

## Fundamentals in Photonics

EEL 4458 Section 0001

**Class Periods:** Tuesday, Periods 8-9 (3pm-4:55pm)/Thursday Period 9 (4:05pm-4:55pm)

**Location:** Little Hall, Room 201

**Academic Term:** Fall 2024

### Instructor:

Name: Prof. Volker J. Sorger

Email Address: [volker.sorger@ufl.edu](mailto:volker.sorger@ufl.edu)

Office Phone Number: 352-846-4990

Office Hours: Email for appointment, office location: MALA 3200

### Teaching Assistant/Peer Mentor/Supervised Teaching Student:

Please contact through the Canvas website

- Dr. Hao Wang, [hwang40@ufl.edu](mailto:hwang40@ufl.edu), MALA 3200, email for office hour appointment.
- Dr. Hangbo Yang, [hangbo.yang@ufl.edu](mailto:hangbo.yang@ufl.edu), MALA 3200, email for office hour appointment.
- Dr. Chandraman Patil, [c.patil@ufl.edu](mailto:c.patil@ufl.edu), MALA 3200, email for office hour appointment.

### Course Description

Review of electromagnetic fields and waves, energy bands in semiconductors, p-n junctions and optical properties of semiconductors. Fundamentals of optical modulators and waveguides, and photonic applications.

### Course Pre-Requisites / Co-Requisites

Physics of Electrical Engineering (EEL 3008). The ability to write a computer program is essential. A working knowledge of Matlab is sufficient.

### Course Objectives

	Course Learning Objective	Student Outcomes	ABET criteria
1	To be able to understand the fundamental limits, and operational details of opto-electronic devices.	Demonstrate an ability to apply knowledge of science and engineering in the field of optoelectronics and fiber optics.	a
2	Be able to design and optimize an optoelectronic device meeting certain requirements.	Be able to design a system, component, or process that meets desired needs, and identify, formulate, and solve engineering problems.	c,e
3	Understand the impact of photonics engineering solutions in the context of nanofabrication and material integration.	Demonstrate an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	k

### Materials and Supply Fees

N.A.

### Relation to Program Outcomes (ABET):

The table below is an example. Please consult with your department's ABET coordinator when filling this out.

Outcome	Coverage*
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	Medium

2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	High
3. An ability to communicate effectively with a range of audiences	
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	Medium
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	Medium

\*Coverage is given as high, medium, or low. An empty box indicates that this outcome is not covered or assessed in the course.

### **Required Textbooks and Software**

None – Extensive course notes developed by the instructor are posted on the Canvas page.

### **Recommended Materials**

- Optical Properties of Solids
- Mark Fox
- May 20, 2010, 2<sup>nd</sup> edition
- 0199573379

### **Course Schedule**

- **Week 1:** (L) Introduction, Optics/Photonics History Outlook in the 21<sup>st</sup> century, Photonics Technologies in every-day life, Syllabus review (textbook, grades etc.), Optics & Photonics Fundamentals, Optics principles (duality, emission, scattering, absorption, refractions, reflection, TIR, polarization), Briefer on: photonics in information processing & Computing (data comm, neural networks, domain-specific co-processors, optical pre-processing, network-edge & 5G networks, optics-AI, VR/AR).
- **Week 2:** (L) Optical Materials and Light Matter Interactions: Drude-Lorentz-Model, Review Maxwell equations, wave equation, band structures & band-gap, 0D-2D quantization, optical material properties, index and permittivity.
- **Week 3:** (L) Semiconductor Electronics: Energy and bandgap, carrier statistics, carriers, PN junctions, DOS & low-dimension materials, (primer) Light absorption/emission.
- **Week 4:** Guiding Light: Helmholtz equation, optical waveguides, mode analysis, fiber optics. Introduction to Lumerical simulation solver, part 1 (CA1 or CA2)
- **Week 5:** (L) Light Generation: optical processes in semiconductors, absorption, exciton generation.
- **Week 6:** (L) LED, Optical Cavities, Lasers (theory and examples): absorption & gain, rate equations, linewidth, coherence, semiconductor, VCSEL, microrings, material considerations Lumerical simulation solver, part 2 (CA1 or CA2).
- **Week 7: Midterm Exam (in class)**
- **Week 8:** (L) Electro-optic Modulators: intro to non-linear optics, electro-absorption and phase modulation. Modulation Formats, performance, Energy-per-bit, modulator speed. Device concepts Lumerical simulation solver, part 1 (CA3)
- **Week 9:** (L, CA3) Nanophotonics: plasmonics, enhancing light-matter-interaction, Recent R&D Devices (detectors & Modulators, heterogeneous photonics, strain-engineering, 2D materials), sub- $\lambda$  optoelectronic devices, Purcell factor, Wheelers Limit.

