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Ph.D. DISSERTATION DEFENSE

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Title:	Exploring Temporal State Basis for Quantum Information Processing
Chairperson:	Dr. Yuping Huang, Department of Physics, School of Engineering & Sciences
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ABSTRACT

In this dissertation, I have studied the generation, manipulation, and applications of optical temporal modes for quantum information processing (QIP). The objective is to overcome some challenges facing classical approaches due to signal contamination by background noise, strong losses, and timing jitter of the measuring electronics. In this pursuit, we have demonstrated QIP applications using a variety of temporal mode measurement techniques, including time-correlated single-photon counting (TCSPC), quantum parametric mode sorting, and those with single-photon detector arrays.

In one application, we have shown how high-speed TCSPC can be used for non-contact vibration measurement and material recognition. By acoustically exciting the samples to induce vibrations and recording their vibrational signatures, we achieved material classification accuracies of 95% for five distinct metals and 91% for a set of twelve materials.

In another, we have explored range-gated 3D imaging, focusing on faster gate stepping using phase-locked loops and employing gradient filters and first peak finding methods for point cloud data generation. Using just 1 mW of laser power, we achieved sub-10 mm resolution scans in only a few seconds, demonstrating a high-speed, range-gated 3D imaging system.

In the third application, we explored temporal mode in quantum key distribution for the Quantum Internet of Things, establishing a three-node quantum network across the Stevens campus and achieving a secure key rate of 600 bits per second using an InGaAs detector with 10 % efficiency.

This work marks only the beginning of harnessing optical temporal modes for quantum processing and sensing. Future efforts will scale these techniques with larger detector arrays, integrated photonic platforms, and real-world implementations to overcome noise, timing, and scalability challenges.