Army scientists take new spin on quantum research

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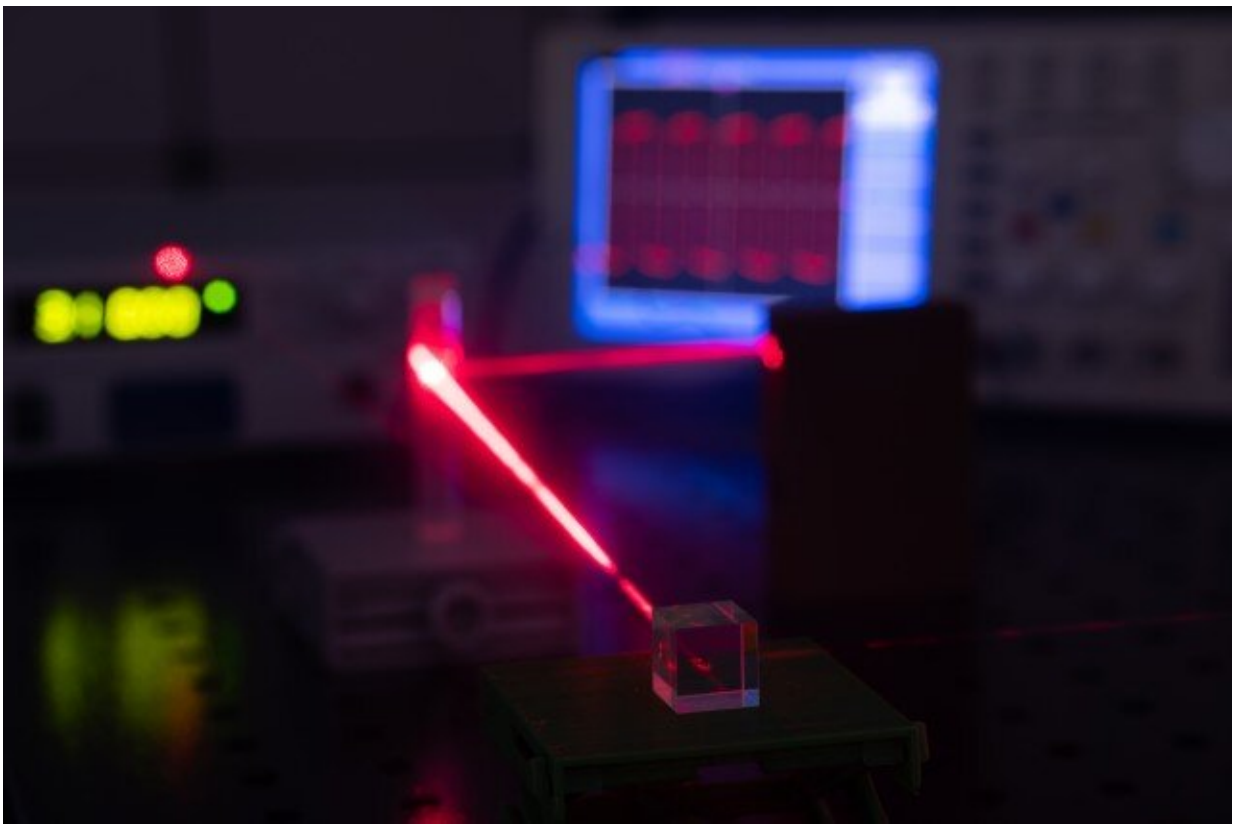

Credit: The Army Research Laboratory

Army researchers discovered a way to further enhance quantum systems to provide soldiers with more reliable and secure capabilities on the battlefield.

Specifically, this research informs how future quantum networks will be designed to deal with the effects of noise and decoherence, or the loss of information from a quantum system in the environment.

As one of the U.S. Army's priority research areas in its Modernization Strategy, quantum research will help transform the service into a multi-domain force by 2035 and deliver on its enduring responsibility as part of the joint force providing for the defense of the United States.

"Quantum networking, and quantum information science as a whole, will potentially lead to unsurpassed capabilities in computation, communication and sensing," said Dr. Brian Kirby, researcher at the U.S. Army Combat Capabilities Development Command's Army Research Laboratory. "Example applications of Army interest include secure secret sharing, distributed network sensing and efficient decision making."

This research effort considers how dispersion, a very common effect found in optical systems, impacts quantum states of three or more particles of light.

Dispersion is an effect where a pulse of light spreads out in time as it is transmitted through a medium, such as a fiber optic. This effect can destroy time correlations in communication systems, which can result in reduced data rates or the introduction of errors.

To understand this, Kirby said, consider the situation where two light pulses are created simultaneously and the goal is to send them to two different detectors so that they arrive at the same time. If each light pulse goes through a different dispersive media, such as two different fiber optic paths, then each pulse will be spread in time, ultimately making the arrival time of the pulses less correlated.

"Amazingly, it was shown that the situation is different in quantum mechanics," Kirby said. "In quantum mechanics, it is possible to describe the behavior of individual particles of light, called photons. Here, it was shown by research team member Professor James Franson from the University of Maryland, Baltimore County, that quantum mechanics allows for certain situations where the dispersion on each photon can actually cancel out so that the arrival times remain correlated."

The key to this is something called entanglement, a strong correlation between quantum systems, which is not possible in classical physics, Kirby said.

In this new work, "Nonlocal Dispersion Cancellation for Three or More Photons," published in the peer-reviewed *Physical Review A,* the researchers extend the analysis to systems of three or more entangled photons and identify in what scenarios quantum systems outperform classical ones. This is unique from similar research as it considers the effects of noise on entangled systems beyond two-qubits, which is where the primary focus has been.

"This informs how future quantum networks will be designed to deal with the effects of noise and decoherence, in this case, dispersion specifically," Kirby said.

Additionally, based on the success of Franson's initial work on systems of two-photons, it was reasonable to assume that dispersion on one part of a quantum system could always be canceled out with the proper application of dispersion on another part of the system.

"Our work clarifies that perfect compensation is not, in general, possible when you move to entangled systems of three or more photons," Kirby said. "Therefore, dispersion mitigation in future quantum networks may

need to take place in each communication channel independently."

Further, Kirby said, this work is valuable for quantum communications because it allows for increased data rates.

"Precise timing is required to correlate detection events at different nodes of a network," Kirby said. "Conventionally the reduction in time correlations between quantum systems due to dispersion would necessitate the use of larger timing windows between transmissions to avoid confusing sequential signals."

Since Kirby and his colleagues' new work describes how to limit the uncertainty in joint detection times of networks, it will allow subsequent transmissions in quicker succession.

The next step for this research is to determine if these results can be readily verified in an experimental setting.

More information: I. C. Nodurft et al, Nonlocal dispersion cancellation for three or more photons, *Physical Review A* (2020). DOI: 10.1103/PhysRevA.102.013713

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