

**EEL 6931**  
**Quantum Materials and Technologies**  
**3-credits**

Department of Electrical & Computer Engineering  
Florida International University  
Spring 2022

<https://policies.fiu.edu/policy/736>

<b>Classroom</b>	: In-person
<b>Class Time</b>	: TU/TH 3:30 PM - 4:45 PM
<b>Faculty</b>	: Dr. Aleksandr (Alex) Krasnok
<b>Office Hours</b>	: FRI 3:00 PM - 4:00 PM
<b>Office</b>	: EC-2777
<b>Skype</b>	: krasnok_alexandr
<b>Email</b>	: akrasnok@fiu.edu
<b>Prerequisite</b>	: PHY 2049 Physics with Calculus; PHY 4604 Quantum Mechanics; EEL 5437 Microwave Engineering; or equivalent or permission of Instructor
<b>Textbook</b>	: <ol style="list-style-type: none"><li>1. Mark Fox, “Quantum Optics: An Introduction” (Oxford University Press, 2006)</li><li>2. Jack D. Hidary, “Quantum Computing: An Applied Approach” (Springer, 2019)</li><li>3. Alexandre Zagoskin, “Quantum Mechanics: A Complete Introduction” (John Murray Learning, 2015)</li><li>4. Alexey Kavokin, et al., “Microcavities” (Oxford University Press, Second Edition, 2017)</li><li>5. Lukas Novotny and Bert Hecht, “Principles of Nano-Optics”, Second Edition (Cambridge university press, 2012)</li><li>6. Reference Books, published articles, and application notes.</li><li>7. Software packages will be made available to students.</li></ol>

## **Who Should Take This Course?**

1. FIU Electrical and Computer Engineering Students interested in Quantum Physics, quantum optics and quantum computing
2. Graduate Students who need to fulfill Mathematics core course requirement.
3. Students (Graduate and advanced undergraduate) at other Universities in Florida or out of State
4. Engineers and technical staff who want to keep current and reach a deep understanding of Quantum physics and quantum computers

## **Course Description**

Quantum Materials and Technologies, EEL 6931 course focuses on (1) fundamentals of quantum theory; (2) quantum physics behind the electrical and optical properties of materials and their fundamental role in modern electronic and optoelectronic devices; (3) novel quantum materials, including 2D semiconductors, Quantum Dots, superconducting Josephson junctions; (4) Quantum gates; (5) implementation and applications to practical problems in quantum physics and computing.

## **Course Objectives**

1. Master fundamentals of quantum theory and quantum computing;
2. Gain an understanding of novel quantum materials;
3. Master quantum calculations and simulations.

## **Topics Covered**

1. Basics of Classic and Nonlinear Optics
2. Basics of Quantum Mechanics
3. Radiative transitions in natural and artificial atoms
4. Coherence and Photon statistics
5. Photon antibunching and nonclassical light
6. Coherent and squeezed states
7. Atom-photon interactions
8. Cavity quantum electrodynamics
9. Entangled states and quantum teleportation
10. Quantum materials: quantum dots
11. Quantum materials: 2D semiconductors
12. Quantum materials: superconducting circuits
13. Quantum materials: cold atoms
14. Quantum bits and quantum gates
15. Quantum computing
16. Quantum cryptography

## **Relationship of course to program objectives**

In this course, the student will have to show:

1. an ability to apply knowledge of quantum calculations, science, and engineering,
2. an ability to design quantum systems, materials and components,
3. an ability to identify, formulate, and solve quantum engineering problems (homework),
4. the broad education necessary to understand the impact of quantum engineering solutions in a global, economic, environmental, and societal context,

- an ability to use the techniques, skills, and modern quantum engineering tools necessary for engineering practice.

### Grading Scheme

All tests and final exam are a closed book closed notes. Homework will be assigned regularly, collected and graded. Efforts in homework indicate that you are studying and caring about the course and, therefore, can have an impact on your final grade. Time for each of the two tests will be announced one week in advance. Any work submitted must be neat, typed and detailed for partial marks. Your Grade will be calculated as Follows:

Home-works	20%
Midterm:	25%
Project	25%
Final	30%
Total	100%

### Tentative Grading Scale (100-58)/7 = 6 pts. / letter grade)

A	94-100	B+	82-87.9	C+	64 - 69.9
A-	88-93.9	B	76-81.9	C	58 - 63.9
		B-	70-75.9		

### Tentative Dates:

- To be announced during the class

### Important Rule:

Students are encouraged to discuss the course topics with the professor and with each other. Any work submitted (Homework, Tests, projects, etc.) should be pledged and signed as the students' own work, and that there is no any unauthorized help was obtained. Violators will be subject to academic misconduct, which might lead to dismissal from the university.

