TO: The Faculty of the College of Engineering

FROM: Elmore Family School of Electrical and Computer Engineering

RE: New Graduate Course, ECE 60432 Nanophotonics Modeling

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 60432 Nanophotonics Modeling
Sem. 2 Lecture 1, Cr. 1.
Restrictions: Concurrent registration for ECE 60400

Description: This engineering course is an introduction to photonic materials and devices structured on the wavelength scale. Generally, these systems will be characterized as having critical dimensions at the nanometer scale. These can include nanophotonic, plasmonic, and metamaterials components and systems.

Reason: This course is intended for audiences with background in the physical sciences or engineering. Basic familiarity with the principles of Maxwell's equations, covered in a first year class on physics is needed. Some working knowledge of integral and vector calculus, as well as basic linear algebra, is assumed. Prior experience with basic programming techniques and algorithms is useful but not strictly required; pointers to web-based resources covering these background topics will be available.

Milind Kulkarni,
Associate Head for Teaching and Learning
Elmore Family School of Electrical and Computer Engineering

Course History: Spring 2020 – 0, Spring 2022 – 3, Students in the edX Micromaster program also take this course.
ECE 695: Nanophotonic Modeling

Spring 2020: Location and times TBA; approximately January 13 – February 14 (first five weeks of the semester).

Instructor: Peter Bermel <pbermel@purdue.edu>

Office Hours: In EE 332, immediately after our class meets (or email for another time)

In addition to office hours, students are encouraged to make use of the following online resources:

- Nanophotonic Modeling-- Primary Course Page
- ECE 695 Blackboard website (for non-public information, such as grades and homework)

The primary course textbook by J. D. Joannopoulos, S. G. Johnson, J. N. Winn, and R. B. Meade, is entitled "Photonic Crystals: Molding the Flow of Light," Princeton University Press, 2008. ISBN Number: 9780691124568

Course Description:

This course is an introduction to photonic materials and devices structured on the wavelength scale. Generally, these systems will be characterized as having critical dimensions at the nanometer scale. These can include nanophotonic, plasmonic, and metamaterials components and systems. This course will aim to introduce students to computational techniques employed in current design and research efforts in nanophotonics. You will learn the strengths and weaknesses of each approach; what types of problems call for which one; and how your simulation will perform. Techniques include eigenvalue problems, fast Fourier transforms, band structure calculations, rigorous-coupled wave analysis, and finite-difference time-domain. Applications include photovoltaics, thermal management, radiative control, and nonlinear optics. It is expected to be useful for graduate students interested in incorporating these techniques into their design projects or thesis research.

Lecture Format:

Students are expected to watch the assigned material on edX prior to class. Class periods will be devoted to providing an opportunity for relevant discussions and solving problems in class.

Class Schedule:

TBA.

Grading:

Your course grade will be based on a total of 300 points from quizzes. Up to 50 extra points can also be earned from attendance and extra credit assignments. Your course grade will be calculated by dividing your total by 400, and assigning letter grades on a 10-point scale.

Each quiz will be worth 100 points, and your lowest grade will be dropped. However, if you miss an quiz without a valid reason, it will be averaged into your final grade as a zero. If your quiz averages are lower than the target average, they will be curved at the discretion of the instructor.

Quiz Schedule:

Quiz 1	Wednesday, January 22, 2020
Quiz 2	Wednesday, January 29, 2020
Quiz 3	Wednesday, February 5, 2020
Quiz 4	Wednesday, February 12, 2020

Quizzes are closed book, but a formula sheet will be provided. You should bring a calculator to each quiz. Following ECE policy, your calculator **must** be a Texas Instruments TI-30X IIS scientific calculator.

Make-up Quiz Policy:

There will be NO written make-up quizzes. If you have a good excuse for missing a quiz, you will either be given an oral quiz, or your missed quiz will be dropped without penalty.

Academic Dishonesty:

Any case of academic dishonesty will result in a grade of F in this course.

Campus Closing/Disruption of Classes:

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. In such an event, information will be posted on the course webpage or emailed to you by the instructor.

Class Attendance:

Your class attendance is important. If you must miss class, you are responsible for any material, information, handouts, announcements, etc. you missed. If you are not in class and have someone else sign the attendence sheet for you, you will both receive an F for the class. Attending class is the only way to earn extra credit for attendance.

Course Outline

Week	Topics	Joannopoulos
1-2	Photonic Bandstructures: physical efforts of periodic media, Bloch solutions	Chapters 2-3
3	Transfer Matrices: transmission and reflection of multi-layer systems, with and without lateral periodicities	Chapter 4
4	Time-domain simulations: leapfrog PDE solvers, Yee lattice, modern FDTD tools	Chapter 10
5	Finite-element methods: Galerkin method, applications to photovoltaics, thermal management, and radiative control	Appendix D

Please come to class on-time!

Class announcements may supersede prior written information

Nanophotonic Modeling - Outcomes

Week 1 - Photonic Bandstructures - Part 1

- Obj 1.1: Write down photonic modes using Bloch's theorem
- Obj 1.2: Calculate standing wave modes at the band edge of a 1D periodic photonic crystal
- Obj. 1.3: Calculate TE and TM modes at the band edge of a 2D square-periodic photonic crystal

Week 2 - Photonic Bandstructures - Part 2

- Obj. 2.1: Draw the irreducible Brillouin zone for a 2D triangular lattice photonic crystal
- Obj. 2.2: Calculate the band structure of a 2D triangular lattice photonic crystal for the lowest 8 bands using MIT Photonic Bands
- Obj. 2.3: Identify the lowest-energy photonic bandgap in TE and TM polarizations associated with a 2D triangular lattice photonic crystal

Week 3 - Transfer Matrices

- Obj. 3.1: Use a ray-optics transfer matrix to calculate the reflection and transmission associated with multiple optical elements
- Obj. 3.2: Use a wave-optics T-matrix to calculate transmission and reflection through several dielectric layers arranged in a 1D stack
- Obj. 3.3: Use a wave-optics S-matrix to calculate transmission and reflection through several dielectric layers arranged in a 1D stack
- Obj. 3.4: Use Singular Value Decomposition in CAMFR to calculate the eigenmodes associated with a photonic crystal waveguide structure consisting of a row of defects.

Week 4 - Time Domain Simulations

- Obj. 4.1: To calculate the quality factor of a resonant mode using the FDTD method
- Obj. 4.2: To calculate the band structure of a 2D periodic structure using the FDTD method
- Obj. 4.3: To calculate the relative enhancement in the local density of photonic states associated with a defect in a 2D photonic crystal using the FDTD method

Week 5 - Finite Element Methods

- Obj. 5.1: To calculate a transmission spectrum using the Finite Element Method
- Obj. 5.2: To calculate a transmission spectrum for a waveguide using the Beam Propagation Method
- Obj. 5.3: To calculate the emission spectrum of a photonic emitter using the Finite Element Method