Photonic Computing

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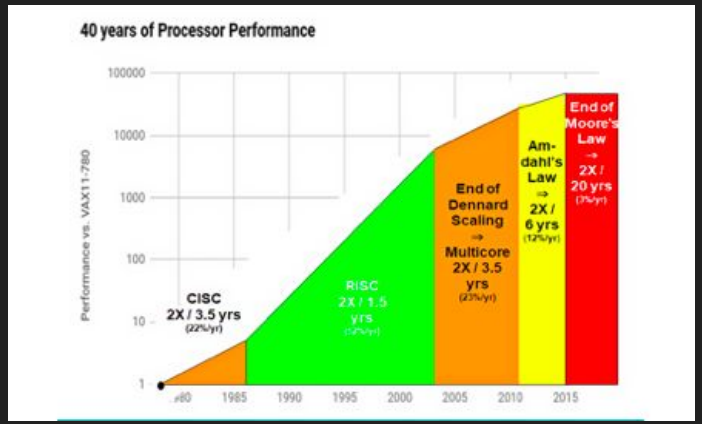
CSC 411 – Final Presentation

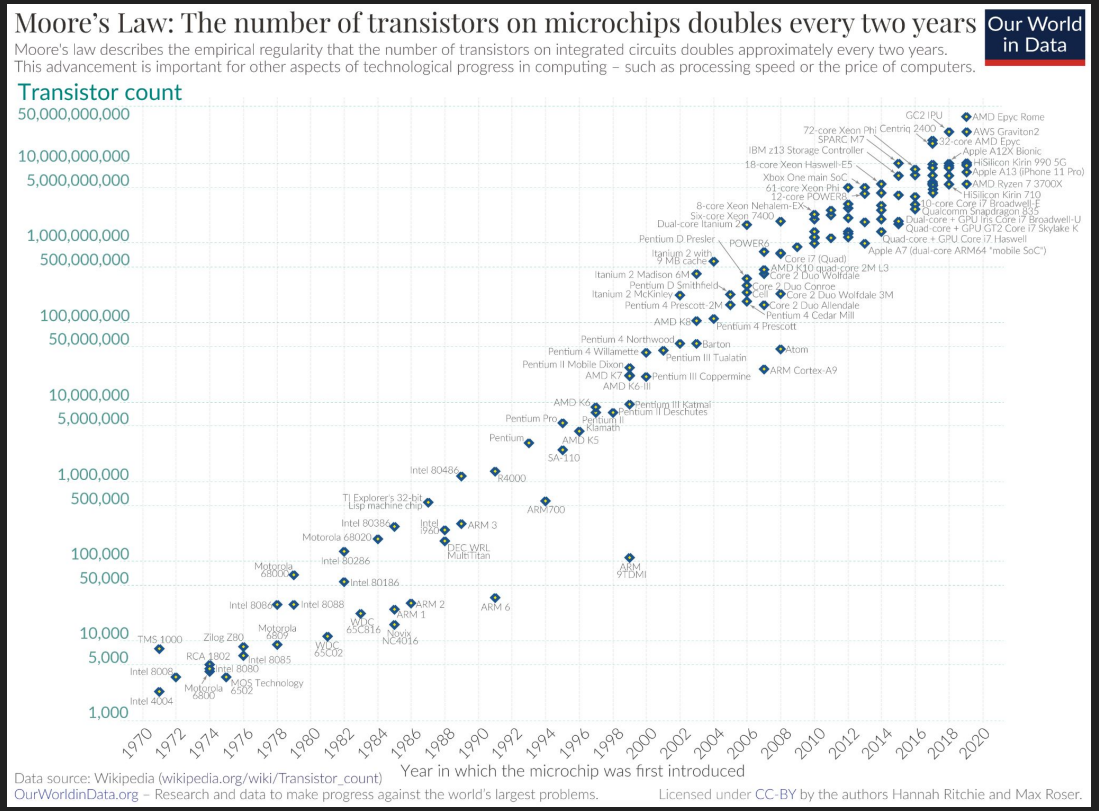
Introduction & Basics

What is photonic computing?

- Computing with light
- Implement Boolean Logic with a faster medium
- Light travels faster than electricity
  - Photons travel at speed of light in vacuum
- Photons having no mass means far fewer interactions that can scatter or absorb the particles in a vacuum.

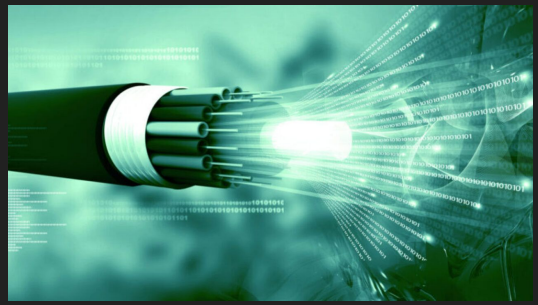
Moore's Law – Why Optical Computing is Important