- **Week 10:** (CA3) ITO photonics: ENZ, nonlinear photonics, modulators, processing, and iPhone screens
- **Week 11:** (L, CA1) Light Detection: photodetection devices, gain-bandwidth-product, energy/bit, signal-to-noise. Smart-phone camera, photodetector limits and future directions.
- **Week 12:** (L) Photonic Electronic Chip Packaging, 2.5D Fan-out and interposers. 3D heterogeneous integration. Packaging landscape. Challenges and future directions.
- **Week 13:** (L) Fiber Optics and Optical Transceivers: light guiding, optical losses and gain, intro to optical data communication. Industry Perspective: integrated photonics, Silicon-Photonics, photonics road-mapping. Photonics in Data Centers (Google, Facebook), Optics and 5G networks. Markets.
- **Week 14:** (L) Photonics in Information Processing, optical computing, free-space data processing, pre-processing, photonics artificial neural networks (matrix multiplication, weights, nonlinear activation function, training neural networks and impact of noise), optics and machine learning. Optical nonvolatile Memory (phase change materials). Markets.

**Week 15:** Final Exam (in class)

Ledged:

Lecture (L) = Prof. Sorger,

Course Assistant (CA): CA1 = Prof. Wang, CA2 = Prof. Yang, CA3 = Prof Patil

### ***Attendance Policy, Class Expectations, and Make-Up Policy***

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies. Click here to read the university attendance policies:

<https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/>

### ***Evaluation of Grades***

<b>Assignment</b>	<b>Total Points</b>	<b>Percentage of Final Grade</b>
Homework Sets (5)	100 each	40%
Midterm Exam	100	25%
Final Exam	100	25%
Review Paper	100	10%
		100%

### ***Grading Policy***

The following is given as an example only.

<b>Percent</b>	<b>Grade</b>	<b>Grade Points</b>
90.0 - 100	A	4.00
87.0 - 89.9	A-	3.67
84.0 - 86.9	B+	3.33
81.0 - 83.9	B	3.00
78.0 - 80.9	B-	2.67
75.0 - 79.9	C+	2.33
72.0 - 74.9	C	2.00
69.0 - 71.9	C-	1.67
66.0 - 68.9	D+	1.33
63.0 - 65.9	D	1.00
60.0 - 62.9	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

### ***Students Requiring Accommodations***

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is

important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

### ***Course Evaluation***

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

### ***In-Class Recording***

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

### ***University Honesty Policy***

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### ***Commitment to a Safe and Inclusive Learning Environment***

The Herbert Wertheim College of Engineering values varied perspectives and lived experiences within our community and is committed to supporting the University’s core values, including the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of race, creed, color, religion, age, disability, sex, sexual orientation, gender identity and expression, marital status, national origin, political opinions or affiliations, genetic information, and veteran status.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- HWCOE Human Resources, 352-392-0904, [student-support-hr@eng.ufl.edu](mailto:student-support-hr@eng.ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

### **Software Use**

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### **Student Privacy**

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

### **Campus Resources:**

#### Health and Wellness

##### **U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**Counseling and Wellness Center:** <https://counseling.ufl.edu>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

##### **Sexual Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

##### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

#### Academic Resources

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu).  
<https://lss.at.ufl.edu/help.shtml>.

**Career Connections Center**, Reitz Union, 392-1601. Career assistance and counseling; <https://career.ufl.edu>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.

<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.

<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus:** <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>; <https://care.dso.ufl.edu>.

**On-Line Students Complaints:** <https://distance.ufl.edu/getting-help/>; <https://distance.ufl.edu/state-authorization-status/#student-complaint>.