The experimental realization of quantum overlapping tomography

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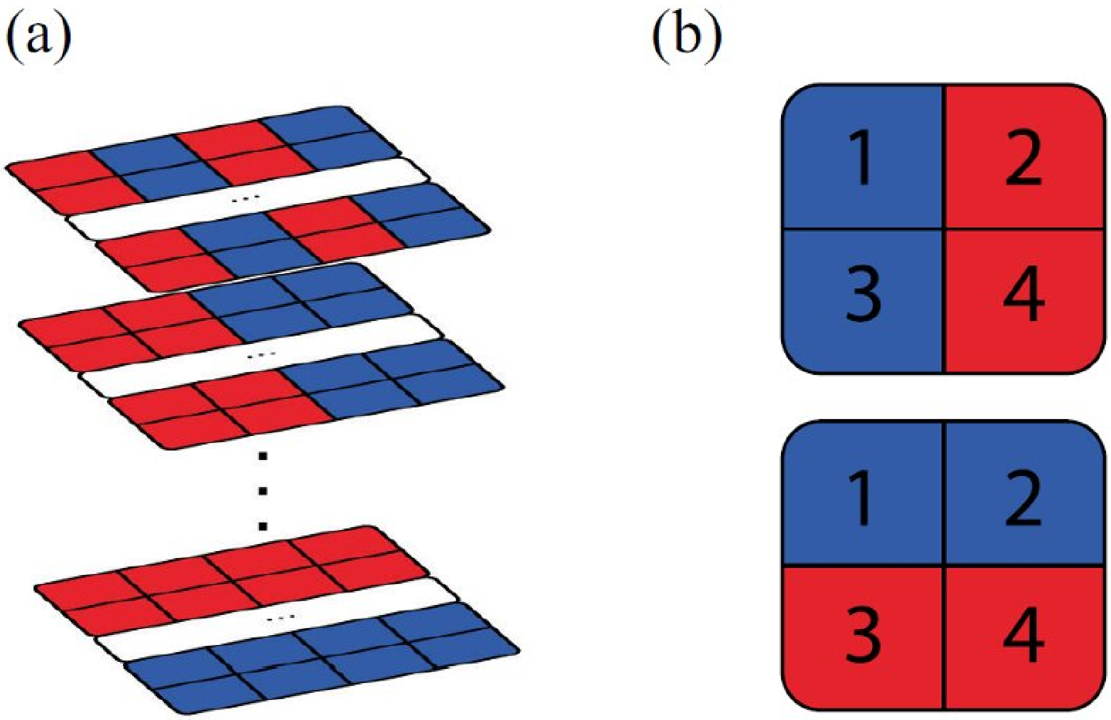


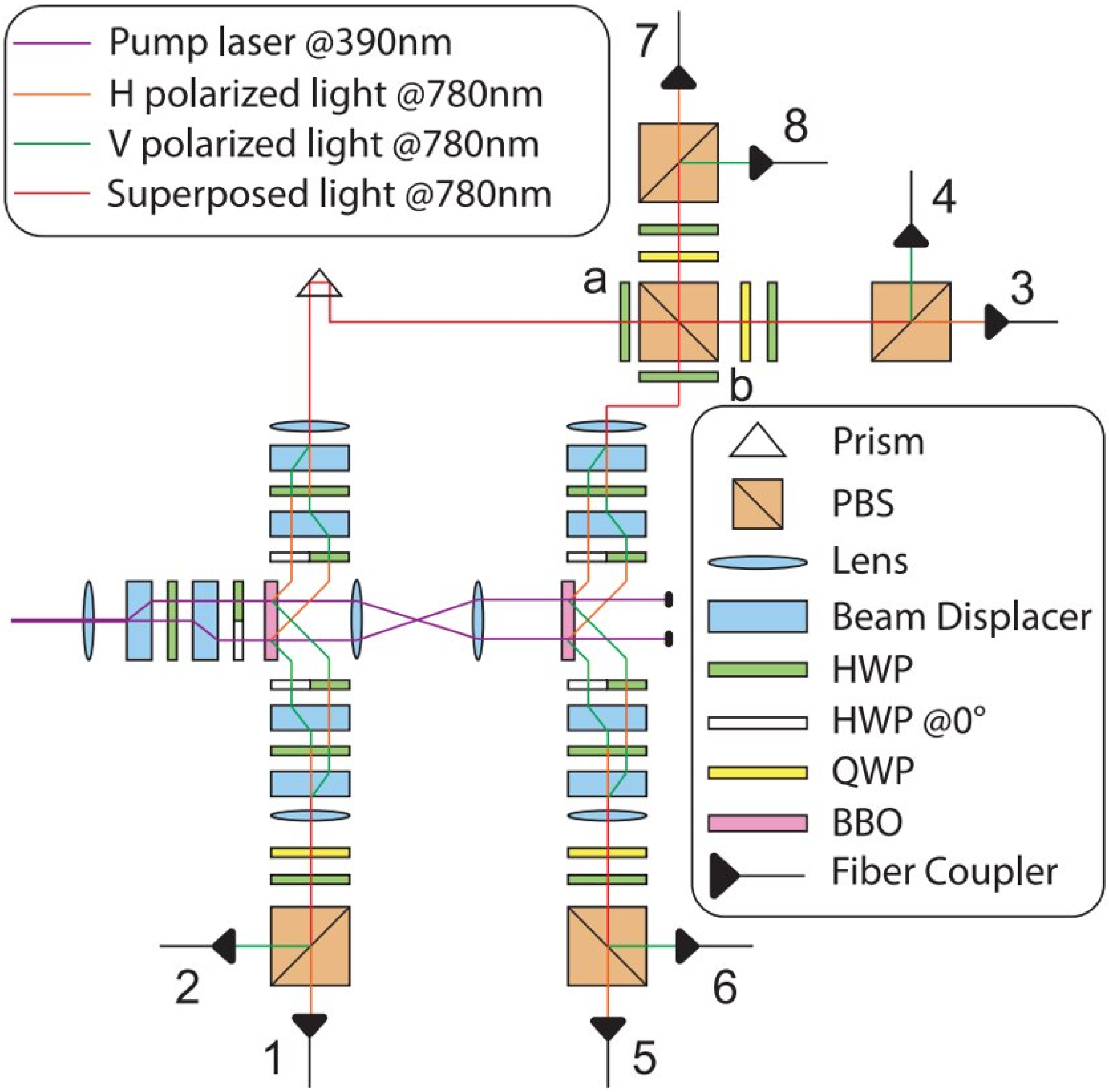
(a) Two-qubit quantum overlapping tomography (QOT) of a large-scale system. The whole system is divided into two groups, red and blue, in different strategies. For each dividing strategy, the two groups are measured on a different basis. (b) QOT dividing strategy for the n=4, k=2 case. Credit: Yang et al

