Structured Quantum Waves

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In quantum mechanics, the wavefunction is a mathematical representation that defines the quantum state of a system. Both photons, the particles of light, and electrons, the carriers of charge, exhibit wavefunctions characterised by various quantum numbers, including frequency/energy, polarisation/spin, as well as spatial and temporal modes. The ability to generate, manipulate, and measure quantum wavefunctions in different regimes is fundamental to quantum information processing. For instance, precise control over photon states is essential for tasks such as quantum key establishment, quantum state determination (tomography), and quantum simulation of complex systems. Similarly, massive quantum objects, like electrons, play a crucial role in quantum imaging and quantum sensing applications, such as detecting objects or measuring magnetic fields. These research areas fall under the broader study of structured quantum waves.

In my talk, I will present an overview of techniques for engineering the quantum states of photons and electrons, demonstrating how structured quantum waves can provide insights into fundamental questions. Moreover, I will highlight their applications in quantum key establishment, quantum simulators, and quantum microscopy.