Tools and Techniques for Wavelength-Multiplexed Optical Neural Networks

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The need for higher performance in optical machine learning accelerators has motivated the move from matrix-vector to matrix-matrix architectures, with wavelength multiplexing used to achieve the increased parallelism. However, most existing photonic architectures are challenging to wavelength multiplex while simultaneously maintaining high precision. In this talk, I present the theory and first experimental demonstration of a new spatial-spectral-multiplexed optical tensor accelerator based on diffractive beam routing, enabling scalable single-shot photonic matrix-matrix multiplication [1]. We have tested this approach on both fully-connected and convolutional layers, with 292,616 weight parameters under ultra-low optical energy (20 aJ) per MAC at 96.4% classification accuracy. Finally, I discuss the technologies that must be developed to scale up this architecture to useful matrix dimensions, including developments in OPO-based light sources for flat frequency comb generation at high power per comb line without amplification [2].

References

[1] C Luan, R Davis III, Z Chen, D Englund and R Hamerly, arXiv:2503.24356 (2025)

[2] R Hamerly, E Laksono, M Jankowski, E Ng, Noah Flemens, M-G Suh and H Mabuchi, Phys. Rev. A **111**, 033532 (2025)