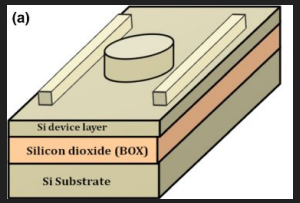




What we need for all-optical computing

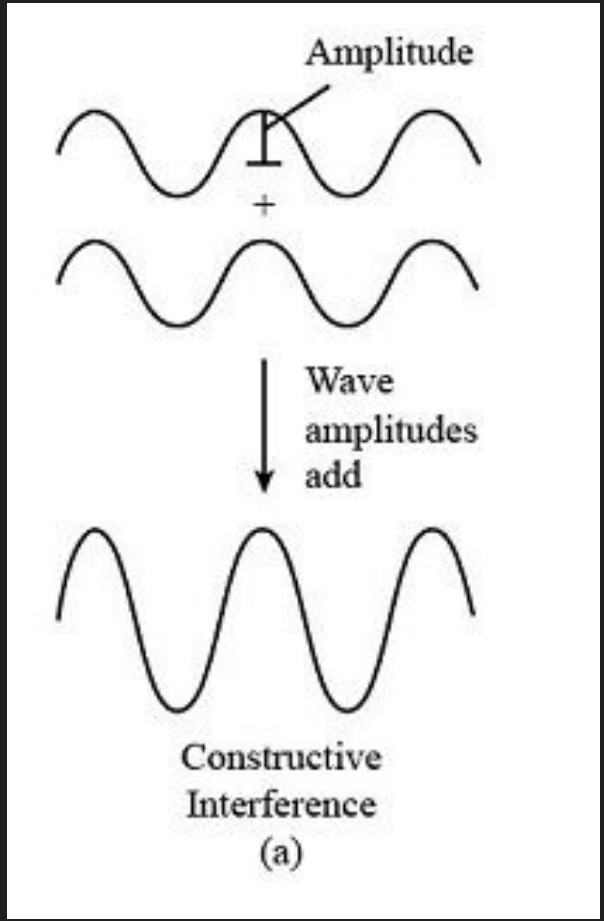
- Components
  - Optical Data Transfer (Fiber optic internet)
  - Optical Storage (CD & DVD)
  - Optical Transistors (!)





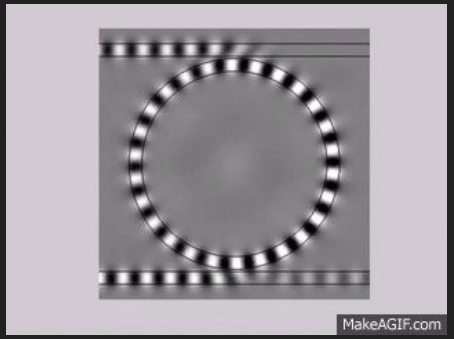
- Mixed systems (electric and optical) are not efficient
  - Reduced speeds due to conversions from one medium to another

Optical transistors may rely on wave interference

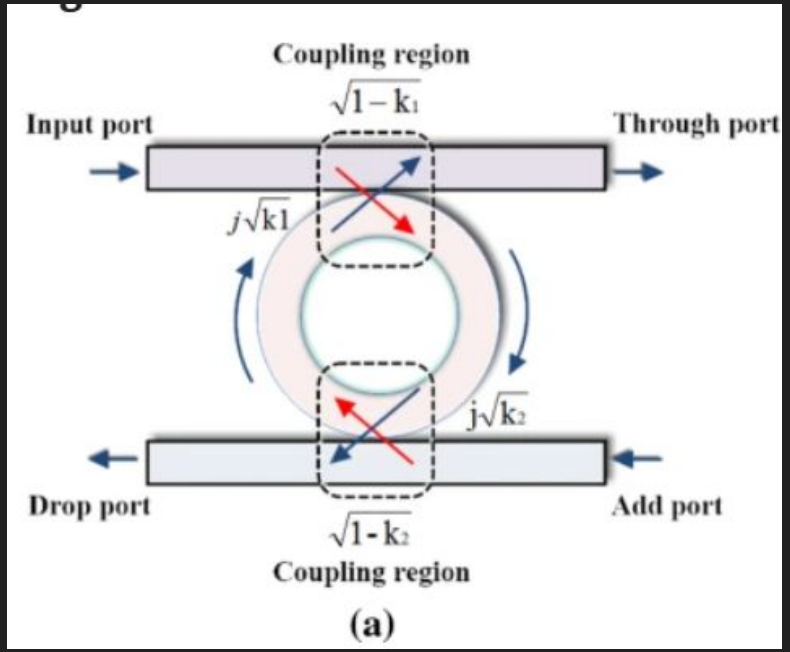


Implementations

Example – Microring Resonator



- Two components: wave guide and microring.
- If the resonant wavelength of input and microring are the same, then input wave gets taken up into ring.



