

Universal parity quantum computing, a new architecture that overcomes performance limitations

October 28 2022, by Christian Flatz

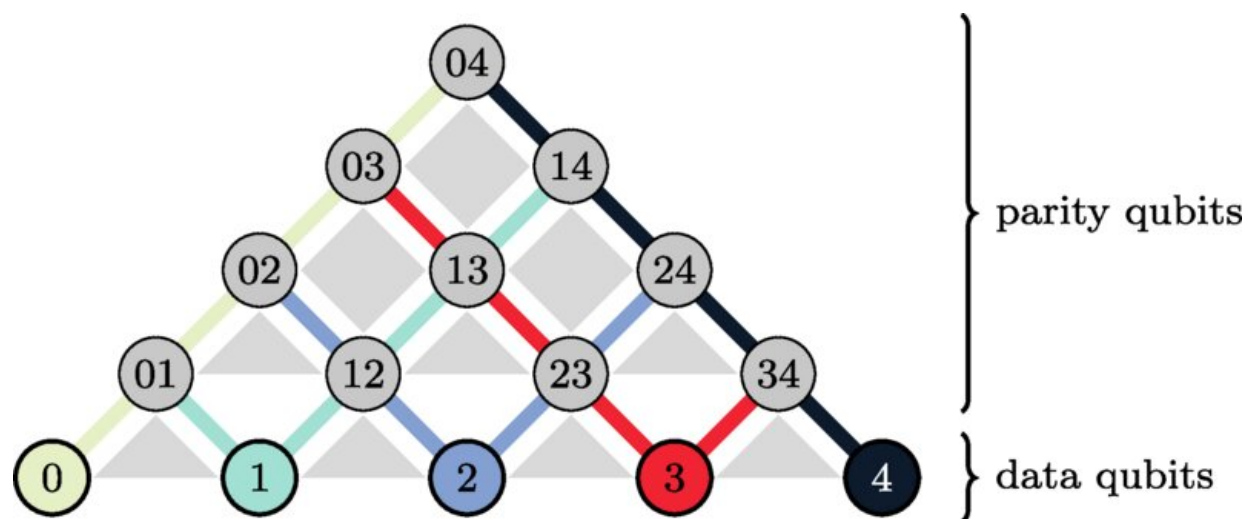


Illustration of the modified LHZ architecture with logical lines. Three- and four-body constraints are represented by light gray triangles and squares between corresponding qubits. Data qubits with single logical indices are added as an additional row at the bottom of the architecture to allow direct access to logical R_z rotations. Colored lines connect all qubits whose labels contain the same logical index. Logical R_x rotations can be realized with chains of cnot gates along the corresponding line. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.180503

The computing power of quantum machines is currently still very low.

Increasing performance is a major challenge. Physicists at the University of Innsbruck, Austria, now present a new architecture for a universal quantum computer that overcomes such limitations and could be the basis of the next generation of quantum computers soon.

Quantum bits (qubits) in a quantum computer serve as a computing unit and memory at the same time. Because quantum information cannot be copied, it cannot be stored in memory as in a classical computer. Due to this limitation, all qubits in a quantum computer must be able to interact with each other.

This is currently still a major challenge for building powerful quantum computers. In 2015, theoretical physicist Wolfgang Lechner, together with Philipp Hauke and Peter Zoller, addressed this difficulty and proposed a new architecture for a quantum computer, now named LHZ architecture after the authors.

"This architecture was originally designed for [optimization problems](#)," says Wolfgang Lechner of the Department of Theoretical Physics at the University of Innsbruck, Austria. "In the process, we reduced the architecture to a minimum in order to solve these optimization problems as efficiently as possible."

The physical qubits in this architecture do not represent individual bits, but encode the relative coordination between the bits. "This means that not all qubits have to interact with each other anymore," explains Wolfgang Lechner. With his team, he has now shown that this parity concept is also suitable for a universal quantum [computer](#).

Complex operations are simplified

Parity computers can perform operations between two or more qubits on a single qubit. "Existing quantum computers already implement such

operations very well on a small scale," Michael Fellner from Wolfgang Lechner's team explains. "However, as the number of qubits increases, it becomes more and more complex to implement these gate operations."

In two publications in *Physical Review Letters* and *Physical Review A*, the Innsbruck scientists now show that parity computers can, for example, perform quantum Fourier transformations—a fundamental building block of many quantum algorithms—with significantly fewer computation steps and thus more quickly. "The high parallelism of our [architecture](#) means that, for example, the well-known Shor algorithm for factoring numbers can be executed very efficiently," Fellner explains.

Two-stage error correction

The new concept also offers hardware-efficient [error](#) correction. Because [quantum systems](#) are very sensitive to disturbances, quantum computers must correct errors continuously. Significant resources must be devoted to protecting [quantum information](#), which greatly increases the number of [qubits](#) required. "Our model operates with a two-stage error correction, one type of error (bit flip error or phase error) is prevented by the hardware used," write Anette Messinger and Kilian Ender, also members of the Innsbruck research team.

There are already initial experimental approaches for this on different platforms. "The other type of error can be detected and corrected via the software," Messinger and Ender say. This would allow a next generation of universal quantum computers to be realized with manageable effort.

The spin-off company ParityQC, co-founded by Wolfgang Lechner and Magdalena Hauser, is already working in Innsbruck with partners from science and industry on possible implementations of the new model.

More information: Michael Fellner et al, Universal Parity Quantum

Computing, *Physical Review Letters* (2022). [DOI: 10.1103/PhysRevLett.129.180503](https://doi.org/10.1103/PhysRevLett.129.180503)

Michael Fellner et al, Applications of universal parity quantum computation, *Physical Review A* (2022). [DOI: 10.1103/PhysRevA.106.042442](https://doi.org/10.1103/PhysRevA.106.042442)

Provided by University of Innsbruck

Citation: Universal parity quantum computing, a new architecture that overcomes performance limitations (2022, October 28) retrieved 27 April 2024 from <https://phys.org/news/2022-10-universal-parity-quantum-architecture-limitations.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.