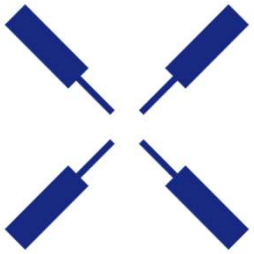


Zurich Instruments

Enabling the second quantum revolution with classical instrumentation

Moritz Kirste

June 26, 2024

Zurich Instruments
Quantum Mission

Accelerate the second quantum revolution.

Help to build the quantum computer.

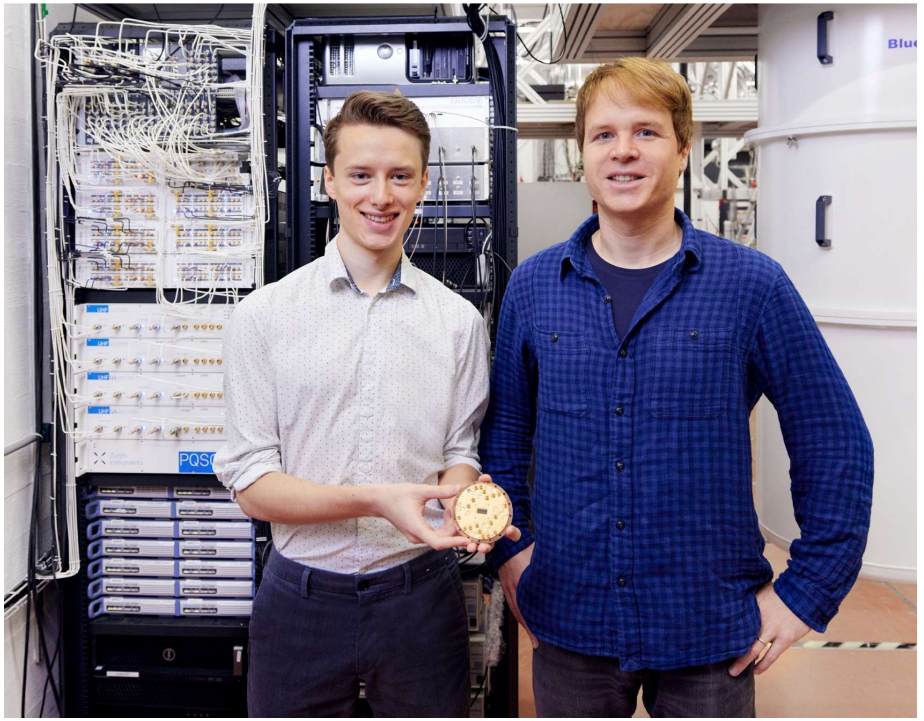
Powered by
LabOne Q

Zurich Instruments
Quantum Mission

Accelerate the second quantum revolution.

Help to build the quantum computer.

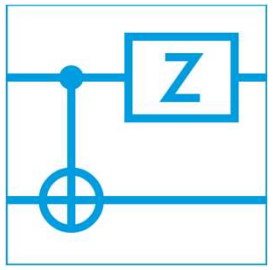
Let our customers focus on their main tasks.



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

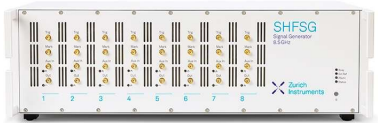
Zurich Instruments Quantum Computing Control System (QCCS)

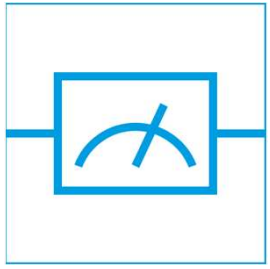
Core functions and components



Qubit Control

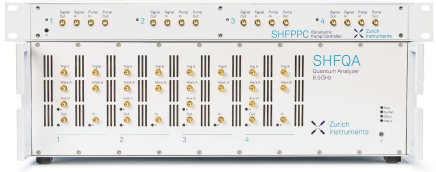
- Maximum gate fidelity
- High channel density
- RF pulses DC-8.5 GHz for gate operations
- DC-0.7 GHz flux pulses

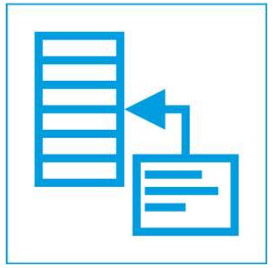




Qubit Readout

- Fast, high-fidelity qubit readout
- Real-time state discrimination
- Multi-qubit, multi-state

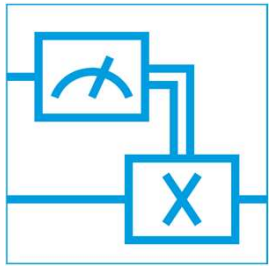




System Control

- Operation as one unit
- Interface and connect

LabOneQ

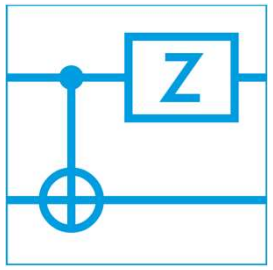


Quantum Feedback

- Low latency
- Error decoding

Zurich Instruments Quantum Computing Control System (QCCS)