Our Implementation of Resonant Ring Logic Gates

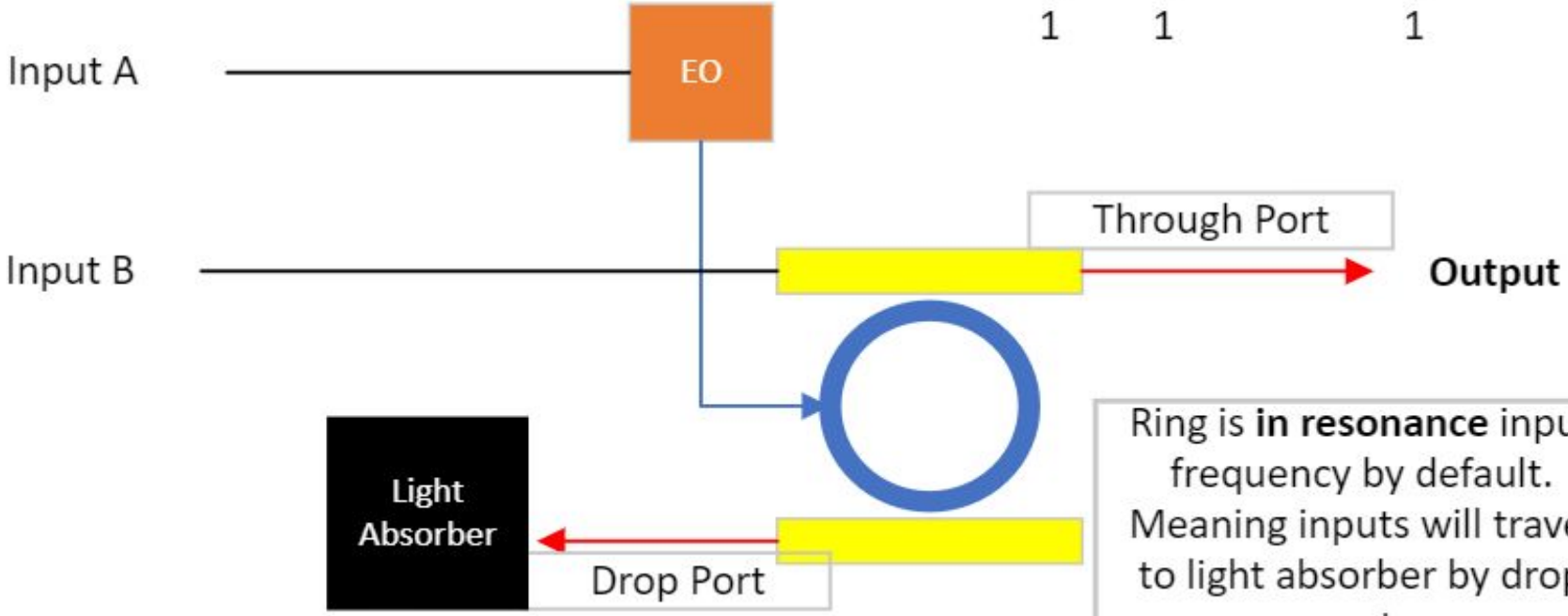
- Photons are not a solution to the problem of trying to create a functional machine. They are the tool.
- As per our theme, we are **not** bending boolean computation to adhere to photons, we are bending photons to adhere to boolean computation.
- Let’s check out a way that can be done.

AND

Electro-Optic Device.
Uses electro-optic effect to alter refractive index of micro ring.

Truth Table

A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

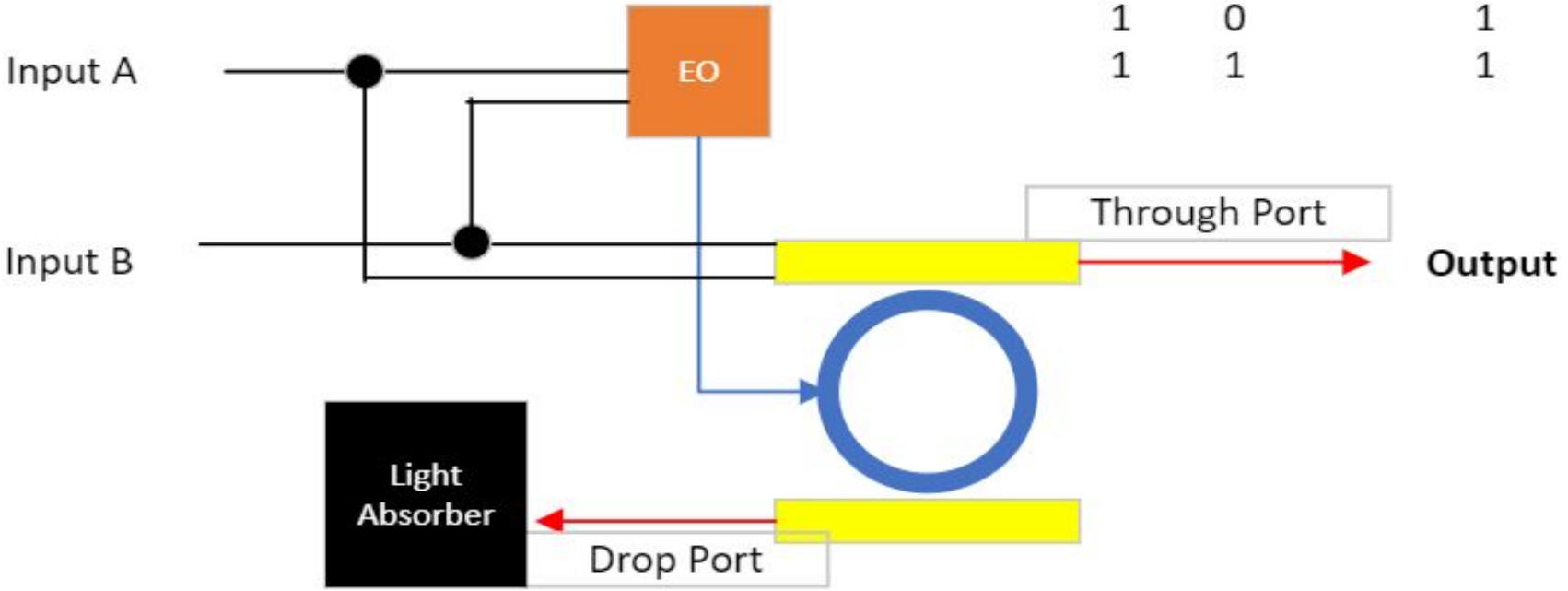


Ring is **in resonance** input frequency by default. Meaning inputs will travel to light absorber by drop port.

