Quantum Information in Physics Dept.

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

WISCONSIN QUANTUM INSTITUTE
Quantum Science and Engineering at UW–Madison

New funding and initiatives

MSPQC - M.S. Degree in Physics-Quantum Computing

First program in the country to offer MS in Quantum computing. Now in year 5

Quantum hiring

Three new hires

Collaborations, projects, funding

Lots going on

MSPQC Program

First professional quantum masters program in the country.

Now in year 5 and there are now close to 10 competing programs.

Despite the competition we have continued to increase enrollment.

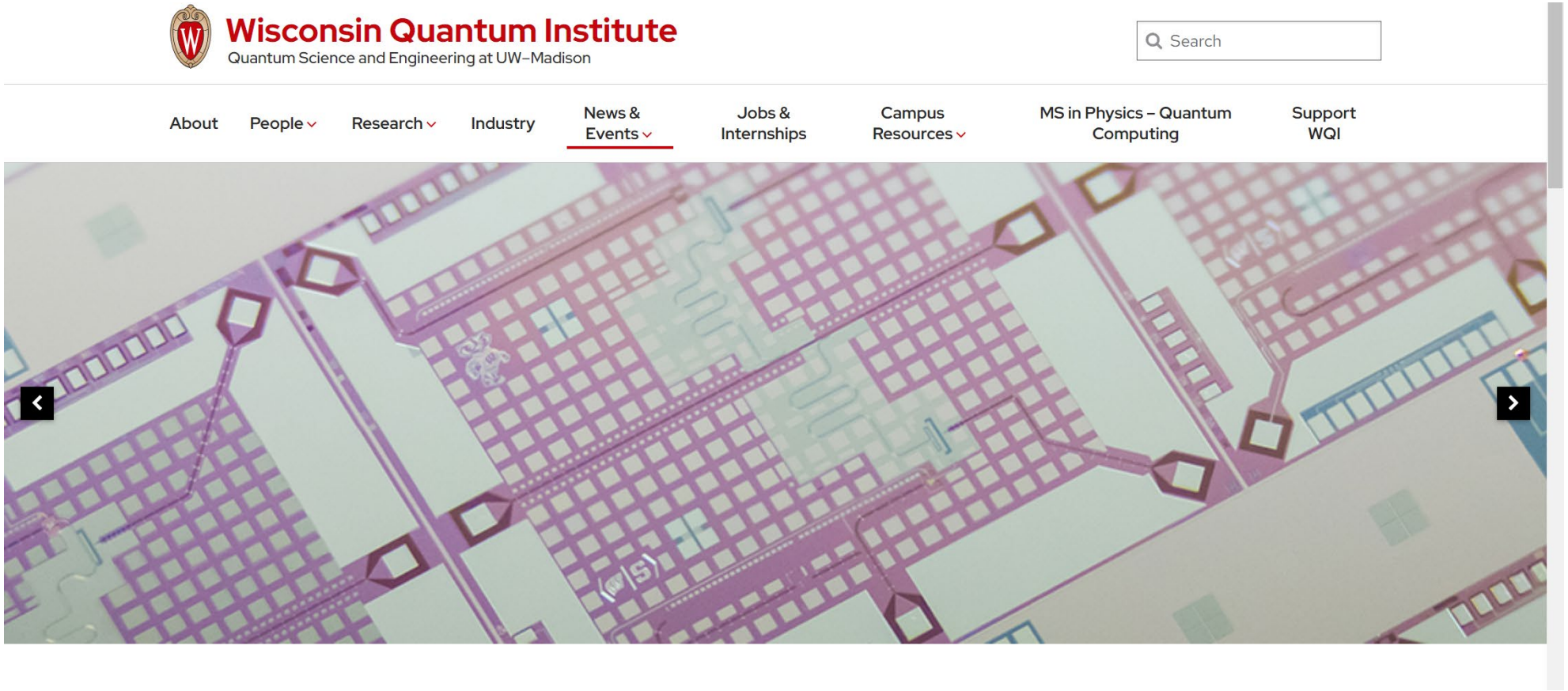
Current cohort 25 students.

