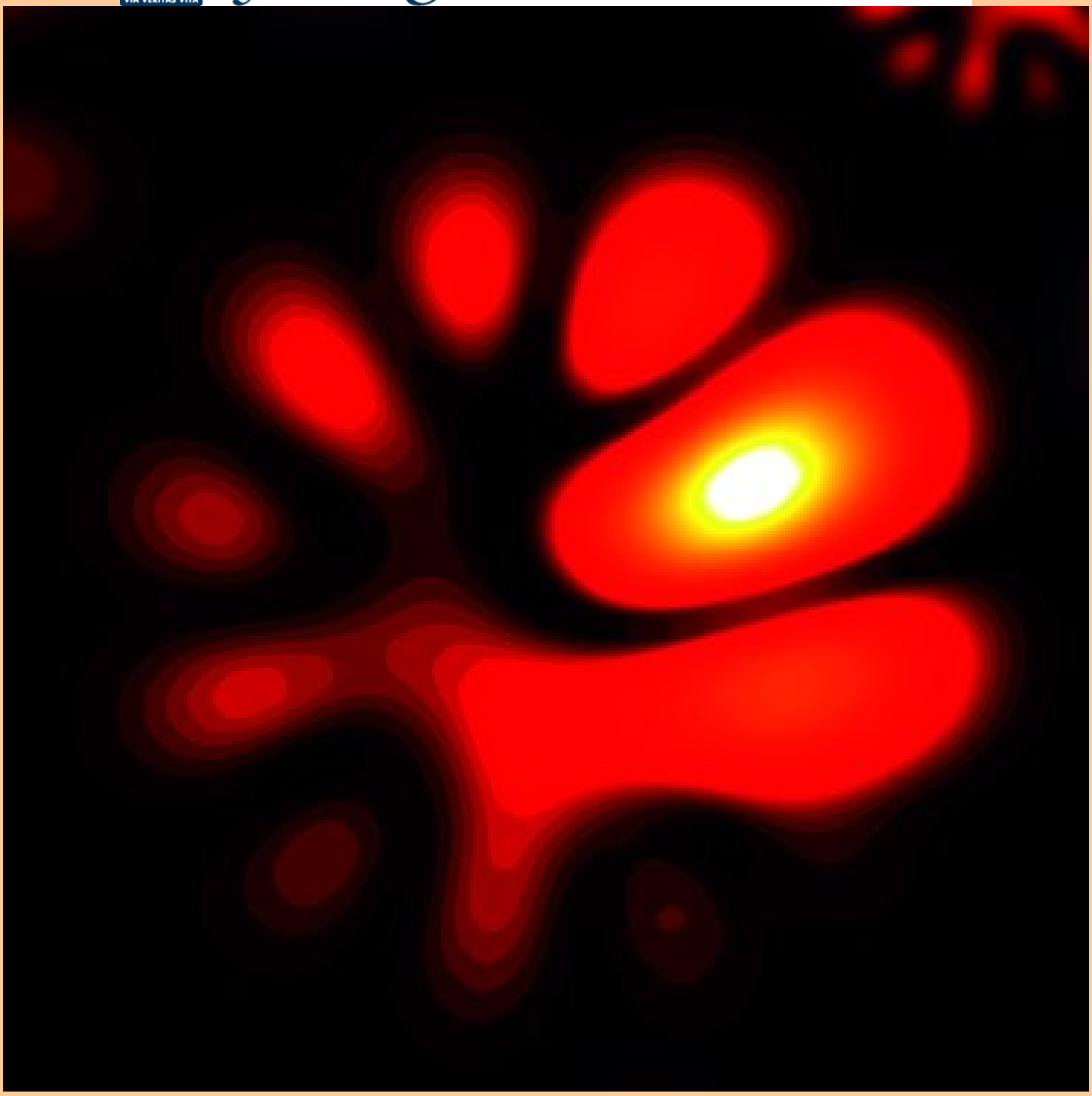
University of Glasgow | School of Physics & Astronomy



PHYS5056: Experimental Techniques in Quantum Optics

Course Information Guide

1 Course Details

Lecturers:	Adetunmise Dada (coordinator)	Schedule:	Typically, 1 session per week
SCQF Credits:	10	ECTS Credits:	5
Assessment:	Oral presentation (25%) Written reports (25%) Project output (50%)	Co-requisites:	None
Level:	Masters	Prerequisites:	None
Typically Offered:	Semester 1		

2 Course Aims

The aim of this course is to introduce some of the basic techniques that are commonly used in a quantum optics lab.

