A Boson Sampling Chip for Graph Perfect Matching

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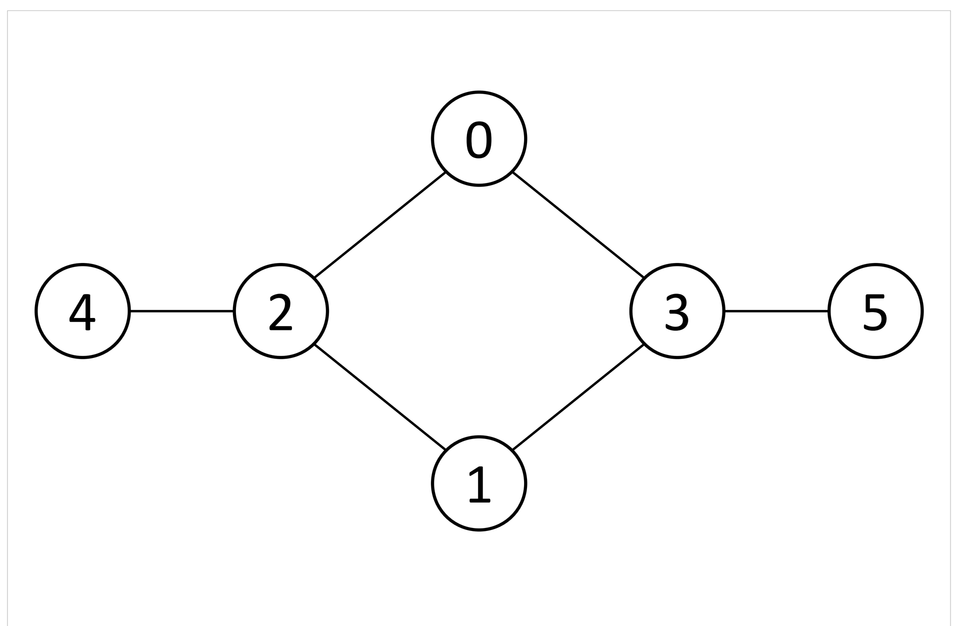
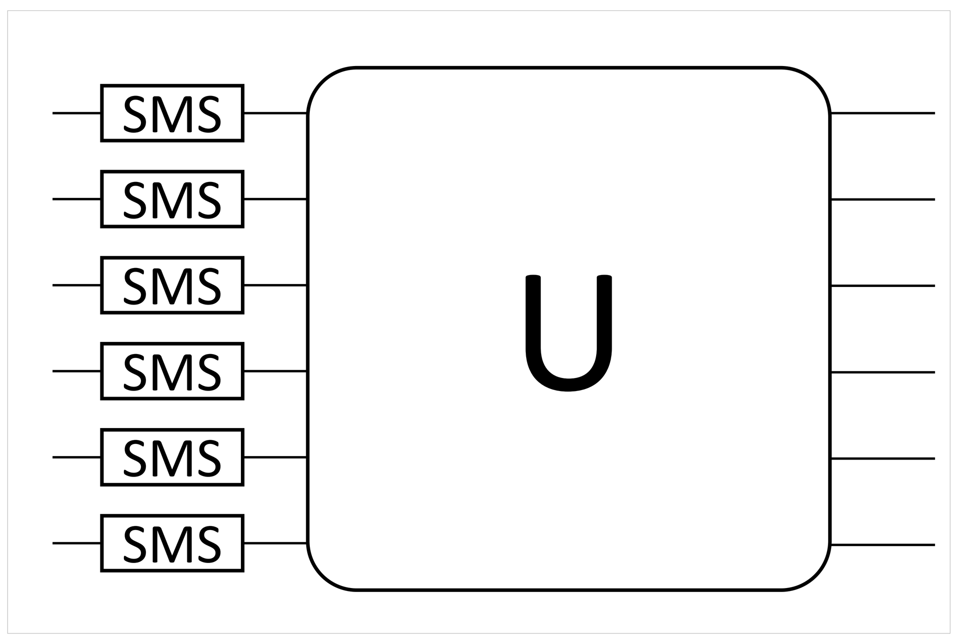
INTRODUCTION AND OBJECTIVES

