Project title: Linear Optical Accelerator for Machine Learning

Motivation: Machine learning techniques, particularly those utilizing artificial neural networks (ANNs), have revolutionized fields such as computer vision, natural language processing, physics, and materials science. Despite significant advancements in AI algorithms and hardware optimizations to reduce model sizes and accelerate both inference and training processes, most efforts have focused on traditional electronic systems, including CPUs, GPUs, FPGAs, and ASICs. While these systems are powerful, they consume substantial amounts of energy and are increasingly struggling to meet the demands of rapidly growing data volumes, particularly as Moore's Law approaches its physical limits.

Optical implementation of AI modules, such as all-optical neural networks (AONNs), offers a promising alternative by harnessing the inherent parallelism, high-speed computation, and potential for low energy consumption. Recent studies suggest that the energy cost of optical implementations could be 2–3 orders of magnitude lower than state-of-the-art CMOS implementations. The wave nature and superposition principle of light allow natural parallel processing, enabling matrix-vector multiplications to be performed in constant time—dramatically contrasting with the quadratic time complexity of digital electronic processors. Furthermore, AONNs can perform complex-valued arithmetic by encoding information in both the phase and magnitude of light, further capitalizing on the unmatched speed of light as an information carrier.

Project goals: The primary objective of this project is to design and implement a fully functional linear optical accelerator, which serves as a crucial building block for deep AONNs. The project will encompass both hardware and software developments. Hardware design and implementation include laser beam waveform shaping using spatial light modulators (SLMs) or digital micromirror devices (DMDs), integration of Fourier optics, and development of control electronics. The software includes developments of electro-optical drivers, machine learning training algorithms, and user interfaces.

Phase I goals: Develop a linear optical accelerator with more than 10,000 training parameters (hardware + software)
Phase II goals: Explore AI applications in machine learning.

Technical interests/keywords: Optical Neural Network, Linear Accelerator, and Machine Learning

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