Core functions and components



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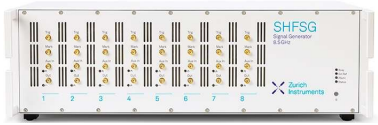

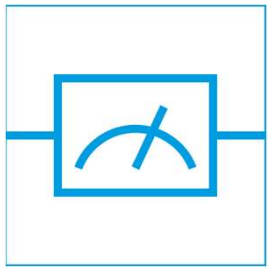

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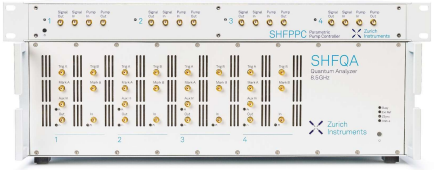
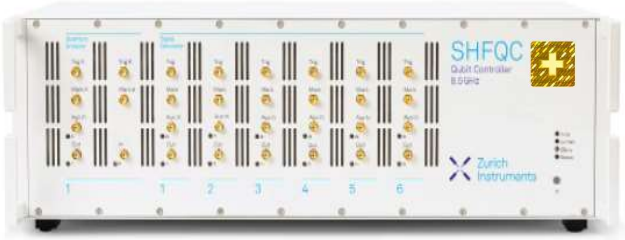


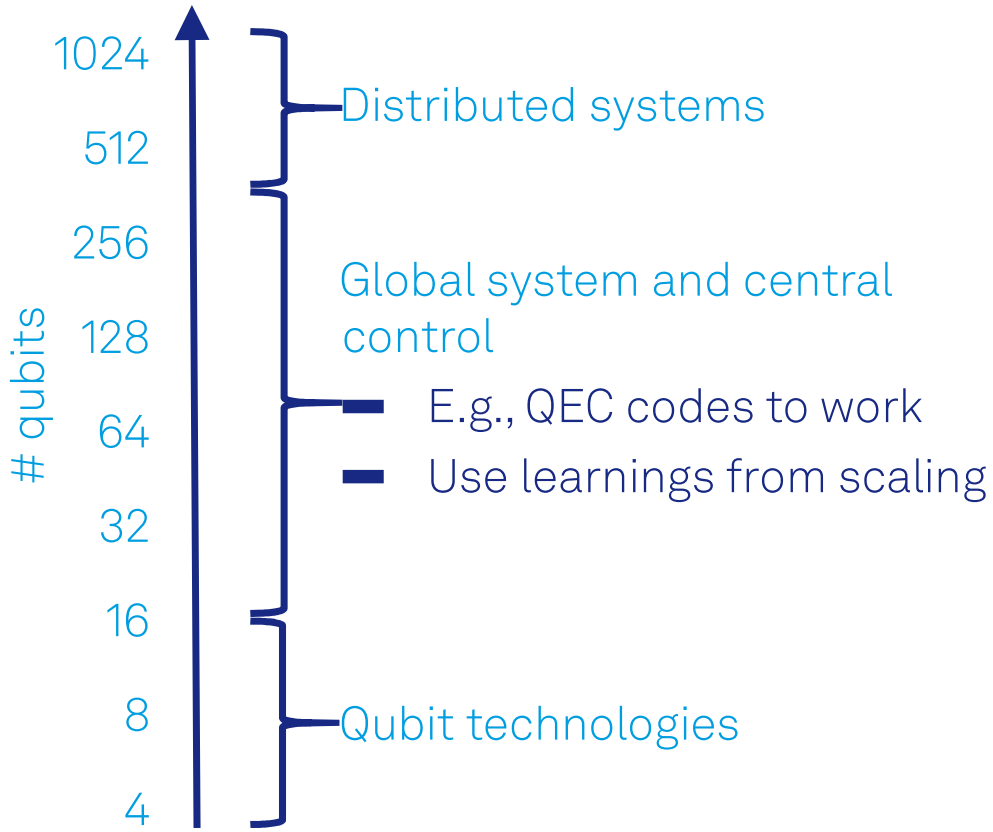


Qubit Control, Readout and Feedback

- Up to 6 qubits
- Active qubit reset

Our view on the road to quantum advantage

The roadmap to large qubit systems

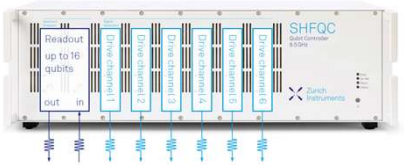