Graduates are placed in industry and PhD programs.

Deniz Yavuz
MSPQC director

Elizabeth Baldridge
MSPQC Student Services Coordinator

Katerina Moloni
Associate Director, MSPQC and WQI



Katerina Moloni
Associate Director
WQI and MSPQC

The WQI started in physics but has grown to a campus wide community.

33 faculty — Physics, Chemistry, Computer Sciences, Electrical & Computer Engineering, Engineering Physics, Materials Science, Mathematics, Statistics

Including 14 physics faculty

New hires:

Ilya Esterlis
Theoretical Solid state physics

Roman Kuzmin
Experimental quantum simulation

Matt Otten
Theoretical/computational quantum information (start Jan. 2024)

This year we have started a monthly seminar series that is bringing 9 distinguished speakers to campus.

Funding:

Physics Dept. (HERB seminars)

MSPQC program

Foundation (QC donations)

September 21 (**Lincoln Carr**, Colorado School of Mines)
October 11 (**Eugene Simon Polzik**, Niels Bohr Institute – University of Copenhagen)
November 16 (**David D. Awschalom**, Director – Chicago Quantum Exchange, University of Chicago)
December 14 (**John Nichol**, University of Rochester)
January 25 (**Menno Veldhorst**, QuTech – Delft University of Technology)
February 22 (**Antoine Browaeys**, LCF – Univ. Paris-Saclay, Institut d'Optique Graduate School, CNRS)
March 12 (**David DiVincenzo**, Forschungszentrum Jülich GmbH)
April 18 **Dan Blumenthal**, UCSB
May 2 (**Evelyn Hu**, Harvard)

Collaborations

Campus as represented by the WQI is a member of

CQE serves as a hub for all things quantum in the midwest.

CHICAGO QUANTUM EXCHANGE

THE UNIVERSITY OF CHICAGO
ILLINOIS
Fermilab
WISCONSIN UNIVERSITY OF WISCONSIN-MADISON
Argonne NATIONAL LABORATORY
Northwestern University

With CQE partners (and other institutions) we have strong participation in two large quantum centers established as part of the NQI:

HQAN

Quantum Leap Challenge Institute:
Hybrid Quantum Architectures and Networks

NSF

$5M/year for 5 years
UWM share $1.8M/year

NEXT
NEXT GENERATION QUANTUM SCIENCE AND ENGINEERING

U.S. DEPARTMENT OF ENERGY
Office of Science

$25M/year for 5 years
UWM share $1.8M/year

Research Areas

Quantum computing: superconductors, Si quantum dots, neutral atoms, quantum error correction

Quantum simulation: superconducting device arrays

Quantum communication: remote entanglement, quantum repeaters, microwave-optical transduction

Quantum sensing: atomic magnetometry, NV centers for magnetometry and noise spectroscopy, atomic clocks

Research Sponsors

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

WARF
Wisconsin Alumni Research Foundation

We have reached quantum speed-up (advantage, supremacy)

Random Circuit Sampling was demonstrated in 2019, but was soon thereafter classically simulated.

By mid 2023 the speed-up of quantum hardware increased exponentially.

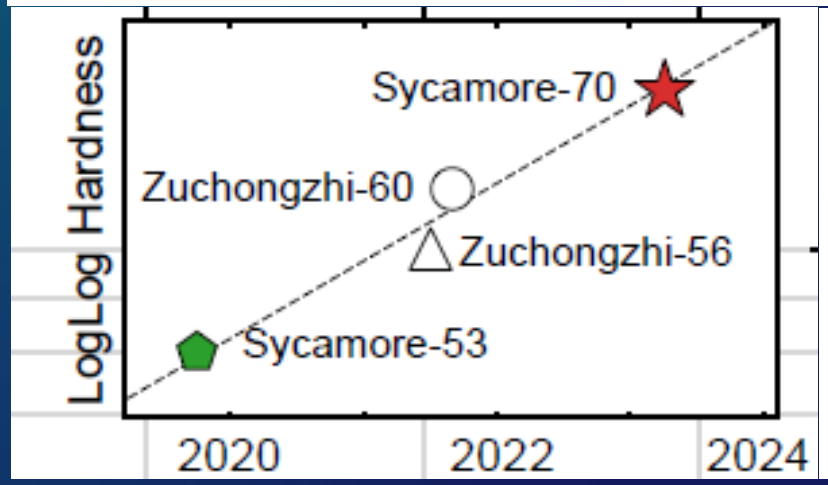
If nothing else, quantum computing has had a major impact on the development of classical techniques for simulating high dimensional quantum problems.