OR

Truth Table

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

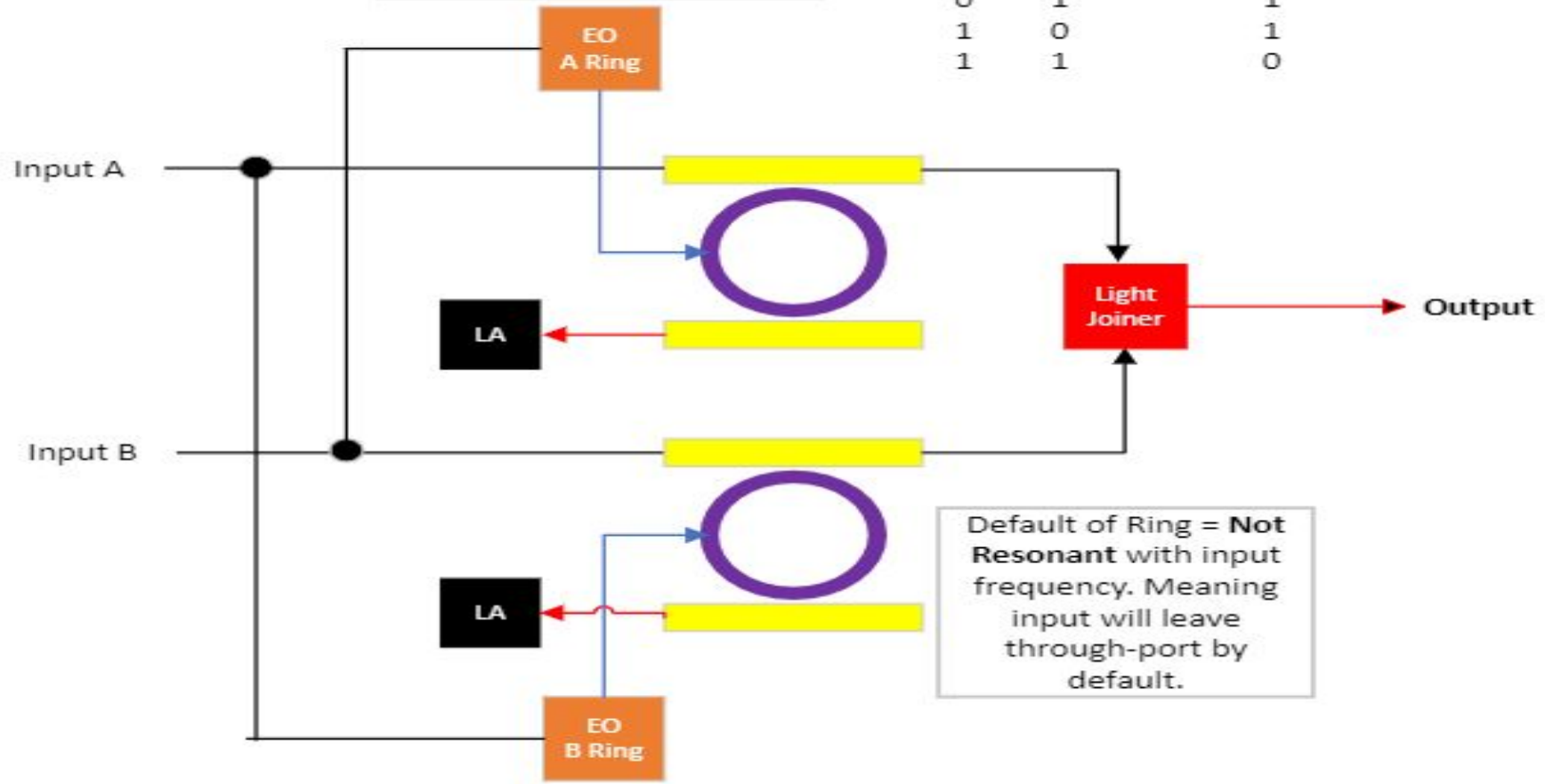


XOR

If B = 1, EO turns ring **resonant** with input A, sending it to the light absorber.

Truth Table

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0



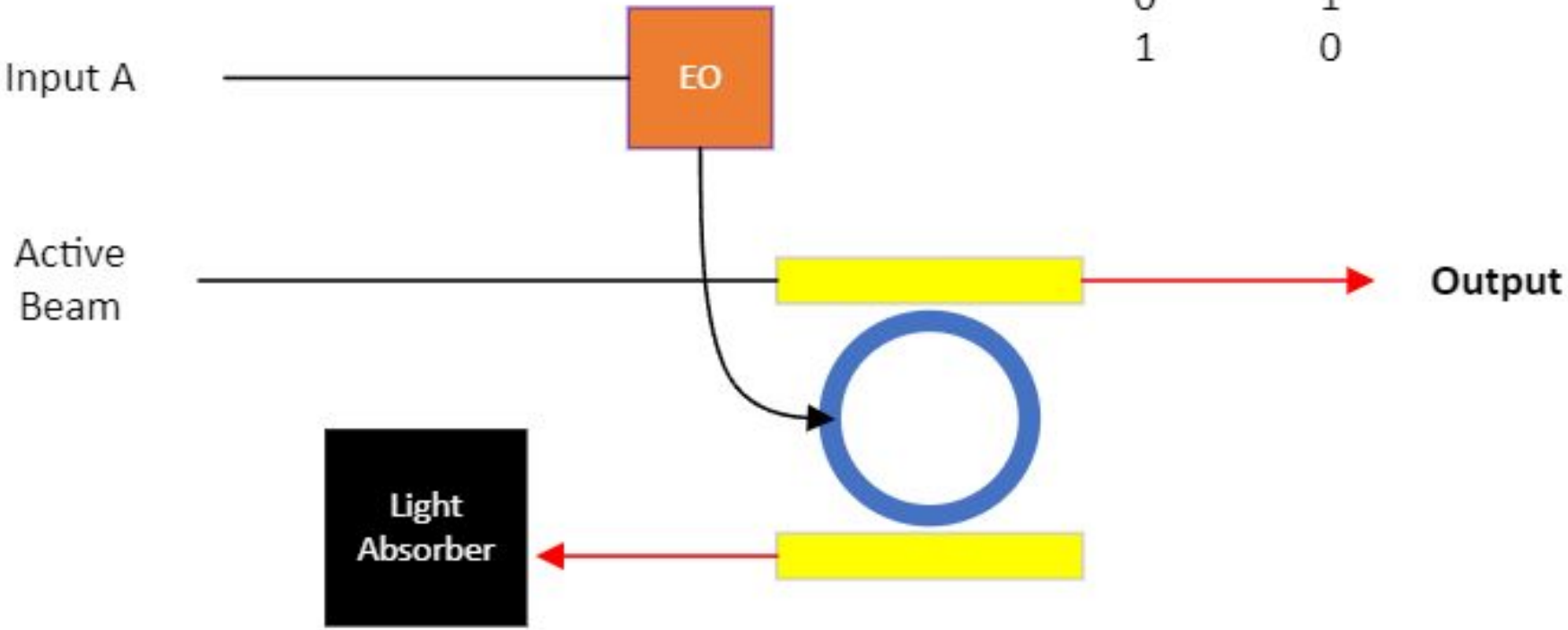
Default of Ring = **Not Resonant** with input frequency. Meaning input will leave through-port by default.