What we think will be needed

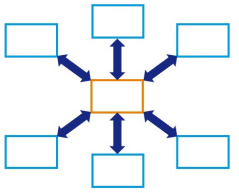
Scalable software

LabOne Q

Proven and dependable hardware



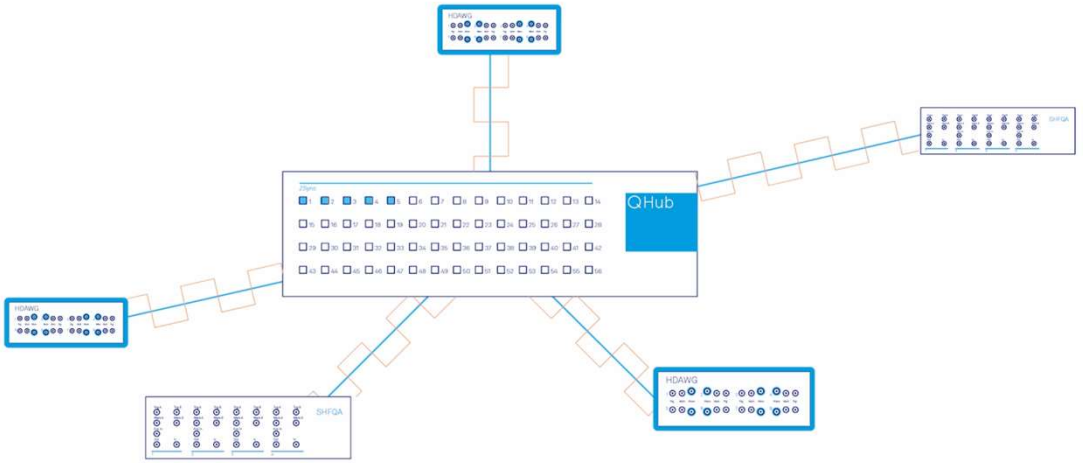
The right control system architecture

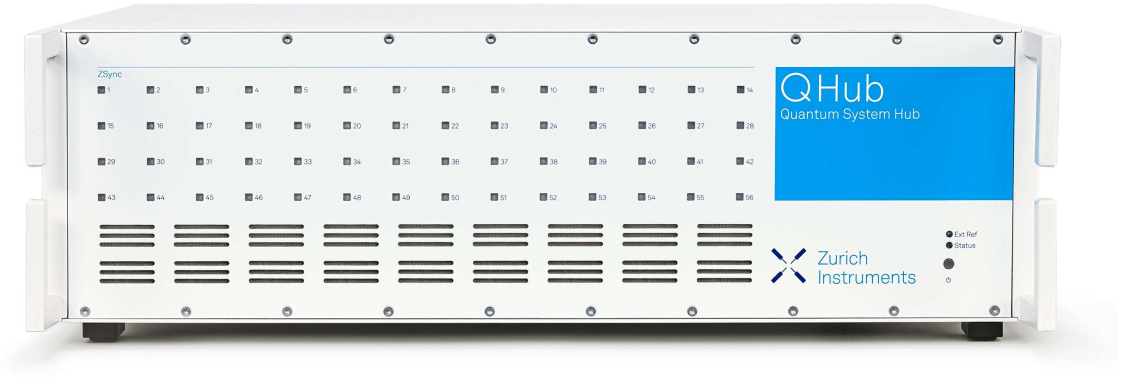


The right architecture

QHub Quantum System Hub

- Accurate clock distribution and synchronization

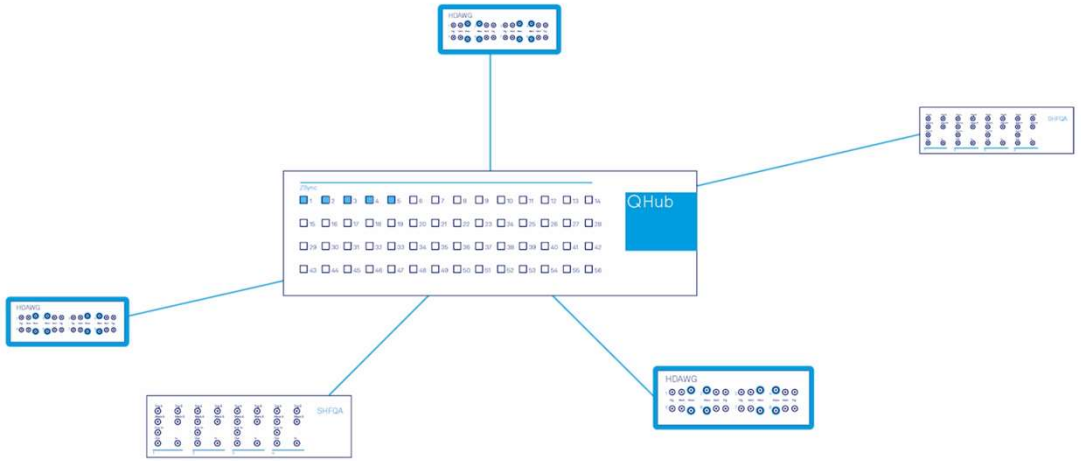


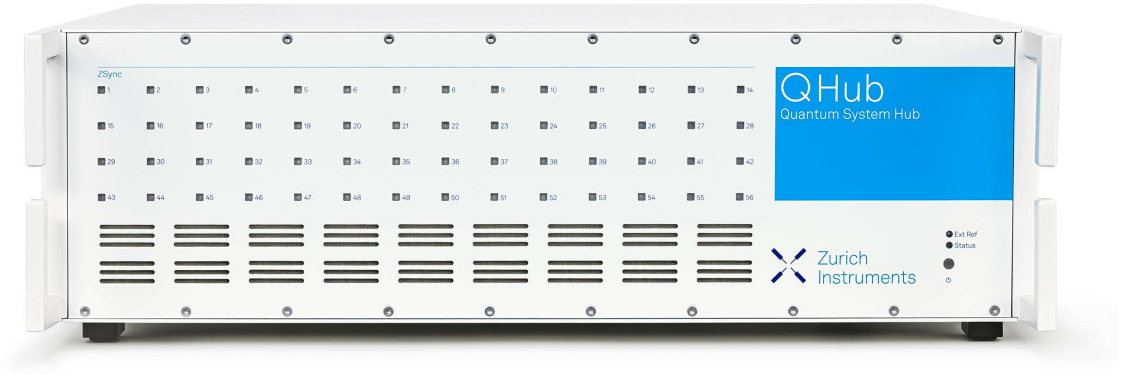


The right architecture

QHub Quantum System Hub

- Accurate clock distribution and synchronization
