Photonic Integrated Circuits (PCC) - Substrate Integrated Waveguide

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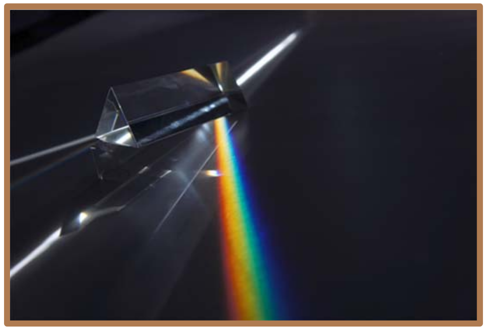
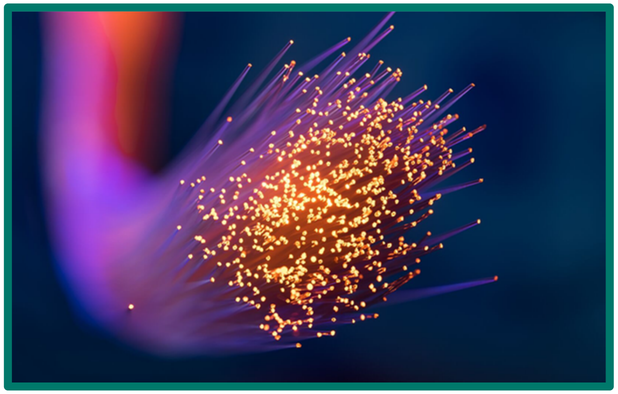
Advisor: Dr. Eric Seabron

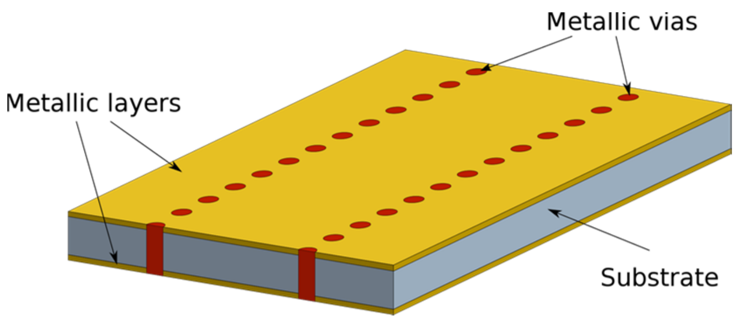
Background: What is a Photonic Integrated Circuit (PIC)?



- Photonic integrated circuits are just like any other integrated circuit
- **<u>Electron</u>**ic vs. **<u>Photon</u>**ic
- Provide benefits over standard electronics
- Photonics are the future of modern devices



Background: What is a Substrate Integrated Waveguide (SIW)?



- Functions like a wire, transmits signal from one end to the next
- Uses resonators and vias to couple and manipulate waves
- Important in photonics, light moves like a wave

Background: Dissatisfied Conditions & Situations

Photonics provide more speed and degrees of freedom than mod

electronics however…

- Photonics are difficult to manufacture
- Size & Material Cost
- Need for testing and functional verification

Background: Customer Needs

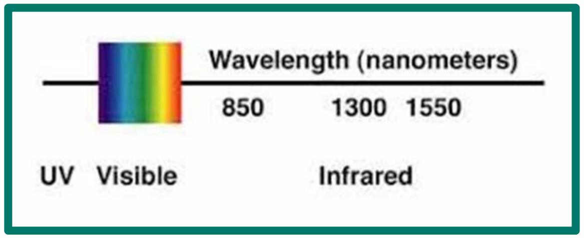
- Who is this for?
- What is the need?
- Why us over the rest?

Problem Statement

- Resonators in SIWs/PICs
  - constitute one of the largest components
  - limited in available ports due to multiplexing
- Design approach:
  - Creating unconventional resonator shapes
  - Utilize different hyperbolic materials
  - Create multiport SIW
- Design goals:
  - Make resonators significantly smaller
  - Increasing the number of ports for the waveguide
  - Overall reduce the circuit footprint
  - Requires less power to operate

Design Requirements

- Must be able to simulate through COMSOL
- Power consumption of 1V or 10mA
- Transmit signals around 1550nm
- No issues with continuous 24+ hour use
- Less than 2.5 x 2.5 mm



Standard & Regulation Requirements

“The IEEE Photonics Society has formed an IEEE Photonics Standards Committee, the scope of which is to cover standards in, but not limited to the following areas of interest: lasers, **optical devices,** optical fibers, and associated lightwave technology and their applications in systems and subsystems, in which the quantum electronic devices are key elements.”

