Research team chase down advantage in quantum race

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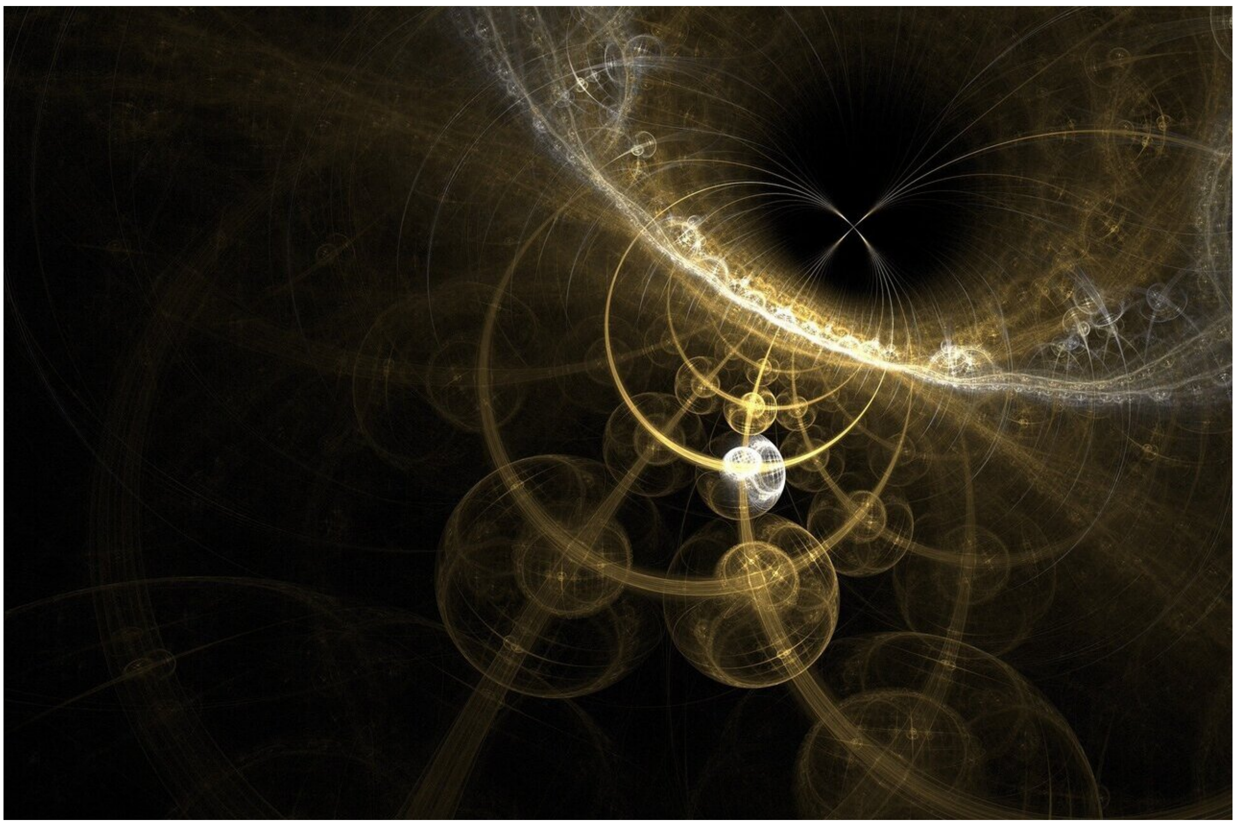

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Quantum researchers at the University of Bristol have dramatically reduced the time to simulate an optical quantum computer, with a speedup of around one billion over previous approaches.

Quantum computers promise exponential speedups for certain problems, with potential applications in areas from drug discovery to new materials for batteries. But quantum computing is still in its early stages, so these are long-term goals. Nevertheless, there are exciting intermediate milestones on the journey to building a useful device. One currently receiving a lot of attention is "quantum advantage", where a quantum computer performs a task beyond the capabilities of even the world's most powerful supercomputers.

Experimental work from the University of Science and Technology of China (USTC) was the first to claim quantum advantage using photons—particles of light, in a protocol called "Gaussian Boson Sampling" (GBS). Their paper claimed that the experiment, performed in 200 seconds, would take 600 million years to simulate on the world's largest supercomputer.

Taking up the challenge, a team at the University of Bristol's Quantum Engineering Technology Labs (QET Labs), in collaboration with researchers at Imperial College London and Hewlett Packard Enterprise, have reduced this simulation time down to just a few months, a speedup factor of around one billion.

Their paper "The boundary for quantum advantage in Gaussian boson sampling", published today in the journal *Science Advances*, comes at a time when other experimental approaches claiming quantum advantage, such as from the quantum computing team at Google, are also leading to improved classical algorithms for simulating these experiments.

Joint first author Jake Bulmer, Ph.D. student in QET Labs, said: "There is an exciting race going on where, on one side, researchers are trying to build increasingly complex quantum computing systems which they claim cannot be simulated by conventional computers. At the same time, researchers like us are improving simulation methods so we *can* simulate these supposedly impossible to simulate machines!"

"As researchers develop larger scale experiments, they will look to make claims of quantum advantage relative to classical simulations. Our results will provide an essential point of comparison by which to establish the computational power of future GBS experiments," said joint first author, Bryn Bell, Marie Curie Research Fellow at Imperial College London, now Senior Quantum Engineer at Oxford Quantum Circuits.

The team's methods do not exploit any errors in the experiment and so one next step for the research is to combine their new methods with techniques that exploit the imperfections of the real-world experiment. This would further speed up simulation time and build a greater understanding of which areas require improvements.

"These quantum advantage experiments represent a tremendous achievement of physics and engineering. As a researcher, it is exciting to contribute to the understanding of where the computational complexity of these experiments arises. We were surprised by the magnitude of the improvements we achieved—it is not often that you can claim to find a one-billion-fold improvement!" said Jake Bulmer.

Anthony Laing, co-Director of QET Labs and an author on the work, said: "As we develop more sophisticated quantum computing technologies, this type of work is vital. It helps us understand the bar we must get over before we can begin to solve problems in clean energy and healthcare that affect us all. The work is a great example of teamwork and collaboration among researchers in the UK Quantum Computing and Simulation Hub and Hewlett Packard Enterprise."

More information: Jacob F. F. Bulmer et al, The boundary for quantum advantage in Gaussian boson sampling, *Science Advances* (2022). DOI: 10.1126/sciadv.abl9236.

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Han-Sen Zhong et al, Quantum computational advantage using photons, *Science* (2021). DOI: 10.1126/science.abe8770

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