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Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
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Date:	December 4
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Title:	Quantum Open System in Quantum Field: Stochastic Schrödinger Equation with Quantum State Diffusion Approach
Chairperson:	Ting Yu, Department of Physics, School of Engineering and Science
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ABSTRACT

This dissertation presents a self-contained exposition of open quantum system dynamics, developing the density-operator formalism, canonical non-Markovian quantum state diffusion (QSD), stochastic-propagator hierarchies, conditional quantum operations, and phase-space and holomorphic functional integrals, together with four applications to quantum field environments, coherent control, encoded teleportation, and oscillator networks.

A central contribution is the formulation of non-Markovian QSD in the detector's proper time for a spatially extended open system coupled linearly to a free real scalar field in Minkowski spacetime. For a factorized initial state with the field in its vacuum, closed-time-path functional integration and canonical mode expansion yield the same memory kernel under compatible interaction ordering: the field Wightman function sampled along the trajectory and averaged over the spatial coupling profile. This construction links detector motion, finite coupling size, and the frame specifying the spatial profile to QSD response-operator equations. Applied to a uniformly accelerated harmonic oscillator in a massless scalar vacuum within the zeroth-order functional expansion (ZOFE), it produces closed deterministic equations for Gaussian moments. Numerical results show that stronger coupling or acceleration increases late-time entropy and lowers purity, detector size enters nonmonotonically, and ground-state and squeezed-vacuum preparations undergo distinct transients before approaching similar late-time mixedness, capturing relaxation effects beyond the Unruh temperature scale alone.

Three further studies examine open-system control, recovery, and entanglement. First, expanding the stochastic propagator in the Gell-Mann basis for a three-level \(\Lambda\) system under stimulated Raman adiabatic passage in a Lorentzian bath shows how reservoir memory time and detuning jointly govern population transfer and can produce similar population histories for different parameter pairs. Second, for logical-qubit teleportation using three-level carriers under monitored Markovian decay, support-restricted reversal lowers the probability cost relative to full-space reversal when the latter exists; with a fixed receiver filter, fidelity constraints determine optimal deterministic and randomized sender-recovery schedules, whereas Bell-outcome-dependent receiver filters restore the state conditionally without positive-time sender reversal. Third, ZOFE covariance equations for harmonic-oscillator networks in a common Ornstein--Uhlenbeck bath distinguish entanglement redistribution from bath-mediated generation and demonstrate frequency-selected pairwise entanglement without direct inter-oscillator coupling.