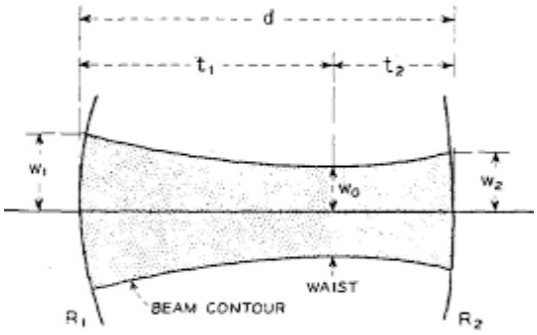
OPTI-600G

Laser Beams and Resonators

Fall 2024



Course Description

Starting from the ray optical treatment of first-order optical systems, this class develops the ideas and approaches underpinning the properties of laser beam propagation and its application to optical resonators. Topics range from ABCD matrices, to classification and stability of optical resonators, to the properties of a variety of common optical resonators. The goal of the class is to provide students with the skills to analyze basic laser beam propagation and resonator properties.

Prerequisites

Ideally students have completed OPTI 501-502; however, a basic understanding of geometric and wave optics, at the level of paraxial optics and the Helmholtz equation, respectively, should suffice. Familiarity with a high-level programming language such as MATLAB is required for assignments.

Number of units/components

1 unit, 5 week module

Location and Times

Class lectures	MWF 11 - 11:50 OM
In-person location:	Meinel 422
Remote location:	arizona.zoom.us/j/4455702729
Class website	d2l.arizona.edu

Instructor

Dalziel Wilson

Office:	Meinel 650
Phone:	520-621-2584 (office)
Email:	dalziel@arizona.edu

Office hours

Thursday 3:30 - 5 PM or by appointment.

Expected Outcomes

- Apply ray transfer matrices to the analysis of optical systems and optical resonators
- Evaluate Guassian and higher-order mode propagation with application to stable two-mirror resonators.
- Analyze the properties of more general optical resonator modes, such as unstable and gain-guided lasers.

Required and optional texts

Lecture and course notes will be provided. A key reference is

1. Kogelnik and Li, "Laser beams and resonators," Appt. Opt. **5**, 1550 (1966)

Additional suggested reading includes

2. A. Siegman, *Lasers*, Ch. 15-16, 22-23
3. P. W. Milonni and J. H. Eberly, *Laser Physics*, Ch. 7
4. J. W. Goodman, *Introduction to Fourier Optics*, App. B
5. E. J. Galvez, "Gaussian beams in the optics course," Am. J. Phys. **74**, 355 (2006)
6. M. Padgett *et. al.*, "An experiment to observe the intensity and phase structure of Laguerre-Gaussian laser modes," Am. J. Phys. **64**, 77 (1996)
7. M. Mansuripur, "The method of Fox & Li," Optics and Photonics News.

Topics and/or general calendar:

Topics to be covered, in approximately chronological order, are

1. Paraxial Ray Optics
   (a) Basics: Fermat's principle, calculus of variations, ray equations, paraxial rays.
   (b) First-order optical systems: Lenses, mirrors, graded-refractive-index (GRIN) media.
   (c) ABCD matrices: Matrix treatment of optical systems, examples, optical path length.
   (d) Periodic optical systems: Eigenray analysis, geometric stability conditions.
   (e) Optical Resonators: Stable and unstable optical resonators, examples.
2. Paraxial Wave Optics
   (a) The paraxial wave equation for beam propagation, Gaussian beam solution and the complex beam parameter in free-space, the Guoy phase-shift.
   (b) Higher-order transverse modes, Hermite-Gaussian and Laguerre-Gaussian modes.
   (c) ABCD law for Gaussian beams, beam propagation through optical systems, examples.
   (d) Plane-parallel Fabry-Perot, transmission characteristics for normal incidence and the Airy function, free-spectral range, frequency bandwidth, and finesse, longitudinal modes, Gaussian mode of a curved mirror Fabry-Perot resonator and mode-matching, higher-order transverse modes, transverse mode resonances.
   (e) Optical resonators with curved mirrors, equivalent periodic systems, wave optical stability, transverse modes of stable optical resonators, transverse mode frequencies.

3. Generalized Resonator Theory
   (a) Complex ABCD transfer matrices, ABCD law for Gaussian beams, generalized Gaussian beam analysis including finite mirror losses and/or a gain profile.
   (b) Unstable optical resonators, transverse mode discrimination, high power lasers.
   (c) Gain-guided lasers, mode properties, optically pumped lasers.
   (d) Numerical results for the properties of unstable and gain guided lasers

Number of Exams and Papers:

Evaluation of knowledge will be based on three homework assignments and a term paper.

Grading

Grades will be based on the following:

Homework Assignments (3 total)	(75%)
Term report	(25%)

Grading policy: A: 90-100%, B: 80-89%, C: 70-79%

Remote course policy

This class is scheduled to be taught in the IN-PERSON modality; however lectures and office hours will be conducted remotely until the University notifies us that in-person meetings may commence. Remote meetings will take place on Zoom at the address listed above. All material will be exchanged through D2L, including homeworks and exams.

Absence and participation policies

Attendance is required at all lectures and encouraged at office hours.

In accordance with UA policy, absences for any sincerely held religious belief, observance, or practice will also be accommodated where reasonable: policy.arizona.edu/human-resources/religious-accommodation-policy. Absences pre-approved by the UA Dean of Students (or dean's designee) will also be honored.

Final Examination Date and Regulations

Final projects are due on the date of the final exam, which can be found at
http://www.registrar.arizona.edu/schedules/finals.htm.

Final Exam Regulations can be found at
https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information.

Classroom behavior policy

To foster a positive learning environment, students are asked to refrain from texting, chatting, reading a newspaper, making phone calls, or surfing the internet.

Threatening Behavior Policy

In accordance with the UA Threatening Behavior by Students Policy, threats of physical harm

to any member of the University community, including to oneself, will not be tolerated. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students .

Academic integrity policy

Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity. In particular, plagiarism is strongly discouraged. See "Grading" for note about homework.

Nondiscrimination and anti-harassment policy

Students are expected, together with the intructor, to foster an environment that encourages expression of ideas without fear of harassment. As such, bullying and discrimination, as described in UA's Nondiscrimination and Anti-harassment Policy, http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy, will not be tolerated.

Accessibility and accommodations

Students faced with accessibility challenges, for example due to pregnancy or due to a disability, will be given reasonable accomodation. Please consult the Disability Resource Center (520-621-3268, https://drc.arizona.edu/) for details.

Subject to change statement

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