IEEE Photonics Society

IEEE SA STANDARDS ASSOCIATION

Standard & Regulation Requirements (cont.)

Current Projects/Meetings & Volunteer Leaders

Upcoming IEEE Photonics Standards Meetings: 6 November 2023

Note: Access to the Project Authorization Requests (PARs) linked below requires a free IEEE Web Account.

- **P2066 – Safety Specification of Laser Transmission in High-Power Industrial Laser System**
  Working Group Chair: Jiaming Gao
- **P2999 – Guide for Technical Requirements and Test Methods for Industrial Ultrashort Pulse Lasers**
  Working Group Chair: Dapeng Yan
  Note: This is an entity standard and you need to be a corporate member to participate in the working group.
- **P3101– Standard for Fiber Optic Distributed Acoustic Sensing (DAS) Interrogator Standard – Terminology and Definitions**
  Working Group Chair: David Krohn

Laser Devices Used for Remote Removal of Foreign Matter in Public Infrastructure Equipment

- **P3111 – Guide for Test and Inspection of Laser Devices Used for Remote Removal of Foreign Matter in Public Infrastructure Equipment**
  Working Group Chair: Qiong Chen

Photonics EPDA Standards

- **P3112 – Standard for Electronic Photonic Design Automation – Open Data Formats – Terminology and Definitions**
  Working Group Chair: Sylwester Latkowski

Photonics Port Simulation

- **P3186 – Photonics Port Simulation**
  Working Group Chair: Gilles S C Lamant

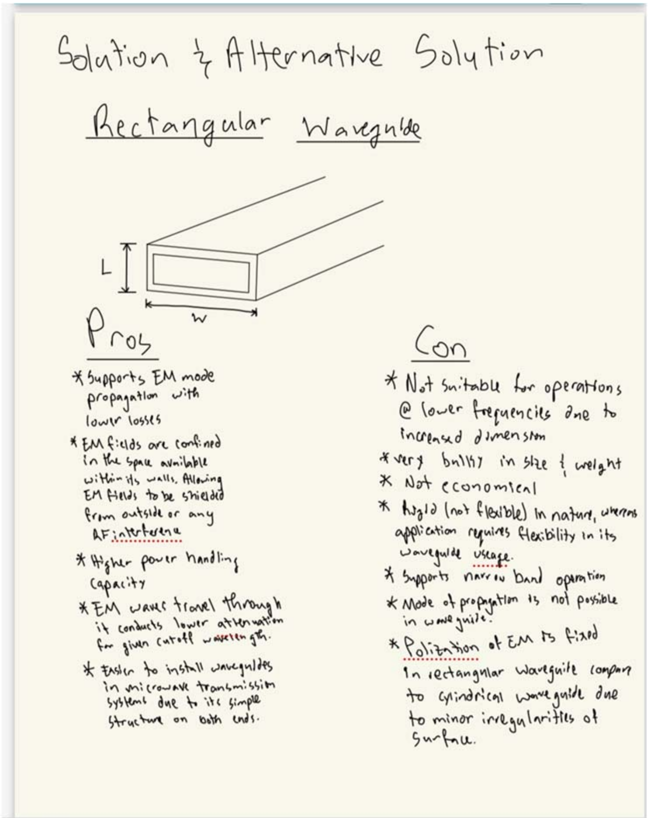
General Requirement for Industrial UV Detection Equipment

- **P3324 – Blue-green Laser Communication System for Industrial Underwater Operations**
  Working Group Chair: Zheng Xinlong
- **P3325 – General Requirement for Industrial UV Detection Equipment**
  Working Group Chair: Yanming Chen

Socio, Cultural & Environmental Constraints

- Unknown fabrication effect
- Material not yet chosen
- Limited environmental availability
- Unethical methods to obtain
- Willingness of the public to switch