### University's Code of Academic Integrity

Florida International University is a community dedicated to generating and imparting knowledge through excellent teaching and research, the rigorous and respectful exchange of ideas, and community service. All students should respect the right of others to have an equitable opportunity to learn and honestly to demonstrate the quality of their learning. Therefore, all students are expected to adhere to a standard of academic conduct, which demonstrates respect for themselves, their fellow students, and the educational Mission of the University. All students are deemed by the University to understand that if they are found responsible for academic misconduct, they will be subject to the Academic Misconduct procedures and sanctions, as outlined in the Student Handbook.

More information can be found at [http://academic.fiu.edu/academic\\_misconduct.html](http://academic.fiu.edu/academic_misconduct.html)

## Department Regulations Concerning Incomplete Grades

To qualify for an Incomplete, a student:

1. Must contact (e.g., phone, email, etc.) the instructor or secretary before or during missed portion of class.
2. Must be passing the course prior to that part of the course that is not completed
3. Must make up the incomplete work through the Instructor of the course
4. Must see the Instructor. All missed work must be finished before last two weeks of the following term.

## University policies on sexual harassment, and religious holidays, and information on services for students with disabilities

Please visit the following websites:

<http://academic.fiu.edu/>

<http://drc.fiu.edu>

### Course Policies:

- **Academic Misconduct:** For work submitted, it is expected that each student will submit their own original work. Any evidence of duplication, cheating or plagiarism will result at least a failing grade for the course.
- **Unexcused Absences:** Two unexcused absences are permitted during the term. More than two will result in the loss of points from your final grade. (1 point per absence above two, 3 points per absence above 5).
- **Excused Absences:** Only emergency medical situations or extenuating circumstances are excused with proper documentation. After reviewing documentation you are required to email a description of the excuse and absence dates as a written record to kaleemf@fiu.edu.
- **On Time:** As in the workplace, on time arrival and preparation are required. Two “lates” are equivalent to one absence. (Leaving class early is counted the same as tardy.)
- **Deadlines:** Assignments are due at the beginning of the class period on the date specified. Assignments submitted late (within 1 week) will receive half credit.
- To get assistance, try to see me by an appointment.
- Students are encouraged to ask questions and to discuss course topics with the Instructor and with each other.
- **Any work submitted should display Panther ID number and should be signed, as the students’ own work, and that no unauthorized help was obtained.**
- Cell phones, communicators, MP3 players, head sets are not allowed to be used in the class.
- **DO NOT** send assignments by email.
- Instructor reserves right to change course materials or dates as necessary.

### Exam policy

1. Make sure to complete the assigned homework in order to do well in the exam.

2. All exams are closed book and closed notes.
3. Use of any electronic device with keyboard is prohibited. This also applies to cellphones with messaging system.
4. No discussion is permitted during the exams.
5. Instructor is not compelled to give credit for something he cannot read or follow logically.
6. Cheating is considered as a serious offense. Students who are caught will receive the appropriate consequences.

## Class Schedule

<b>Week</b>	<b>Date</b>	<b>Topic</b>	<b>Assignment</b>
<b>Week-1</b>		Basics of Classic and Nonlinear Optics	
<b>Week-2</b>		Basics of Quantum Mechanics	
<b>Week-3</b>		Radiative transitions in natural and artificial atoms.	
<b>Week-4</b>		Coherence and Photon statistics	
<b>Week-5</b>		Photon antibunching and nonclassical light	
<b>Week-6</b>		Coherent and squeezed states	
<b>Midterm</b>			
<b>Week-7</b>		Atom-photon interactions	
<b>Week-8</b>		Cavity quantum electrodynamics: weak coupling	
<b>Week-9</b>		Cavity quantum electrodynamics: strong coupling	
<b>Week-10</b>		Simulation of cavity interactions. Purcell factor.	
<b>Week-11</b>		Entangled states and quantum teleportation	
<b>Week-12</b>		Quantum materials: quantum dots and 2D semiconductors	
<b>Week-13</b>		Quantum materials: superconducting circuits and cold atoms	
<b>Week-14</b>		Quantum bits and quantum gates Quantum computing	
<b>Week-15</b>		Quantum computing	
<b>Exam Date</b>			