**Why Linear Optics? Theory and Experiment**

Linear optics is powerful for quantum computing and control:
- Linear optics + detectors is universal for quantum computing.
- Sampling linear optics outputs is classically hard.
- Optical quantum walk nonclassical behaviour.

Rapid advance in experimental implementation:
- On-demand single-photon sources,
- Efficient number-resolving detectors with low dark counts,
- Tunable photonic integrated circuits to implement arbitrary linear optics protocol.

**Problem**

The current procedure for simulation of multi-photon multi-channel interferometers is suboptimal and not intuitive.

**Enter Group Theory (Two-Photon Interference)**

**Brute Force Interferometer Simulation**

- \( n \) photons in \( m \) channels:
  \[
  a_1^\dagger \to \sum_{j=1}^m U_1^j a_j^\dagger \\
  a_2^\dagger \to \sum_{j=1}^m U_2^j a_j^\dagger \\
  \vdots \\
  a_n^\dagger \to \sum_{j=1}^m U_n^j a_j^\dagger
  \]

- Not intuitive for interpreting outputs.
- Expensive. \( O(n!) \) cost of computing outputs.

**Results: Algorithms for Boson Realizations, \( \mathcal{D} \)-Functions and Interferometry**

- New graph-theoretic algorithm for computing boson realizations and \( \mathcal{D} \)-functions of SU(\( n \)) irreps for arbitrary \( n \).
- New algorithms for performing interferometry using \( \mathcal{D} \)-functions.

**Results: Faster Interferometer Simulation**

Representation theory enables us to exploit permutation symmetries inherent in bosons to effect a reduction in the computational cost of simulating interferometers.