Original Solution Designs



Solution & Alternative Solution

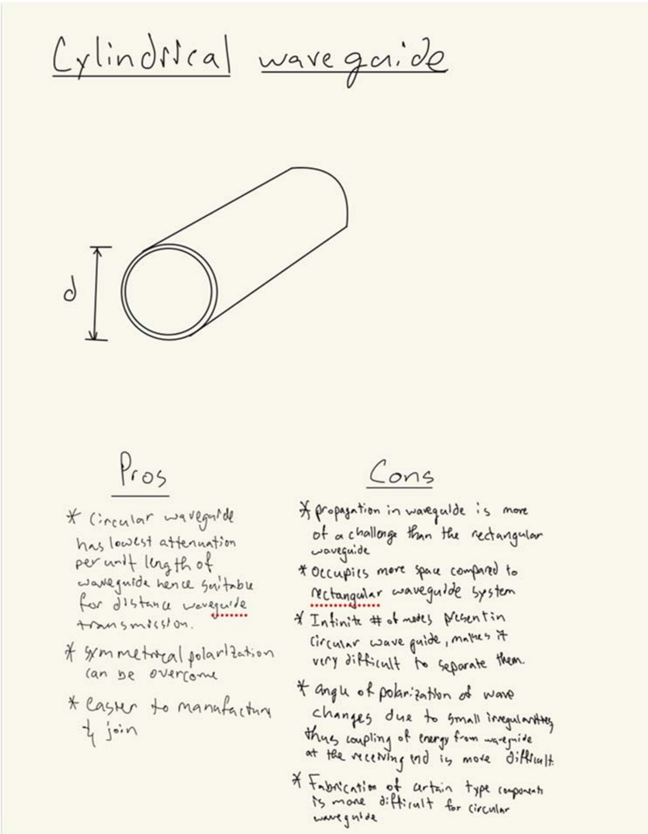
Rectangular Waveguide

Pros

* Supports EM mode propagation with lower losses
* EM fields are confined in the space available within its walls. Allowing EM fields to be shielded from outside or any RF interference
* Higher power handling capacity
* EM waves travel through it conducts lower attenuation for given cutoff wavelength.
* Easier to install waveguides in microwave transmission systems due to its simple structure on both ends.

Con

* Not suitable for operations @ lower frequencies due to increased dimension
* very bulky in size & weight
* Not economical
* Rigid (not flexible) in nature, whereas application requires flexibility in its waveguide usage.
* Supports narrow band operation
* Mode of propagation is not possible in waveguide.
* Polization of EM is fixed In rectangular waveguide compare to cylindrical waveguide due to minor irregularities of surface.



