College of Optics & Photonics

OSE-3053 Electromagnetic Waves for Photonics

Spring 2021

Place & Time: CREOL 0102, Mon, Wed, 3:00 PM – 4:15 PM From Jan 11 to May 4, 2020
Prerequisites: OSE3052 or consent of instructor.
Credit Hours: 3 hours
Instructor: Dr. Luca Argenti, e-mail: luca.argenti@ucf.edu
Office Hours: Tuesday and Thursday 1:30pm – 2:30 pm on zoom, or by appointment.
Description: The course covers the foundation of electromagnetic optics, the propagation of optical plane waves within homogeneous, isotropic, and non-isotropic dielectric media, across planar boundaries between them, through dielectric layers, and in planar waveguides.

Learning Outcomes: Upon completing this course, the student will be able to:

- Explain the concept of electromagnetic fields and Maxwell's equations.
- Apply Maxwell's equations to determine the electric and the magnetic fields and the power and their dependence on the medium electromagnetic properties.
- Analyze the propagation characteristics of plane waves including the propagation constants, electric and magnetic fields, and power flow.
- Determine the polarization state for a given field.
- Analyze the reflection and transmission of light at planar interfaces and the dependence on the incident wave polarization and angle of incidence.
- Analyze the reflection/transmission from a film on a substrate and design a thin film AR coating.
- Explain the principles of crystal optics and analyze simple components that control the polarization and the intensity of light.
- Explain the principles of waveguides and determine the guided modes.

Reference Material:

- *Class Notes*
- *Fundamentals of Photonics*, 2nd Edition, by B. E. A. Saleh and M. C. Teich (Wiley, 2009)
- *Optics*, 5th Edition, by E. Hecht (Pearson, 2017)

Content of the course:

PART A. Mathematical Background and Electromagnetic Field Theory

A1: Mathematical Background (2 lectures):

- Scalar and vector representation.
- Coordinate systems and vector coordinate transformation
- Vector algebra – Scalar and vector products.
- Vector integration: The divergence theorem and Stoke's theorem
- Vector Calculus: Gradient, divergence, curl of vector function, and Laplacian.

A2: Electromagnetic Theory in Vacuum and in Materials (2 lectures):

- Coulomb's Law, electric field intensity, electric flux density - permittivity of free-space.
- Biot-Savart Law, magnetic field intensity, magnetic flux density, and permeability of free-space.
- Lorentz force equation.
- Electromagnetic properties of materials:
    - Conductor and conduction current - Conductivity.
    - Dielectric materials and their polarization – Permittivity.
    - Magnetic materials and their magnetization – Permeability.
    - The constitutive relations between the field intensity and the flux density in materials.

A3: Maxwell's Equations and Boundary Conditions (4 lectures):

- Maxwell's equations in integral form.
- Maxwell's equations in differential form.
- Continuity equation and the displacement current.
- The Poynting's theory and electromagnetic power.
- Time harmonic fields and their representations.
- Time harmonic Maxwell's equations.
- Maxwell's equations in material regions.
- The concept of complex permittivity.
- Electromagnetic field boundary conditions at the interface between two layers.

PART B. Propagation across boundaries and in isotropic media

B1: Plane Wave Propagation in Materials (3 lectures):

- The wave equation in source free region.
- The time harmonic wave (Helmholtz) equation in source free region.
- Plane wave solution of the Helmholtz equation.
- The concept of refractive index.
- Propagation vector, phase velocity, wavelength.
- Relationship between the propagation vector and electric and magnetic fields.
- The Poynting's theory and electromagnetic power for a plane wave.
- Polarization of plane waves: Linear, circular, and elliptical.

B2: Plane Wave Reflection and Transmission at Planar Boundaries: (4 lectures)

- Plane wave reflection and transmission at plane boundary between two media.
- Parallel (TM) and perpendicular (TE) polarizations.
- Brewster angle and total transmission, the critical angle and total reflection.
- Surface and evanescent waves.
- Plane wave reflection at a perfectly conducting plane.

