# SYLLABUS

# OPTI 560 Quantum Nanophotonics

**Monday/Wednesday, 4:00 – 5:15 PM, Meinel 432**

## Description of Course

This course will introduce the field of quantum nanophotonics: how to implement quantum technology and quantum information processing based on integrated photonic circuits. Different nanophotonic devices for quantum light control will be introduced. The methods to generate quantum states of light, manipulate light at quantum level with different degrees of freedoms, and detect quantum states of light with various approaches will be covered. Major achievements and future challenges in the field will be discussed. This course aims to provide basic knowledge about quantum nanophotonics from experiment prospective to students from broad backgrounds including quantum/classical photonics, quantum information theory, atomic physics, etc.

## Course Prerequisites or Co-requisites

Knowledge of electromagnetic wave and optics is required. Knowledge in quantum mechanics and quantum optics is preferred. If a prospective student has not taken any undergraduate or graduate course in quantum physics, prior consultation with the instructor is recommended.

## Number of Units: 3

## Instructor and Contact Information

Instructor name: Linran Fan
office location: Meinel 501B
Email: lfan@optics.arizona.edu
Phone: (520)621-0174
Office Hours: By appointment

## Course Objectives

- The course aims to introduce the nanophotonic approach to realize quantum information processing from an experimental prospective.
- The course aims to cover different methods to control light at quantum level with nanophotonic components.
- The course aims to provide students basic knowledge to understand the frontier and rapid-growing research of quantum information processing with nanophotonics.

## Expected Learning Outcomes

- Students will be able to design basic nanophotonic components and their functions for quantum light control.
- Students will be able to understand different approaches and architectures to realize quantum information processing with nanophotonics.
- Students will be familiar with current status and challenges of quantum information processing with nanophotonics.

## Scheduled Topics

1. Overview of quantum nanophotonics

2. Basic quantum optics
    a. Quantization of electromagnetic field
    b. Quantum states of light
    c. Quantum interference
3. Basic nanophotonics
    a. Optical propagation in nanophotonic waveguides
    b. Nanophotonic cavities
    c. Passive nanophotonic devices
    d. Active nanophotonic devices
4. Generation of quantum states with nonlinear nanophotonics
    a. Optical second-order nonlinearity
    b. Optical third-order nonlinearity
    c. Squeezed light generation
    d. Heralded single photons
    e. Towards deterministic single photon source
5. On-chip linear optical quantum computing
    a. Quantum information encoding with photons
    b. KLM protocol
    c. Realization of quantum gates
    d. Unitary transformation with path encoding
6. Quantum frequency conversion
    a. Sum/different frequency generation
    b. Noise and fidelity of frequency conversion
    c. Frequency shifting with phase chirp
    d. Photon bandwidth control
    e. Frequency conversion between microwave and optical frequencies
7. Detectors for quantum state detection
    a. Homodyne and Heterodyne detection
    b. Silicon avalanche detector for single photons
    c. Superconducting single photon detectors
    d. Photon number resolving detectors
8. Survey of current material platforms for quantum nanophotonics
9. Solid state quantum electrodynamics
    a. Semiconductor quantum dot
    b. Diamond defect center
    c. Rare earth ion
10. Applications of quantum nanophotonics

## Grading Scale and Policies

Homework: 30%, Mid-term exam: 30%, Final project: 40%
90-100% = A, 80-89% = B, 70-79% = C, 60-69% = D, below 60% = E

## Absence and Class Participation Policy

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: https://deanofstudents.arizona.edu/absences

Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. Students who miss class due to illness or emergency are required to bring documentation from their health-

care provider or other relevant, professional third parties. Failure to submit third-party documentation will result in unexcused absences.

## Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

## Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

## Accessibility and Accommodations

At the University of Arizona we strive to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability or pregnancy, you are welcome to let me know so that we can discuss options. You are also encouraged to contact Disability Resources (520-621-3268) to explore reasonable accommodation.
If our class meets at a campus location: Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

## Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at http://new.library.arizona.edu/research/citing/plagiarism.

*Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent*. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

## UA Nondiscrimination and Anti-harassment Policy

The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

## Subject to Change Statement

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