Cylindrical waveguide

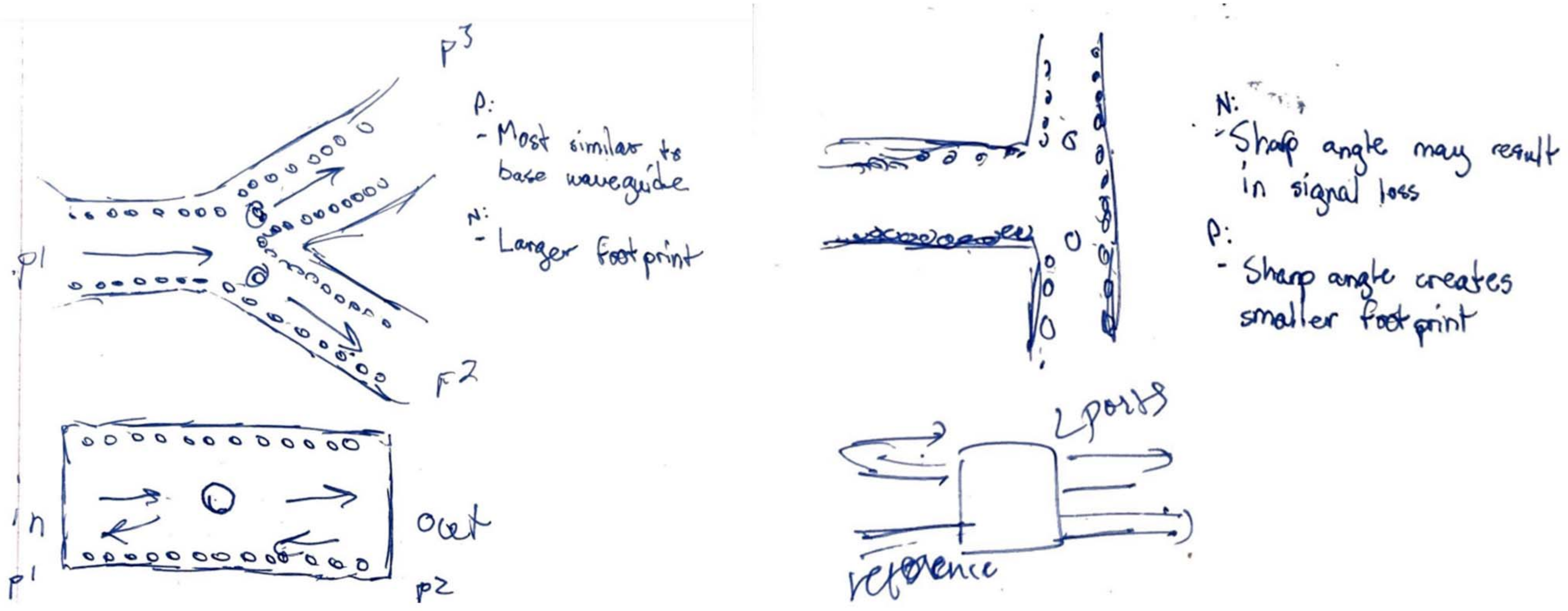
Pros

* Circular waveguide has lowest attenuation per unit length of waveguide hence suitable for distance waveguide transmission.
* symmetrical polarization can be overcome
* easier to manufacture & join

