

Integrated Quantum Photonic Architectures for High-Throughput

Simulation and Optimization of Industrial Manufacturing Processes

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Abstract—The rapid advancement of Noisy Intermediate-Scale Quantum (NISQ) devices has driven the integration of quantum photonic architectures into industrial computation represents a transformative approach to addressing the growing complexity, precision demands, and energy inefficiencies of modern manufacturing systems. This research explores the development and application of integrated quantum photonic platforms for high-throughput simulation and optimization, enabling large-scale, parallelized modeling of manufacturing processes. Unlike traditional electronic-based computation, photonic architectures exploit the quantum properties of light—such as superposition, entanglement, and interference—to achieve massive computational concurrency with low latency and high energy efficiency. The study focuses on applying quantum photonics to enhance industrial process optimization, including workflow scheduling, supply chain coordination, defect detection, and material design optimization. Through simulations and conceptual modeling, the research demonstrates how photon-based qubits and integrated optical circuits can execute optimization algorithms more efficiently than classical architectures when managing large, interdependent datasets. The findings underscore the potential of quantum-enhanced photonic computing to achieve scalable, real-time decision-making in sectors such as semiconductor fabrication, automotive manufacturing, and energy systems engineering. Conducted in collaboration with academic scholars, the project provided hands-on exposure to algorithmic modeling, quantum heuristic design, and analytical evaluation, deepening the researcher’s understanding of both theoretical and applied quantum systems. Additionally, the experience cultivated transferable skills in critical thinking, interdisciplinary collaboration, and scientific communication—core competencies essential for the next generation of engineers and scientists navigating the quantum industrial era. This study ultimately highlights quantum photonics as a foundational enabler of intelligent, high-performance, and sustainable manufacturing ecosystems.

■ In an era defined by the digital transformation of manufacturing, industries are increasingly reliant on computational models to simulate, predict, and optimize every stage of production—from raw

material processing to distribution logistics [5]. Yet as manufacturing systems evolve in complexity, classical computational approaches are reaching their limits in speed, scalability, and energy efficiency. Traditional high-performance computing (HPC) and AI-driven optimization frameworks, while effective, often struggle to balance the exponential growth

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