- Star architecture provides central knowledge of QPU state
- Feedback latency ~550 ns last sample in to first sample out

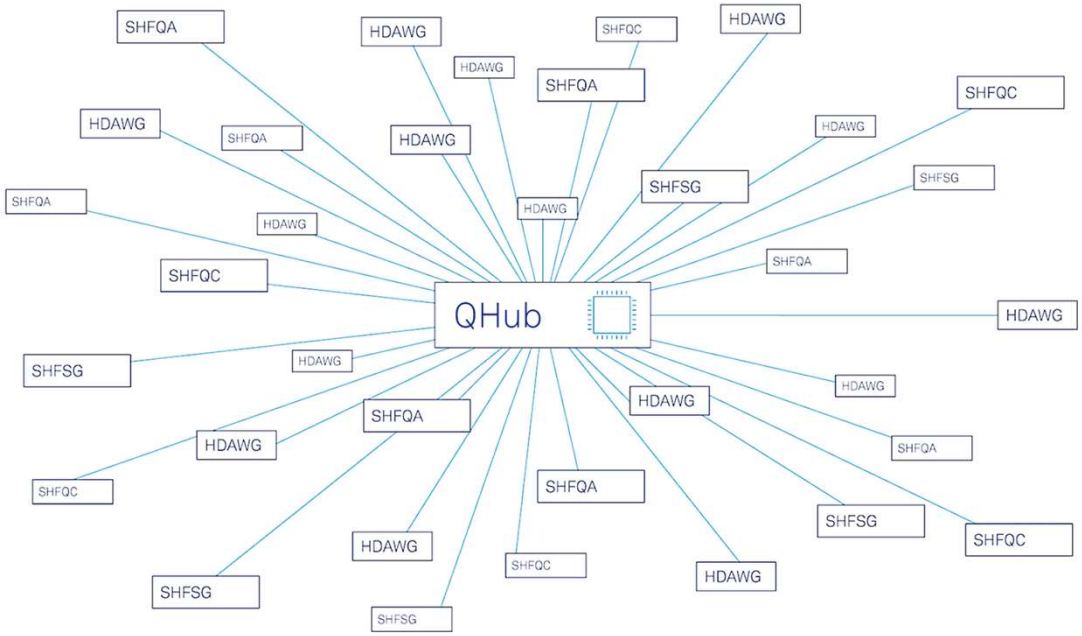


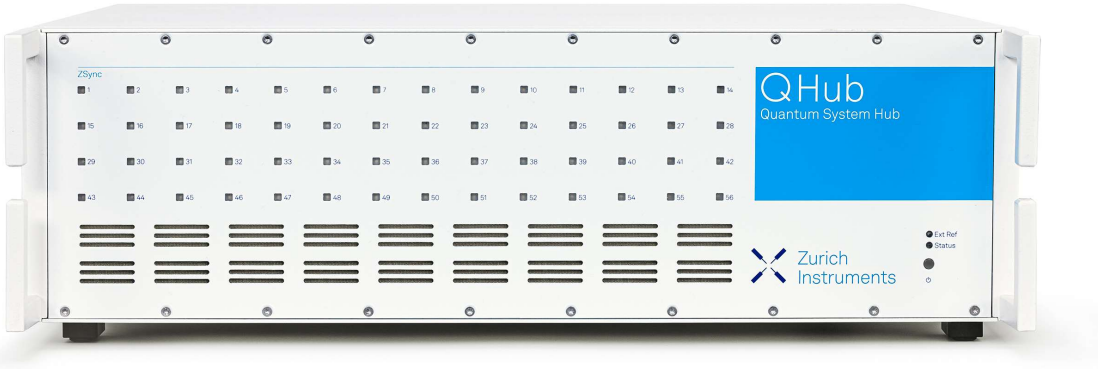


The right architecture

QHub Quantum System Hub

- Accurate clock distribution and synchronization
- Star architecture provides central knowledge of QPU state
- Feedback latency ~550 ns last sample in to first sample out
- Up to 448 channels
- Architecture extends to 1000s of qubits: star of stars, ...





