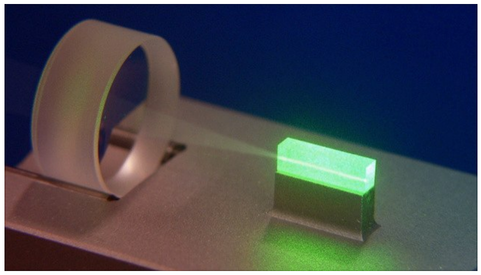
OPTI-596

The Quantum Optics Toolbox (Lab)

Fall 2025



Class lectures	Monday 8:00 - 8:50 (option to change)
Class location	Meinel 422
Lab location	Meinel 452
Class website	d2l.arizona.edu/d2l/home/1630714

Instructor

Dalziel Wilson

Office:	GCRB 014
Lab:	GCRB 070, 065, 060
Phone:	707-302-9646
Email:	dalziel@arizona.edu

Office hours

During scheduled lab sessions. You are also welcome to track me down at my office or lab, or schedule an appointment.

TA

You. (Since this is the inaugural year of the course, we do not have a TA. I'll be proctoring sessions, and you will be helping me—and future students—sort out the kinks!)

Learning outcomes

This course provides a hands-on introduction to experimental techniques in quantum optics, including single photon generation and measurement; interferometry with coherent and squeezed states of light; and cooling and trapping of neutral atoms. Learning outcomes are based on 3 course modules: Squeezed Light, Photonics, and Cold Atoms. At the end of these modules, students will be able to:

Squeezed Light

1. Characterize the quantum efficiency and noise-equivalent-power of a linear photodetector.
2. Characterize the intensity and phase noise of a continuous laser in the frequency domain.
3. Align, lock, and characterize the visibility of a homodyne interferometer.
4. Characterize the conversion efficiency and threshold behavior of a nonlinear optical crystal.
5. Characterize the noise spectrum of a squeezed light source as a function of quadrature angle.

Photonics

1. Characterize the quantum efficiency, dark current, and latency of a single photon detector.
2. Build a heralded single-photon source via spontaneous parametric down-conversion.
3. Distinguish between classical and non-classical states of light by coincidence counting.
4. Analyze the polarization state of a single photon.
5. Analyze the interference of two photons using the Hong-Ou-Mandel effect.
6. (optional) Demonstrate particle/wave duality via the quantum eraser experiment.

Cold Atoms

1. Characterize the hyperfine spectrum of Rubidium using saturated absorption spectroscopy.
2. Stabilize a laser to an atomic transition.
3. Produce a magneto-optical trap and understand its various control parameters.
4. Characterize the size and temperature of an atomic cloud using time-of-flight measurements.

References

Course notes and selected articles will be provided. Two lab-oriented quantum optics textbooks may be useful for Photonics and Metrology modules, but are not required:

A Guide to Experiments in Quantum Optics, Bachor and Ralph, 2019.
- focus on continuous variable quantum optics (linear photodetection, squeezed light)

Quantum Optics for Experimentalists, Z.J. Ou, 2017.
- focus on discrete variable quantum optics (single photon detection, photonics)

Course structure

The course consists of weekly lectures and 12 lab projects (4 for each module) to be completed over the semester during weekly lab sessions. For lab sessions, the class will be divided into groups of ∼3 students. Each group will meet at a scheduled time each week, with a TA, for up to 3 hours, to work on the assigned project. Longer stay is possible if it doesn't interfere with other groups.

For each lab there will be a handout covering experimental objectives, procedures, and topics to explore. Fundamental concepts related to the labs will be briefly reviewed and discussed in the lectures prior to the labs. Lecture attendance is expected.

Each student needs to acquire a physical or virtual lab notebook for recording data and observations and answering questions on handouts. For physical notebooks, please purchase a computation notebook (no spiraled notebooks or 3-ring binders, please). If the pages are not numbered, please number them and reserve the first page as a Table of Contents to record the starting page for each lab section. For virtual notebooks, Microsoft OneNote is recommended. **The objective of the lab notebook is to provide you, by the end of the semester, with a helpful reference for concepts, calculations, and observations you made during the course. The lab book will also be used for grading,** so please do not use it for lecture notes.

Grading

Grades will be based on the following:

Lab participation	(20%)
Lab notebook	(50%)
Final project/report	(30%)

Grading policy: A: 90-100%, B: 80-90%, C: 70-80%

Participation: **Full participation in each lab session is a required part this course.** This does not mean you need to excel at experimental technique. Rather, you need to make a serious effort to contribute to each project. **Please understand that successfully completed experiments are not required for a good grade.**

To the last point: Experiments fail often and for many reasons. It is usually **more beneficial to understand why an experiment did not work than to not understand why an experiment did work**. Due to the structure of this course, lab sessions generally cannot be made up at a later point in the semester. If you foresee an absence from your weekly lab session, discuss with me and the TA beforehand to find an alternative time during the week when you can participate with another lab group, or better yet, arrange to swap places with someone in another lab group.

Lab notebook: For each of the labs, you will be required to record data in your lab notebook and answer questions asked in the handouts (record answers in your lab notebook). I expect that you will maintain legible and complete records of experimental setups, observations, data collected, experiments tried, results obtained, and answers to questions asked in the handouts. Be sure to make careful sketches of the experimental setup. There may be pre-lab or post-lab questions assigned. In these cases, it is required that these are recorded in your lab notebook. Lab notebooks will be collection three times during the semester (after each module) for evaluation.

Final project and report: The last three weeks of the semester—including the finals period—will be dedicated to an independent research project and report. It is expected that the project will be related to one of the three course modules. It may consist of a more careful re-analysis of an experiment or a new experiment that builds on the course content. Partnering with the same or new lab partners is encouraged. The project will culminate in a 3-4 page report (by each student individually) written in latex. More details on the final project will be provided in class.

Working in the laboratory

Please (1) show up on time and (2) familiarize yourself with the principles discussed in class and in the lab handouts *before* working on the experiments. The Monday morning lecture format is meant to facilitate this habit.

You should not plan on relying on your lab partners or your TA to walk you through all of the concepts and procedures of an experiment. This may mean that you need to spend some time reviewing fundamental concepts discussed in the Monday lectures or the lab handouts. A good conceptual understanding will be extremely helpful when working in the lab.

Lasers can be dangerous tools. Some of the lasers you will be using can burn your skin or permanently damage your eye if the beam is pointed directly into your eye. Either can inadvertently happen during laser beam alignment with mirrors and lenses. Laser safety eyewear is provided and should be worn as needed. If necessary, watches, rings, and other reflective objects and jewelry that can obstruct a laser beam and reflect light into your eyes or your partners' eyes should be removed prior to laser work. **You and your lab partners should watch out for each other, and remind each other of laser safety precautions. No rules can replace common sense in a laser lab!**