NOT

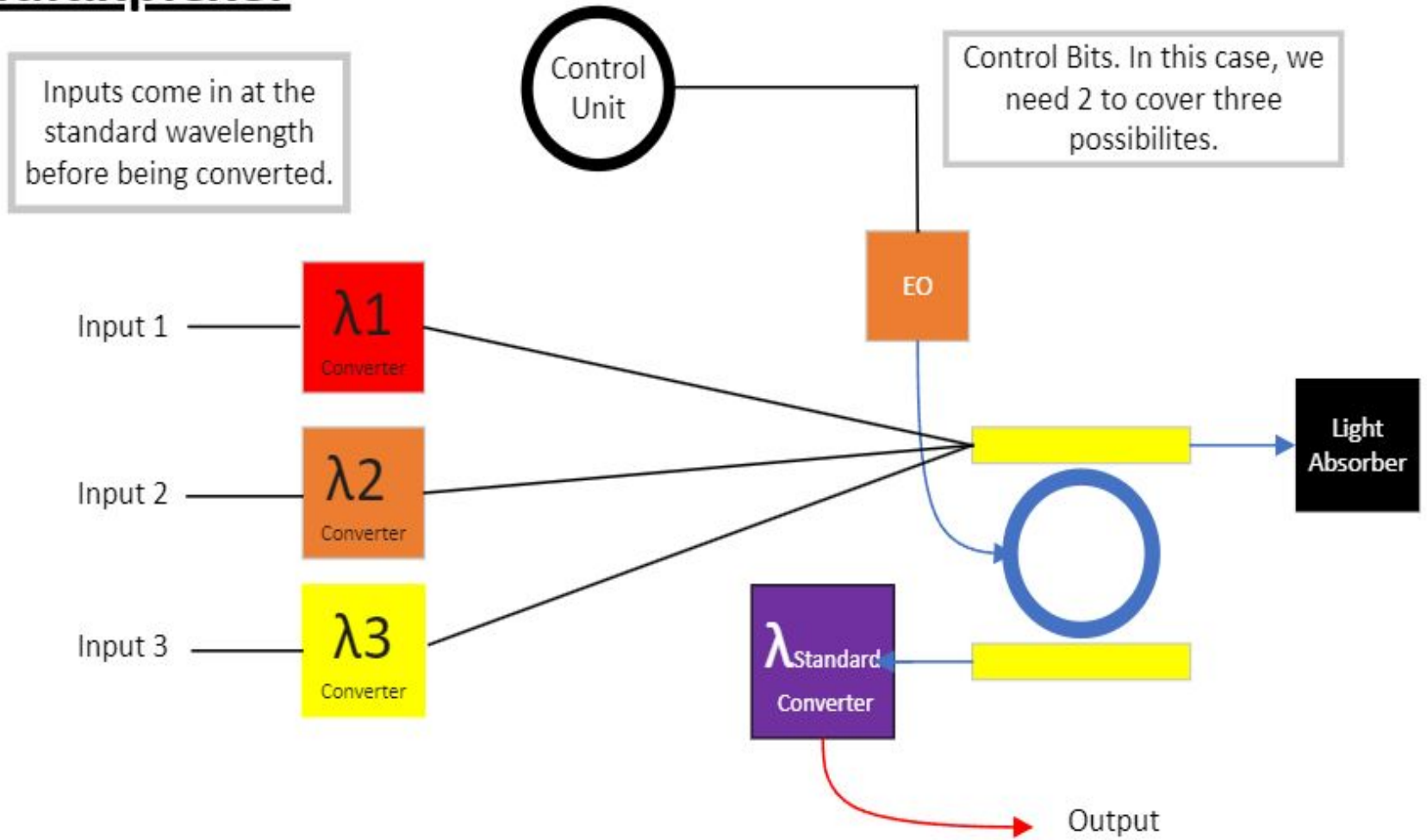
If EO recieves low photons(logic 0), ring becomes **non resonant.**