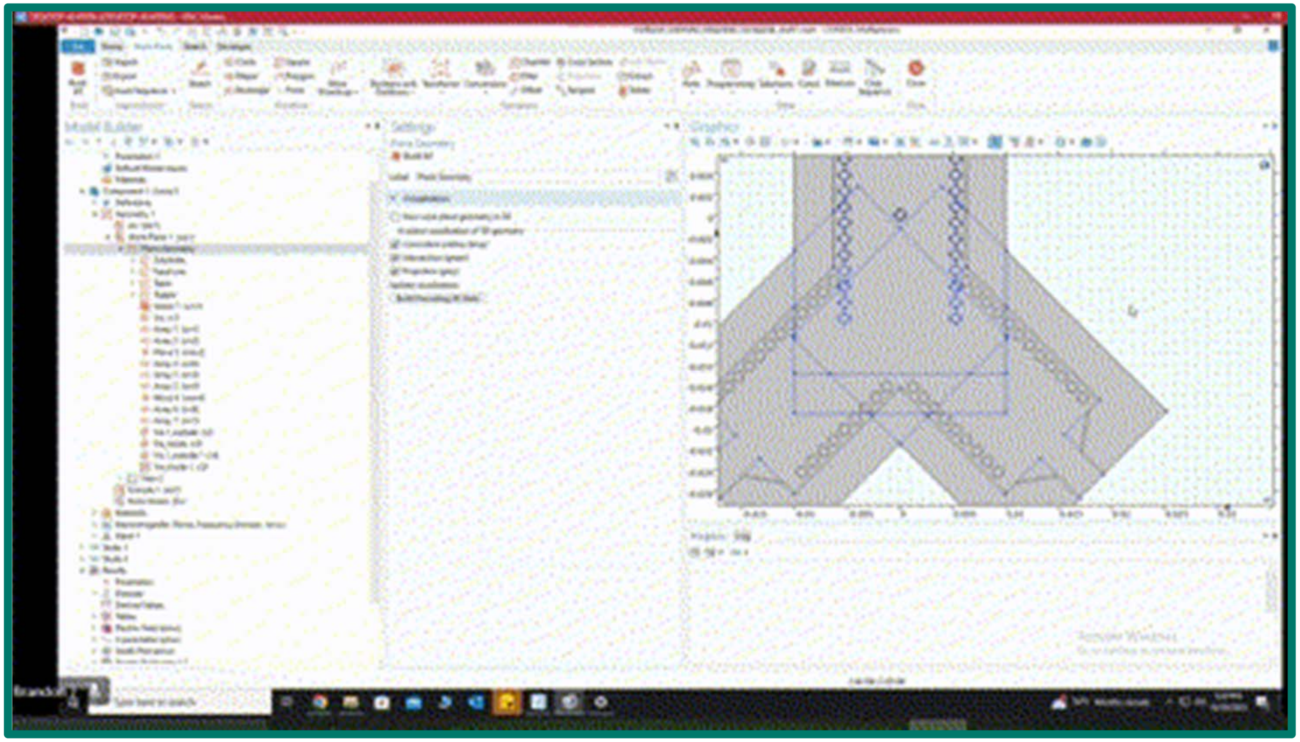
Cons

* propagation in waveguide is more of a challenge than the rectangular waveguide
* Occupies more space compared to rectangular waveguide system
* Infinite # of modes present in circular wave guide, makes it very difficult to separate them.
* angle of polarization of wave changes due to small irregularities thus coupling of energy from waveguide at the receiving end is more difficult.
* Fabrication of certain type components is more difficult for circular waveguide

