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Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
School/Department:	Charles V. Schaefer, Jr. School of Engineering and Science / Physics
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Title:	Next-Generation Information Processing Architectures with Quantum and Photonics Hardware
Chairperson:	Dr. Yuping Huang, Department of Physics, School of Engineering and Sciences
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ABSTRACT

This dissertation explores how novel hardware architectures and emerging technologies can accelerate or improve the energy efficiency of certain types of computationally demanding problems. It focuses on two cutting-edge application fields: NP-hard combinatorial optimization problems and Transformers.

The first part deals with methods to find the shortest paths in large interconnected graphs and networks, a very well studied combinatorial optimization problem using the Quadratic Unconstrained Binary Optimization (QUBO) algorithm on adiabatic and analog quantum computers, and compares the resulting performance against classical counterparts.
The second presents a comparative study of the Traveling Salesman Problem (TSP) across three quantum computing paradigms: the Quantum Approximate Optimization Algorithm (QAOA), Quantum Phase Estimation (QPE) for gate based quantum computers, the Quadratic Unconstrained Binary Optimization (QUBO) on adiabatic quantum computers and photonic quantum annealers. It analyzes the overhead of each problem formulation, the scaling of run time with problem size, and the experimental constraints that limit each platform as instances grow and methods used to improve the accuracy of solutions at larger problem sizes. The third part introduces a hybrid opto-digital architecture: a recurrent attention transformer-based optical neural network (ONN) for long-text processing. By offloading the matrix operations at the core of the attention mechanism to optical hardware, the architecture reduces power consumption on the optical layer relative to conventional digital accelerators. An extension of this work is a binary classifier for which, the mapping, training and inference is implemented completely on the optical hardware.

Together, the findings in this dissertation highlight the exciting prospect of new computing horizons for the next generation of information processing platforms.