# Opti 541A: Introduction to Laser Physics

## Semester and Year this Document Covers

Fall 2022

Five Week – First Session (8/22/22 – 9/23/22)

## Course Number and Title

OPTI 541A: Introduction to Laser Physics
(1 credit)

## Instructor Information

R. Jason Jones, Professor

Email: rjjones@optics.arizona.edu

Phone: 520-626-4634

Wyant College of Optical Sciences

Office Hours: By appointment, Regular hours TBA

## Course Description

Introduction to physical principals of laser operation, including: semiclassical laser theory, optical resonators, Gaussian beam propagation, rate equations and population inversion, 3-level and 4-level laser systems, threshold conditions for CW lasing, steady-state and transient dynamics of laser oscillation. It is recommended students have a prior graduate level understanding of optical physics and semiclassical light-matter interactions, as covered in OPTI 511R (Optical Physics and Lasers) or OPTI 544 (Quantum Optics).

## Course Prerequisites or Co-requisites

It is recommended students have a prior graduate level understanding of optical physics and semiclassical light-matter interactions, as covered in OPTI 544 (Quantum Optics). 541A covers topics from the last few weeks of 511R (Spring 2022 and earlier) and is thus not necessary for students who have taken 511R in Spring 2022 or earlier.

## Course Format and Teaching Methods

Lecture only. Flex in person, Distance Learning

## Course Objectives

Course objectives:

1. Provide students with a basic understanding of laser operation.
2. Develop framework for understanding laser characteristics such as lasing threshold levels, and predicting performance of various laser systems for cw and pulsed operation (e.g. single frequency operation, minimum possible pulse duration, etc…).
3. Learn fundamentals of stable laser cavity design and Gaussian beam propagation.

## Expected Learning Outcomes

Students will be conversant with basics of laser operation and learn the skills required to calculate essential design requirements such as minimum pumping threshold for lasing in 3-level versus 4-level laser systems. Students will be able to design stable optical laser cavities and predict performance, including lasing threshold, single-frequency versus multi-mode operation and pulsed operation including Fourier-limited pulse durations. It is expected that students will be able to calculate laser beam propagation through linear systems.

## 400/500 Co-convened Course Information

Not Applicable.

## Required Texts and Materials

Portions of the textbook "Laser Physics" by Peter Milonni and Joseph Eberly will be utilized in this course and is freely available as an e-book through the UA libraries. Supplementary notes and other readings will be provided.

## Schedule of Topics and Activities

Topics to be covered include:

1. Brief overview of light-matter interactions and semi-classical laser theory.
2. Characterization of laser gain media (homogeneous vs. inhomogeneous, 3-level vs 4-level systems).
3. Optical resonator theory and Gaussian beam propagation.
4. Pumping threshold for lasing and output power.
5. Single-frequency laser operation in the steady-state.

6. Transient laser dynamics and Q-switched operation.
7. Mode-locked laser operation.

## Assessments

Homework 70%, Exam 30%

## Grading Scale and Policies

90-100% = A, 75-89% = B, 60-74% = C, 40-59% = D, <40% = 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.

## Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

## University Policies

All university policies related to this syllabus are available at: https://academicaffairs.arizona.edu/syllabus-policies.

## Subject to Change Notice

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

## Graduate Student Resources

University of Arizona's Basic Needs Resources page: http://basicneeds.arizona.edu/index.html

## 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.

# Opti 541B: Laser Systems and Applications

## Semester and Year this Document Covers

Fall 2022

Five Week - Second Session (9/26/22 – 10/28/22)

## Course Number and Title

OPTI 541B: Laser Systems and Applications
(1 credit)

## Instructor Information

R. Jason Jones, Professor

Email: rjjones@optics.arizona.edu

Phone: 520-626-4634

Wyant College of Optical Sciences

Office Hours: By appointment, Regular hours TBA

## Course Description

This course will cover a brief overview of different laser systems (solid-state and fiber lasers, gas lasers, semiconductor lasers) and select applications. Characterization of laser performance will include noise in laser systems and its measurement, laser coherence and quantum-limited laser linewidth. The course will cover basics of laser stabilization including frequency discriminators and active feedback through the use of phase, frequency, and amplitude modulation. Advanced applications will include linear and nonlinear spectroscopy, laser cooling and trapping, and optical atomic clocks. It is recommended students have a prior graduate level understanding of optical physics and semiclassical light-matter interactions, we well as a previous course covering the basics of laser operation such as OPTI 541A: Introduction to Lasers.

## Course Prerequisites or Co-requisites

It is recommended students have a prior graduate level understanding of optical physics and semiclassical light-matter interactions, we well as a previous course covering the basics of laser operation such as OPTI 541A: Introduction to Lasers or OPTI 511R completed in Spring 2022 or earlier.

