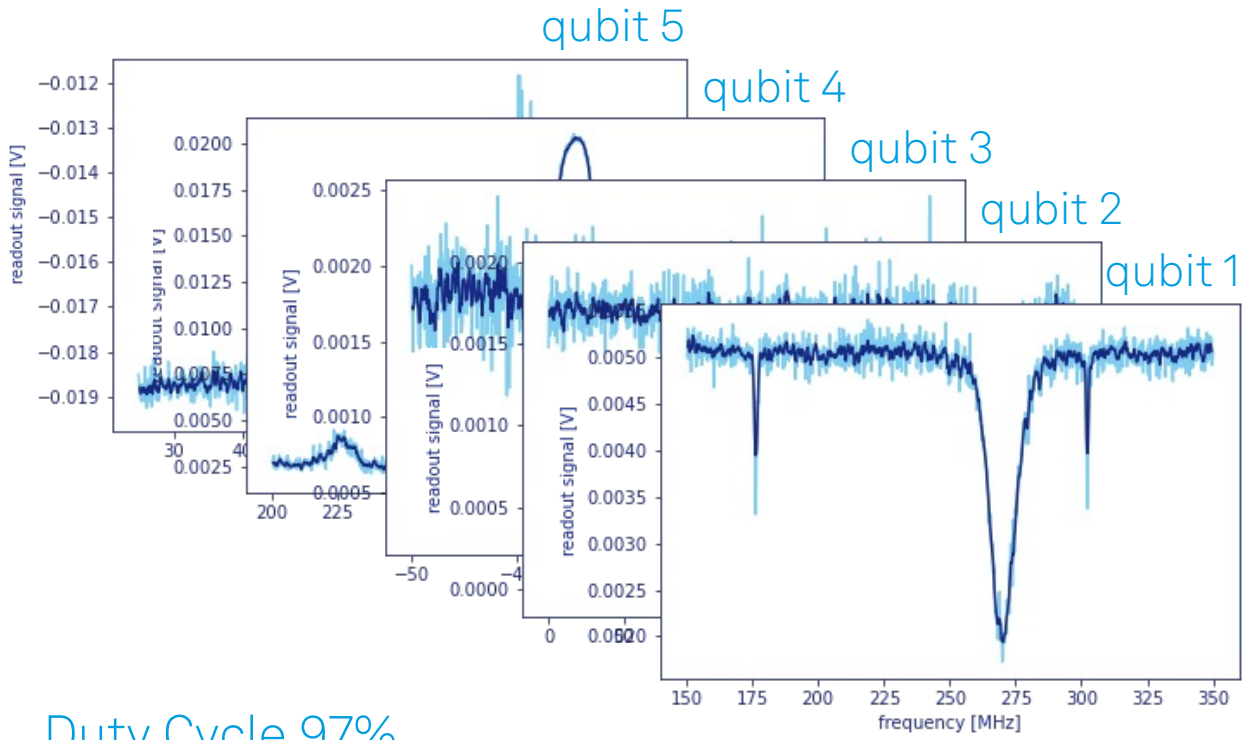
Completed < 10.5s including data download

→ Minimal overhead

Reality Check: Parallel Qubit Spectroscopy in Seconds

Parallel qubit spectroscopy of 5 qubits

```
# loop over qubit signal lines
for qubit in range(qubit_number):
    with exp.sweep(parameter=f_drive[qubit]):
        with exp.section(uid=f"qubit_excitation_{qubit}"):
            exp.play(signal=drive[qubit], pulse=spectroscopy_pulse)
        with exp.section(play_after=f"qubit_excitation_{qubit}"):
            exp.play(
                signal=measure[qubit],
                pulse=read_pulse[qubit],
            )
            exp.acquire(
                signal=acquire[qubit],
                handle="qubit_spec",
                kernel=read_kernel[qubit],
            )
```



Build parallel experiments by a loop

- Loop activates channels on different instruments

Duty Cycle 97%

1,000 points, 20 ms integration per point

→ Theoretical limit: 20 sec

→ Measurement time: <20.5 sec

- One-time setup time for 5 qubits ~ 6 sec

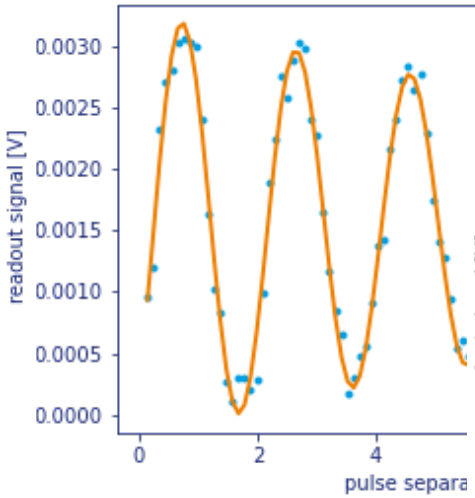
Reality Check: Parallel Pulsed Measurements

