School of Physics: Structured Light Laboratory

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MSc and PhD Projects for 2016

The Structured Light Laboratory has scholarships to offer for Masters or Doctoral study in the following projects:

1. Packing information into light
   How much information can we pack into a photon? In this project we will attempt to demonstrate high bandwidth optical communication using patterns (spatial modes) of light. The optical link will be in both free space and in fibres. This work is in collaboration with a local communications company as well as the CSIR, U. Jena (Germany) and the U. Glasgow (Scotland).

2. Secure quantum communication
   Can we use high-dimensional entanglement as a resource for secure quantum communication? Entanglement holds such promise, yet is frustratingly fragile. In this project we will attempt means to cover a large distance with photonic quantum states entangled in high-dimensions. Quantum key distribution and quantum teleportation will be the main aims. This work is in collaboration with the CSIR, UKZN and Heriot-Watt U. (Scotland).

3. Interaction free measurement
   Is it possible to detect an object without any interaction with it? In this project we will implement the "bomb" thought experiment (following Elitzur-Vaidman) with light entangled in orbital angular momentum to detect objects by quantum interference, e.g., light sensitive biological matter.

4. Digital quantum imaging
   Can we image a 2D object with a single pixel detector? In this project we will use our entanglement experiment to demonstrate ghost imaging, and use digital holograms to enable single pixel detection of the image. This work is in collaboration with the U. Glasgow (Scotland).

5. Sub-diffraction-limited quantum imaging
   Can we image sub-nanometre structures such as those within biological cells? Combining the techniques used in generating quantum entanglement together with those used to achieve optical trapping, the spatial resolution of sub-nanometre structures may be improved.

6. Multi-dimensional quantum walks
   Can we implement quantum walks with classical light? In this project we will use spin and orbital angular momentum light in the form of vector fields to realize >100 steps in a quantum walk, exceeding the present maximum by an order of magnitude. This work is in collaboration with UKZN, the U. Calgary (Canada) and the CSIR.

7. Building nano-structures with optical lattices
   Can we use light as a glue to build 3D objects with nano-structured materials? In this project we will use holographic optical trapping and tweezing to manipulate nano materials into organized structures. This work is in collaboration with the MPRI (Wits).

8. Orbital angular momentum spectroscopy
   Is it possible to slow the rotation of molecules with orbital angular momentum? Doppler-free spectroscopy slows molecules down in their linear momentum, enabling higher resolution. In this project we will consider the argument for using light's angular momentum to achieve rotation-free spectroscopy. This work is in collaboration with the U. Stellenbosch.

9. Classical entanglement
   Is it possible to build a quantum computer with classical light? Non-separability, the quintessential property of quantum entanglement, is not unique to quantum mechanics. In this project we will explore which quantum protocols can be implemented with non-separable classical light fields, which we refer to as classical entanglement. This work is in collaboration with UKZN.

10. Custom lasers
    Can lasers be made to output any desired optical field? In particular, can we create arbitrarily selected vector beams directly from a laser? In this project we will explore intra-cavity control of both the dynamic and geometric phase of light to generate high-order Poincare sphere beams directly from a laser. This work is in collaboration with the U. Caen (France), the U. Naples (Italy), the CSIR and an international laser company.

11. Structured electron waves
    Can we make accelerating electron wave packets that are non-radiating? Using tools traditionally associated with light, we wish to created structured electron wave packets that "break" the rules of physics. This work is in collaboration with the U. Ottawa (Canada).

12. Aero-optics
    Can we use the principles of aerodynamics to manipulate light with air? By combining computational fluid dynamics with optics we will create novel gas and flame lenses for focusing of high power laser beams. This work is in collaboration with the Rutherford Appleton Laboratories (Oxford, England).

13. Optical beams in new coordinate systems
    How do we experimentally realize the mathematical solutions to the Helmholtz equation? To date solutions in eleven coordinate systems have been found, but only a few of them have been demonstrated experimentally. In this project we would like to explore the experimental implementation of optical beams in coordinate systems that up to now have only been studied theoretically. This work is in collaboration with the National Institute of Optics Electronics and Astrophysics (Mexico).

In addition to the above we have active research in topics such as non-diffracting light, accelerating light, the Hall effect for light, self-healing light fields, digital holography, and creation and detection tools for laser light. We are also interested in creating educational portals for outreach.

We invite above average students in Physics or a related discipline to apply. A passion for science, the ability to work in a team environment, and the willingness to travel are essential. To apply, please send us a link to your **You Tube** video (or equivalent) where you explain why we should consider you. If possible, please come to our lab and introduce yourself in person.