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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: High-Q Resonators and Single Photon Nonlinearity on Thin Film Lithium Niobate

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

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ABSTRACT

Lithium Niobate is revitalized in the field of photonics due to its outstanding optical properties, including a broad transparency window, low propagation loss, and high nonlinearity on a thin film platform. These properties position Lithium Niobate as a competitive candidate to become ‘the Silicon of photonics’. To explore the applications of thin film Lithium Niobate, in this thesis, I demonstrate the workings of a High-Q resonator and single-photon nonlinearity on thin film Lithium Niobate platform. A high-Q resonance of 4×10^{6} for transverse-electric mode is reached with specialized pattern design and fabrication process. To fully use the high Q resonance, periodical poled Lithium Niobate is introduced for its high nonlinear coefficient χ^{2}.

By combining the high Q resonance and periodical poled Lithium Niobate, a high frequency conversion efficiency of 65% at 100 µW and high photon interaction rate of 9.1 MHz are reached on periodical poled microring resonator, which indicates photon quantum conversion probability of 10^{-5} and once the world record. With the high-performance device, the high extinction ratio of 85.7% all optical modulation is realized at 6 mW pump power, which marks 30 times efficiency improvement than previous research. With the same device, for the first time, a stronger signal at 4 mW can be modulated by a weaker pump at 2 mW, achieving an extinction ratio of 43.0%. Lastly, I demonstrate a new form of optical modulation that the role of signal and pump can alter by adjusting the relative delay time between the two pulses, which broadens the potential of optical logic gate on Lithium Niobate nonlinear cavity.

These results, together with inherent advantages in such photonic integrated circuits, open the door to scalable technology for all-optical and quantum information processing.