

A Novel Optical Approach: Developing a Generic Nanophotonic Processor (GNP) for Classical and Quantum Computing Applications

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Progress within many modern scientific fields has increasingly relied on the continued advancement of computational power. However, thermodynamic and physical limits associated with electronic-based processors are hindering future progress. Photonics could provide a solution to these problems. The goal of this engineering project was to design and simulate a generic nanophotonic processor (GNP) which would outperform its digital counterpart at computing linear algebraic operations. If successful, the GNP could overcome current challenges within microelectronics. This GNP proof-of-concept design consisted of 50:50 optical beamsplitters, phase shifters, and optical attenuators interconnected and arranged into a lattice, which was controlled and optimized via a layer of algorithms based on graph theory. Using Singular Value Decomposition (SVD), the GNP demonstrated an exponential reduction in the computational complexity of performing matrix-vector and vector-on-vector operations to $O(3)$ and $O(1)$ respectively; microelectronics operate at $O(n^2.37)$. The mapping of physical optical paths for information processing was achieved by developing algorithms based on Dijkstra's algorithm, which were simulated on path distribution problems ($n=100,000$): averaging 13.3 times faster than published research. These novel routing algorithms have displayed self-healing and multi-path routing capabilities. Artificial neural networks (ANNs) require frequent memory access, where the need for localized memory (e.g., RAM) can be eliminated with the GNP, allowing for more efficient training. The first room-temperature quantum computer could be developed, in which quantum information can be encoded, propagated, and manipulated as beams of light on the GNP.

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