Rabi, Ramsey and T1 on 3 qubits

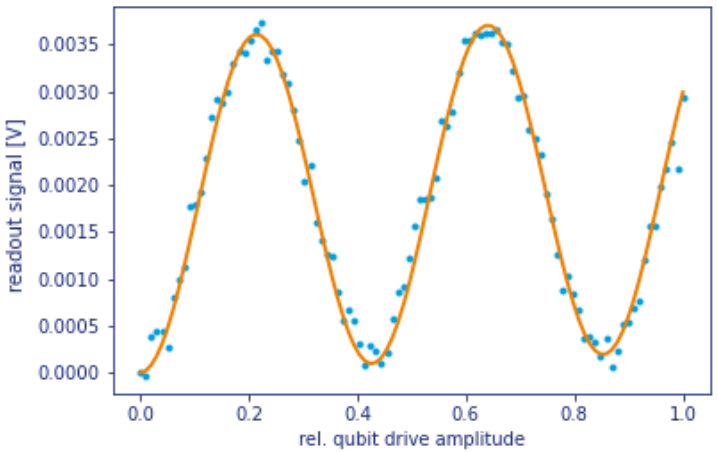
```
with exp_ramsey.acquire_loop_rt(uid="ramsey_shots",
    count=n_average, averaging_mode=cyclic,
):
    with exp_ramsey.sweep(parameter=ramsey_sweep):
        with exp_ramsey.section( alignment=right,
            length=2*x90.length+ramsey_max
        ):
            exp_ramsey.play(signal="drive", pulse=x90)
            exp_ramsey.delay(signal="drive", time=ramsey_sweep)
            exp_ramsey.play(signal="drive", pulse=x90)

        readoutQubit(exp_ramsey, qubit="q0")
```

Ramsey



Rabi



LabOne Q compiles hardware-efficient

- Optimal pulse-level sequencing automatically generated for each channel

→ Minimal computer-to-QCCS data transfer

Reality Check: Parallel Pulsed Measurements

Rabi, Ramsey and T1 on 3 qubits

```
with exp_ramsey.acquire_loop_rt(uid="ramsey_shots",
    count=n_average, averaging_mode=cyclic,
):
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        with exp_ramsey.section( alignment=right,
            length=2*x90.length+ramsey_max
        ):
            exp_ramsey.play(signal="drive", pulse=x90)
            exp_ramsey.delay(signal="drive", time=ramsey_sweep)
            exp_ramsey.play(signal="drive", pulse=x90)

        readoutQubit(exp_ramsey, qubit="q0")
```
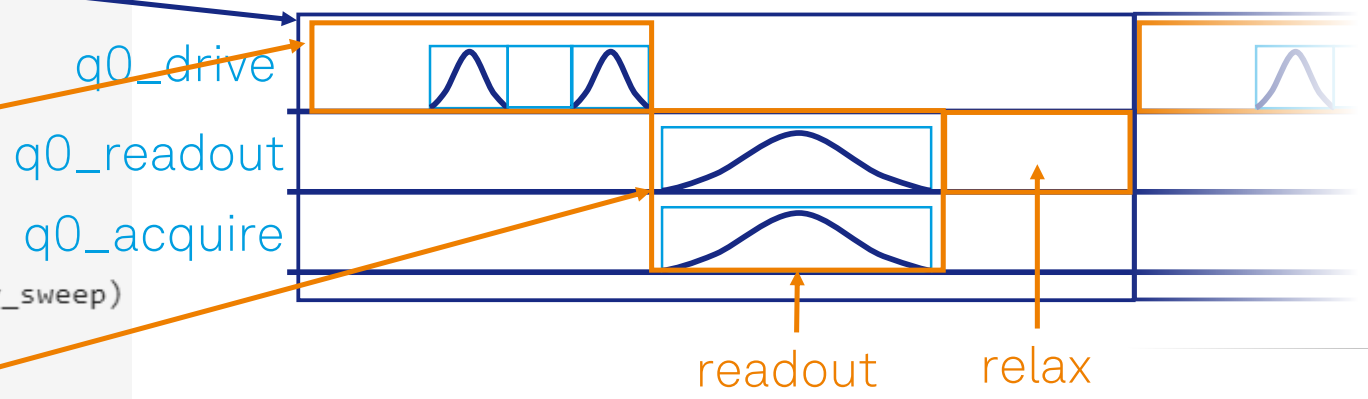



