Introduction to Quantum Devices and Quantum Engineering

EEL 5934 Section #0003
Class Periods: Tuesday 10:30am – 11:30am; Thursday 10:30am – 12:35pm
Location: LAR 0330
Academic Term: Fall 2021

Instructor:

Name: Prof. Philip Feng
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Office Phone Number: (352) 294-6320
Office Hours: Tuesday 11:30am – 12:30pm

Teaching Assistant/Peer Mentor/Supervised Teaching Student:

Please contact through the Canvas website

- Mr. Tahmid Kaisar: kaisart@ufl.edu

Course Description

This course will provide both physics and engineering fundamentals of emerging quantum information science and technologies (QIST), and focus on quantum hardware – from fundamental building blocks for encoding quantum information (qubits) to state-of-the-art quantum devices, circuits, and systems, help the students develop a comprehensive knowledge base to understand the key principles, milestone demonstrations, promises and potential applications of QIST, and today's main challenges and opportunities in quantum devices and hardware engineering.

Course Pre-Requisites / Co-Requisites

EEE3396c, basic knowledge of solid-state physics and quantum mechanics would be a plus.

Course Objectives

The main objective of this course is to expose the graduate students to the forefronts of QIST and prepare them for the second quantum revolution. In order to achieve this overarching goal, the course will be developed from the following modules.

- Physics Foundation: The course will start with reviewing the history of the first quantum revolution and recapping the fundamentals in solid-state physics and quantum mechanics.
- Quantum Computing: By comparing with the development of classical computers, the basic concepts of quantum computers and overall architecture will be introduced. The hardware implementation of quantum bits (qubits) will be discussed in detail.
- Quantum Communication: By reviewing the major milestones, quantum key distribution, quantum cryptography, and quantum network will be introduced.
- Quantum Sensing: Practicing a similar protocol, quantum sensing will be introduced, by reviewing the key demonstrations, below nanoscale or uncertainty principle limit.
- Quantum Simulation: In this module, we will review how simulation is widely used and take quantum materials design and IBM-Q online experience as examples to show how quantum simulation works.
- Perspectives and Future Applications of QIST: The course will be concluded with a discussion session on the future development and potential applications of QIST.

Materials and Supply Fees

NA

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	
3. An ability to communicate effectively with a range of audiences	Medium
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	
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

- No Required Textbook. It will be based on the Reference Books and latest materials assembled by the instructor.

Recommended Materials

- **Exploring the Quantum – Atoms, Cavities, and Photons**
  Authors: Serge Haroche and Jean-Michel Raimond
  Publisher: Oxford University Press – Oxford Graduate Texts
  https://www.amazon.com/Exploring-Quantum-Cavities-Photons-Graduate/dp/0199680310/
- **Quantum Computing Devices: Principles, Designs & Analysis**
  Authors: Goong Chen, David Church, Berthold-Georg Englert, Carsten Henkel, Bernd Rohwedder, Marlan O. Scully, Suhail Zubairy
  Publisher: Chapman and Hall/CRC; 1 Edition (2007)
  https://www.amazon.com/Quantum-Computing-Devices-Principles-Mathematics/dp/1584886811
- **National Academies 2019 Report - Quantum Computing: Progress & Prospects**
  Editors: Emily Grumbling & Mark Horowitz
  The National Academies Press (2019).
  Free PDF Download:
  https://www.nap.edu/catalog/25196/quantum-computing-progress-and-prospects

Course Schedule

	Module	Topics	Description
Week 1	Physics Foundation	History of First Quantum Revolution	• Reviewing the history of the first quantum revolution • Recapping the fundamentals in solid-state physics and quantum mechanics

Week 2	Physics Foundation	Impact of First Quantum Revolution	• Demonstrating how quantum mechanics leads to the major technological breakthroughs • Case study with lasers and transistors, *etc*.
Week 3	Quantum Computing	Introduction to Quantum Computing	• Introducing the basic concepts of quantum computing • Comparison with classical computing
Week 4	Quantum Computing	Key Milestones in Quantum Computing	• Reviewing the development of quantum computing • Deriving roadmap and Figures of Merit (FoM)
Week 5	Quantum Computing	Building Blocks of Quantum Computer (I)	• Introducing hardware implementation based on atoms/ions/molecules, superconducting junctions
Week 6	Quantum Computing	Building Blocks of Quantum Computer (II)	• Introducing hardware implementation based on quantum dots, solid-state defect centers, topological insulators, and others
Week 7	Quantum Computing	Quantum Computing Algorithm, Compiling and Architecture	• Introducing the overall architecture of quantum computer and the concept of error correction
Week 8	Midterm Exam		
Week 9	Quantum Communication	Introduction to Quantum Communication	• Introducing the basic concepts of quantum communication • Comparing with current optical communication
Week 10	Quantum Communication	Key Milestones in Quantum Communication	• Reviewing the development of quantum communication • Deriving roadmap and figures of merit (FoM)
Week 11	Quantum Communication	Quantum Network Architecture and Implementation	• Introducing the overall architecture of quantum network and communication protocols
Week 12	Quantum Sensing	Introduction to Quantum Sensing	• Introducing the concept of quantum sensing • Case study of optically detected magnetic resonance and quantum N/MEMS sensing

Week 13	Quantum Simulation	Introduction to Quantum Simulation	• Introducing the concept of quantum simulation • Experiencing IBM-Q
Week 14	Perspectives and Future Applications	Perspectives and Future Applications of QIST	• Open discussion and final project presentation
Week 15	Final Presentation and Final Paper Due		

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

Assignment	Total Points	Percentage of Final Grade
Homework Sets	100 each	25%
Quizzes	100 each	20%
Exam	100	15%
Final Presentation	100	20%
Final Paper	100	20%
		100%

This course is co-listed with the undergraduate course EEL 4930. The homework portion of the graduate section may involve additional work and more advanced concepts with respect to the undergraduate section. The exams may also involve additional questions for the graduate section with respect to the undergraduate section.

Grading for the homework sets, exams, and final presentation/paper are different from the undergraduate course. The graduate and undergraduate sections will be graded separately, for which the graduate section may have additional problems and different weights for the problems.

Grading Policy

The following is given as an example only.

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	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 Conduct 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. 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 broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

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
• Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@ufl.edu
• Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
• Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, 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

Covid-19 Protocols:

- You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated. Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.

- If you are sick, stay home and self-quarantine. Please visit the UF Health Screen, Test & Protect website about next steps, retake the questionnaire and schedule your test for no sooner than 24 hours after your symptoms began. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 (or email covid@shcc.ufl.edu) to be evaluated for testing and to receive further instructions about returning to campus. UF Health Screen, Test & Protect offers guidance when you are sick, have been exposed to someone who has tested positive or have tested positive yourself. Visit the UF Health Screen, Test & Protect website for more information.

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 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

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 suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource 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*:* http://www.distance.ufl.edu/student-complaint-process.