
Supplementary information

Quantum circuits with many photons on a programmable nanophotonic chip

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Supplemental Information

for

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Quantum circuits with many photons

on a programmable nanophotonic chip

Strawberry Fields code

```
>>> import strawberryfields as sf
>>> from strawberryfields import RemoteEngine, ops
>>> from strawberryfields.utils import random_interferometer

>>> U = random_interferometer(4)
>>> prog = sf.Program(8)
>>> with prog.context as q:
...     # Two-mode squeezing gates on all pairs of modes
...     ops.S2gate(1.0) | (q[0], q[4])
...     ops.S2gate(1.0) | (q[1], q[5])
...     ops.S2gate(1.0) | (q[2], q[6])
...     ops.S2gate(1.0) | (q[3], q[7])
...     # Interferometer on the signal modes (0-3)
...     ops.Interferometer(U) | q[0:4]
...     # Interferometer on the idler modes (4-7)
...     ops.Interferometer(U) | q[4:8]
...     # Fock basis measurement
...     ops.MeasureFock() | q

>>> # Run the program on the remote engine with 400k samples
>>> eng = RemoteEngine('X8_01')
>>> results = eng.run(prog, shots=400000)
>>> samples = results.samples
```

Model parameters

Mode	0	1	2	3	4	5	6	7
Transmissivity η	0.154(2)	0.120(2)	0.173(2)	0.139(2)	0.152(2)	0.128(2)	0.197(2)	0.170(2)
Noise $\bar{n}$	0.0205(1)	0.0091(1)	0.0131(1)	0.0193(1)	0.0223(1)	0.0175(1)	0.0158(1)	0.0187(1)

Table 1: **Transmissivity and background noise parameters.** These are used to construct the theoretical model of the device. The noise values denote the mean photon numbers measured when all squeezers are off.

Modes	(0, 4)	(1, 5)	(2, 6)	(3, 7)
Squeezing (r_1)	1.162(6)	1.101(7)	1.050(5)	1.005(6)
Squeezing (r_2)	0.345(9)	0.367(9)	0.393(7)	0.336(9)

Table 2: **Two-mode squeezing parameters.** These are used to construct the theoretical model of the device. The parameter r_1 denotes the squeezing level of the main Schmidt mode, while r_2 is the parameter for the second Schmidt mode.

Gaussian Boson Sampling unitaries

$$\begin{aligned}
U_1 &= \begin{pmatrix} -0.3250 - 0.4190i & -0.3362 - 0.1772i & -0.3803 + 0.1376i & 0.3149 + 0.5582i \\ -0.6316 - 0.03660i & 0.4966 - 0.4024i & -0.2632 - 0.0127i & -0.1553 - 0.31230i \\ -0.1518 + 0.0883i & -0.5153 + 0.0818i & -0.3063 - 0.7007i & -0.0142 - 0.3346i \\ 0.3766 - 0.3819i & -0.2557 - 0.3306i & -0.1885 + 0.3830i & 0.0749 - 0.5915i \end{pmatrix} \\
U_2 &= \begin{pmatrix} -0.1621 + 0.2429i & 0.4073 + 0.6121i & 0.4713 - 0.2842i & 0.0488 + 0.2626i \\ 0.3262 + 0.4577i & -0.4901 - 0.1377i & 0.2527 - 0.0627i & 0.5493 + 0.2355i \\ -0.4460 + 0.1968i & -0.3531 - 0.1724i & 0.1236 - 0.6339i & -0.2267 - 0.3734i \\ -0.5004 - 0.3330i & -0.1408 + 0.1615i & -0.4257 - 0.1757i & 0.5296 + 0.3166i \end{pmatrix} \\
U_3 &= \begin{pmatrix} 0.2109 + 0.4077i & 0.0582 - 0.6129i & -0.0306 - 0.0996i & 0.1638 + 0.6103i \\ -0.6817 + 0.5319i & -0.2335 + 0.1715i & -0.0690 - 0.0395i & 0.4004 - 0.0425i \\ 0.0795 + 0.1160i & -0.3216 + 0.25723i & 0.7731 + 0.3231i & -0.1189 + 0.3074i \\ -0.1254 - 0.0784i & 0.4136 - 0.4431i & 0.4785 + 0.2279i & 0.3809 - 0.4299i \end{pmatrix}
\end{aligned}$$