B3: Reflection and Transmission at multiple interfaces: (2 lecture)

- Quarter and half-wave transformers
- Applications include anti-reflection coating

PART C. Optical propagation through anisotropic media and waveguides

C1: Crystal Optics (3 lectures)

- Anisotropic media
- Propagation of light through anisotropic media
- Phase retardation and Jones' calculus
- Polarization devices – wave plates, polarization rotators, amplitude modulators

C2: Metallic planar waveguides (2 lectures)

- TEM, TE, and TM modes in two plate planar waveguides.
- Dispersion relation, cut-off condition, field distribution, and power flow.

C3: Dielectric planar waveguides (3 lectures)

- Symmetric waveguides
- TM and TE modes in planar waveguides.
- Dispersion relation, cut-off condition, field distribution, and power flow.
- Single mode waveguides

Webcourses: Course materials, homework assignments, solutions, notes and announcements will be posted on Webcourses. The preferred mode of communication is through the email within Webcourses. It is the student's responsibility to check the "coursemail" tool frequently. All communication between student and instructor and between student and student should be respectful and professional. The instructor will try to answer emails within 1 working day. If you need to directly write to the instructor at the @ucf.edu address, prepend the string "[OSE 5053]" to the subject.

BlendFlex: This course will be using BlendFlex option in order to maintain academic quality while meeting social-distancing requirements. This means that the face-to-face classroom sessions will take place on the days and times noted on the class schedule, but will also be recorded for remote student participation. The idea is to provide all students with continued access to learning experiences.
Students will be divided into two groups with the following classroom attendance pattern:

- Group One will attend: - in person on Monday, 3:00pm-4:15pm, in CREOL 201; - remotely through Zoom on Wednesday, 3:00pm-4:15pm (or choose to view the recording later).
- Group Two will attend: - remotely through Zoom on Monday, 3:00pm-4:15pm (or choose to view the recording later); - in person on Wednesday, 3:00pm-4:15pm, in CREOL 201.

To find out which group you are in, your group number is available in the Webcourses@UCF People section under Groups.

- You will only be permitted to attend physical class on the day you are assigned.
- Please inform me as soon as possible if you are not be able to attend in-person sessions.
- I will inform you as soon as possible if I cannot be in class, and lecture remotely, if viable.

All assignments will be managed online. One of the two midterms will be held on a Monday and the other on Wednesday. Remote students will be able to upload the portion of an exam that requires handwriting by scanning and uploading it online.

Grading Policy:

- Engagement Quiz **(1%)**
- Homework assignments (**19%**),
- Mid-term exam #1 (**20%**)
- Mid-term exam #2 (**20%**)
- Final exam (**40%**)

Grading Scale (%) Interpretation: Plus and minus grades will be used

85-100	A, A-	Excellent, has a strong understanding of all concepts and is able to apply the concepts in all and novel situations. Has full mastery of the content of the course.
75 - 85	B+, B	Good, has a strong understanding of most or all of the concepts and is able to apply them to stated and defined situations.
60 -75	B-, Cx	Average, has a basic understanding of the major concepts of the course and is able to apply to basic situations.
50 - 60	Dx	Below average, has a basic understanding of only the simple concepts and is able to apply to only a limited number of the most basic situations.
0 - 50	F	Demonstrates no understanding of the course content.

Homework: Homework will be assigned on an approximately weekly basis. It is anticipated that there will be 9 total assignments, three for each of the main three parts of the course (HA1-3, HB1-3, HC1-3). A typical assignment will comprise a list of exercises to be solved online or in writing. Students are free to interact outside class time and discuss homework assignments. However, the solutions must be worked out individually, *formulated in clear handwriting*, scanned, and uploaded *as a single legible pdf file* to the webcourse page. Late homework will receive zero points.

Exams: The provisional schedule for the mid-term exams is **Friday February 10th** and **Friday March 17th**, during normal lecture time (3:00 PM – 4:15 PM). The final exam will be on **Wednesday April 28th**, from 1:00 PM to 3:50 PM. Exams are comprehensive and closed book; each student will be allowed to use a single-page formula sheet of his/her own making.

Calendar: The codes HA1-3, HB1-3, HC1-3, indicate the 9 homework assignments. Each assignment will normally be due the week after it is made available on webcourses.