Truth Table

A	Output
0	1
1	0



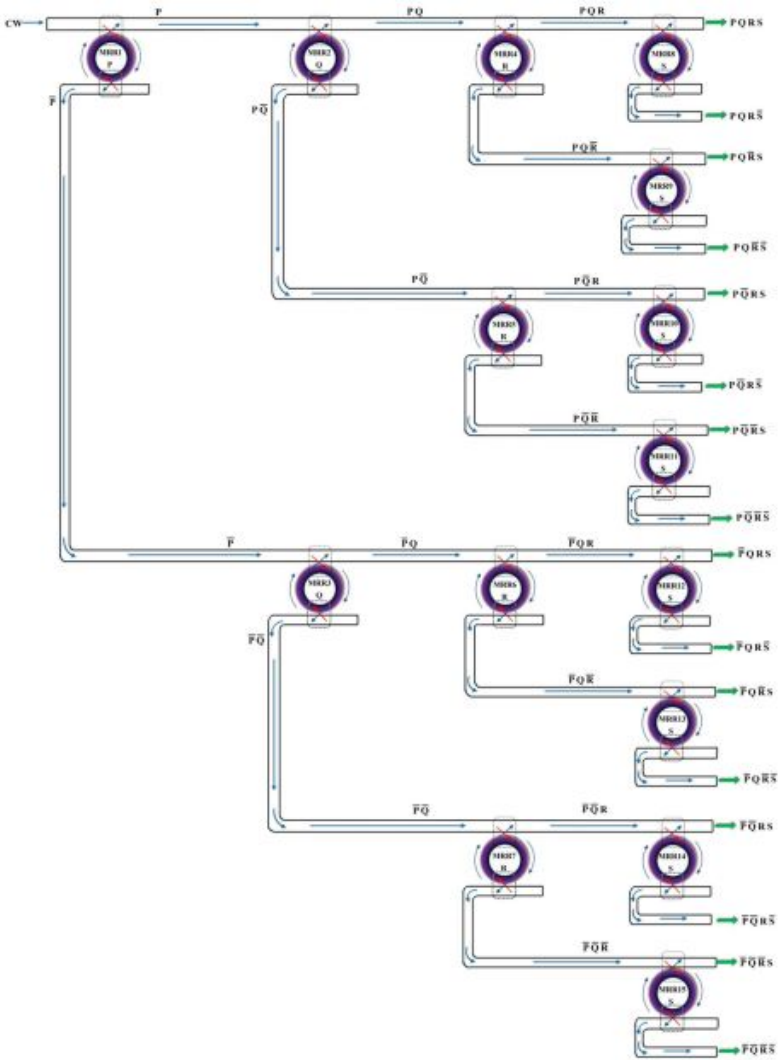
Multixplexer

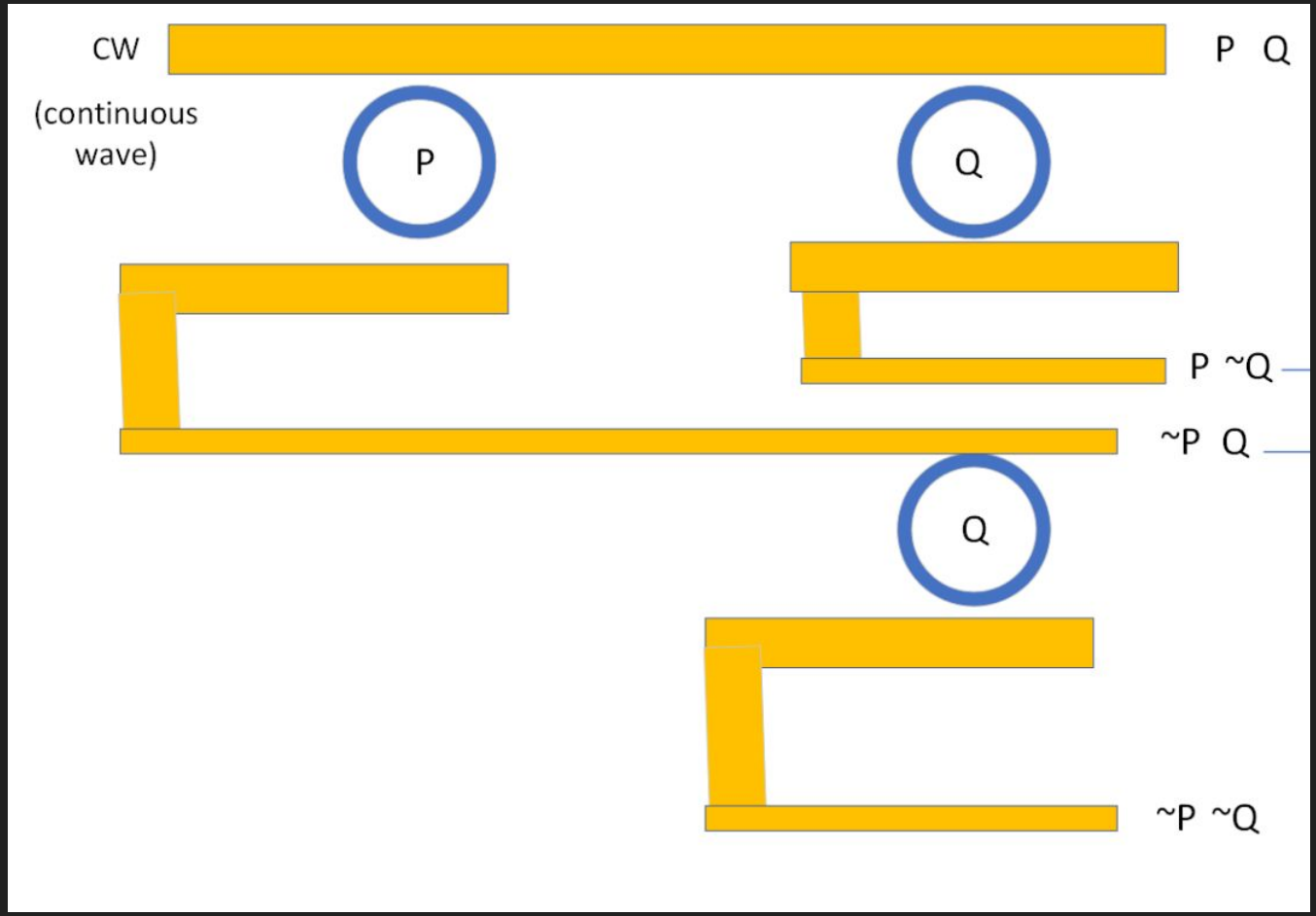


