

QUDORA's QIR-Based Software Stack for Trapped-Ion Quantum Computing ■

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QUDORA TECHNOLOGIES GMBH

IN A NUTSHELL



2021

FOUNDED

33+

TEAM MEMBERS

€30M

SECURED REVENUE

QCaaS

LIVE -> cloud.qudora.com



Hamburg



Hannover



Braunschweig

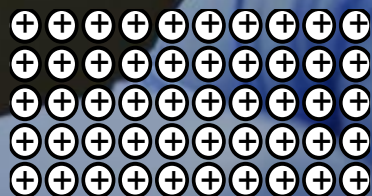


XAPHIRO

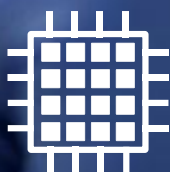


50

QUBITS



NFQC™
TECHNOLOGY



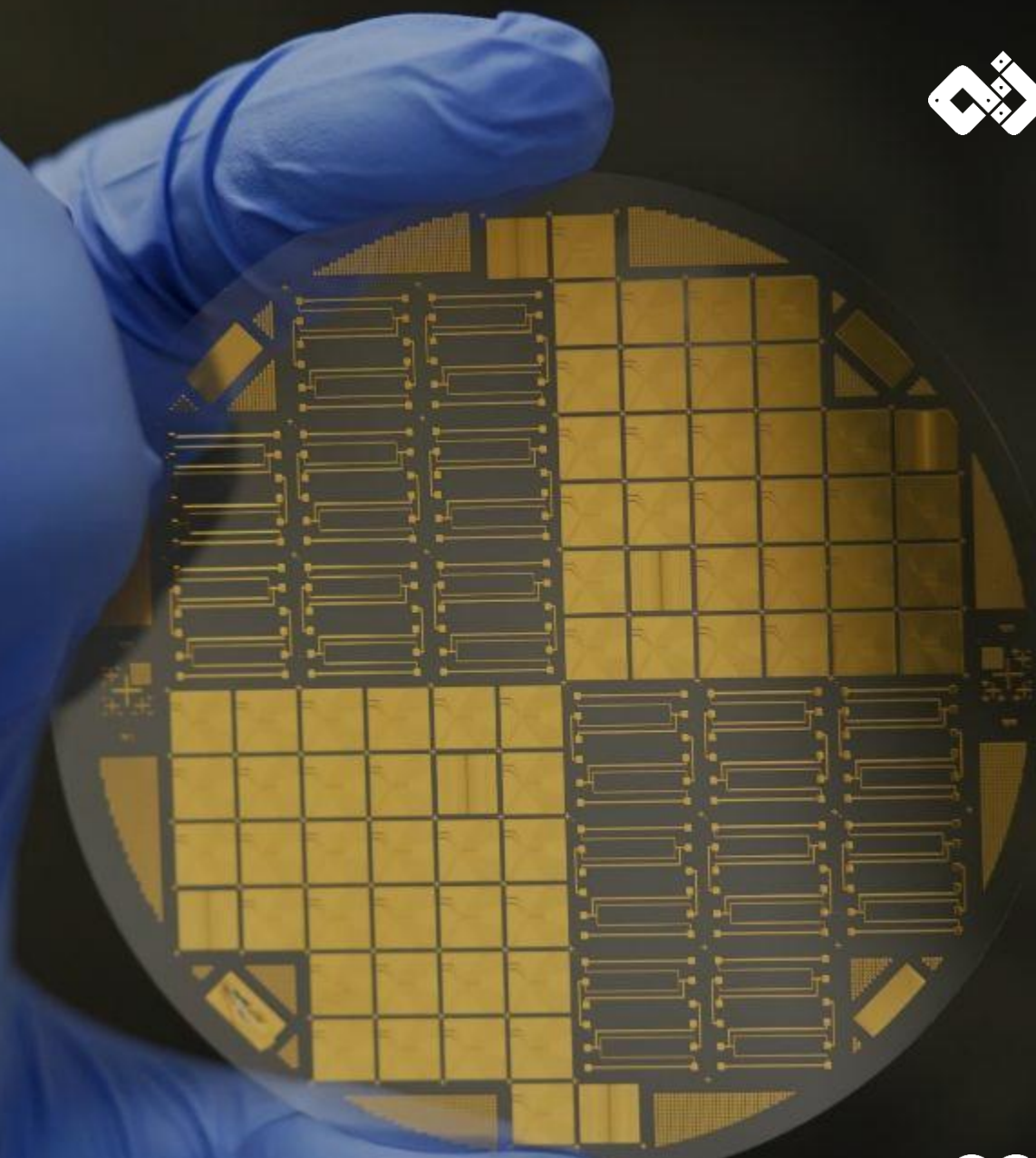
SPAD
QUBIT READOUT

2+

LOGICAL QUBITS

2025

STARTING
OPERATION



QCi DLR
Quantencomputing
Initiative

Gefördert durch:



Bundesministerium
für Wirtschaft
und Klimaschutz

aufgrund eines Beschlusses
des Deutschen Bundestages

QUDORA

NFQC® INSIDE



NFQC® Inside

The path to 1 Million qubits

In-house QPU

Proprietary fab & integration.
Made in Germany

Long Coherence

Deeper quantum circuits
with lower error

3m

1.5m

QUDORA's Core Technology



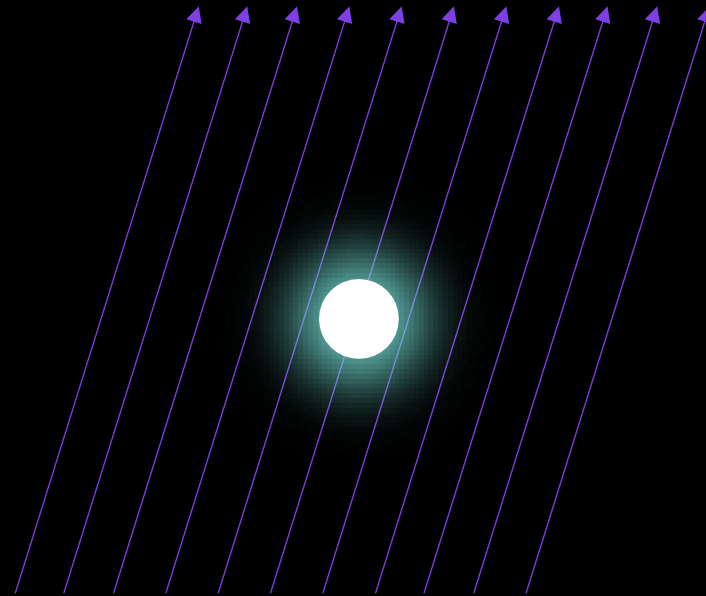
**CLOCK
QUBITS**



**NFQC™
TECHNOLOGY**

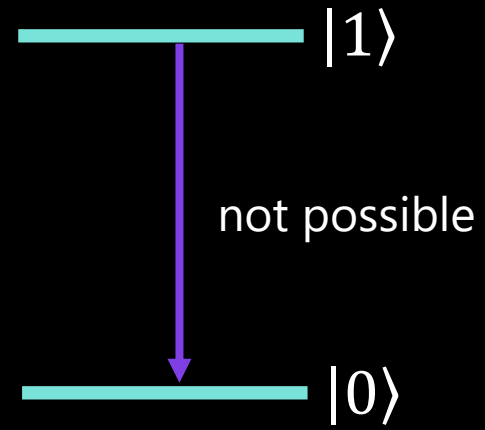
Clock Qubits

- T1 time: ∞
- T2 time: $> 60\text{s}$



Clock Qubits

- T1 time: ∞