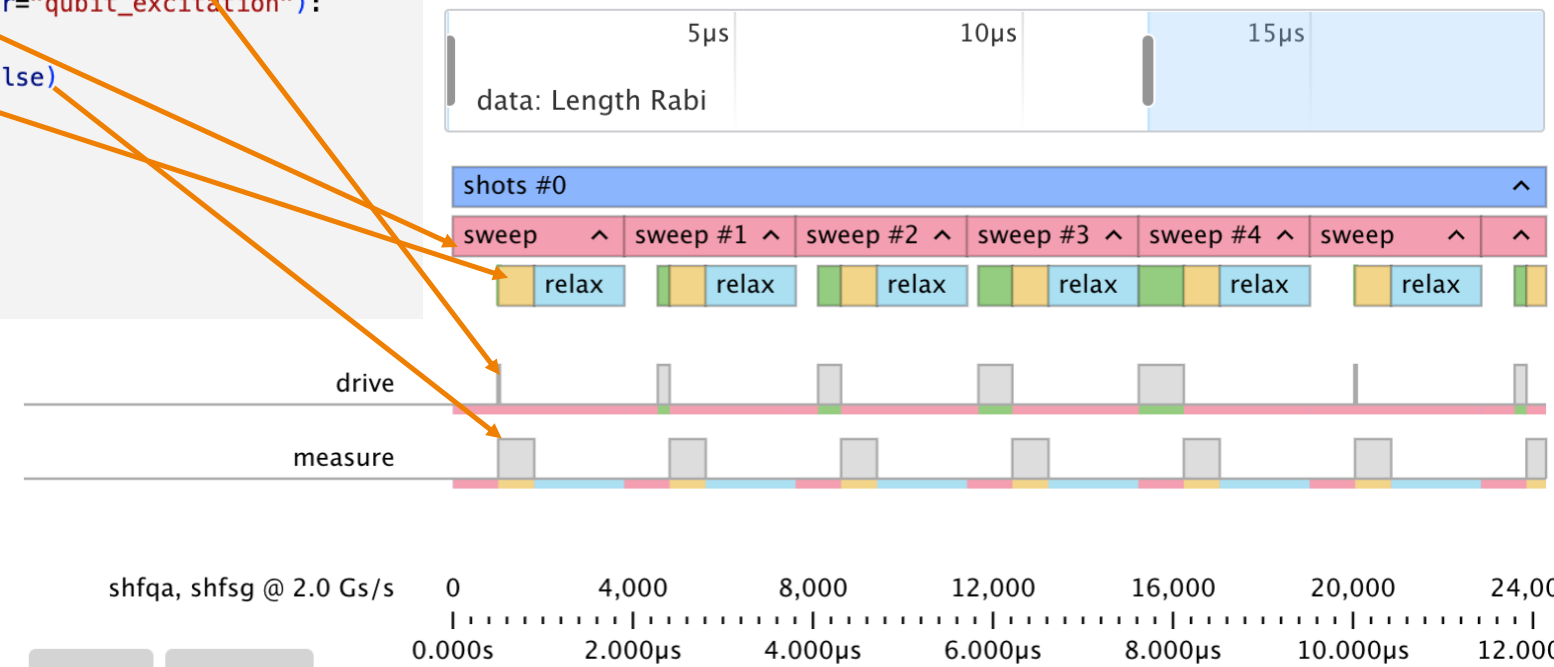
LabOne Q Sections

- Intuitively align pulses in a scalable fashion
- Single-sample accuracy guarantee
- Code easily applied to different qubits

Reality Check: User experience and rapid programming

Rabi in Pulse Sheet Viewer

```python
# inner loop - real-time sweep of qubit drive pulse amplitude
with exp.sweep(
    uid="sweep", parameter=length_sweep, alignment=SectionAlignment.RIGHT
):
    # qubit excitation - pulse length will be swept
    with exp.section(uid="qubit_excitation", alignment=SectionAlignment.RIGHT):
        exp.play(signal="drive", pulse=x90, length=length_sweep)
    # qubit readout pulse and data acquisition
    with exp.section(uid="qubit_readout", play_after="qubit_excitation"):
        # play readout pulse
        exp.play(signal="measure", pulse=readout_pulse)
        # signal data acquisition
        exp.acquire(
            signal="acquire",
            handle="ac_0",
            kernel=readout_weighting_function,
        )
```



What do we focus on today?

Support research groups and QC companies

- Projects with leading groups world-wide (ETH, Berkeley, KRISS, …)
- Grow Zurich Instruments' quantum team in Asia (open positions on www.zhinst.com)

Reduce setup size, complexity and price per qubit

- More QC-specific hardware products
- More automatic bring-up, characterization and benchmarking methods

Add features

- Extend support for Qiskit, PycQED, Q-Ctrl, …
- Speed-up run-time performance
- Extend support for Quantum Error Correction

Zurich Instruments

Challenge us.

What are your requirements?

Contact us today

www.zhinst.com