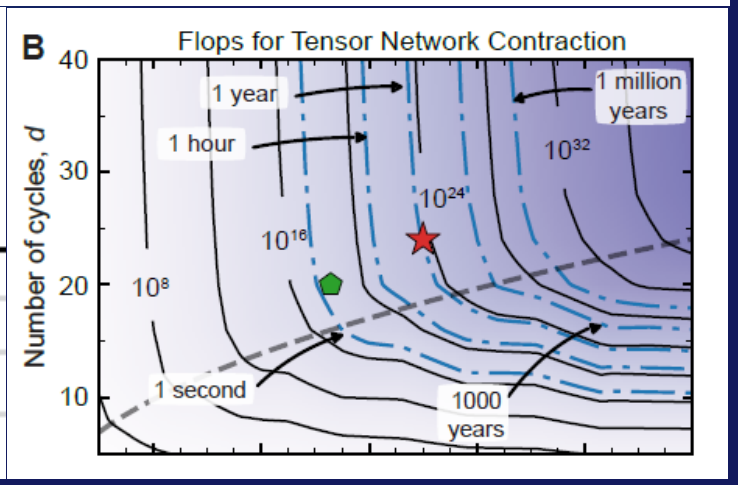
Phase transition in Random Circuit Sampling

Google Quantum AI and Collaborators

arXiv:2304.11119

Quantum computers hold the promise of executing tasks beyond the capability of classical computers. Noise competes with coherent evolution and destroys long-range correlations, making it an outstanding challenge to fully leverage the computation power of near-term quantum processors. We report Random Circuit Sampling (RCS) experiments where we identify distinct phases driven by the interplay between quantum dynamics and noise. Using cross-entropy benchmarking, we observe phase boundaries which can define the computational complexity of noisy quantum evolution. We conclude by presenting an RCS experiment with 70 qubits at 24 cycles. We estimate the computational cost against improved classical methods and demonstrate that our experiment is beyond the capabilities of existing classical supercomputers.





