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Researchers develop quantum gate enabling investigation of optimization problems

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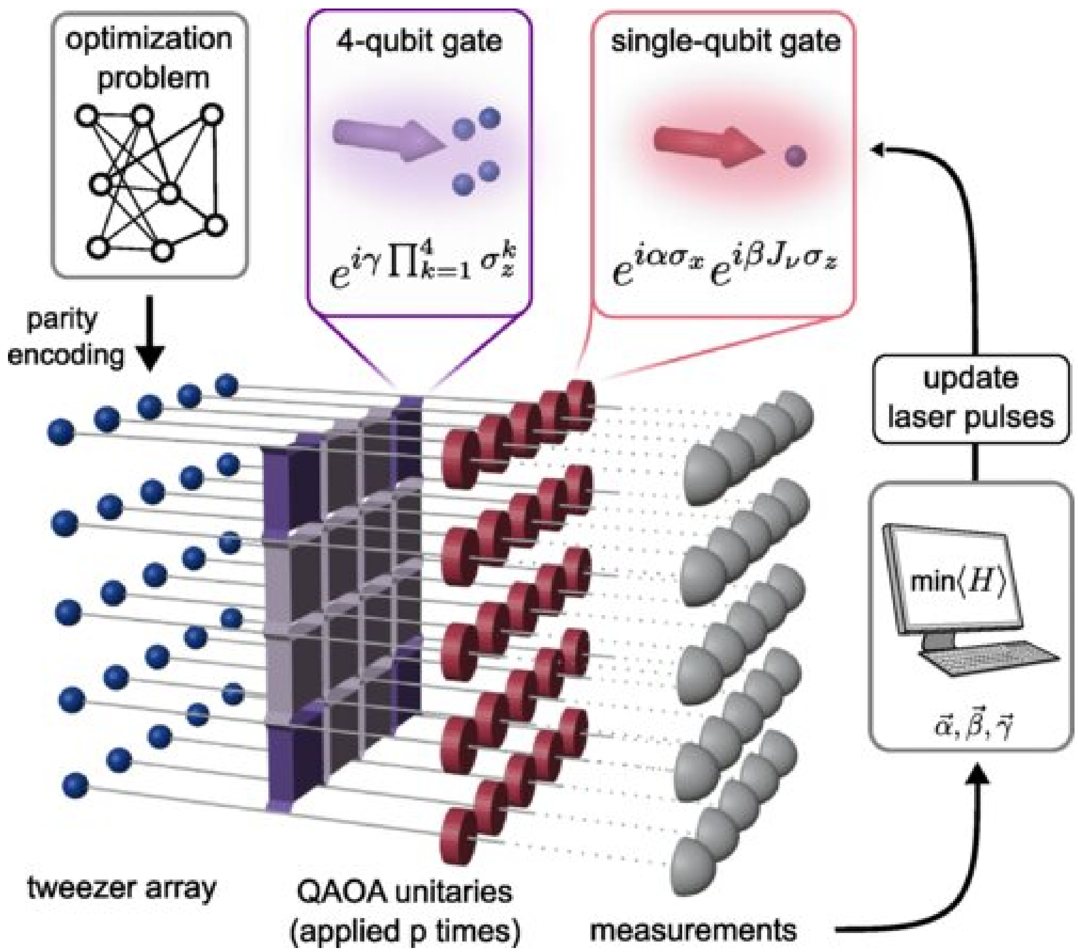

Rydberg parity QAOA protocol. Arbitrarily connected optimization problems can be parity encoded in a regular geometry of neutral atoms trapped in, e.g., optical tweezers. After initializing the Rydberg quantum processor in an equal superposition state, generating variational wave functions by applying QAOA unitaries only requires local control of laser fields generating quasilocal four-qubit (square boxes) and single-qubit gates (disks). Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.120503

The development of quantum computers is being pursued worldwide, and there are various concepts of how computing using the properties of the quantum world can be implemented. Many of these have already advanced experimentally into areas that can no longer be emulated on classical computers. But the technologies have not yet reached the point where they can be used to solve larger computational problems. Therefore, researchers are currently looking for applications that can be implemented on existing platforms. "We are looking for tasks that we can compute on existing hardware," says Rick van Bijnen of the Institute of Quantum Optics and Quantum Information at the Austrian Academy of Sciences in Innsbruck. A team around Van Bijnen and the Lechner research group is now proposing a method to solve optimization problems using neutral atoms.

Software solution

To develop scientifically and industrially relevant applications for existing quantum hardware in the near future, researchers are looking for special algorithms that structurally match the strengths of a quantum platform. "This co-design of algorithms and experimental platforms allows these systems to work without error correction, which is still difficult to achieve today," explains Wolfgang Lechner from the Department of Theoretical Physics at the University of Innsbruck. The physicists envision their optimization algorithm to be implemented on neutral atoms trapped and arranged in optical tweezers. They can be programmed via the interaction of highly excited Rydberg states. To avoid the limitations of previous approaches, the physicists do not implement the algorithm directly, but use the so-called parity architecture, a scalable and problem-independent hardware design for combinatorial optimization problems, which Wolfgang Lechner developed together with Philipp Hauke and Peter Zoller in Innsbruck.

In this way, the optimization algorithm requires only problem-dependent single-qubit operations and problem-independent four-qubit operations. Finding a direct and simple implementation for these four-qubit operations was the biggest challenge for the Innsbruck researchers. For this purpose, they have designed a special quantum gate. "We implemented the algorithm directly in the language of the experiment," explains first author Clemens Dlaska. "Thus, the algorithm can be realized on current quantum hardware by simply optimizing the duration of laser pulses in a feedback loop."

Arbitrarily scalable

With the proposed concept, the performance of existing quantum hardware in solving relevant optimization problems can be investigated for problem-sizes currently impossible to simulate on classical supercomputers. The fact that both the hardware platform and the software solution can be extended to a large extent without modifications is an important advantage of the new method.

The Innsbruck team has now presented its new concept in *Physical Review Letters*.

More information: Clemens Dlaska et al, Quantum Optimization via Four-Body Rydberg Gates, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.120503

Provided by University of Innsbruck

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