The Resurgence of the Linear Optics Interferometer — Recent Advances & Applications

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Contents

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I. INTRODUCTION

Si-Hui can colour code things she adds like this
And Peter can do it like this
Let's add comments and questions like this

II. MATHEMATICAL BACKGROUND

Mathematical representation for LO networks, and very basic background on quantum optics
A idealized single photon in a quantum interferometer is described by its creation operator $\hat{a}_j^\dagger$, where j is the label of the mode the photon is in within the interferometer. The creation and annihilation operators satisfy the bosonic comutator relationship $[\hat{a}_j, \hat{a}_k^\dagger] = \delta_{j,k}$. A similar commutator relationship can be written up when more degrees of freedom, such as polarization, orbital angular momentum, and time-bins (Tillmann et al., 2015; Bozinovic et al., 2013; Nicolas et al., 2014; Humphreys et al., 2013; Donohue et al., 2013), are present. When multiple photons are present, they experience quantum interference when all quantum labels are the same.

The action of a $2d$-port linear optical interferometer (with an equal number of input and output ports) is expressed as an application of unitary operations on the creation operators,

$$b_i^\dagger = \sum_{j=1}^{d} U_{ij} a_j^\dagger \ , \tag{1}$$

where $a_j^\dagger$ and $b_i^\dagger$ are the creation operators of a single input and output photon in the j-th and i-th modes respectively, and $U \in SU(d)$. All such transformation can be expressed as sequence of beamsplitters and waveplates (Reck et al., 1994). In the case when photons have additional labels, for instance, if they have internal labels on top of spatial labels, it is also possible to derive an analogous decomposition, known as a cosine-sine decomposition (Dhand and Goyal, 2015), that realizes the unitary transformation on the photons into a sequence of beamsplitters and internal transformations. Toolkits using group theory are being developed to deal with partial distinguishabilities among interfering photons (Tan et al., 2013; de Guise et al., 2014, 2016). Others use quantum-to-classical transitions to explain multiparticle interference (Ra et al., 2013).

III. OPTICAL ENCODING OF QUANTUM INFORMATION

A. Single-photons

1. Polarisation

2. Dual-rail

3. Time-bins

B. Continuous-variables

1. Coherent states

2. Squeezed states

IV. EFFICIENT CIRCUIT DECOMPOSITIONS OF LINEAR OPTICS NETWORKS

Discuss the Reck et al. decomposition The task of implementing an arbitrary quantum computation on linear optics comes down to implementing an arbitrary $n \times n$ unitary matrix. If a non-unitary transformation is desired, it can be embedded within a unitary matrix with larger dimensions. An algorithm for expressing an arbitrary unitary matrix in terms of beamsplitters and phase-shifters, or equivalently Mach-Zedner interferometers, exists (Reck et al., 1994; Englert et al., 2001) and has been widely used **(find examples)**. Later, it has been shown that any nontrivial beam splitter is universal for linear optics (Bouland and Aaronson, 2014).

V. EXPERIMENTAL IMPLEMENTATION

A. State preparation

1. Single-photons

2. Bell pairs

3. Coherent states

4. Squeezed states

B. Linear optics networks

1. Bulk-optics

2. Waveguides

3. Time-bins

Discuss fibre-loop architecture

C. Measurement

1. Photodetection

Discuss number-resolved and bucket detectors, multiplexed detection, APDs, current micropillar detectors

2. Homodyning

VI. APPLICATIONS FOR LINEAR OPTICS INTERFEROMETRY

A. Linear optics quantum computation

B. Boson-sampling

C. Quantum metrology

Discuss NOON states - Heisenberg limited
Discuss MORDOR scheme

D. Encrypted quantum computation

VII. STATE OF THE ART

Discuss where experiments are at at the moment

VIII. CONCLUSION

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