A: EM Field Theory			B: Electromagnetic Optics			C: OWP In layered media		
M	W	F	M	W	F	M	W	F
J11	J13		F15	F17		M22	M24	**HC1**
	J20	**HA1**	F22	F24	**HB1**	M29	M32	**HC2**
J25	J27	**HA2**	M1	M3	**HB2**	A5	A7	**HC3**
F1	F3	**HA3**	M8	M10	**HB3**	SPRING BREAK		
F8	**F10 MT1**		M15	**M17 MT2**		A19	A21	
						A26	**A28 FE**	

Online meetings: Because of the continued remote instruction requirement due to the COVID-19 pandemic, this course will use Zoom for synchronous ("real time") class meetings. Meeting dates and times will be scheduled through Webcourses@UCF and should appear on your calendar. Please take the time to familiarize yourself with Zoom by visiting the UCF Zoom Guides. You may choose to use Zoom on your mobile device (phone or tablet).

Things to Know About Zoom: You must sign in to my Zoom session using your UCF NID and password. The Zoom sessions are recorded. Improper classroom behavior is not tolerated within Zoom sessions and may result in a referral to the Office of Student Conduct. You can contact Webcourses@UCF Support if you have any technical issues accessing Zoom.

Record of Academic Engagement: All faculty are required to document students' academic activity at the beginning of each course. Please, complete the activity online by the end of the first week of classes. Failure to do so may result in a delay in the disbursement of your financial aid.

Accessibility Services for Students: UCF is committed to providing reasonable accommodations for all persons with disabilities. Students with disabilities who need accommodations must be registered with Student Accessibility Services (SAS) http://sas.sdes.ucf.edu/ (Ferrell Commons 185, sas@ucf.edu, phone 407-823-2371) before requesting accommodations from the instructor. Students who are registered with SAS and need accommodations to attend class must contact the instructor at the beginning of the semester to discuss accommodations that might be necessary and reasonable.

Face Covering Policy for Common Spaces and Face-to-Face Classes: To protect members of our community, everyone is required to wear a facial covering inside all common spaces including classrooms. Students who choose not to wear facial coverings will be asked to leave the classroom by the instructor. If they refuse to leave the classroom or put on a facial covering, they may be considered disruptive (please see the Golden Rule for student behavior expectations). Faculty have the right to cancel class if the safety and well-being of class members are in jeopardy. Students will be responsible for the material that would have been covered in class as provided by the instructor.

Notifications in Case of Changes to Course Modality: Depending on the course of the circumstances, the class may exceptionally move fully online. If that happens, please look for announcements or messages in Webcourses@UCF or Knights email about changes specific to this course.

Attendance: Students are normally required to attend in person during their designated day. The attendance requirement can be waived if notified in advance to the instructor with an acceptable motivation, namely: i) perceived exceeding risk for their health or the health of their housemates, ii) illness, iii) family emergencies, iv) special curricular requirements (e.g., field trips and professional

conferences), v) military obligations, vi) religious holidays. If you are a deployed active duty military student and feel that you may need a special accommodation due to that unique status, please contact your instructor to discuss your circumstances.

Make-up exams: Only given to students taking part in University-sanctioned activities. Authentic justifying documentation must be provided in advance. Exceptions are to be made for medical and family emergencies at the discretion of the instructor.

Plagiarism and cheating: Many incidents of plagiarism result from students' lack of understanding about what constitutes academic misconduct. However, students are expected to familiarize themselves with UCF's Golden Rule, which defines plagiarism as follows: ``whereby another's work is used or appropriated without any indication of the source, thereby attempting to convey the impression that such work is the student's own.'' Plagiarism and cheating of any kind on an exam or assignment will result in zero points (and may, depending on the severity of the case, lead to an "F" for the entire course) and may be subjected to appropriate referral to the Office of Student Conduct for further action. See the UCF Golden Rule for further information. Students are assumed to adhere to the academic creed of this University and maintain the highest standards of academic integrity. The instructor will also adhere to the highest standards of academic integrity.

Diversity and Inclusion: Diversity of students, faculty, and staff is a strength of UCF and a critical component of its educational mission. Dimensions of diversity can include sex, race, age, national origin, ethnicity, gender identity and expression, intellectual and physical ability, sexual orientation, income, faith and non-faith perspectives, socio-economic class, political ideology, education, primary language, family status, military experience, cognitive style, and communication style. Participants to OSE6111 are expected to contribute creating an inclusive and respectful classroom environment.