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Ph.D. DISSERTATION DEFENSE

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Date:	06/03/2026
Time/Location:	9:30 am, Babio 210
Title:	**High-Dimensional Photonic Quantum States: Mode-Selective Engineering and Photon-Number–Resolved Characterization**
Chairperson:	Prof Yuping Huang, Department of Physics, School of Engineering & Sciences
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ABSTRACT

High-dimensional photonic quantum states provide a powerful route toward scalable quantum communication, networking, and photonic quantum computing due to their large information-encoding capacity. In particular, the time–frequency and photon-number degrees of freedom of entangled photons enable access to a significantly larger Hilbert space compared to conventional two-dimensional quantum systems. In this dissertation, I investigate the generation, mode-selective manipulation, and photon-number–resolved characterization of high-dimensional entangled photonic states generated through spontaneous parametric down-conversion in nonlinear waveguides. Using nonlinear sum-frequency generation, I demonstrate selective access to individual temporal modes within a multimode entangled quantum state, enabling programmable and scalable temporal encoding. The work further extends into the photon-number domain through photon-number–resolved detection, allowing direct observation and applications of multiphoton temporal correlations and detector calibration.

Together, this work establishes a scalable photonic platform that combines high-dimensional temporal encoding, mode-selective engineering, and photon-number–resolved detection for future quantum information technologies with broad applications.