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## Matrix Optimisation with Light-speed Multiplication

Structured light, which involves the precise manipulation of an optical fields the internal degrees of freedom, has emerged as a key tool in both quantum and classical information processing protocols. Its benefit in the realm of photonic computing lies in its ability for high-dimensional, light-speed information processing. In this work, the high dimensional nature of light is leveraged by modulating its transverse spatial degree of freedom to develop a flexible approach for learning unitary operations. Using optical vector-matrix multiplication together with methods found in variational quantum computing, we transfer the task of solving for a parametrised unitary onto that of solving the minimum ground energy of a specified cost function. The operations themselves are performed using arrays of Gaussian modes, representing the corresponding matrices and vectors being multiplied while the parameter space of the unitary operation is searched through using a guided random walk procedure. For the measurement, we take advantage of the partial Fourier transformation that is applied by a cylindrical lens and capture the resultant output vector using a CCD camera. We cover both the theoretical framework and the experimental implementation to demonstrate that we are able to learn optical unitary matrices up to 16-dimensions, achieving fidelities greater than 90% in all cases. Our work contributes to the advancement of high dimensional information processing and can be applied to both process and quantum state tomography of unknown states and channels.

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