OPTI-CCC: Computational optics: Light-matter interactions

(1 Unit)

Updated 06/28/2020

Semester and Year this Document Covers
Spring 2021

Course Number and Title
OPTI-551 – Computational Optics: Light-Matter Interactions

Course Description
This course concentrates on theory, modeling, and simulation of light-matter interactions in extremely nonlinear regimes. The material is organized into a series of case studies, each consisting of a theoretical introduction, overview of models and corresponding numerical methods, computer-aided modeling practice sessions, and overview of open problems. Topics covered are selected to give the students a) the overview of modern nonlinear optics including its applications in strong-field science, b) hands-on experience with numerical modeling, and c) opportunity to gain skills needed to build light-matter interaction models applicable in various contexts. The course starts with an in-depth discussion of different approaches to numerical simulation of ultrashort-duration optical pulses. Next, third-order interactions in solids and gases, including Kerr effect, Raman effect and molecular orientation response are discussed with the emphasis on the numerical modeling and simulation practice. Second-order nonlinear interactions are covered with emphasis on solid-state media (crystals and polycrystalline). Section dealing with the strong-field physics concentrates on ionization in gaseous media, and includes a discussion of various approaches from quantum-level to phenomenological.

Instructor Information

Professor Miroslav Kolesik,

James Wyant Collecge of Optical Sciences

Room: 538

Office hours: TBA

Learning Outcomes
After completion of this course, it is expected that students will have: (i) developed a deeper understanding of of the connection between the Maxwell equations and their numerical modeling in regimes that include strongly nonlinear light-matter interactions (ii) developed a deeper understanding of numerical methods with emphasis on application in nonlinear optics and strong-field physics (iii) honed their skills in design, implementation, and testing of numerical algorithms (iv) deepened their experience in execution of numerical experiments and in assessment of the outcomes of simulations (v) gained confidence to embark on projects that require design of new models for light-matter interactions in various fields of NLO. These skills will be useful for PhD students, experimentalist and theorists alike, who need to hone their numerical modeling skills.

400/500 Co-convened Course Information
N/A

Required Texts and Materials
Required text-books: None.
Students will be given access to a simulation software utilized for case studies and numerical simulation practice.
Students will be required to study selected journal papers dealing with the topics relevant to this course.

Schedule of Topics and Activities
Weeks and topics:

Weeks 1. **Maxwell equations and light-matter interactions**

Equation discretization and the numerical challenges it causes in free-wave propagation and with coupling to material models.

Motivation for alternative approaches.

Week 2-4. **Ultra-short duration optical pulse propagation**

Traditional nonlinear optics approaches, including Nonlinear Schrodinger Equation, and related envelope equations.

Carrier-wave resolving pulse propagation methods.

Week 5.-6. **Optical-pulse simulator anatomy.**

Implementation of the unidirectional pulse propagation equations.

Basic usage of the simulator software.

Week 7.-8. **Third-order nonlinear interactions.**

Kerr effect, Raman effect and molecular reorientation.
Nonlinear self-focusing and beam collapse.
Self-focusing collapse arrest mechanisms, supercontinuum generation in bulk media and in fibers.

Week 9. -10: **Second-order nonlinearity in crystals and poly-crystalline media**
Full-field treatment and comparison to envelope based modeling. Second-harmonic generation simulation in mono-crystals with emphasis on the modeling considerations. Supercontinuum and higher-harmonic generation in polycrystalline materials.

Weeks 11-13. **Strong-field interactions with atoms and molecules**
Strong-field approximation, high-harmonic generation, phase-matching and scaling considerations. Modeling challenges.

Week 14. & 15. **Final project presentations**

Assessments

Assessment Categories	**Percentage of final grade**
Attendance and participation in class activities	10%
Reading assignments	10%
Simulation case studies	40%
Final project	40%
Total	100%

Grading Scale and Policies

The following score ranges will be used to assign grades:
100%-90%:A|75%-89%:B|65%-74%:C|55%-64%:D|0%-54%:E

University Policies

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 subject to change with reasonable advance notice, as deemed appropriate by the instructor of this course.

Graduate Student Resources

http://basicneeds.arizona.edu/index.html