- T2 time: $> 60\text{s}$



Clock Qubits

- T1 time: ∞
- T2 time: $> 60\text{s}$

————— $|1\rangle$

not possible

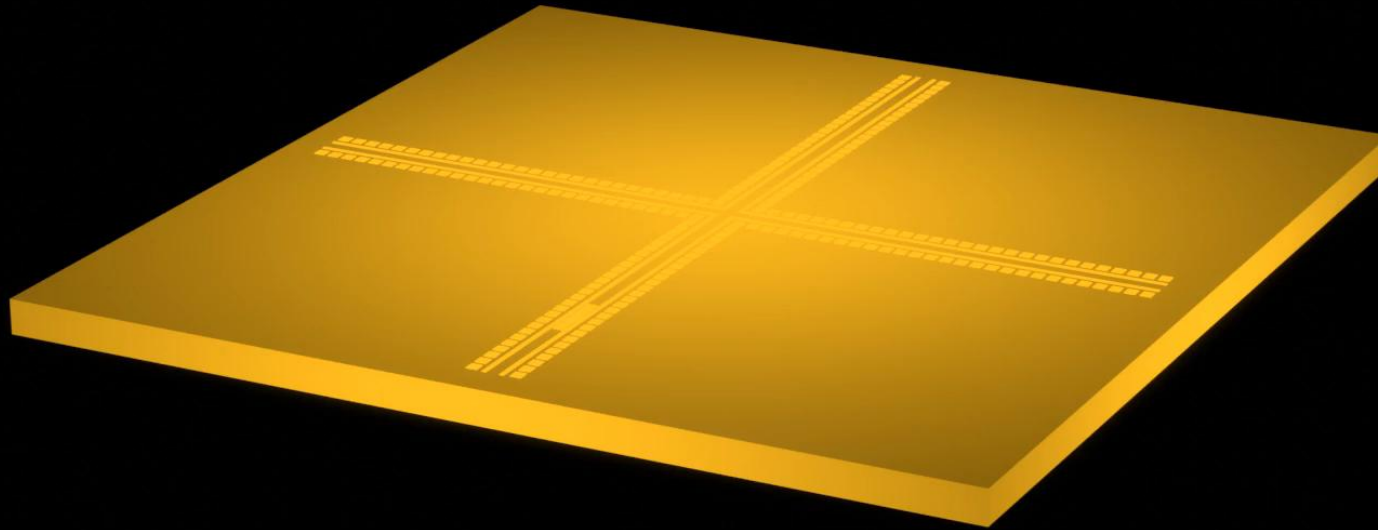
————— $|0\rangle$

NFQC Technology

- Near Field Quantum Control (NFQC)
- Chip integrated microwave source
- Two qubit gate fidelities $> 99.9\%$



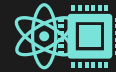
QCCD Architecture



Key Software Challenges



Optimize ion transport



Enable hybrid computations



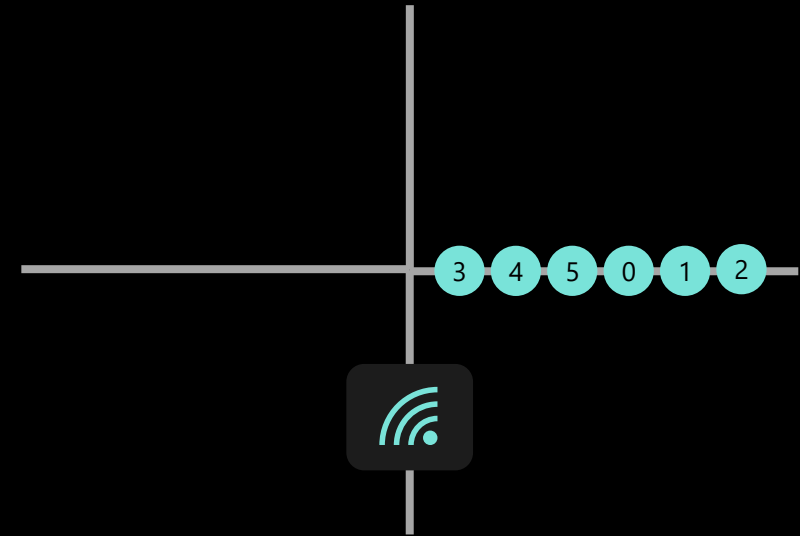
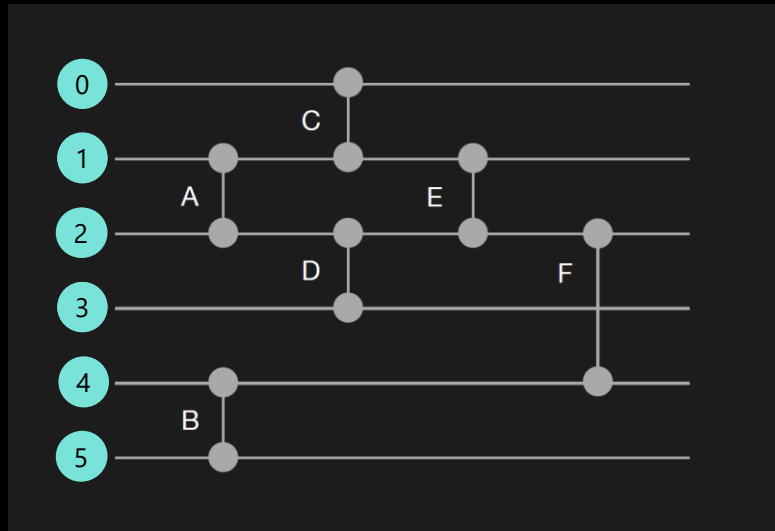
Reduce Noise



