Ultra-Secure Quantum Cryptography with Structured Photons

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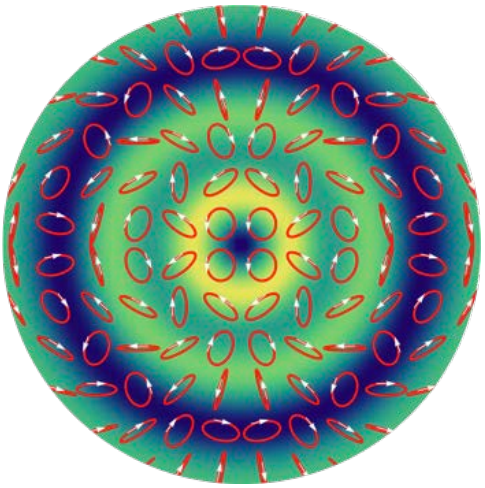
Abstract

Complementarity prohibits one to measure two conjugate quantities simultaneously, such as position and momentum, relying on the existence of the Heisenberg uncertainty principle. This property can be used for sharing information securely between two parties, e.g. through the use of quantum key distribution (QKD). Moreover, the no-cloning theorem, a fundamental law in quantum mechanic, guarantees that attempts to copy the sent information will introduce detectable imperfections on the carrier. Therefore, monitoring imperfections (the channel noise), during key sharing, reveals the existence of an eavesdropper.

Photons, the quanta of light, are an excellent candidate for quantum communication since the encoded information can be transmitted with maximum speed, the speed of light, between separated parties without being significantly affected by the environment. The latter lies on the fact that light barely interacts with air, thus the information can be sent over very long distances. There have been efforts to utilise photons as information carriers; protocols using photonic polarisation have been explored, but are limited to a bi-dimensional encoding *alphabet*. Unlike polarisation, photonic orbital angular momentum (OAM) and radial quantum number (RQN), two newly used photon's degrees of freedom, are inherently unbounded, and thus can be used as an unbounded alphabet for communication purposes.Quantum states of light resulting from an arbitrary coherent superposition of different polarisations, OAM and RQN, are referred to as structured photons; structuring photons may be used to realise higher-dimensional states of light.



An example of structured quantum waves. Probability density distribution of finding photon is shown in avocado colour, while red ellipses indicate the polarisation distribution.

In my talk, I will present the recent progress, challenges and development in performing high-dimensional quantum key distribution, quantum hacking as well as our recent achievements in simulating quantum computations with structure photons. These results show that implementing high-dimensional protocols will improve noise resistance, security, and increase data transmission rates.