Researchers move closer to practical photonic quantum computing

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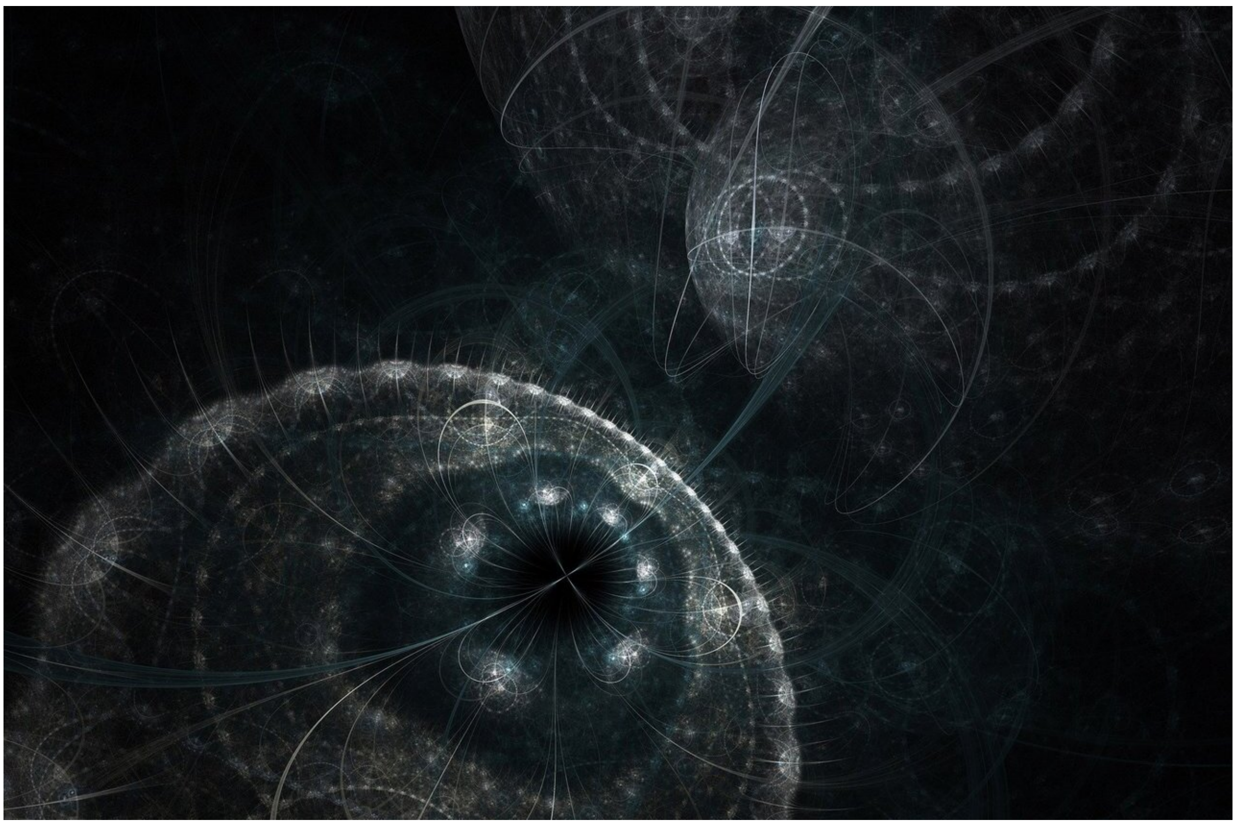

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For the first time, researchers have demonstrated a way to map and measure large-scale photonic quantum correlation with single-photon sensitivity. The ability to measure thousands of instances of quantum correlation is critical for making photon-based quantum computing practical.

In *Optica*, The Optical Society's journal for high impact research, a multi-institutional group of researchers reports the new measurement technique, which is called correlation on spatially-mapped photon-level image (COSPLI). They also developed a way to detect signals from single photons and their correlations in tens of millions of images.

"COSPLI has the potential to become a versatile solution for performing quantum particle measurements in large-scale photonic quantum computers," said the research team leader Xian-Min Jin, from Shanghai Jiao Tong University, China. "This unique approach would also be useful for quantum simulation, quantum communication, quantum sensing and single-photon biomedical imaging."

Interacting photons

Quantum computing technology promises to be significantly faster than traditional computing, which reads and writes data encoded as bits that are either a zero or one. Instead of bits, quantum computing uses qubits that can be in two states at the same time and will interact, or correlate, with each other. These qubits, which can be an electron or photon, allow many processes to be performed simultaneously.

One important challenge in the development of quantum computers is finding a way to measure and manipulate the thousands of qubits needed to process extremely large data sets. For photon-based methods, the number of qubits can be increased without using more photons by increasing the number of modes encoded in photonic degrees of freedom— such as polarization, frequency, time and location—measured for each photon. This allows each photon to exhibit more than two modes, or states, simultaneously. The researchers previously used this approach to fabricate the world's largest photonic quantum chips, which could possess a state space equivalent to thousands of qubits.

However, incorporating the new photonic quantum chips into a quantum computer requires measuring all the modes and their photonic correlations at a single-photon level. Until now, the only way to accomplish this would be to use one single-photon detector for each mode exhibited by each photon. This would require thousands of single-photon detectors and cost around 12 million dollars for a single computer.

"It is economically unfeasible and technically challenging to address thousands of modes simultaneously with single-photon detectors," said Jin. "This problem represents a decisive bottleneck to realizing a large-scale photonic quantum computer."

Single-photon sensitivity

Although commercially available CCD cameras are sensitive to single photons and much cheaper than single-photon detectors, the signals from individual photons are often obscured by large amounts of noise. After two years of work, the researchers developed methods for suppressing the noise so that single photons could be detected with each pixel of a CCD camera.

The other challenge was to determine a single photon's polarization, frequency, time and location, each of which requires a different measurement technique. With COSPLI, the photonic correlations from other modes are all mapped onto the spatial mode, which allows correlations of all the modes to be measured with the CCD camera.

To demonstrate COSPLI, the researchers used their approach to measure the joint spectra of correlated photons in ten million image frames. The reconstructed spectra agreed well with theoretical calculations, thus demonstrating the reliability of the measurement and mapping method as well as the single-photon detection. The researchers are now working to improve the imaging speed of the system from tens to millions of frames per second.

"We know it is very hard to build a practical quantum computer, and it isn't clear yet which implementation will be the best," said Jin. "This work adds confidence that a quantum computer based on photons may be a practical route forward."

More information: K. Sun, J. Gao, M.-M. Cao, Z.-Q. Jiao, Y. Liu, Z.-M. Li, E. Poem, A. Eckstein, R.-J. Ren, X.-L. Pang, H. Tang, I. A. Walmsley, X.-M. Jin, "Mapping and Measuring Large-scale Photonic Correlation with Single-photon Imaging," *Optica*, 6, 3, 244-249 (2019). DOI: 10.1364/OPTICA.6.000244

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