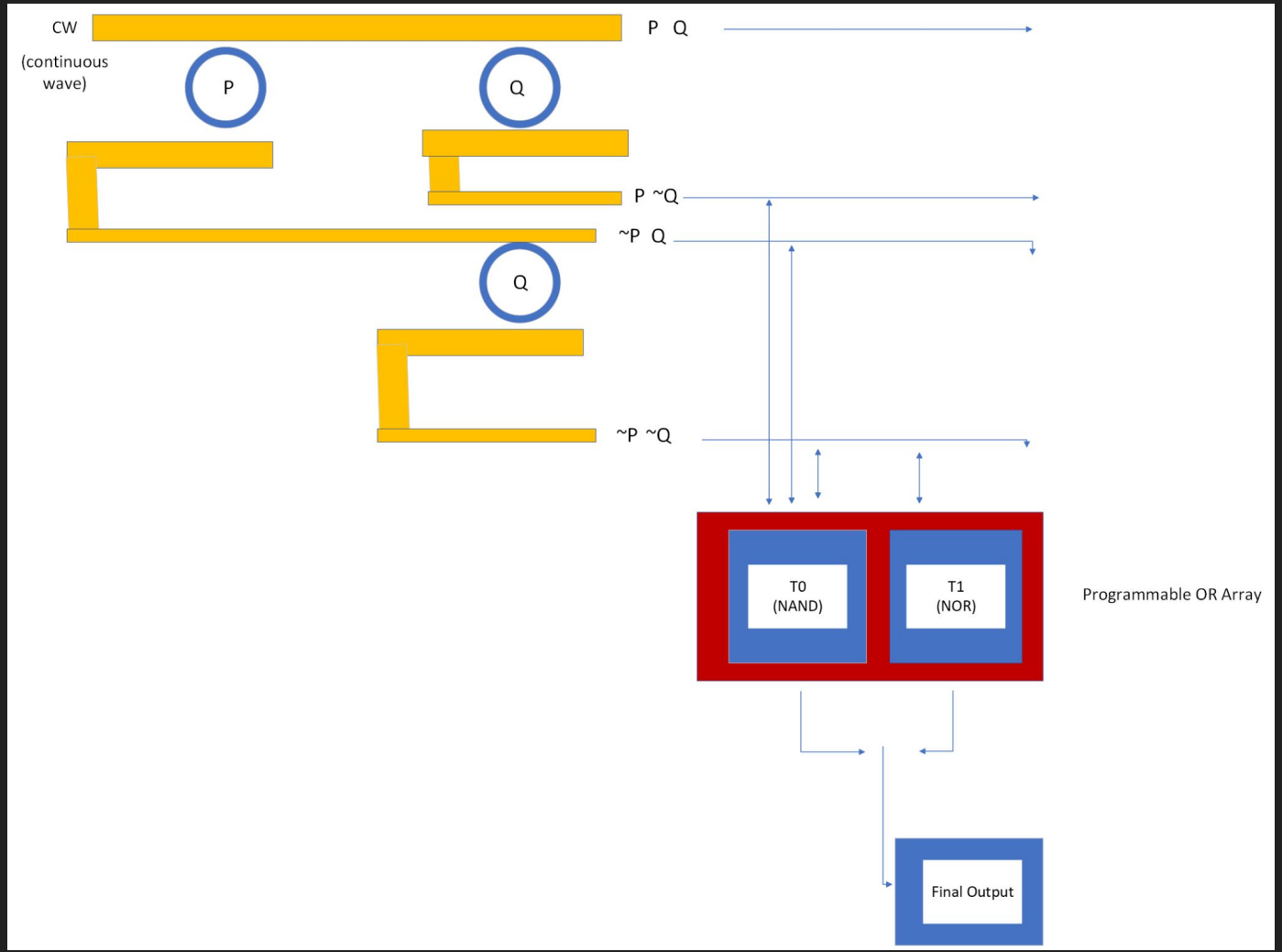
“Modeling of silicon microring resonator-based programmable logic device for various arithmetic and logic operation in Z-domain.”

