STEVENS
INSTITUTE OF TECHNOLOGY
1870

Ph.D. DISSERTATION DEFENSE

Candidate:	Zhaotong Li
Degree:	Doctor of Philosophy
School/Department:	Charles V. Schaefer, Jr. School of Engineering and Science / Physics
Date:	Wednesday, May 6th, 2026
Time/Location:	12:00 p.m. / Burchard 104
Title:	Harnessing Optical Dynamics for Optimization, Neural Computation, and Non-Hermitian Photonics
Chairperson:	Dr. Chunlei Qu, Department of Physics, School of Engineering & Science
Committee Members:	Dr. Yuping Huang, Department of Physics, School of Engineering & Science Dr. Ting Yu, Department of Physics, School of Engineering & Science Dr. Michael Zabarankin, Department of Mathematical Sciences, School of Engineering & Science

ABSTRACT

Conventional electronic computing architectures face increasing challenges in energy efficiency, scalability, and parallel information processing, motivating the search for alternative physical platforms for computation and information control. Optical systems provide a compelling route due to their stability, fast speed, intrinsic parallelism, and access to rich nonlinear and non-Hermitian dynamics. This dissertation explores how engineered optical interactions can be harnessed for optimization, neural computation, and non-Hermitian transport physics.

First, a generalized spatial photonic Ising machine is developed using second harmonic generation to introduce an effective four-body interaction term into the Ising Hamiltonian. This nonlinear extension reshapes the optimization energy landscape, enables the emergence of first-order phase transition, and produces novel multi-domain ground-state patterns induced by engineered frustrations.

Second, an optical Hopfield neural network based on optical parametric amplification is investigated. The nonlinear process realizes a generalized Hopfield Hamiltonian with a hyperbolic cosine interaction function, leading to an exponential enhancement of storage capacity relative to the conventional Hopfield model. The resulting architecture functions as a dense associative memory with significantly improved information capacity.

Third, non-Hermitian and quantum transport phenomena are studied in a three-waveguide periodically poled lithium niobate platform supporting a third-order exceptional point. When photons are injected into the coupled waveguides, spontaneous parametric down-conversion generates entangled signal-idler photon pairs

whose propagation, transmission characteristics, and entanglement behavior are analyzed in the vicinity of the exceptional points.

These results demonstrate that nonlinear and non-Hermitian optical dynamics provide versatile tools for controlling collective states, enhancing computational functionality, and engineering quantum photonic behavior. This work advances photonics as a platform for next-generation computing and information science.