Quantum tomography is a process that involves the reconstruction and characterization of a quantum state using a series of collected measurements. Over the past few years, many physicists have been trying to use this process to learn more about quantum states, as this could also advance the development of quantum technologies.

Researchers at Nanyang Technological University in Singapore have recently demonstrated quantum overlapping tomography (QOT), a sub-type of quantum tomography that was recently a mere theoretical construct, in an experimental setting. Their paper, published in *Physical Review Letters*, could inform future quantum physics research by offering a new effective tool to examine these systems.

"We experimentally implement QOT with a linear optical system and demonstrate its advantage comparing to widely accepted full state tomography," Zhengning Yang, one of the researchers who carried out the study, told Phys.org. "QOT is a method to reconstruct subsystems of an unknown quantum many-body state with a small dataset, which was first theoretically proposed by Jordan Cotler and Frank Wilczek at Stanford and MIT."

The recent work by Yang and his colleagues builds on the 2020 study by Cotler and Wilczek, who proposed that an unknown entangled state could be fully characterized by leveraging a series of single-qubit measurements, through the process that they dubbed QOT. The team at Nanyang Technological University wished to verify this theoretical idea in an experimental setting.



Schematic of experimental setup for generating four-photon entanglement, with the detectors labeled by order. Credit: Yang et al

"We built an optical platform to reproduce a 4/6-qubit quantum state carried by single photon qubits," Yang explained. "The copies of states are then measured in a complete set of quantum bases. We then used the measurement dataset to statistically estimate the original quantum state with two different methods, full-state tomography (FST) and QOT, to compare how well they perform."

The researchers' experiments yielded very promising results, as they suggested that QOT is a more reliable method to characterize quantum states than FST, the conventional quantum tomography process used to characterize integral quantum states. In addition, QOT can accurately characterize quantum states using significantly fewer measurements.

"We discovered that QOT can get significantly more precise results than FST with same numbers of measurement without introducing apparent systematic errors," Yang said.

The findings gathered by Yang and his colleagues highlight the great potential of QOT for studying quantum states. In the future, they could thus encourage the use of this quantum state characterization method in both research and industrial settings, for instance aiding the development of more advanced quantum computers or other quantum technologies.

"As we go through all the works on QOT, we find 'overlapping' is a powerful tool to extract information from a quantum state efficiently," Yang added. "Thus, we now plan to figure out how good it can do in estimating the whole system instead of just the subsystems. We hope it will be the most efficient quantum tomography protocol that is feasible for most systems."

More information: Zhengning Yang et al, Experimental Demonstration of Quantum Overlapping Tomography, *Physical Review Letters* (2023). DOI: 10.1103/PhysRevLett.130.050804

Jordan Cotler et al, Quantum Overlapping Tomography, *Physical Review Letters* (2020). DOI: 10.1103/PhysRevLett.124.100401