



## Course Syllabus: Special Topics in Photonics - EE 390D

<b>Division</b>	Computer, Electrical and Mathematical Sciences & Engineering
<b>Course Number</b>	EE 390D
<b>Course Title</b>	Special Topics in Photonics
<b>Academic Semester</b>	Summer
<b>Academic Year</b>	2017/2018
<b>Semester Start Date</b>	06/10/2018
<b>Semester End Date</b>	08/09/2018
<b>Class Schedule</b> (Days & Time)	01:00 PM - 04:00 PM   Sun Mon

Instructor(s)				
Name	Email	Phone	Office Location	Office Hours
Andrea Fratalocchi	Andrea.Fratalocchi@kaust.edu.sa	+966128080348		Anytime in my office. If I am in the lab just send an email and I will arrange a meeting

Teaching Assistant(s)	
Name	Email
TBD	TBD

Course Information
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<b>Comprehensive Course Description</b>	<p>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 through coupled mode analysis. Conservation of 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. Planck's law. Stefan-Boltzmann law. Photons fluctuations. Einstein theory of radiative processes. Einstein A and B coefficients.</p>
<b>Course Description from Program Guide</b>	
<b>Goals and Objectives</b>	<p>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.</p>
<b>Required Knowledge</b>	<b>EE231 Introduction to Optics</b>
<b>Reference Texts</b>	<ol style="list-style-type: none"> <li>1. Yariv, Photonics: Optical Electronics in Modern Communications (Oxford University Press, USA, 2006).</li> <li>2. Yariv, Quantum Electronics (Wiley, 1989).</li> <li>3. S. A. Maier, Plasmonics (Springer, 2007).</li> <li>4. D. Jackson, Classical Electrodynamics (Wiley, 1998).</li> <li>5. R. Loudon, The Quantum Theory of Light (Oxford University Press, New York, 2001).</li> <li>6. H. Haus, Wave and Fields in Optoelectronics (Prentice Hall, 1989).</li> <li>7. J. T. Verdeyen, Laser Electronics (Prentice Hall, 1995).</li> <li>8. H. Nishiara, Optical Integrated Circuits (McGraw Hill, 1989)</li> </ol> <p><b>Updated slides are found at my group website <a href="http://www.primallight.org">www.primallight.org</a>-&gt;teaching. <u>The slides are not reference texts, the texts are listed above.</u></b></p>
<b>Method of evaluation</b>	<p>50.00% - Exam 1 50.00% - Exam 2</p>
<b>Nature of the assignments</b>	<p>Homeworks, not graded, after every lesson</p>
<b>Course Policies</b>	<p><b>ATTENDANCE POLICY strictly required. Students that miss more that 10% of the course with no valid justification will not be admitted at the exam</b></p>
<b>Additional Information</b>	

## Tentative Course Schedule

*(Time, topic/emphasis & resources)*

Week	Lectures	Topic
1	Sun 06/10/2018 Mon 06/11/2018	Light propagation in anisotropic crystals. Dielectric and susceptibility tensors. Symmetric nature of the Dielectric tensor. Reduction to diagonal form.
2	Sun 06/17/2018 Mon 06/18/2018	Plane wave solutions in anisotropic materials. Ellipsoid equation and fields distribution. Birefringence. Classification of solutions into ordinary and extraordinary waves.
3	Sun 06/24/2018 Mon 06/25/2018	Plane wave solutions in uniaxial crystal. Ordinary "o" and extraordinary "e" waves. Index ellipsoid.
4	Sun 07/01/2018 Mon 07/02/2018	Analysis of a generic waveplate retarder system. Ordinary and extraordinary waves. Jones matrices. Half-wave retarder: theory and application. Quarter-wave retarder
5	Sun 07/08/2018 Mon 07/09/2018	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 07/15/2018 Mon 07/16/2018	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 07/22/2018 Mon 07/23/2018	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 07/29/2018 Mon 07/30/2018	Waveguide theory. Decomposition into transverse and longitudinal components. Definition of Modes. Modes orthogonality relations.
9	Sun 08/05/2018 Mon 08/06/2018	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		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		Coupled mode theory in space. Exact formalism based on the reciprocity theorem of Maxwell's equations.
12		The directional coupler. Coupled mode equations and their solutions. Discussion on the concept of resonance and its ubiquity in physics
13		Side coupling with a waveguide. Prism and grating assisted coupling. Coupled mode equations. Discussion and applications
14		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		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		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		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.