

NVIDIA Runs Record Simulation of Fault-Tolerant Quantum Computing at Jülich Supercomputing Centre

Researchers Use JUPITER, Europe's First Exascale Supercomputer, to Understand Quantum's Most Complex and Critical Computations

News Summary:

- NVIDIA researchers are using JUPITER -- the largest supercomputer in Europe, built at Jülich Supercomputing Centre -- for a record-breaking fault-tolerant quantum computing simulation.
- The 104-qubit simulation is the largest comprehensive simulation of a fault-tolerant quantum computing system to date, with no prior simulations modeling quantum processors in such full detail.
- The simulation validates a quantum computing approach that uses 90% fewer physical qubits than previous methods, accelerating progress toward useful applications in drug discovery, financial modeling and materials science.
- JUPITER simulations are providing the quantum industry with actionable insight into the impact of noise on fault-tolerant quantum computing, enabling researchers to refine designs before building hardware -- shortening the path to viable quantum computers by years.

NVIDIA today announced a record-breaking quantum computing simulation on JUPITER, Europe's first exascale supercomputer, allowing researchers to fully explore and validate magic state cultivation -- a leading approach to fault-tolerant quantum computing that requires 90% fewer qubits than previous methods.

Running on a system of NVIDIA GH200 superchips at Jülich Supercomputing Centre, the 104-qubit simulation is the largest comprehensive simulation of a fault-tolerant quantum processor to date, modeling how a realistic quantum processor performs fault-tolerant computation at record scale.

That level of fidelity gives researchers the data and tools needed to predict the performance of future designs before they are built -- reducing reliance on hardware trial and error, and accelerating the path to useful quantum applications in fields like drug discovery, financial modeling and materials science.

"Useful quantum computing will require fantastically complex, fault-tolerant systems -- and understanding how they behave at scale is essential to building them," said Jensen Huang, founder and CEO of NVIDIA. "Our results from Jülich show how quantum processors and GPU supercomputers can work together to tackle research that would otherwise be out of reach -- accelerating the discovery of transformative quantum applications."

"Europe's investment in JUPITER gives researchers the ability to investigate questions that were previously beyond reach," said Kristel Michielsen, director of the Jülich Supercomputing Centre at the Forschungszentrum Jülich facility. "Working with NVIDIA, we're bringing that capability to quantum computing -- helping scientists make better-informed decisions about the designs most likely to deliver useful applications."

Reducing the Resources Needed for Useful Quantum Computing

Because qubits operate at the limits of physics, the interactions needed to control them introduce unavoidable, error-inducing noise. Computing in the presence of such noise -- known as fault-tolerant quantum computing -- requires the use of magic states, a specific arrangement of qubits that is continually consumed during a fault-tolerant quantum computation.

Fault-tolerant quantum computers rely crucially on repeatedly producing magic states -- meaning that any optimization in how they are made drastically reduces the difficulty of building a useful quantum computer.

By simulating this process under realistic noise, NVIDIA researchers validated a state-of-the-art magic-state cultivation approach, giving researchers the tools needed to develop and test future improvements.

Earlier, groundbreaking research from Jülich simulated 50 qubits under ideal, noiseless conditions. This work simulates magic-state cultivation under realistic hardware noise, helping researchers understand the impact of errors.

From Research Development to Exascale Simulation

Simulating magic-state cultivation helps researchers evaluate and improve designs before building quantum hardware. But the memory required can grow exponentially with the number of qubits, putting large-scale simulations beyond the reach of conventional computing systems.

An NVIDIA GB200 NVL72 system at the [NVIDIA Accelerated Quantum Research Center](#) (NVAQC) served as the development platform for the JUPITER project, enabling researchers to scale tests from four GPUs to hundreds before moving to 8,192 GPUs on JUPITER.

Researchers used the center to accelerate the development and testing of their simulation methods, compare results with JUPITER and explore how accuracy scaled with additional computing resources. This work helped reduce a weekslong simulation effort to days while preparing the team to use JUPITER's exascale computing capacity effectively.

The project demonstrates how simulation will grow increasingly important and complex as quantum computing systems grow in size. It also shows the utility of accelerated computing clusters, like at NVAQC, in allowing researchers to develop and validate simulation methods before tapping into world-class supercomputers for their most demanding calculations.

The simulations ran using [NVIDIA cuQuantum](#) software to achieve highly optimized performance and scale, along with the [NVIDIA CUDA-Q™](#) platform's fault-tolerant logical layer to express the magic-state circuit.

Read the [GitHub blog](#) on the JUPITER simulation.

Watch the [GTC Berlin keynote](#) from Huang and [explore sessions](#).

About NVIDIA

[NVIDIA](#) (NASDAQ: NVDA) is the world leader in AI and accelerated computing.

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