OPTI 647A: Photonic Gaussian Information

Graduate Course Syllabus

Semester and Year this Document Covers:

Fall 2024

Course Number and Title:

OPTI 647A: Photonic Gaussian Information

Instructor Information:

Instructor: Professor Daniel Soh
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Teaching Assistant (TA): TA information is announced at the beginning of each semester.

Lecture Schedule and Office Hours:

Lecture time and place: Tuesday/Thursday 12:30PM-01:45PM, Meinel 432
Office Hours: To be announced at the beginning of each semester and by appointment

Course Description:

This course provides a strong foundation in continuous-variable quantum information, utilizing the recently established Gaussian Quantum Information formalism. It examines the two main approaches in quantum information science. The first, discrete-variable, involves defining qubits from discrete quantum states, while the second, continuous-variable, uses observables with continuous quantities. Historically, quantum computation relied on discrete-variable quantum information, but recent developments have shifted focus to continuous-variable quantum information using boson fields like photons and phonons. This new paradigm is facilitated by existing photonic devices such as amplitude and phase modulators, and homodyne detectors. The course explores photonic fields through second quantization, emphasizing Gaussian quantum information, which impacts areas like computation, communication, sensing, and quantum machine learning.

Lecture topics:

1. Second Quantization of Photonic Fields
2. Quadrature Operators and Displacement Operator
3. Gaussian States
4. Williamson Theorem
5. Symplectic Formalism
6. Characteristic Functions and Quasi-Probability Distributions
7. Gaussian Quantum Channels
8. Gaussian Measurements – Homodyne Detection
9. Gaussian Measurements – Heterodyne Detection
10. Fidelity of Gaussian States
11. Entropies of Gaussian States
12. Entanglement of Gaussian States
13. Dynamics of Gaussian States
14. Bosonic Quantum Teleportation

Learning Outcomes upon completion of this course:

Upon successful completion, students will be able to

- understand basic structures of Gaussian quantum information processing, which is critical for modern quantum information theory and applications,
- calculate the state evolutions and information extraction in Gaussian quantum information processing,
- understand and analyze the modern quantum computation algorithms that use continuous-variable formalism for advanced functional quantum computers,
- use the continuous-variable quantum information formalism for quantum sensing, quantum simulation, quantum computation, and quantum networking & communications.

Course Prerequisite:

Mathematical structure of quantum mechanics including the use of Dirac notation (kets and bras), orthogonal basis, Schrodinger and Heisenberg equations, matrix representation of operators. It is highly recommended that students should have taken OPTI570, which covers all the required basics of quantum mechanics.

Grading Policy:

Homework Assignments	60%
In-class participations (questioning)	20%

Final presentation		20%
	TOTAL	**100%**

Grading scale: A (>=90%), B (>=80%), C (>=70%), D (>=60%), E (<60%)

Homework Assignments:

There will be a homework problem set assigned approximately every two weeks. The due date will be listed in the problem set handouts. Homework submission delays up to 72 hours past the deadline will see a 50% grade penalty. Submission beyond 72 hours after the deadline will see zero credit. If a student has a reasonable excuse that the instructor agrees with BEFORE the deadline will see a potential extension of deadline. The homework grading for each problem will be as follows (assuming 5 points in each problem): ANY attempt of solving the problem will earn 2 points. Small mistakes will see 1 point penalty. A conceptual error (or a significant misunderstanding will see 2 point penalty.

Final Presentation:

Each student will give a 20 – 30 minute presentation at the end of semester. The presentation topics should be the literature (journal articles) of a recently published continuous-variable quantum information research. The topic could be either theoretical or experimental.

Textbook and Lecture Materials:

This course uses Dr. Soh's own lecture notes, which will be distributed after each lecture in D2L. A useful textbook is

- Alessio Serafini – Quantum Continuous Variables, Second Edition, CRC Press (2023)

Course Policies:

It is ***very important*** to attend all lectures. If you must be absent, it is your responsibility to obtain and review the information you missed. Approximately up to 10% of missed attendance will be allowed. However, if a student is absent more than 10% of the entire class, they must have a serious conversation with the instructor, which may result in a substantial damage in grading. The students are very strongly encouraged to ask questions during the lecture.

If you need to leave the room during lecture, please do so discretely, so that you won't disturb the professor and the students.

You are encouraged to work with each other as a team. You should not, however, copy each other's homework.

Additional Information:

Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

University Policies

All university policies related to a syllabus are available at: https://academicaffairs.arizona.edu/syllabus-policies. By placing this link in your syllabus, you no longer need to have each individual policy included in your syllabus.

Subject to Change Notice

Information contained in the course syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor of this course.

Graduate Student Resources

Please refer to the University of Arizona's Basic Needs Resources page http://basicneeds.arizona.edu/index.html