جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

Course Syllabus: Advanced Topics in Photonics - EE 391D

Division	Computer, Electrical and Mathematical Sciences & Engineering
Course Number	EE 391D
Course Title	Advanced Topics in Photonics
Academic Semester	Spring
Academic Year	2016/2017
Semester Start Date	01/22/2017
Semester End Date	05/18/2017
Class Schedule (Days & Time)	04:00 PM - 05:30 PM | Sun Wed

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Andrea Fratalocchi	Andrea.Fratalocchi@kaust.edu.sa	+966128080348 8080348		Building 1, Room 3222. I give 100% time availability to my students. If for some reason I am out of my office, please send me an email and we will arrange a meeting.

Teaching Assistant(s)

Name	Email
TBD	TBD

Course Information

Comprehensive Course Description	Light propagation in anisotropic crystals. Dielectric and susceptibility tensors. Symmetric nature of the Dielectric tensor. Plane wave solutions in anisotropic materials. Ellipsoid equation and fields distribution. Birefringence. Classification of solutions into ordinary and extraordinary waves. Plane wave solutions in uniaxial crystal. Ordinary “o” and extraordinary “e” waves. Index ellipsoid. Analysis of a generic waveplate retarder system. Ordinary and extraordinary waves. Jones matrices. Half-wave retarder: theory and application. Quarter-wave retarder. The Electro-Optic effect. General formulation with the electro-optic tensor. Example of application with KDP crystal. Introduction to the electro-optic amplitude modulation of light. Reduction to diagonal form of the index ellipsoid in the presence of an electric field. Frequency modulation of light with anisotropic crystals. introduction to the problem of the interaction of light with sound waves. Interaction of light and sound. Vectorial solution of Maxwell’s equations though coupled mode analysis. Conservation o f energy and momentum of photons. Bragg interaction. Coupled mode analysis of acousto-optic interactions. Full wave solution of Bragg interaction. Acousto-optic amplitude modulation of light. Introduction to plasmonic. Macroscopic formulation and classical microscopic theory via free-electron gas model. Waveguide theory. Decomposition into transverse and longitudinal components. Definition of Modes. Modes orthogonality relations. Physical meaning of modes orthogonality and completeness of the modal set. Field decomposition into guided modes and radiation modes. Planar structures. TE and TM modes. Full wave analysis of the multilayer structure. Transfer matrix approach. General dispersion relation for TE modes. Coupled mode theory in space. Exact formalism based on the reciprocity theorem of Maxwell’s equations. The directional coupler. Coupled mode equations and their solutions. Side coupling with a waveguide. Prism and grating assisted coupling. Coupled mode equations. Coupled mode theory of periodic one dimensional systems. Bragg interactions with waveguide modes. Reflection and transmission of a bragg filter. Applications. Photonic bandgap. Physical origin of bandgaps. Time Dependent Coupled Mode Theory. (TDCMT) Quality factors. Energy and power flows in TDCMT. Equivalent circuit and mechanical representations. Model of a resonator coupled to the waveguide. Relationship between coupling factor and losses. TDCMT analysis of a resonator coupled to a waveguide. Calculation of Reflection. Analysis of a resonator coupled to input and output waveguides. Transmission. Discussion on frequency selective filtering applications and waveguide interconnects. Introduction to Quantum Optics. The black-body problem. Plank’s law. Stefan-Boltzmann law. Photons fluctuations. Einstein theory of radiative processes. Einstein A and B coefficients.
Course Description from Program Guide	The course introduces the student to different types of photonics systems. The course focuses on real-world devices and modern theories, which can be used in research to study advanced light-matter interactions and in industrial environments to model, design, and optimize different types of light-wave architectures.
Goals and Objectives	The course introduces the student to different types of photonics systems. The course focuses on real-world devices and modern theories, which can be used in research to study advanced light-matter interactions and in industrial environments to model, design, and optimize different types of light-wave architectures.
Required Knowledge	**EE231 Introduction to Optics**
Reference Texts	1. Yariv,·Photonics: Optical Electronics in Modern Communications (Oxford University Press, USA, 2006). 2. Yariv,·Quantum Electronics (Wiley, 1989). 3. S. A. Maier, Plasmonics (Springer, 2007). 4. D. Jackson, Classical Electrodynamics·(Wiley, 1998). 5. R. Loudon, The Quantum Theory of Light (Oxford University Press, New York, 2001). 6. H. Haus, Wave and Fields in Optoelectronics (Prentice Hall, 1989). 7. J. T. Verdeyen, Laser Electronics (Prentice Hall, 1995). 8. H. Nishiara, Optical Integrated Circuits (McGraw Hill, 1989) **Updated slides are found at my group website www.primalight.org->teaching. The slides are not reference texts, the texts are listed above.**
Method of evaluation	**50.00**% - Exam 2 **50.00**% - Exam 1
Nature of the assignments	Homeworks, not graded, after every lesson
Course Policies	**ATTENDANCE POLICY strictly required. Students that miss more that 10% of the course with no valid justification will not be admitted at the exam**
Additional Information	

