



Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
School/Department:	Charles V. Schaefer, Jr. School of Engineering & Sciences/Physics
Date:	Friday, May 1 st , 2026
Time/Location:	5:00 p.m./Burchard 103
Title:	Dynamics of Quantum State Transfer and Entanglement Networks in Open Quantum Systems
Chairperson:	Dr. Ting Yu, Department of Physics, School of Engineering & Sciences
Committee Members:	Dr. Knut Stamnes, Department of Physics, School of Engineering & Sciences, Dr. Chunlei Qu, Department of Physics, School of Engineering & Sciences, Dr. Rupak Chatterjee, Applied Physics Department, Tandon School of Engineering – Polytechnic Institute

ABSTRACT

Quantum technologies leverage the unique properties of quantum states and entanglement to improve or enable tools such as state transfer, teleportation, integer factorization, and the simulation of complex molecules or materials. However, the realization of these technologies hinges on our ability to control quantum states and protect them from decay caused by dissipation and decoherence into the surrounding environment. While many in industry and academia work on improving the protection quantum states through isolation techniques like shielding and other active feedback control techniques, my dissertation work instead focuses on utilizing the environment to our advantage.

Markovian and non-Markovian environments are the two main types of open quantum systems. Environmental memory is the ability for the environment to facilitate and exchange quantum information with a system of interest and is what sets a non-Markovian one apart. My studies include two main parts.

First, I solved both the Markovian and non-Markovian master equations that govern the open system dynamics for N-harmonic oscillator coupled in a ring configuration from first principles. I use these solutions to simulate the entanglement dynamics within these rings and extract the governing system and environmental parameters that enhance and preserve entanglement. Afterwards, I use these results to propose a method to use environmental memory and resonance to generate entanglement among multiple initially uncoupled oscillators to distribute entanglement and create hidden quantum networks in a passive manner.

Second, my colleague and I extend existing theoretical work that simulates the transfer of quantum information from atoms to photons and vice versa into the non-Markovian regime and with Gaussian states. We show that a non-Markovian environment can significantly enhance quantum state transfer with respect to multiple parameters: state size, decay rate, vibrational frequency, and the atomic motional mode. By combining my two studies, I propose a method to transfer the quantum state of the vibrational mode of a diatomic molecule modeled as a coupled harmonic oscillator to a distant pair of uncoupled atoms in both Markovian and non-Markovian environments.