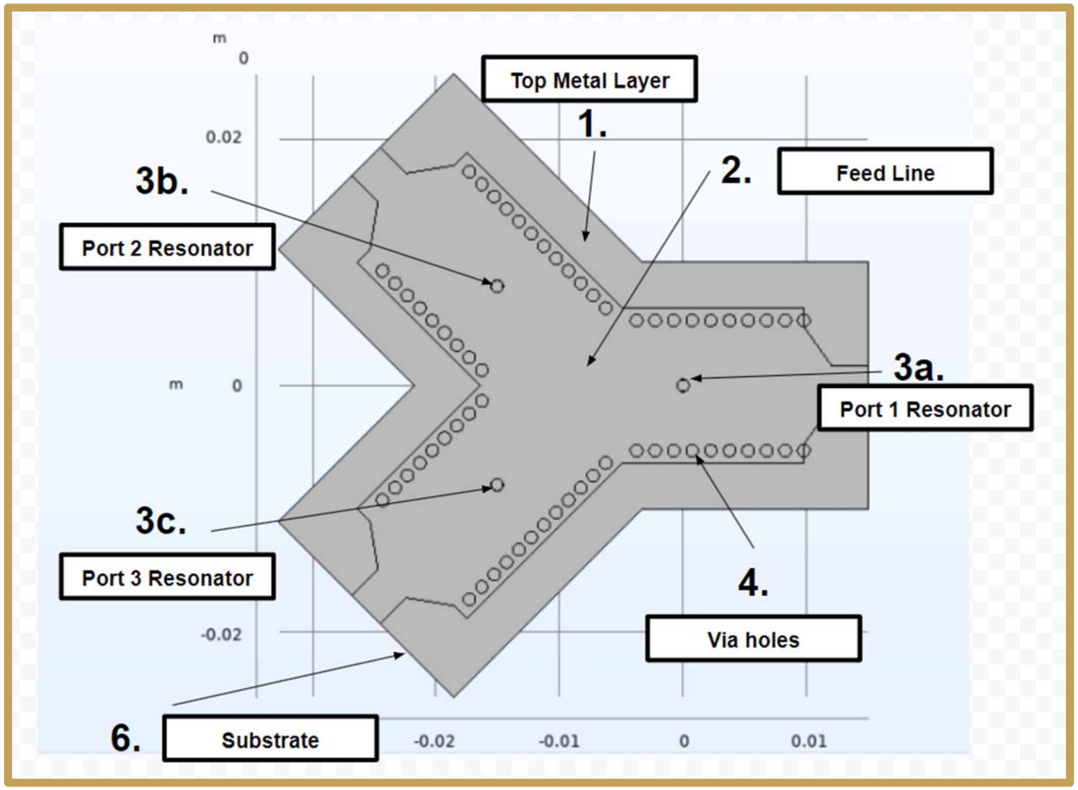
Deviations of Chosen Solution Design



Top Solution Design Selection



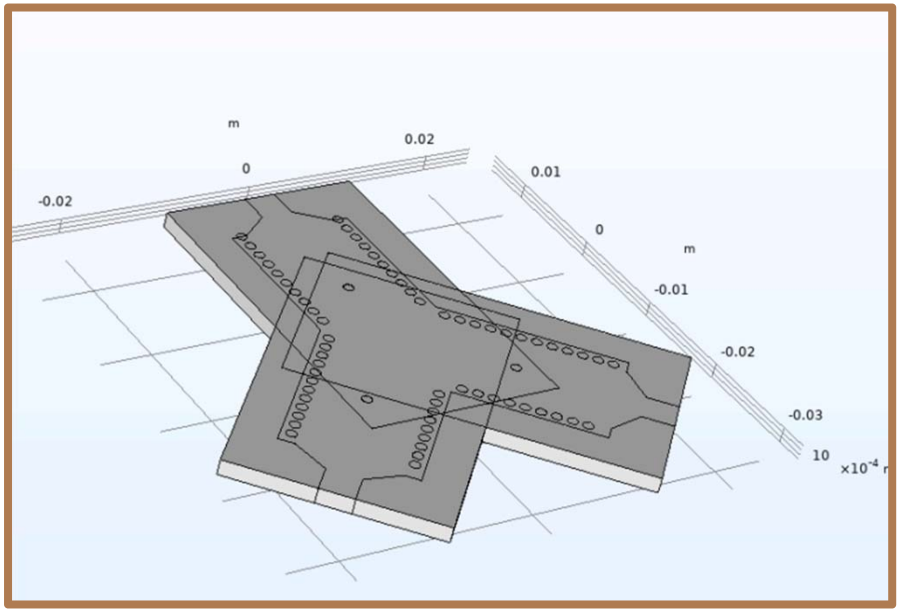
Component-Level Blueprint



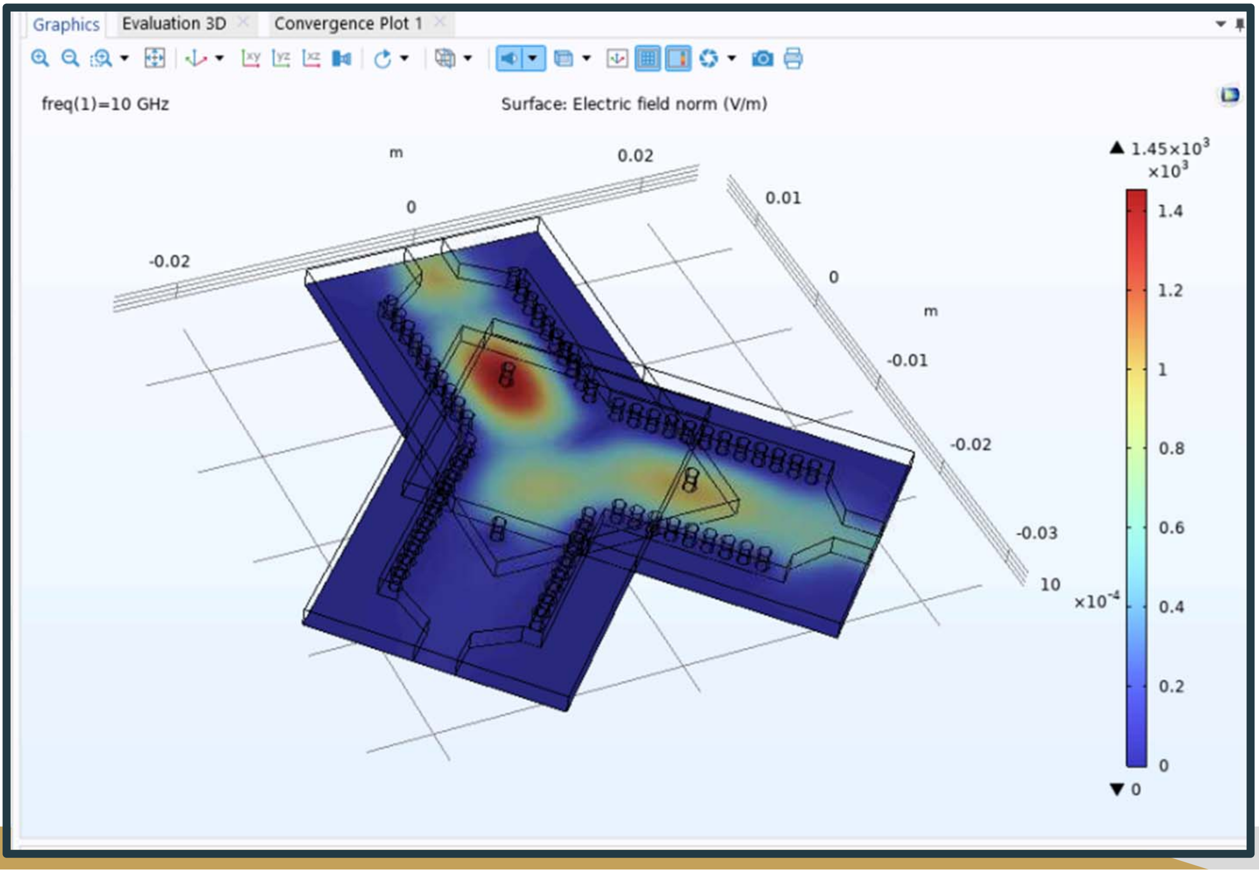
In our component, we have designed an electromagnetic waveguide consisting of a thin dielectric substrate **(6)** that has a thin metal layer **(1)** on the top and the bottom which is connected through the metallized posts, or via holes **(4)** arranged to guide the wave. This component is designed to send a signal through the feed line **(2)** which can be multiplexed through the resonators **(3)** at the different ports which will be made out of a conductive or phase change material to operate as a switch.

