Photonic Quantum State Engineering in Silicon Nanophotonics: design, analysis, and optimization of scalable circuits for quantum information processing

INFORMATION INSTITUTE®

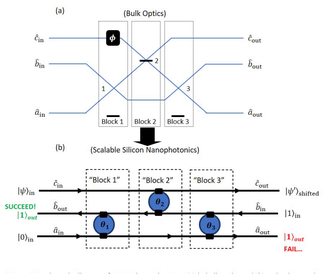
CAD

AIR FORCE RESEARCH LABORATORY

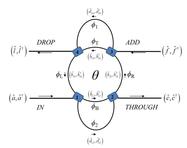
INFORMATION INSTITUTE MISSION: Strengthen and expand information technology research, develop collaborative relationships, and increase research emphasis in areas of information technologies for the Information Directorate.

BACKGROUND:

- Integrated nanophotonics allow for easy fabrication of scalable linear optical devices
- Our work is intended to find quantum advantages through careful analysis and design



- We collaborate closely with experimental and engineering teams in trying to realize practical quantum systems



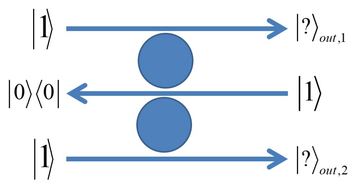
METHODS:

- We model simple linear optical systems in an inherently scalable architecture using the methods of theoretical quantum optics
- We propose, design, and optimize photonic circuit elements for deployment in devices or gates for quantum information processing
- We use isometric (state-reductive) techniques associated with measurement-induced nonlinearities to generate quantum states needed for the function of these devices or gates

RESULTS:

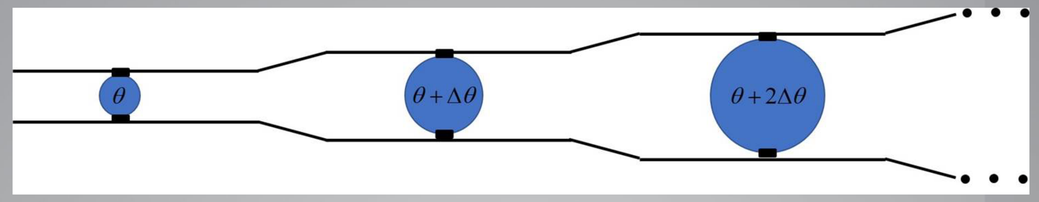
Calculations imply probabilistic output of 3-photon NOON state $|3\rangle_{out,1}\otimes|0\rangle_{out,2}+|0\rangle_{out,1}\otimes|3\rangle_{out,2}$

$P_{success}$=1/6

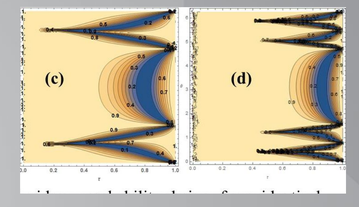


We emphasize two major recent results.

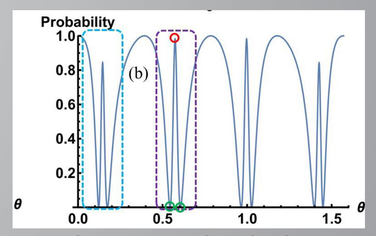
1)We have predicted further enhanced Hong-Ou-Mandel Manifolds (HOMM) from linear chains on non-identical, double-bus Micro-Ring Resonators (db-MRRs)



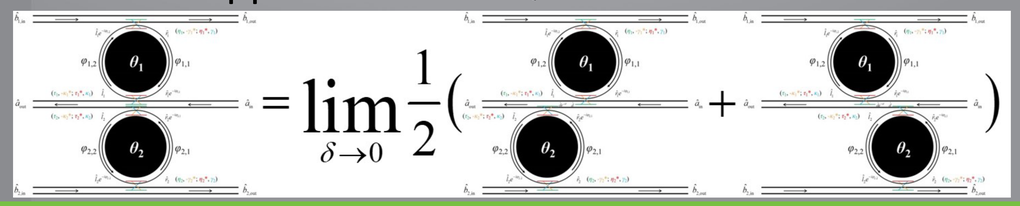
The resulting HOMM are found extend into the parameter regime where the HOM effect is not observable from a single db-MRR (or beam splitter), creating a sort of higher-order diffraction pattern for the HOM effect.



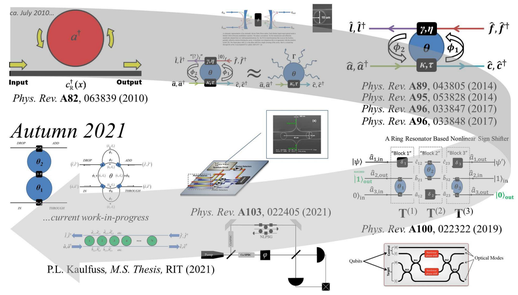
This, in turn, implies the possibility of designing a dynamically controllable, high visibility "switch" for path entangling two photons.

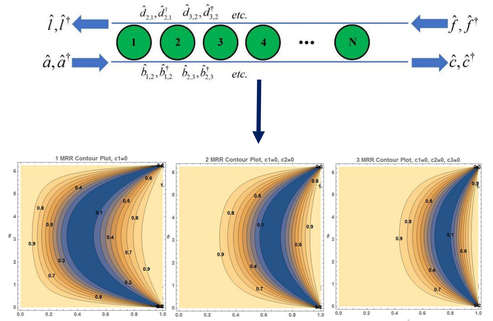


2) Motivated by the encouraging result regarding the probabilistic generation of the 3-photon NOON state, we are developing an operational model for the 3-in, 3-out unitary couplers that occur generally in all planar MRR-based quantum photonic networks. By resolving the 3x3 couplers in terms of effective 2x2 couplers, we hope to generate operable scripts by which facilities such as AIM Photonics can reliably fabricate scalable circuits for producing highly nonclassical photon states, including but not limited to "High" (N>2) NOON States for applications in Quantum Information Processing (QIP)

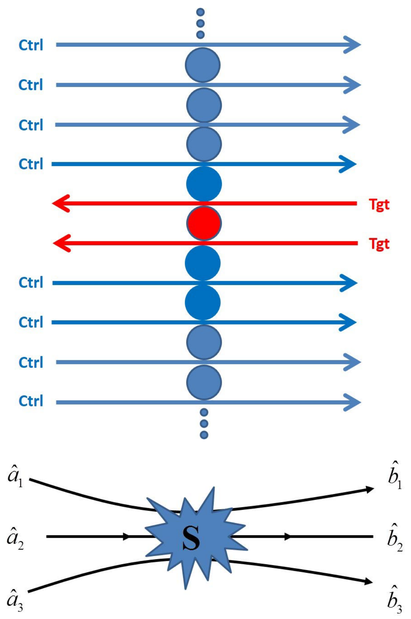


Approved for Public Release; Distribution Unlimited: AFRL-2023-3651





Published in Phys Rev Research, May 2023



Peter L. Kaulfuss, A. Matthew Smith, Paul M. Alsing, EEHIII

Edwin E. Hach, III

Associate Professor of Physics

Rochester Institute of Technology