Single Qubit Quantum Ring Oscillator and Applications for Storage and True Random Number Generation

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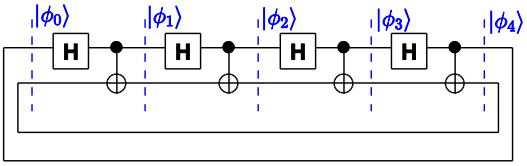
Introduction

- Bell State Oscillator
  - Loop of 4 Bell State Generators (Hadamard cascaded with C-NOT Gate)
- Generation and Maintenance of EPR Pairs
- Timing and Synchronization
- Qubit Storage
- TRNG possible with CNOT and H-Gate cascades
- Free Space Optic and QPIC Realizations

Architecture



Quantum Circuit of Bell State Oscillator

- Output state, $|\phi_4\rangle$, becomes input state $|\phi_0\rangle$.
- Dashed lines denote quantum state evolutions, $|\phi_0\rangle$, $|\phi_1\rangle$, $|\phi_2\rangle$, $|\phi_3\rangle$, $|\phi_4\rangle$.
- When $|\phi_0\rangle=|00\rangle$, then $|\phi_4\rangle=|01\rangle$, a basis state.
- When $|\phi_0\rangle=|01\rangle$, then $|\phi_4\rangle=|00\rangle$, a basis state.
- Subsequent quantum states $|\phi_0\rangle$, or $|\phi_4\rangle$, oscillate between $|00\rangle$ and $|01\rangle$.

Analysis

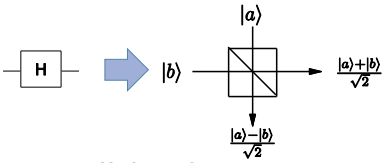
Transfer Matrix for each Bell State Generator:

$$B = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix} \left(\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \otimes \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right) = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & -1 \\ 1 & 0 & -1 & 0 \end{bmatrix}.$$

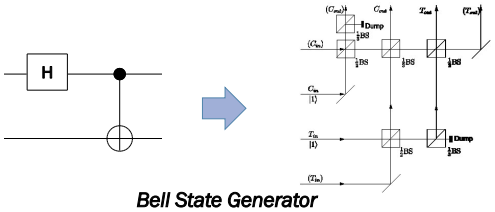
Overall (open loop) Transfer Matrix (Permutation Matrix):

$$B^4 = \left(\frac{1}{\sqrt{2}} \right)^4 \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & -1 \\ 1 & 0 & -1 & 0 \end{bmatrix}^4 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}.$$

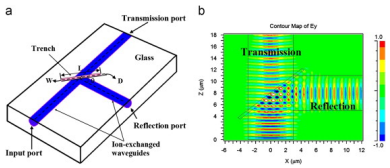
Photonic Implementation



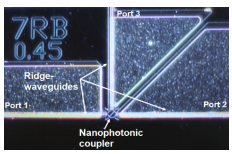
Hadamard



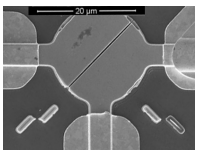
Bell State Generator



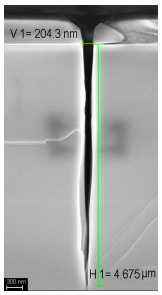
Nanophotonic trench coupler theory



Optical micrograph of photonic integrated circuit with waveguides and integrated nanophotonic coupler

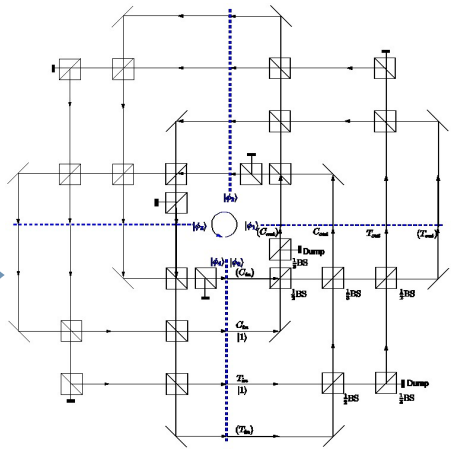


SEM of fabricated, integrated nanophotonic coupler



Cross-section of etched nanoscale trench that comprises the integrated nanophotonic coupler

Inject/Eject with 2x2 Electro-optic switch



Bell State Oscillator

A Hadamard gate may be realized in integrated photonics using a nanophotonic coupler