Symposium Quantum Information and the Quest for Fault-Tolerant Quantum Computing (SYQI)

Guido Burkard
University of Konstanz
Universitaetsstrasse 10
78464 Konstanz, Germany
guido.burkard@uni-konstanz.de

Quantum computers have the potential to transform information technology. However, to reach the full potential of quantum computing, errors introduced by external disturbances need to be corrected. Fault-tolerant quantum computing allows for the construction of essentially error-free hardware using error-prone components. In this symposium, three leading experts talk about the beginnings and state of the art of quantum computing hardware and quantum error correction.

Overview of Invited Talks and Sessions

(Lecture hall ZHG010)

Invited Talks

SYQI 1.1	Wed	10:45–11:25	ZHG010	**Quantum Computing and Simulation in the presence of errors** — •Ignacio Cirac
SYQI 1.2	Wed	11:25–12:05	ZHG010	**Scalable quantum computing with trapped ions** — •Ferdinand Schmidt-Kaler
SYQI 1.3	Wed	12:05–12:45	ZHG010	**New opportunities in hybrid atom arrays combining single atoms and ensembles** — •Wenchao Xu

Sessions

SYQI 1.1–1.3	Wed	10:45–12:45	ZHG010	**Quantum Information and the Quest for Fault-Tolerant Quantum Computing**

SYQI 1: Quantum Information and the Quest for Fault-Tolerant Quantum Computing

Time: Wednesday 10:45–12:45 Location: ZHG010

Invited Talk SYQI 1.1 Wed 10:45 ZHG010
Quantum Computing and Simulation in the presence of errors — •Ignacio Cirac — Max Planck Institute of Quantum Optics, Garching, Germany

Advancements in quantum computing have enabled the development of small-scale quantum computers and simulators that adhere to the principles of quantum physics. Despite its rapid progress, those devices are not yet flawless and errors accumulate, posing serious challenges to their application to interesting problems. In this talk I will first address how those errors affect the results of both quantum computations and the simulation of quantum many-body systems. In particular, I will present several quantum simulation algorithms, and discuss the potentiality of displaying quantum advantage in the presence of imperfections. Finally, I will describe some new ingredients of such algorithms, like the preparation of highly entangled states, and discuss how they can be sped up with the help of measurements.

Invited Talk SYQI 1.2 Wed 11:25 ZHG010
Scalable quantum computing with trapped ions — •Ferdinand Schmidt-Kaler — QUANTUM, Univ. Mainz

I will describe the challenges on the way to a scalable, eventually a fault tolerant quantum computer [1]. Efforts from physics, informatics [2,3] and mathematics but also engineering [4] are concentrated in BMBF-funded demonstrator setups. The hardware is suited for the implementation of topological quantum error correction with fault-tolerant syndrome readout [1] and feedforward operations. As a first glance into the power of quantum computing, I will describe a couple of usecases: the VQE-simulation of a two-flavor Schwinger quark model executed on a trapped-ion quantum processor [5], and the quantum autoencoder [6], as a simple instance of machine learning error codes of the specific hardware.

References: [1] Hilder et al., Phys. Rev. X.12.011032 (2022), [2] Kreppel et al., Quantum 7, 1176 (2023), [3] Durandeau et al., Quantum 7, 1175 (2023), [4] Kaustal et al., AVS Qu. Sci. 2, 014101 (2020), [5] Melzer et al., arXiv:2504.20824, [6] Locher et al., Quantum 7, 942 (2023).

Invited Talk SYQI 1.3 Wed 12:05 ZHG010
New opportunities in hybrid atom arrays combining single atoms and ensembles — •Wenchao Xu — ETH Zurich

Neutral-atom array platforms have advanced rapidly in recent years and are now among the leading candidates for realizing quantum technologies. However, achieving fault-tolerant quantum computation requires overcoming key challenges, including reconfigurable individual qubit addressability, fast, mid-circuit readout, and scaling beyond 10,000 qubits.

To tackle these limitations, we are developing a novel dual-type, dual-species atom array architecture. In our approach, single ytterbium (Yb) atoms*with their long nuclear spin coherence times*serve as data qubits, while rubidium (Rb) atomic ensembles*with their strong collective optical response*function as ancilla. This combination enables reconfigurable local operations, fast and non-destructive readout of both single- and multi-qubit states and introduces a new scheme for establishing quantum optical links. As part of this effort, we are currently conducting spectroscopic measurements of Yb*Rb Rydberg pair interactions. These studies will benchmark theoretical models of Rydberg states in multi-valence-electron atoms and lay the groundwork for experimental realization of our proposed architecture.