Proven and dependable hardware

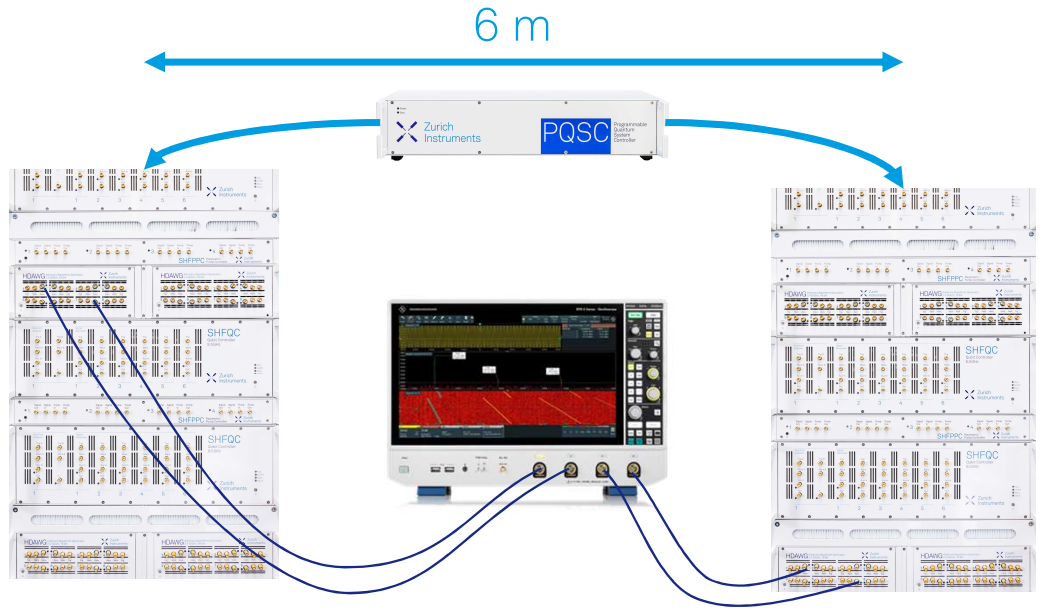
System stability measured over weeks

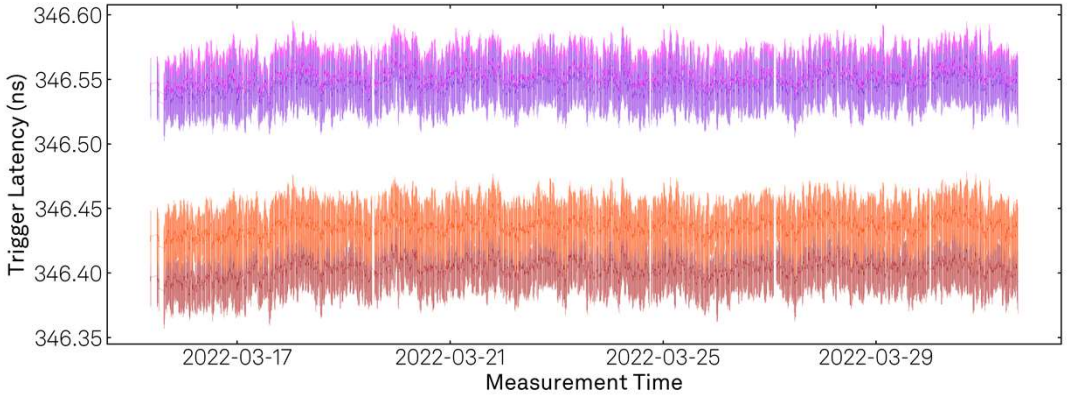
Success story

- 6-meter link between two instrument racks
- System operating without jitter for >**14 days**
- → Skew: inter-instrument: 150 ps, intra: <50 ps
- → Measured standard deviation: 20 ps

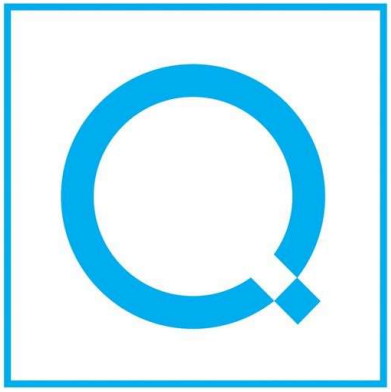
Out of the box

- Time and frequency synchronization
- Distribution of measurement results
- → Reduces setup and calibration time





Hardware is nothing without control...

