# Researchers develop improved quantum gate testing method

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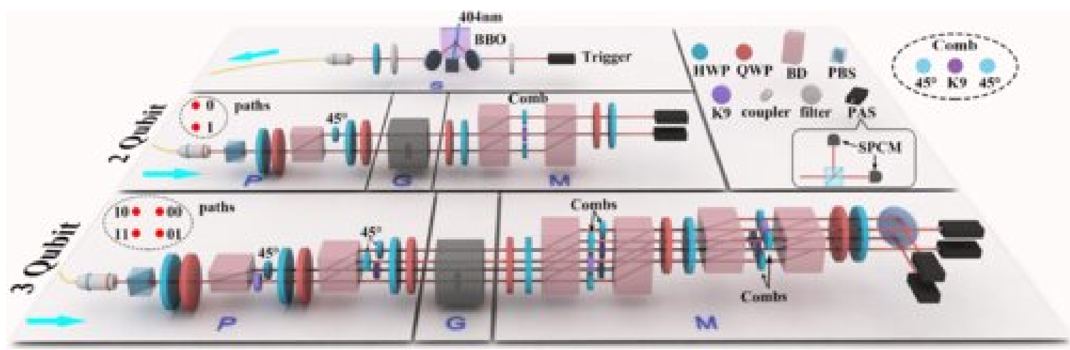


Experimental setup. The heralded single-photon source (labeled by S) is realized by spontaneous parametric down-conversion in a type-I BBO crystal. The figure shows two independent setups employed for implementing the verification protocols for the 2-qubit CNOT gate and 3-qubit Toffoli gate, respectively. Each setup consists of three modules: a state-preparation module (labeled by P), a quantum gate module (labeled by G), and a measurement module (labeled by M). The inset in the component panel (upper right) shows the details of the polarization analyzing system (PAS). Each PAS consists of one polarizing beam splitter (PBS) and two single-photon counting modules (SPCMs) and can measure the photons in the {|H⟩,|V⟩} polarization basis. BD, beam displacer; K9, K9 glass plate with the same optical length as other wave plates used. Credit: DOI: 10.1103/PhysRevLett.128.020502

The development of quantum technology is currently one of the most popular frontiers of advanced science, and is considered as a significant indicator of a country's sci-tech level. On a structural basis, a quantum computer consists of multiple quantum gates. Fault-tolerant quantum computation requires high-fidelity operation on the gates, stressing the priority of developing a reliable and efficient way to examine the fidelity of prepared quantum gates.

Recently, the research group led by Academician Guo Guangcan from the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences, has developed techniques of measuring and examining quantum gates. Related work was published in *Physical Review Letters*.

Due to the exponential growth of measurements and computation, the traditional quantum state tomography method no longer remains its practicability as the future of quantum technology lies in the gates and routes of large scale. A new theoretical method known as quantum gate testing has been suggested lately, but problems remain regarding defects of quantum gates and experimental error.

The research group combined the idea of a quantum gate test with the multi-parameter quantum precision measurement platform they developed in recent years, improved the algorithm applied in quantum gate testing, and increased its robustness to error while retaining high efficiency.

Through multiple local projection measurements of the output of the quantum gate, the improved testing method achieved optimal sample complexity ($1/\in$), proven by experimental results. More importantly, the sample complexity required by this method does not increase in the quantum gates' scale.

Using the newly developed quantum gate testing method, the research group then tested the 2-bits CNOT gate (Control-not gate) and the 3-bits Toffoli gate (Controlled-controlled-not gate), and obtained an average

1600 and 2600 times of measurements required for examining whether the fidelity has surpassed 99 percent and 97 percent, using 20 and 32 measuring bases. In contrast, the traditional method needs 324 and 4096 bases, while requiring millions of times of measurement.

**More information:** Rui-Qi Zhang et al, Efficient Experimental Verification of Quantum Gates with Local Operations, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.020502

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