Top Solution Description

- Sizing: ~(0.04*10^-4) by (0.04*10^-4)
  meters
- Material: (TBA)
- Y-Shape twin-port design (45° angle):
  created by modelling three rectangular
  waveguides together

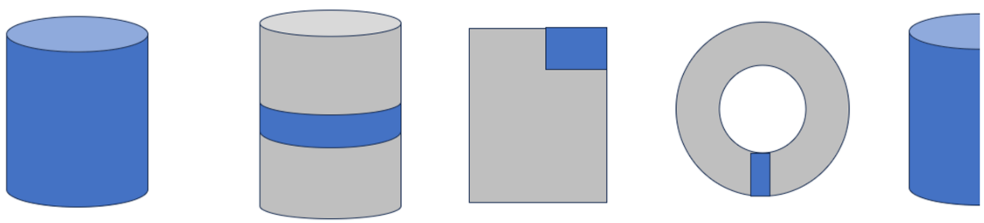


Top Solution Operation



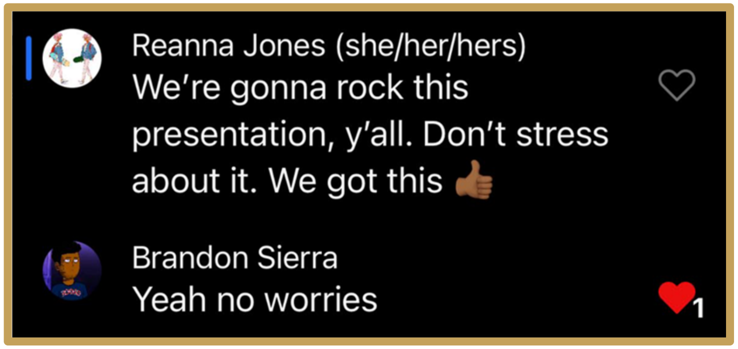
Plans for the Future (This & Next Semester)

- Finalize edits to top solution design & final COMSOL test simulations
- Traveling to UMD - College Park to fully test designs on their lab equipment alongside Seabron's other groups
- Making necessary changes as needed after UMD testing, going back into COMSOL to redesign blueprint and resimulate based off of feedback ,etc.



Conclusion

- PICs are the future of modern electronics, and we wish to be at the forefront of this change
- Our top solution design strives better operating power and more ports within a smaller size
- Repeated simulations and editing are key to perfecting the waveguide
- Lots of trial and error, but we are confident nonetheless



THANK YOU FOR YOUR TIME, PATIENCE, AND ATTENTION

We shall now take questions, comments, concerns, etc.