Ph.D. DISSERTATION DEFENSE

Candidate: Yifan Du
Degree: Doctor of Philosophy
School/Department: Charles V. Schaefer, Jr. School of Engineering and Science / Physics
Date: Wednesday, April 15th, 2026
Time/Location: 11:00 a.m. / Burchard 714
Title: Non-Hermitian Multiphoton Quantum Interference and On-Chip Spectroscopy in Thin-Film Lithium Niobate

Chairperson: Dr. Yuping Huang, Department of Physics, School of Engineering & Sciences

Committee Members: Dr. Igor Pikovski, Department of Physics, School of Engineering & Sciences
Dr. Xiaofeng Qian, Department of Physics, School of Engineering & Sciences
Dr. Hong Man, Department of Electrical and Computer Engineering, School of Engineering & Sciences

ABSTRACT

Thin-film lithium niobate (TFLN) has emerged as a versatile platform for quantum optics because of its scalability, high nonlinear conversion efficiency, wide transparency window, room-temperature operation, and compact, lightweight structure. In the quantum regime, it offers low propagation loss that helps preserve fragile quantum states, precise engineering of photon profiles, high tunability of quantum states, and efficient generation of entangled photon pairs through spontaneous parametric down-conversion (SPDC). These advantages make TFLN highly attractive for both fundamental studies of quantum physics and practical photonic applications.

Using the TFLN platform, this dissertation explores two major research directions in the quantum optics regime. The first focuses on open quantum systems and non-Hermitian physics, where loss and decoherence do not function as defects, but as potential resources for quantum information processing. In particular, our work studies multiphoton interference in a dissipatively coupled anti-parity-time (anti-PT) symmetry system. On a TFLN chip, two SPDC sources are incoherently linked through a highly lossy channel, enabling the generation of coherent multiphoton states. The experimental results demonstrate controllable and faithful quantum correlations among two, three, and four photons by tuning the relative phase of the driving pumps. We conclude that the common loss reservoir serves a dual role by protecting the robustness of the system while simultaneously sustaining nontrivial quantum correlations. The studies reveal new opportunities for using dissipation as a resource in quantum photonics and for exploring quantum interference beyond conventional Hermitian systems.

The second part of this dissertation explores TFLN as an integrated spectroscopy platform for remote sensing. We demonstrate a chip-integrated emission spectrometer capable of retrieving the temperature of the light sources. The system consists of a single photon detector with a low dark count rate of 147 Hz and a sweeping on-chip filter with 2-pm spectral resolution in the visible and near-infrared regimes. With wildfire sensing applications in mind, we test our system with a hollow cathode lamp to emulate potassium D_1 and D_2 line emission and show how the models of Doppler and collision broadening in the plasma can be used for temperature retrieval. These results highlight the potential of this approach for a wide range of applications, including environmental monitoring, astrophysics, and plasma physics.