Support common languages

Optimize Ion Transport

COUPLED OPTIMIZATION PROBLEM

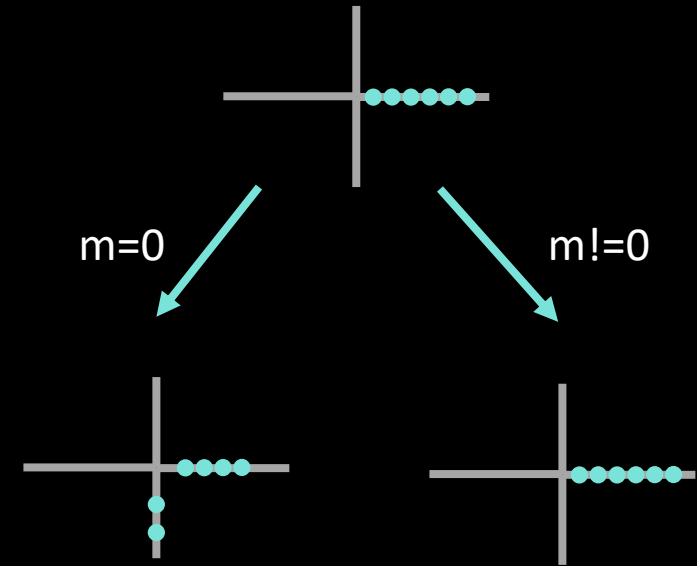


Publication: T. Schmale, et al. "Backend compiler phases for trapped-ion quantum computers." (2022)

Enable Hybrid Computations

BRANCH EXPLOSION

```
...  
m = measure(0)  
if m == 0:  
    cx(0,1)  
...
```



Enable Hybrid Computations

BRANCH EXPLOSION

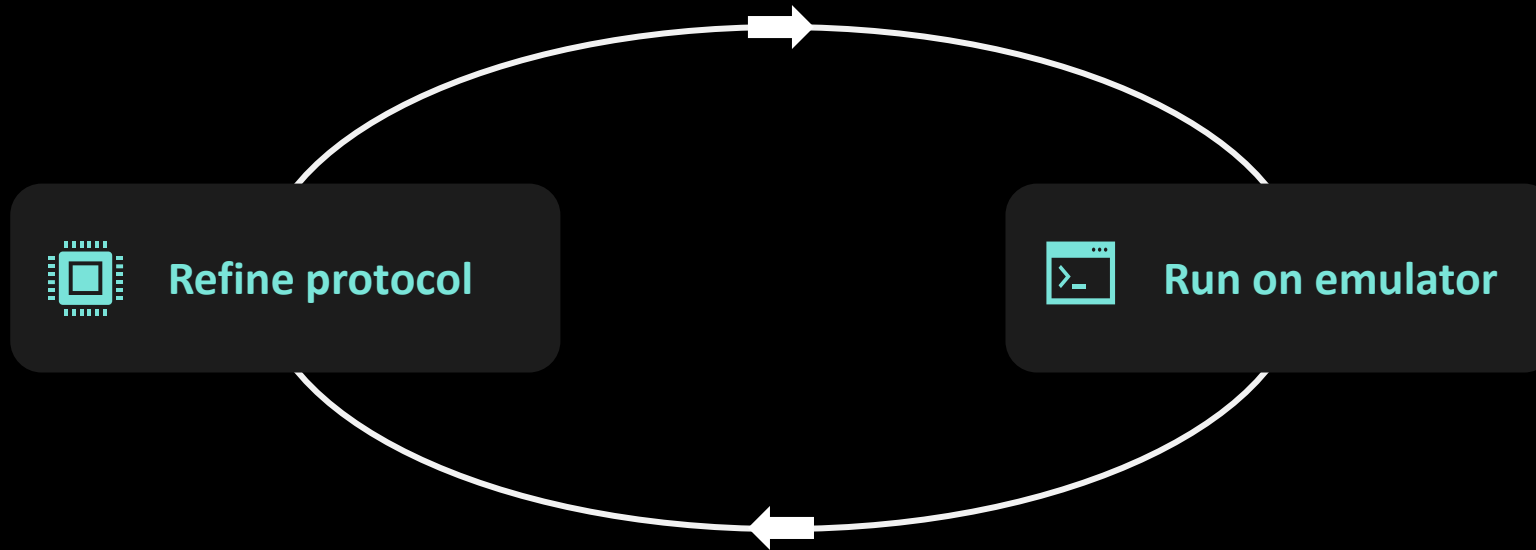
Just-In-Time (JIT)