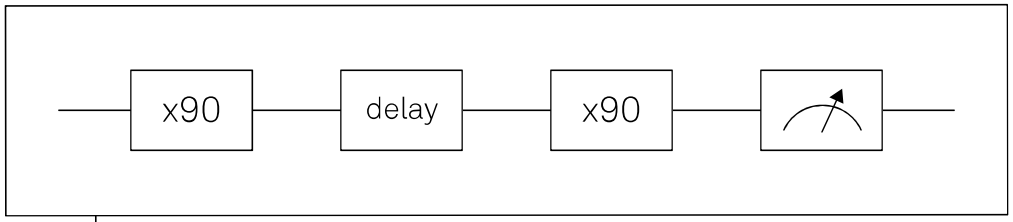


LabOneQ

Let´s take a look at how to support scaling...

Real time control and intuitive programming

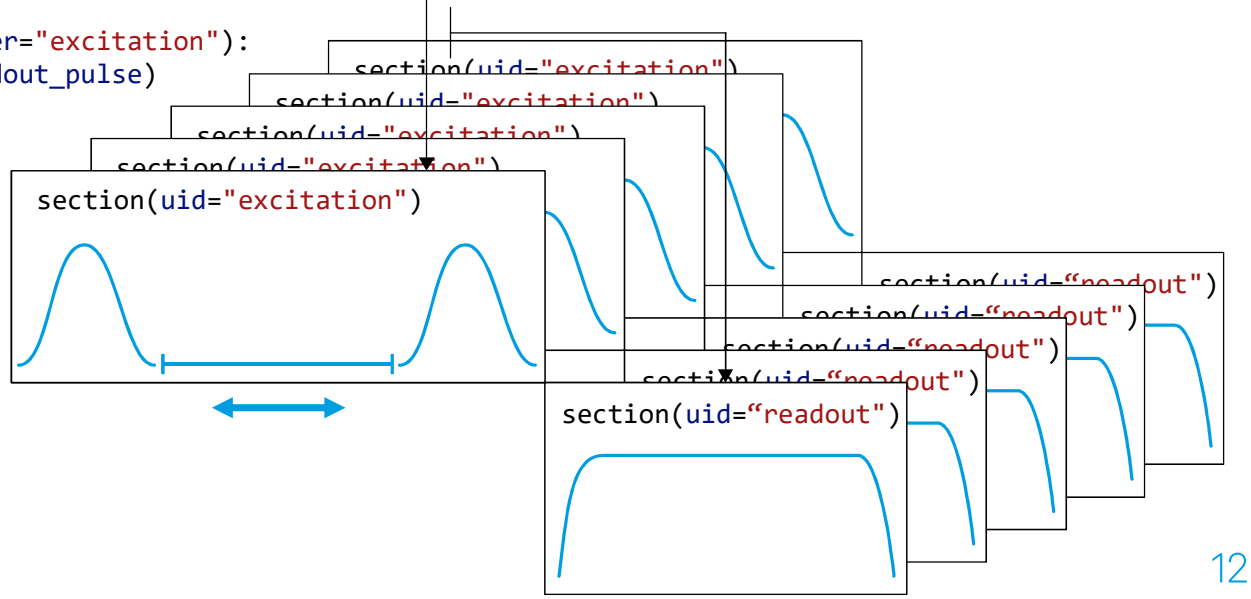
Transform quantum circuits into simple code




```
with exp.sweep(uid="sweep", parameter=time_sweep):

    with exp.section(uid=excitation"):
        exp.play(signal="drive", pulse = x90)
        exp.delay(signal="drive", time = delay)
        exp.play(signal="drive", pulse = x90)

    with exp.section(uid="readout", play_after="excitation"):
        exp.play(signal="measure", pulse=readout_pulse)
```



Intuitive programming

- Guaranteed sample precise 100% runtime control and predictability
- Real-time control of pulse parameters
- Apache license

Master complex sequence timing

Using sections and code blocks

Combine intuitive programming with visualization

- Example here: part of surface 7 code
- Write & read sequences like you think of them
- Showing entire experiment and individual pulses

```
# Z Stabilizer
with exp.section(uid="parity_map_z"):
    with exp.section(uid="rot_posz"):
        for z_qubit in z_qubits:
            exp.reserve(signal=f"{z_qubit}_flux")
            exp.play(signal=f"{z_qubit}_drive", pulse=y90)
    with exp.section(uid="S_Z1"):
        cz_gate(exp,"z0_flux",cphase,"q3_flux",cphase)
        cz_gate(exp,"z1_flux",cphase,"q7_flux",cphase)
        cz_gate(exp,"z2_flux",cphase,"q4_flux",cphase)
    with exp.section(uid="S_Z2"):
        cz_gate(exp,"z0_flux",cphase,"q0_flux",cphase)
        cz_gate(exp,"z1_flux",cphase,"q4_flux",cphase)
        cz_gate(exp,"z2_flux",cphase,"q2_flux",cphase)
```