## Course Format and Teaching Methods

Lecture only. Flex in person, Distance Learning

## Course Objectives

Course objectives:

1. Provide students with a basic understanding of different laser system including solid-state and fiber, gas, and semiconductor lasers.
2. Characterization of laser noise and performance (laser coherence, linewidth, and measurement of these quantities).
3. Basic understanding of laser stabilization (detection, servo-controlled feedback, frequency and amplitude actuators).
4. Introduce a variety of topical laser applications including linear and nonlinear spectroscopy, laser cooling and trapping, and atomic clocks.

## Expected Learning Outcomes

Students will be conversant with a variety of laser systems, the basic underlying physics, and differences in their operation. At the completion of the course, it is expected they will understand origins of fundamental noise processes in different lasers, how to characterize the noise, and some techniques to mitigate noise in laser systems through active feedback control. Students will also learn topical applications of laser systems in optical physics, and will explore specific applications of interest in a final term paper.

## 400/500 Co-convened Course Information

Not Applicable.

## Required Texts and Materials

To be announced. Supplementary notes and other readings will be provided.

## Schedule of Topics and Activities

Topics to be covered include:

1. Overview of solid-state and fiber, gas, and semiconductor laser systems
2. Characterization of noise in laser systems
3. Electro-optic and acousto-optic modulators for phase, frequency, and amplitude control

4. Laser stabilization
5. Miscellaneous laser topics (spectroscopy, precision measurements, high-harmonic generation…)

## Assessments

Homework 50%, Course Project 50%

## Grading Scale and Policies

90-100% = A, 75-89% = B, 60-74% = C, 40-59% = D, <40% = 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.

## Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

## University Policies

All university policies related to this syllabus are available at: https://academicaffairs.arizona.edu/syllabus-policies.

## Subject to Change Notice

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

## Graduate Student Resources

University of Arizona's Basic Needs Resources page: http://basicneeds.arizona.edu/index.html

## 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.

# Opti 541C: Ultrafast Optics

## Semester and Year this Document Covers

Fall 2022

Five Week – Third Session (10/31/22 – 12/7/22)

## Course Number and Title

OPTI 541C: Ultrafast Optics
(1 credit)

## Instructor Information

R. Jason Jones, Professor

Email: rjjones@optics.arizona.edu

Phone: 520-626-4634

Wyant College of Optical Sciences

Office Hours: By appointment, Regular hours TBA

## Course Description

Fundamentals of ultrashort pulse generation and measurement. This course covers topics from the master equations for active and passive mode-locking and Q-switching to practical laser cavity designs for ultrashort pulse generation. Topics include pulse propagation in linear and nonlinear systems, including material dispersion and dispersion compensation optics, and an introduction to nonlinear optics and related phenomena. Common laser systems used for ultrashort pulse generation will be reviewed along with topical applications including femtosecond frequency combs and high-harmonic generation.

## Course Prerequisites or Co-requisites

It is recommended students have a prior course in optical physics and introductory laser physics, such as OPTI 541A and OPTI 541B.

## Course Format and Teaching Methods

Lecture only. Flex in person, Distance Learning

## Course Objectives

Course objectives:

1. Provide students with a theoretical understanding of Q-switched and mode-locked laser operation.
2. Develop tools for predicting pulse propagation in linear and nonlinear systems
3. Explore common ultrashort pulse laser systems and designs
4. Provide understanding of ultrashort pulse measurement and characterization
5. Review topical applications of ultrashort pulse laser systems

## Expected Learning Outcomes

Students will be conversant in ultrashort pulse laser technology and practical implementations. They will develop tools to understand and predict propagation of ultrashort pulses through linear and nonlinear optical systems and modelling of ultrashort pulse laser operation utilizing the master equations for mode-locking and Q-switching. Students will also become familiar with a variety of techniques used for characterization of ultrashort pulses.

## 400/500 Co-convened Course Information

Not Applicable.

## Required Texts and Materials

To be announced. Supplementary notes and other readings will be provided.

## Schedule of Topics and Activities

Topics to be covered include:

1. Transient laser dynamics and Q-switched operation.
2. Mode-locked laser operation and techniques (e.g. passive versus active)
3. Ultrashort pulse descriptions and characterization.

4. Ultrashort pulse propagation and dispersion compensation.
5. Ultrafast nonlinear optics.
6. Master equations for Q-switching and Modelocking
7. Measurement techniques for ultrashort pulse characterization
8. Femtosecond frequency combs and applications
9. Miscellaneous advanced topics (e.g. high-harmonic generation)

## Assessments

Homework 50%, Course Project 50%

## Grading Scale and Policies

90-100% = A, 75-89% = B, 60-74% = C, 40-59% = D, <40% = 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.

## Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

## University Policies

All university policies related to this syllabus are available at: https://academicaffairs.arizona.edu/syllabus-policies.

## Subject to Change Notice

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

## Graduate Student Resources

University of Arizona's Basic Needs Resources page: http://basicneeds.arizona.edu/index.html

## 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.