Vibronic spectra parameters

Ethylene:

$$\Omega = \text{diag}(54.58, 39.75, 35.86, 31.26), \quad (1)$$

$$\Omega' = \text{diag}(53.18, 37.39, 35.03, 29.24). \quad (2)$$

$$U_D = \begin{pmatrix} 0.79893782 & -0.14677806 & 0.01138051 & 0.58311666 \\ 0.08883764 & -0.86299347 & -0.37056306 & -0.33171246 \\ -0.1025589 & 0.29536634 & -0.92088379 & 0.23283781 \\ -0.58590776 & -0.38269726 & 0.12052614 & 0.70407979 \end{pmatrix} \quad (3)$$

(E)-phenylvinylacetylene:

$$\Omega = \text{diag}(6.56, 9.38, 15.43, 19.95), \quad (4)$$

$$\Omega' = \text{diag}(8.19, 11.27, 14.18, 18.68). \quad (5)$$

$$U_D = \begin{pmatrix} -0.53491056 & 0.83826709 & 0.10356058 & -0.02131166 \\ -0.67951341 & -0.49990836 & 0.53698308 & 0.00152286 \\ -0.42950848 & -0.17320834 & -0.70628009 & 0.53543419 \\ 0.26010513 & 0.13190447 & 0.44954733 & 0.84430665 \end{pmatrix} \quad (6)$$

Graph similarity

The following are the adjacency matrices of the bipartite graphs used in the algorithm.

$$\begin{aligned}
A_1 &= \begin{pmatrix} 0 & 0 & 0 & 0 & 0.0826 & 0.1231 & 0.0789 & -0.1969 \\ 0 & 0 & 0 & 0 & 0.1231 & 0.1834 & 0.1176 & -0.2935 \\ 0 & 0 & 0 & 0 & 0.0789 & 0.1176 & 0.0754 & -0.1882 \\ 0 & 0 & 0 & 0 & -0.1969 & -0.2935 & -0.1882 & 0.4697 \\ 0.0826 & 0.1231 & 0.0789 & -0.1969 & 0 & 0 & 0 & 0 \\ 0.1231 & 0.1834 & 0.1176 & -0.2935 & 0 & 0 & 0 & 0 \\ 0.0789 & 0.1176 & 0.0754 & -0.1882 & 0 & 0 & 0 & 0 \\ -0.1969 & -0.2935 & -0.1882 & 0.4697 & 0 & 0 & 0 & 0 \end{pmatrix} \\
A_2 &= \begin{pmatrix} 0 & 0 & 0 & 0 & 0.4574 & 0.0915 & 0.3864 & 0.0637 \\ 0 & 0 & 0 & 0 & 0.0915 & 0.1861 & 0.0917 & -0.3155 \\ 0 & 0 & 0 & 0 & 0.3864 & 0.0917 & 0.3277 & 0.0256 \\ 0 & 0 & 0 & 0 & 0.0637 & -0.3155 & 0.0257 & 0.6509 \\ 0.4574 & 0.0915 & 0.3864 & 0.0637 & 0 & 0 & 0 & 0 \\ 0.0915 & 0.1861 & 0.0917 & -0.3155 & 0 & 0 & 0 & 0 \\ 0.3864 & 0.0917 & 0.3277 & 0.0257 & 0 & 0 & 0 & 0 \\ 0.0637 & -0.3155 & 0.0257 & 0.6509 & 0 & 0 & 0 & 0 \end{pmatrix} \\
A_3 &= \begin{pmatrix} 0 & 0 & 0 & 0 & 0.7925 & 0.1076 & -0.0125 & 0.0545 \\ 0 & 0 & 0 & 0 & 0.1076 & 0.1869 & 0.0725 & -0.3160 \\ 0 & 0 & 0 & 0 & -0.0125 & 0.0725 & 0.8026 & 0.0367 \\ 0 & 0 & 0 & 0 & 0.0545 & -0.3160 & 0.0367 & 0.6511 \\ 0.7925 & 0.1076 & -0.0125 & 0.0545 & 0 & 0 & 0 & 0 \\ 0.1076 & 0.1869 & 0.0725 & -0.3160 & 0 & 0 & 0 & 0 \\ -0.0125 & 0.0725 & 0.8026 & 0.0367 & 0 & 0 & 0 & 0 \\ 0.0545 & -0.3160 & 0.0367 & 0.6511 & 0 & 0 & 0 & 0 \end{pmatrix} \\
A_4 &= \begin{pmatrix} 0 & 0 & 0 & 0 & 0.8110 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.8110 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.8110 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8110 \\ 0.8110 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.8110 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.8110 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.8110 & 0 & 0 & 0 & 0 \end{pmatrix}
\end{aligned}$$