...code continues

...continues

Feedback operation

Design your conditions

Active reset

- Gain tune-up & computing time
- Real-time execution without HDL coding
- Multi-state capable: e, f, h

```
with exp.match(handle="qubit_state"):
        exp.measure(handle="qubit_state")
        with exp.case(state=0):
                pass
        with exp.case(state=1):
                exp.play(signal="drive", pulse=pi)
```

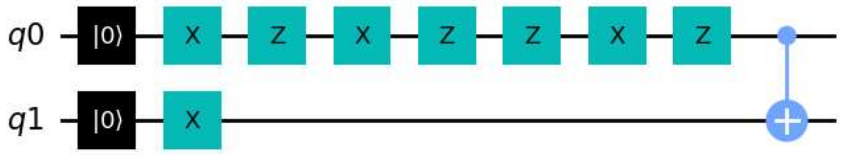
Repeat until success

- Real-time branching
- Manage parallel non-deterministic processes

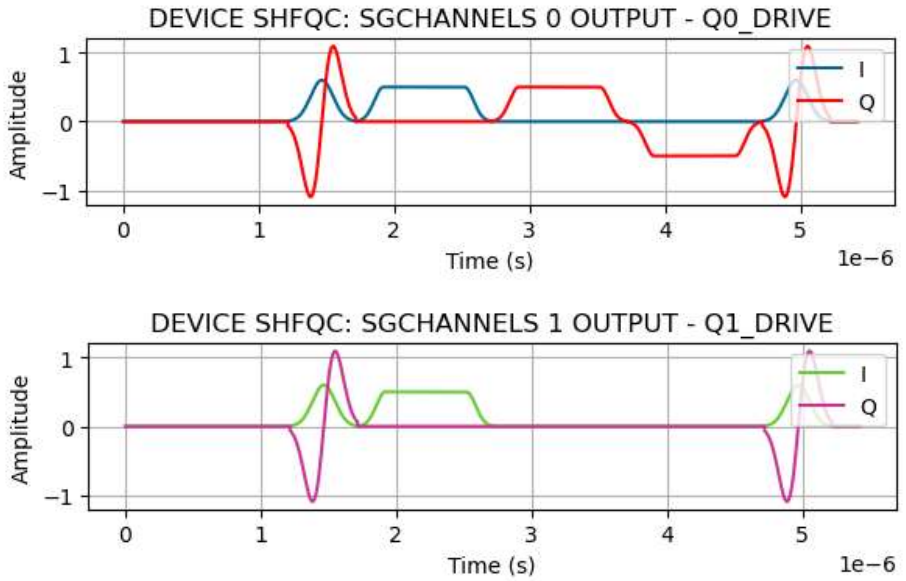
```
with exp.while(handle="qubit_state",
                success_condition=0b11):
        exp.play(signal="drive", pulse=pi)
        exp.measure(handle="qubit_state")
```

Transparent interfaces for upper software layer integration

Intuitive OpenQASM3 Integration




```
circuit = QuantumCircuit(
    QuantumRegister(1,"q0"), QuantumRegister(1,"q1")    )
circuit.reset(0)
circuit.reset(1)
circuit.x(0)
circuit.z(0)
circuit.x(0)
circuit.z(0)
circuit.z(0)
circuit.x(0)
circuit.z(0)
circuit.x(1)
circuit.cx(0,1)
```



LabOne Q output simulator

- Instrument output is simulated
- Can be connected to your preferred qubit simulator