Kundu, Sumanta, et al. Jan. 2023,

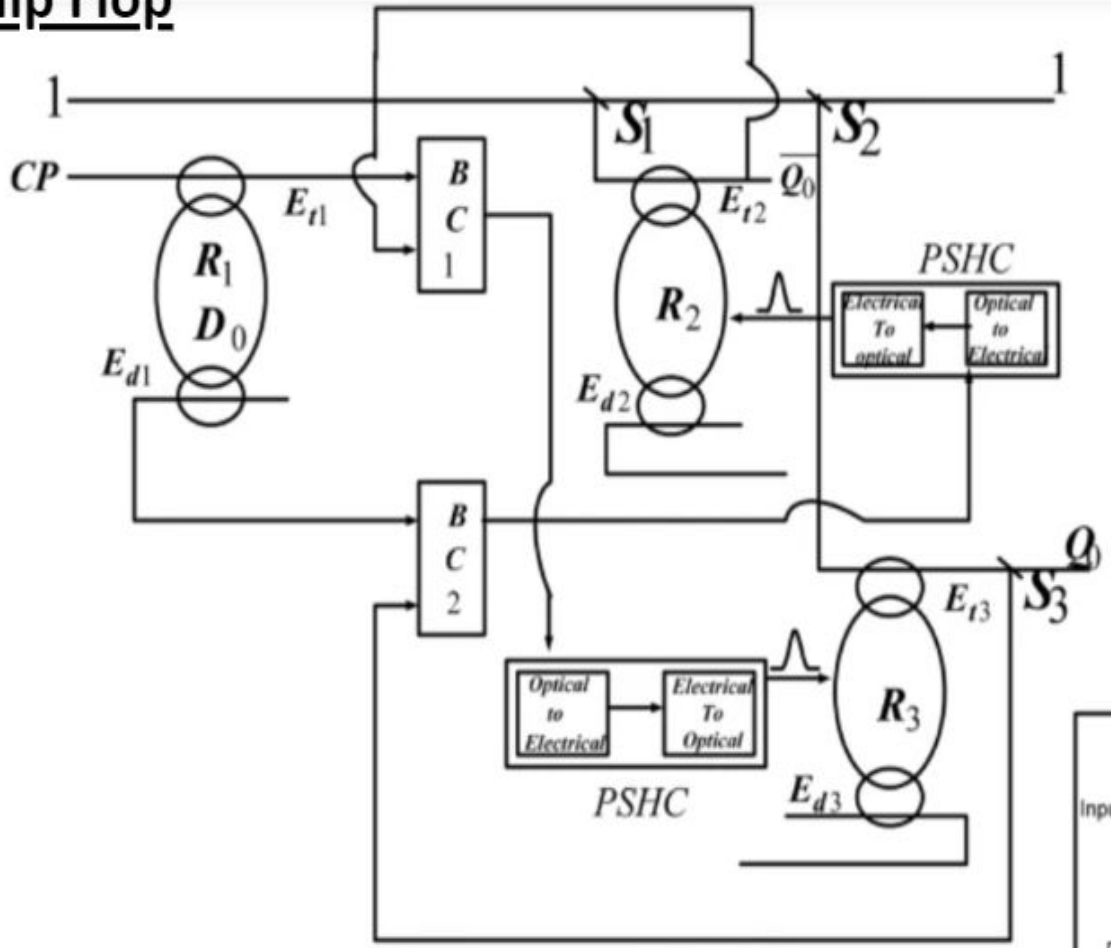
“In the present paper, for the first time to our knowledge, we have implemented an all-optical PLD using OMRRs only that can perform all-optical arithmetic and logical operations. The silicon OMRR based all optical switch has been utilized for our design due to its… ultra-fast switching, compact size, improved bandwidth, less power consumption and ease in fabrication, etc. in contrast to other techniques… and it has enormous predominance over other all optical switches. Theoretical analysis of an efficient and unique approach to design optical arithmetic logic unit (OALU) using PLD has been done in the present communication.”



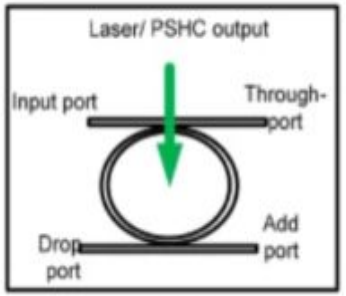

CW
(continuous wave)
P
Q
P Q
P ~Q
~P Q
Q
~P ~Q


CW
(continuous wave)
P
Q
P Q
P ~Q
~P Q
Q
~P ~Q
T0 (NAND)
T1 (NOR)
Programmable OR Array
Final Output

D-Flip Flop



(a)



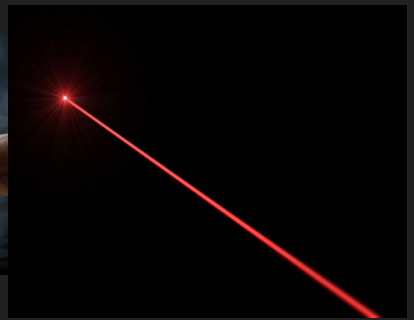
Truth Table

CP	D(input)	Q(output)
0	0	Q
0	1	Q
1	0	0
1	1	1

Conclusion

Future & Challenges

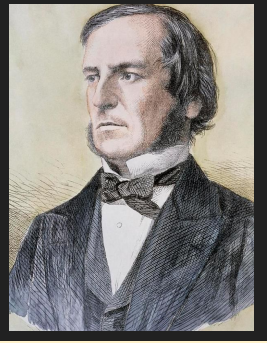
- Size of parts
- Cost
- Industry



Closing Statements

- Computation exists only in our minds. We impose our mental axioms of computation onto this world, and can build different mediums to mimic these laws of thought (!!) at different speeds, which in this case, is the speed of light.

- We are using the speed constants the Universe has already provided us to optimize how we compute.



!! - George Boole first outlined his logic within his book entitled *The Laws of Thought*

Thank You!

Sources

Optical computing status and perspectives [source]

“Modeling of silicon microring…” Kundu, et. al (2023) [source]

Design of ring resonator based all optical switch for logic and arithmetic operations [source]

Numerical analysis of silicon microring [source]

Roadmap on all-optical processing [source]

New approach to design d-flip-fop (not silicon) [source]

While we did not provide sources for exactly what we said, everything said can be backed up by content from these articles – all of which are from academic journals and are published papers.