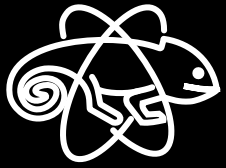
- Compilation during the coherence time
- Publication: T. Schmale, et al. "Real-time hybrid quantum-classical computations for trapped-ions with Python control-flow." (2023)

Ahead-Of-Time (AOT)

- Introduce extra movements to reduce amount of branches

Reduce Noise





Qamelion Emulator

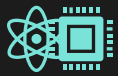
ADAPTIVE NOISE MODEL



Adjustable noise model for
NQFC technology



Mid-circuit measurements



Decoherence effects
during hybrid computations



Qiskit / QIR support



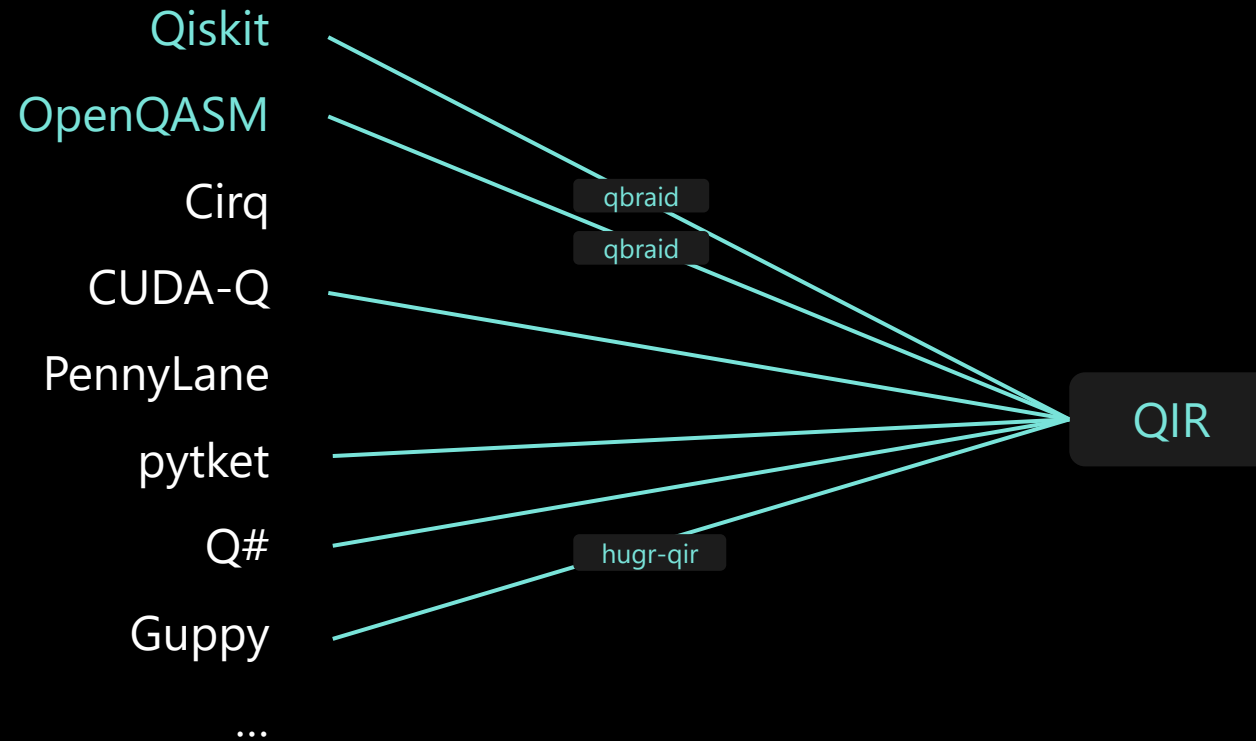
1 hour free trial



29 Qubits

Available soon at cloud.qudora.com

Support Common Languages



Software Stack

