Optical Quantum effects

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B9 experimental, suitable for 1 student

Core aims: construct a quantum optics experiment that allows a student to prepare polarization entangled photon pairs, as well as manipulate and detect polarization states of single photons. The project will enable a student to directly observe the phenomena of quantum measurement, interference, entanglement and nonlocality.

Method/output: Several experiments can be investigated including:

- Preparation of single photons and experiments with them, using parametric down-conversion to prepare photon pairs. When one photon in a pair is detected by a single-photon counter, we know that the second photon is emitted as well. The student will experiment with this photon: prove its indivisible nature and observe its interference with itself.
- Entanglement and nonlocality: by adding a crystal to the down-conversion setup, a polarization entangled photon pair can be prepared. By sending one of the photons onto a detector through a polarization filter (a set of waveplates and a polarizer), a specific polarization state can be detected. The other photon will then be remotely prepared in a correlated polarization state, which the student will be able to check by means of the polarization measurement. The student will then use the observed statistics to demonstrate quantum nonlocality through the violation of the Bell inequality.
- The student will investigate these and other experiments to determine which demonstrate the core aims of the project most effectively.

Equipment: A new quantum optics set up has been created within the teaching laboratories and this project offers the first opportunity to use the new equipment.

Examination method: 70% Written report comprising: Introduction and theory, experimental methodology, results detailing results from several of the possible experiments and a detailed lab script for at least one of them. Oral examination 30%.

Additional comments: There may be an option to convert the electronics which detect the photons into an FPGA and learn how to program this. The project links optics and quantum mechanics, both second year topics within the Physics degree, and links to some material covered in B3.