



SYLLABUS

OPTI 600L Cavity Optomechanics II (1 unit)

Spring 2019

3/28/19 – 5/9/19

M/W/F: 11:00 – 11:50 AM

Location: Meinel 422

Description of Course

This course (2nd in a two-module series) will explore contemporary topics in the field of cavity optomechanics. Early lectures will survey paradigmatic experimental systems such as gravitational wave detectors, optomechanical crystals, levitated nanoparticles, and superconducting LC circuits. Recent milestones in the field of cavity “quantum” optomechanics will then be studied, including ground-state cooling of a micromechanical oscillator, observation of radiation pressure shot noise, ponderomotive light squeezing, and optomechanical entanglement. Finally, emerging applications such as ultra-sensitive accelerometry, quantum-noise-calibrated thermometry, and quantum-coherent electro-optic conversion will be discussed.

Course Prerequisites or Co-requisites

Students must have completed a course in graduate level quantum mechanics (e.g. OPTI-570 or equivalent) and introductory cavity optomechanics (the 1st module of this series OPTI 600L).

Instructor and Contact Information

Prof. Dalziel J. Wilson

Meinel 650

621-2584

dalziel@optics.arizona.edu

Office Hours:

Web information:

Course Format and Teaching Methods

Lecture only.

Course Objectives and Expected Learning Outcomes

Course objectives:

1. Study in detail various paradigmatic cavity optomechanical systems.
2. Survey recent landmark demonstrations of quantum optomechanics.
3. Explore current/proposed applications of cavity optomechanics.

Expected learning outcomes:

1. Students will be able to articulate the key features of various paradigmatic cavity optomechanical systems: gravitational wave detectors, trapped atomic ensembles, levitated nanospheres, superconducting LC circuits, whispering gallery mode micro-resonators, and the “membrane-in-the-middle” cavity optomechanical system.
2. Students will be able to articulate the key concepts underlying recent breakthroughs in quantum optomechanics:
 - Ground-state cooling by radiation pressure,
 - Observation of radiation pressure shot noise,
 - Ponderomotive squeezing, and
 - Optomechanical entanglement.
3. Students will be able to answer the question: “What are the applications of cavity (quantum) optomechanics?”

Absence and Class Participation Policy

The UA’s policy concerning Class Attendance, Participation, and Administrative Drops is available at: <http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop>

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, <http://policy.arizona.edu/human-resources/religious-accommodation-policy>.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: <https://deanofstudents.arizona.edu/absences>

Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. Students who miss class due to illness or emergency are required to bring documentation from their health-care provider or other relevant, professional third parties. Failure to submit third-party documentation will result in unexcused absences.

Required Texts or Readings

There are no required texts for the class, and class notes will be made available through the webpage. Alternative reading sources will be referred to throughout the class and made available in the reading room and Science Library. As a starting point, the student is strongly recommended to download the recent review on cavity optomechanics by Aspelmeyer *et. al.* ([Rev. Mod. Phys. 86, 1391 \(2014\)](#)).

Required or Special Materials

Students may find a symbolic programming language like *Mathematica* useful.

Assignments and Examinations: Schedule/Due Dates

The class shall include weekly homework, two midterm exams, and a final exam.

Final Examination or Project

The date and time of the final exam or project, along with links to the Final Exam Regulations, <https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information>, and Final Exam Schedule, <http://www.registrar.arizona.edu/schedules/finals.htm>

Grading Scale and Policies

The final grade will be based on weekly homework and the final exam.

Homework	50%
Final exam	50%
Total	100%

The grade will be determined according to the cumulative percentage earned such that 80-100% = A, 60-80% = B, 40-60% = C, 30-40% = D, below 30% = E.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at <http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete> and <http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal> respectively.

Scheduled Topics/Activities

The intended topics to be included are as follows:

1. Survey of cavity optomechanical systems:
 - Whispering gallery mode resonators
 - Gravitation wave interferometers
 - Optomechanical crystals
 - Membrane-in-the-middle systems
 - Brillouin optomechanics
 - Superconducting LC circuits
2. Survey of landmark quantum optomechanics demonstrations:
 - Ground state cooling of a micromechanical oscillator
 - Observation of radiation pressure shot noise
 - Ponderomotive squeezing
 - Motional sideband asymmetry
 - Optomechanical entanglement
3. Present and future applications of cavity optomechanics:
 - Gravitational wave astronomy
 - Low noise force, acceleration, and mass sensing
 - Quantum-noise thermometry
 - Quantum-coherent electro-optic conversion
 - Hybrid quantum systems

The final exam date will be on the date set by the UA.

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See <http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students>.

Accessibility and Accommodations

At the University of Arizona we strive to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability or pregnancy, you are welcome to let me know so that we can discuss options. You are also encouraged to contact Disability Resources (520-621-3268) to explore reasonable accommodation.

If our class meets at a campus location: Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See:

<http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity>.

The University Libraries have some excellent tips for avoiding plagiarism, available at <http://new.library.arizona.edu/research/citing/plagiarism>.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy

The University is committed to creating and maintaining an environment free of discrimination; see <http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy>

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students

UA Academic policies and procedures are available at <http://catalog.arizona.edu/policies>

Student Assistance and Advocacy information is available at

<http://deanofstudents.arizona.edu/student-assistance/students/student-assistance>

Confidentiality of Student Records

<http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-act-1974-ferpa?topic=ferpa>

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.