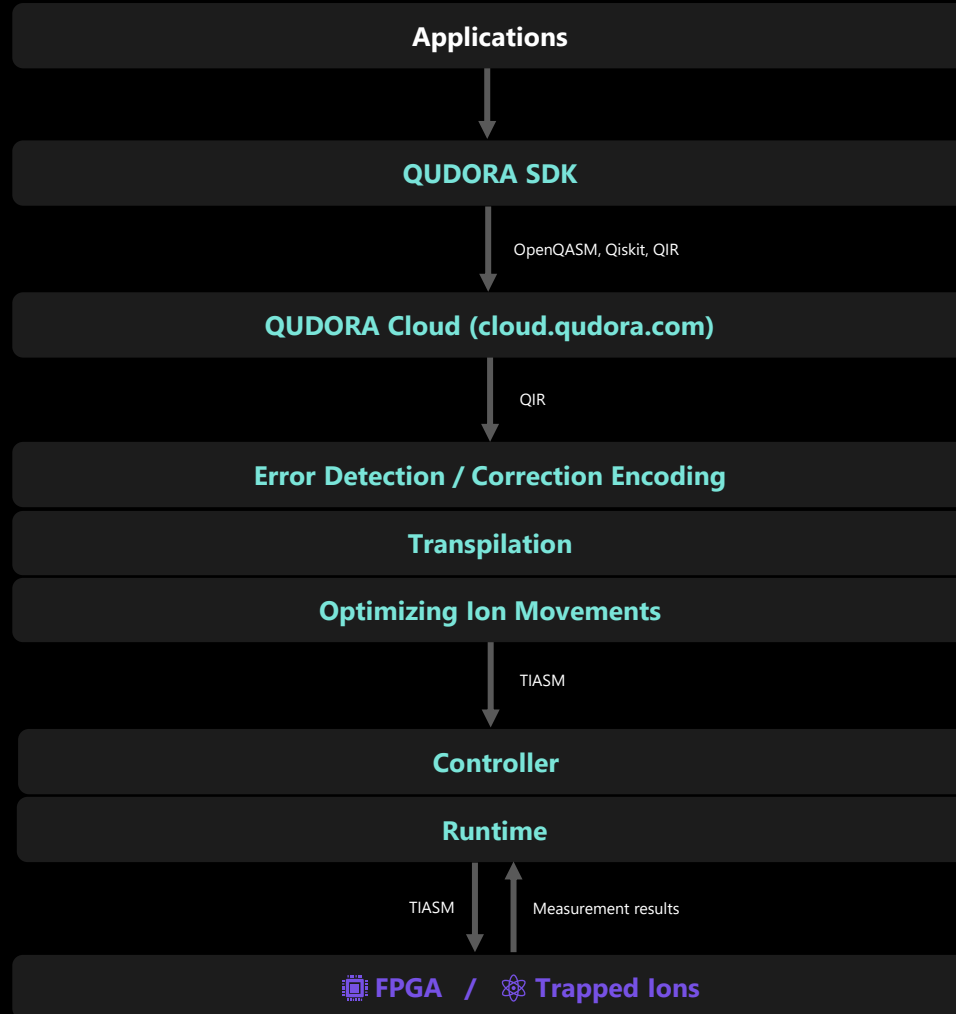
FROM QIR TO TIASM

 Developer Suite

 Cloud

 Compiler

 Real-Time OS



QIR vs. MLIR



- „standard“ way to encode quantum instructions
- based on mature and widely used LLVM infrastructure
- quantum instructions as function calls
- semantic checks via full-stack tests



- simple way to define dialects (like qccd instructions)
- semantic checks on IR level
- more flexibility for high-level optimizations

The Software Team



Tobias Schmale

Compiler Engineering, Quantum Algorithms



Christian Staufenberg

Full-Stack Developer



Niko Trittschanke

QEC, Emulator



Marius Schulte

Compiler Engineering, Error Modeling



Hans Langehein

Real-Time OS