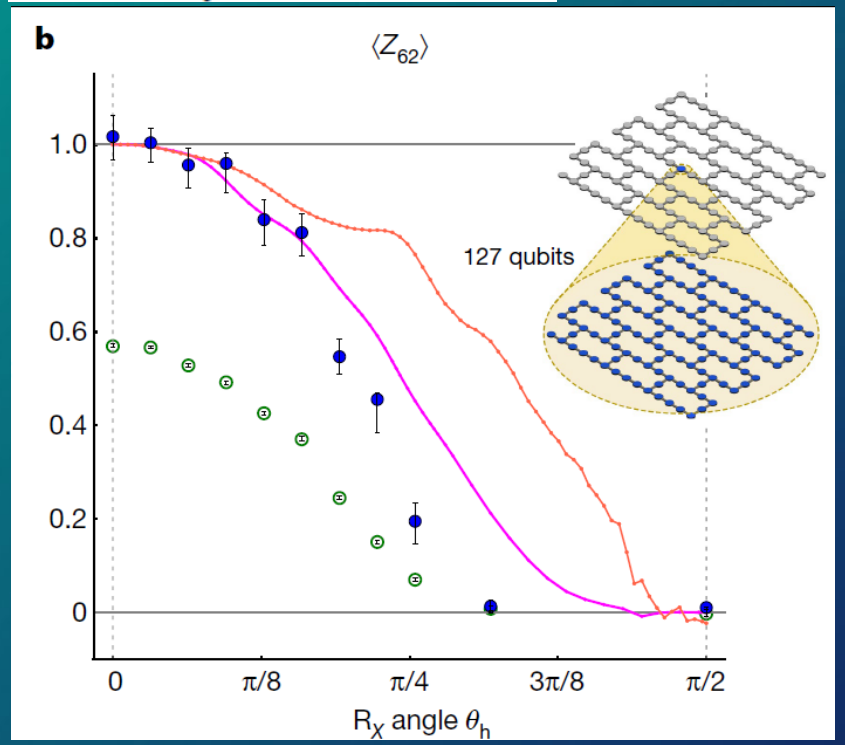
We have not reached quantum utility

A recent claim of quantum utility by IBM was premature.

Evidence for the utility of quantum computing before fault tolerance

500 | Nature | Vol 618 | 15 June 2023

$$H = -J \sum_{\langle i,j \rangle} Z_i Z_j + h \sum_i X_i,$$



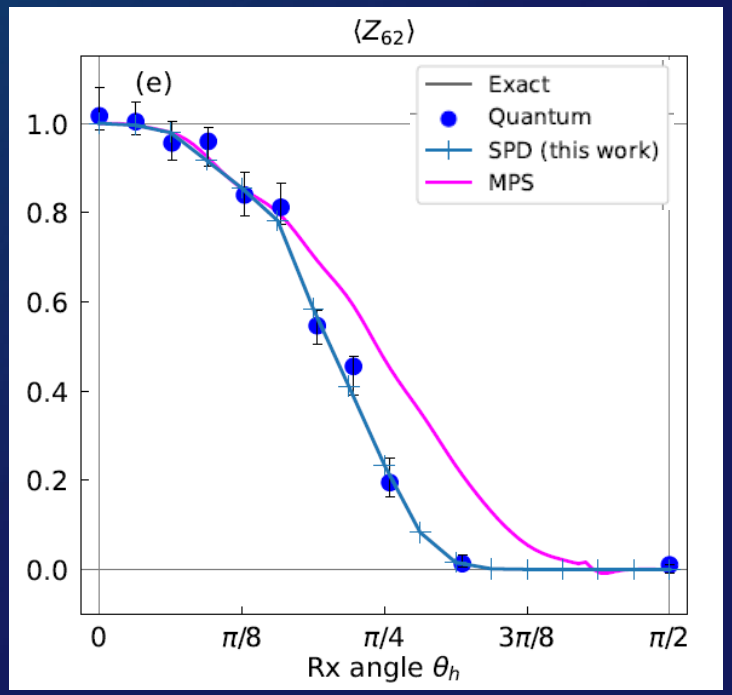
The results have been duplicated in seconds on a laptop.

Fast classical simulation of evidence for the utility of quantum computing before fault tolerance

arXiv:2306.16372

Tomislav Begušić and Garnet Kin-Lic Chan*
Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California 91125, USA
(Dated: June 29, 2023)

We show that a classical algorithm based on sparse Pauli dynamics can efficiently simulate quantum circuits studied in a recent experiment on 127 qubits of IBM's Eagle processor [*Nature* **618**, 500 (2023)]. Our classical simulations on a single core of a laptop are orders of magnitude faster than the reported walltime of the quantum simulations, as well as faster than the estimated quantum hardware runtime without classical processing, and are in good agreement with the zero-noise extrapolated experimental results.



Paths to utility

NISQ

HP-NISQ (high performance)

Higher gate fidelity >0.999
More qubits >1000
Error mitigation
New or tailored algorithms

May enable utility for specific scientific or commercial applications
Timeline: 2-5 years

FTQC (fault tolerant QC)

Higher gate fidelity 0.999
Many more qubits >100,000
Quantum error correction
Advanced classical control hw&sw

Will unlock the full range of valuable applications
Timeline: 5-10 years or longer

Challenges

- Research space to expand experimental activities
- Start up packages for experimentalists
- Under-represented in theoretical quantum information: quantum algorithms, error correction theory, quantum networking
- Victims of success – it has become very difficult to hire good postdocs because of competition with quantum industry