Korean success stories from SKKU

Speeding up variational quantum algorithms

Challenge

- Iterative preparation of trial quantum state based on variational parameters

→ Time-intensive and difficult experiments

QCCS key capabilities

- In-place waveform exchange

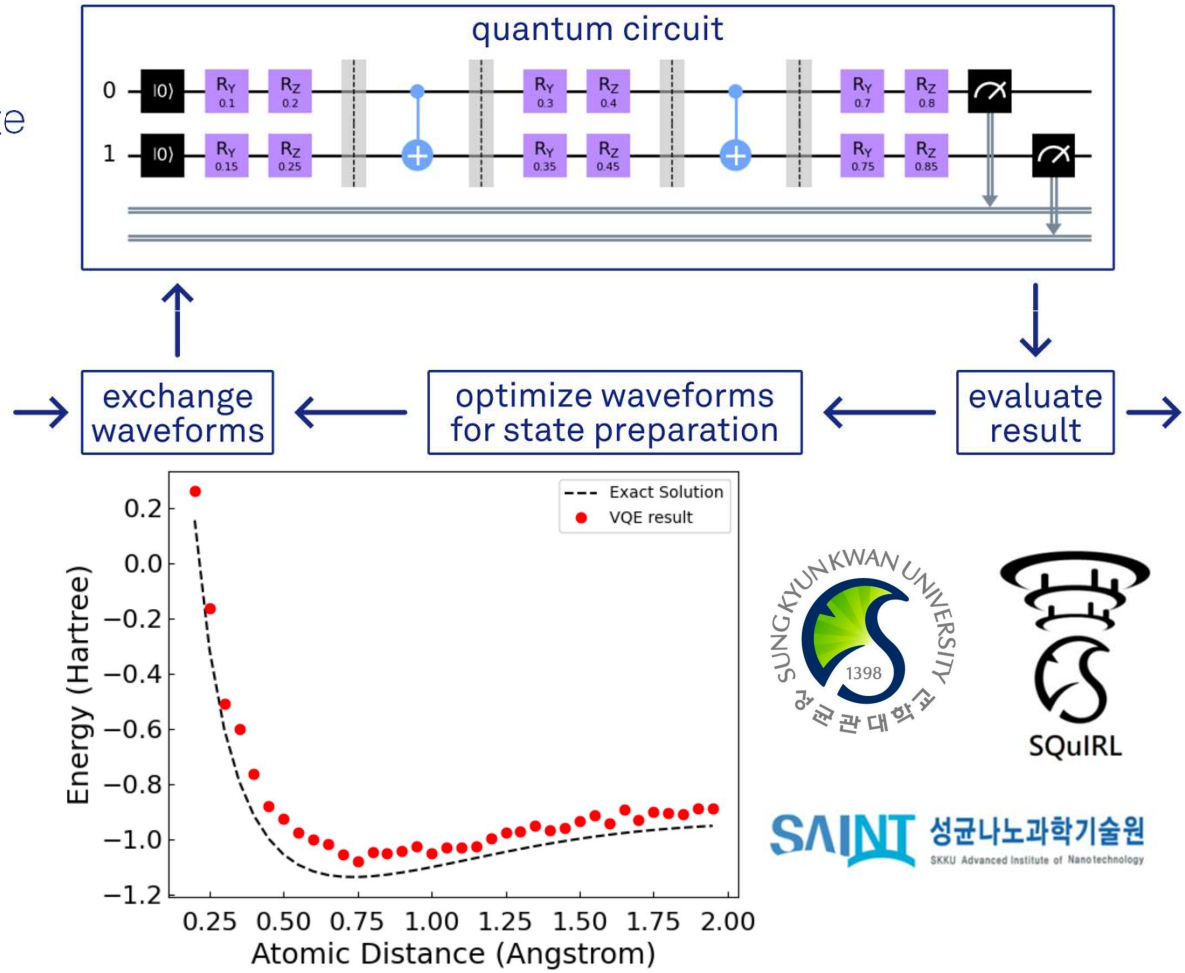
→ Minimize communication overhead

→ Maximize duty-cycle

- OpenQASM import from high-level languages e.g. Qiskit

Acknowledgement

- Prof. Yonuk Chong
- YoungDu Kim



SUNGKYUNKWAN UNIVERSITY 1398 성균관대학교

SQuIRL

SAINT 성균나노과학기술원 SKKU Advanced Institute of Nanotechnology

Material courtesy Yonuk Chong Lab, SKKU

Korean success stories from KRISS

Live demonstration of 20 qubit device

Challenge

- Live demonstration to show 20-qubit Rabi measurements, 10-qubit IQ blobs, 5-qubit X gates, 7-qubit H gates, and 2-qubit entanglement

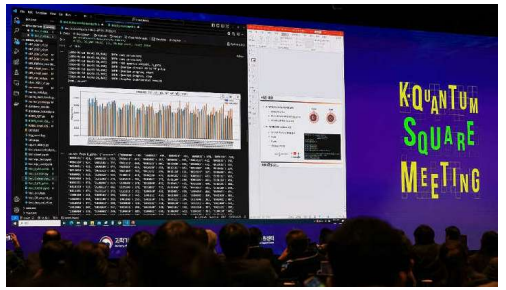
Held at K-Quantum Square Meeting 2024.01.10

- Done at Superconducting Quantum Computing system at KRISS
- Used Zurich Instruments Control Electronics

Acknowledgement

- Dr. Lee Yong-ho (Director of Center for Superconducting Quantum Computing System, KRISS)
- Dr. Hwan-Seop Yeo

KRISS Korea Research Institute of Standards and Science



Material courtesy Lee Yong-Ho Lab, KRISS

Announcement of two new Korean collaborations

Officially signed today during Quantum Korea conference

Memorandum of understanding between Norma and Zurich Instruments

- Develop interface between Norma's Q Platform software and LabOne Q
- Joint offering tailored to the specific needs and technological focus of Korean customers

Memorandum of understanding between KAIST Graduate School of Quantum Science And Technology and Zurich Instruments

- Aims to elevate quantum computing education in Korea
- Develop educational programs that prepare the next generation of quantum computing professionals

Zurich Instruments Quantum Mission

In summary

- Technology leading hardware
- Intuitive and scale-able open software
- System architecture future ready

For our partners

→ Support your research with local Korean subsidiary

→ For academia: Focus on cutting-edge research

→ For companies: Reduced risk, time to market and capital requirement

LabOne Q

Zurich Instruments

Come by at our booth

Thank you for your attention