A short series of lectures will provide an overview of the basic techniques and recent examples of important scientific developments in the following topics:

1) Generation of entangled photon pairs
2) Single-photon detection techniques and measurement of photon entanglement
3) Ghost imaging
4) Hong-Ou-Mandel interferometry

The course will also involve home reading of original research articles that will be assigned during the course. Time slots will then be devoted during each lecture to discuss these articles.

Following the lectures, a series of lab-based experiments will be carried out with the aim of investigating specific aspects of the technologies discussed during the lectures. These will be group-based projects (roughly 3-4 students per project) with the expectation that each group will perform at least 2 out of 4 of the planned experiments.

3 Intended Learning Outcomes

By the end of this course students will be able to demonstrate a knowledge and broad understanding of current research topics in the area of experimental quantum optics.

In more detail, they should be able to:
1) Formulate and follow a project plan in a clear, methodical manner; research the scientific and engineering literature relevant to a specific area of quantum optics
2) Demonstrate the methodologies and techniques associated with a particular area of experimental quantum optics, including:

(i) the basic elements of a quantum optics experiment
(ii) photon-pair generation, single-photon and coincidence detection
(iii) the basic operating principle of a single-photon avalanche diode (SPAD)
(iv) the concept of single photon/particle interference
(v) the operating principle of ghost imaging and how to build a ghost imaging setup
(vi) how the basic elements of a quantum interferometer works

3) Conduct high quality technical work as a team
4) Summarise a particular aspect of the field in a clear and properly structured review, in the form of a written report
5) Give a presentation in front of their peers and academic members of staff on the project/literature review carried out

4 Course Outline

Basic concepts of quantum physics: A brief historical overview of the development of the photon from Newton to Einstein that revisits the main basic ideas and philosophical implications of quantum physics, with an emphasis on the role of optics.
Single photon interference: a key experiment in quantum physics that exhibits all of the weirdness of quantum physics and is still an ongoing topic of active research.
Photon detection: How do we actually detect single photons or photon pairs? An overview of the basic methods and techniques for single photon detection and single photon cameras, with an overview of recent innovations and ongoing research in the field.
Photon generation: How do we generate light and, more specifically, quantum light including single photons and photon pairs? We will also provide an overview of photon statistics from different light sources and current ongoing research in the field.
The topics will be discussed during lectures but will also be complemented with home reading based on the original research articles in which the concepts were initially introduced and applied, together with recent research articles.
Ghost imaging: A prime example of a quantum concept (entanglement) applied to an imaging problem. We will give an overview the history of this imaging technique, revealing the quantum aspects but also underlining how other practical approaches to ghost imaging can be implemented in classical optics.

5 Further Information

Further information can be found on the course Moodle page and also using the links below:

- Course specification

- Reading list:
  Wave-particle duality:
  1) https://en.m.wikipedia.org/wiki/Wave%E2%80%93particle_duality
  2) P. Knight, Nature volume **395**, pages 12–13 (1998)
  3) R. Aspden et al., Am. J. Phys. Vol. 84, p. 671 (2016)
  4) A. Ananthaswarmy, "Through two doors at once" (Book)

Photon-pair generation, entanglement, and measurement:
1) C. Couteau, **arXiv:1809.00127v1**
2) Bell Inequality, https://en.wikipedia.org/wiki/Bell%27s_theorem
3) A. Aspect et al., Phys. Rev. Lett. **49**, 91–94 (1982)
4) S. Prabhakar et al., Science Advances, **6**(13), eaay5195 (2020)
5) A. C. Dada, et al., Phys. Rev. Applied **16**, L051005 (2021)
6) A. C. Dada, et al., Nature Physics **7**, 677-680 (2011)

Ghost Imaging reading material:
1) https://en.wikipedia.org/wiki/Ghost_imaging
2) T.B. Pittman et al., Phys. Rev. A, vol 52, p. R3429 (1995)
3) J. Shapiro, Phys. Rev. A, vol 78, p. 061802 (2008)
4) M.J. Padgett and R.W. Boyd, Phil. Trans. A, vol. 375, 20160233 (2017)
5) M. Edgar et al., Nature Photonics **13**, 13-20 (2019)
6) P-A Moreau et al., Laser Photon. Rev., vol. 12, p. 1700143 (2018)
7) DMD tutorial: https://www.youtube.com/watch?v=N4aUU3-PKQ4&feature=youtu.be

Further reading:
- A guide to Experiments in Quantum Optics—Bachor & Ralph, Wiley Ed.
- Essential Quantum Optics—U. Leonhardt, Cambridge University Press.