The computation of the number of perfect matching for a graph is difficult to solve as it requires to calculate the hafnian of the matrix, which belongs to #-P hard problem. However, the Gaussian Boson Sampling (GBS) provides an experimentally feasible way to implement the computation power of quantum mechanics relying solely on photon source, linear optical circuit and detectors. The connection of perfect matching and Gaussian Boson Sampling is built on that the number of perfect matchings of an undirected graph equals to the hafnian of the graph's adjacency matrix, while the gaussian boson sampling can efficiently sample the output distribution based on the hafnian, using quantum computation. Here, we demonstrate a Gaussian Boson Sampling chip with 6 modes to realize the counting of perfect matchings that contains 4 nodes out of a 6-node undirected graph.

THEORETICAL MODEL



$$M_{adj} = \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}$$

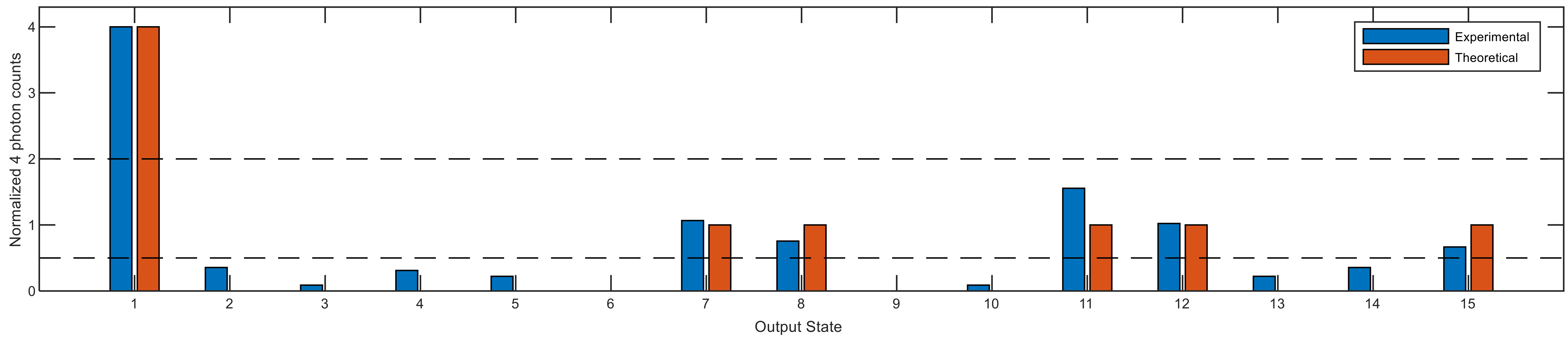


A typical n-node undirect graph is contains some nodes and their connection is represented by edges. By labeling each nodes from 0 to $n-1$, a graph can be converted to an adjacent matrix M_{adj} with each elements $a_{i,j}$ being 1 if there is an edge connecting node i and j, otherwise, the element is defined as 0. By taking the Takagi-Autonne decomposition as

$$cM_{adj} = U \cdot diag(c\lambda_1, \cdots, c\lambda_n) \cdot U^{\dagger}, \tanh r = c\lambda$$

where c is the free parameter, the squeeze parameter r and unitary matrix U for GBS model is settled. The photon distribution probability can e directly sampled from this model and further map to the perfect matching numbers of the target graph.

TESTING RESULTS



The blue bars in measured results are the normalized experimental 4-photon coincidence counts for all 15 combinations from {0,1,2,3} to {2,3,4,5}. The red bars are the corresponding theoretical results. The similarity of distribution is defined as $F = |\vec{D}_{exp} \cdot \vec{D}_{the}|/|\vec{D}_{exp}| \cdot |\vec{D}_{the}| = 0.9783$. The two dashed horizontal lines $y = 0.5$ and $y = 2$ are to separate the data into three groups of {0,1,4}, which maps to the perfect matching numbers of {0,1,2}.

CONCLUSIONS

In conclusion, we use a boson sampling chip to simulate the perfect matching numbers with different connections of graphs. A quantum photonic chip is designed, fabricated and demonstrated with functions as tunable squeeze parameters and reconfigurable linear optical circuits. The graph parameter is mapped to the GBS model and the perfect matching numbers of the sub-graphs are simulated with an accuracy of 100% and a distribution similarity of 0.98.