Tentative Course Schedule

(Time, topic/emphasis & resources)

Week	Lectures	Topic
1	Sun 01/22/2017 Wed 01/25/2017	Light propagation in anisotropic crystals. Dielectric and susceptibility tensors. Symmetric nature of the Dielectric tensor. Reduction to diagonal form.
2	Sun 01/29/2017 Wed 02/01/2017	Plane wave solutions in anisotropic materials. Ellipsoid equation and fields distribution. Birefringence. Classification of solutions into ordinary and extraordinary waves.
3	Sun 02/05/2017 Wed 02/08/2017	Plane wave solutions in uniaxial crystal. Ordinary “o” and extraordinary “e” waves. Index ellipsoid.
4	Sun 02/12/2017 Wed 02/15/2017	Analysis of a generic waveplate retarder system. Ordinary and extraordinary waves. Jones matrices. Half-wave retarder: theory and application. Quarter-wave retarder
5	Sun 02/19/2017 Wed 02/22/2017	Refraction of plane waves at interfaces with anisotropic media. Applications to polarizing beam splitters. Elements of nonlinear optics and nonlinear light-matter interactions. Introduction to second order nonlinear interactions. The Electro-Optic (EO) effect.
6	Sun 02/26/2017 Wed 03/01/2017	General formulation of EO effect with the electro-optic tensor. Example of application with KDP crystal. Introduction to the electro-optic amplitude modulation of light. Reduction to diagonal form of the index ellipsoid in the presence of an electric field.
7	Sun 03/05/2017 Wed 03/08/2017	Frequency modulation of light with anisotropic crystals. Transverse electro-optic modulators. Introduction to plasmonics. Maxwell equations in lossy materials. Plasma model. Volume plasmons.
8	Sun 03/12/2017 Wed 03/15/2017	Waveguide theory. Decomposition into transverse and longitudinal components. Definition of Modes. Modes orthogonality relations.
9	Sun 03/19/2017 Wed 03/22/2017	Physical meaning of modes orthogonality and completeness of the modal set. Field decomposition into guided modes and radiation modes. Planar structures. TE and TM modes.
10	Sun 03/26/2017 Wed 03/29/2017	Full wave analysis of the multilayer structure. Transfer matrix approach. General dispersion relation for TE modes. 2D waveguides. Discussion on full vectorial, semi-vectorial and scalar modal solvers for general dielectric waveguides.
11	Sun 04/02/2017 Wed 04/05/2017	Coupled mode theory in space. Exact formalism based on the reciprocity theorem of Maxwell’s equations.
12	Sun 04/09/2017 Wed 04/12/2017	The directional coupler. Coupled mode equations and their solutions. Discussion on the concept of resonance and its ubiquity in physics
13	Sun 04/16/2017 Wed 04/19/2017	Side coupling with a waveguide. Prism and grating assisted coupling. Coupled mode equations. Discussion and applications
14	Sun 04/23/2017 Wed 04/26/2017	Coupled mode theory of periodic one dimensional systems. Bragg interactions with waveguide modes. Reflection and transmission of a bragg filter. Applications. Photonic bandgap. Physical origin of bandgaps. Time Dependent Coupled Mode Theory. (TDCMT) Quality factors.
15	Sun 04/30/2017 Wed 05/03/2017	Energy and power flows in TDCMT. Equivalent circuit and mechanical representations. Model of a resonator coupled to the waveguide. Relationship between coupling factor and losses.
16	Sun 05/07/2017 Wed 05/10/2017	TDCMT analysis of a resonator coupled to a waveguide. Calculation of Reflection. Analysis of a resonator coupled to input and output waveguides. Transmission. Discussion on frequency selective filtering applications and waveguide interconnects.
17	Sun 05/14/2017 Wed 05/17/2017	Introduction to Quantum Optics. The black-body problem. Plank’s law. Stefan-Boltzmann law.
18		Photons fluctuations. Einstein theory of radiative processes. Einstein A and B coefficients.

Note

The instructor reserves the right to make changes to this syllabus as necessary.