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Ph.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy
School/Department: Charles V. Schaefer, Jr. School of Engineering and Science / Physics

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Title: Quantum light generation in thin film lithium niobate

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

Committee Members: Dr. Stefan Strauf, Department of Physics, School of Engineering & Science
Dr. Edward Whittaker, Department of Physics, School of Engineering & Science
Dr. Eui-Hyeok Yang, Department of Mechanical Engineering, School of Engineering & Science

ABSTRACT

Lithium niobate stands as a cornerstone material in the optics and photonics landscape, distinguished by its superlative attributes in both linear and nonlinear optics. Its wide transparency window, relatively high quadratic nonlinear coefficient, and strong electro-optic response make it an exceptional candidate for various optical applications.

However, the development of thin film lithium niobate (TFLN) as a nanophotonic platform has not been as smooth as its counterparts like silicon nitride or other silicon family materials. This slower pace is primarily attributed to the challenges associated with its material processing and nanofabrication. Over the past eight years, our laboratory has contributed to breakthroughs in TFLN nanofabrication techniques. We have successfully fabricated nanophotonic TFLN waveguides characterized by ultra-low propagation losses, consistently measured at less than 0.5 dB/cm.

In my dissertation, I will explore the utilization of our laboratory's leading research in enhancing nonlinear effects within micro-ring resonators and straight waveguides. Focusing on the spontaneous parametric down-conversion process, the periodically poled lithium niobate micro-ring (PPLN-MR) demonstrates a remarkable photon pair generation rate of 2.7MHz per microwatt, along with an exceptional purity indicated by a coincidence-to-accidental ratio exceeding 14,000, all while maintaining low noise performance. These results affirm the potential of TFLN micro-rings for future quantum applications that are particularly sensitive to extraneous noise, such as quantum key distribution. Furthermore, our research has successfully demonstrated highly efficient few-photon generation using a uniquely designed PPLN-MR. This achievement lays the groundwork for on-chip squeezed light generation, photon-photon interaction, nanophotonic information processors, all leveraging similar design principles. Then, we delve into the generation of entangled photon pairs from a PPLN racetrack micro-ring resonator and compared the χ^2 and χ^3 processes. Finally, I will give an outlook on integrated and quantum nanophotonics and suggest future advancements in this rapidly evolving field.