IIA project – Q&A and Some Extra Knowledge

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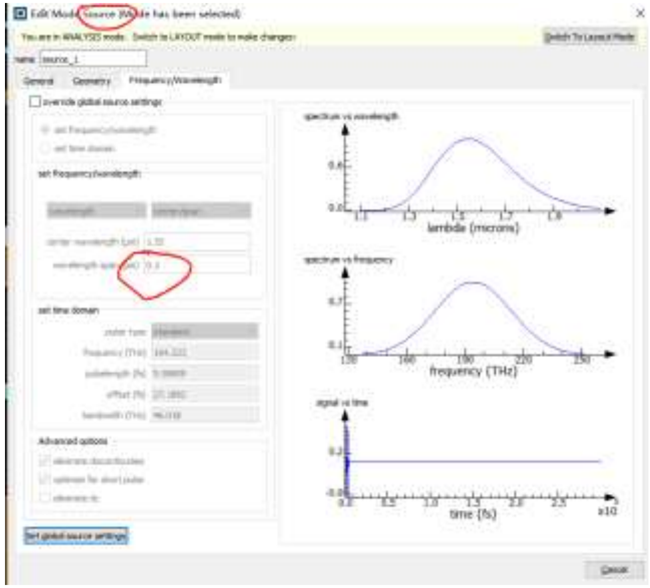
Outline

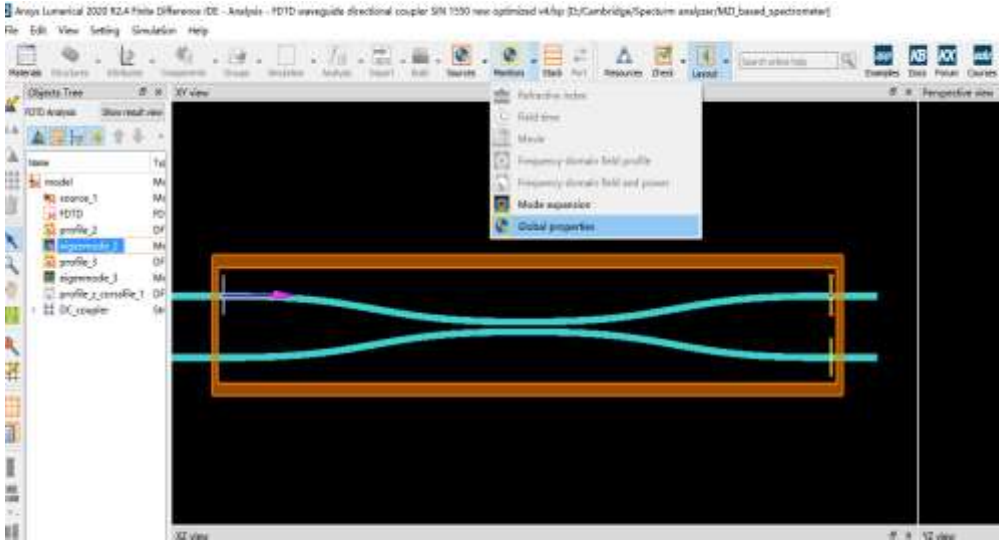
1. Q&A

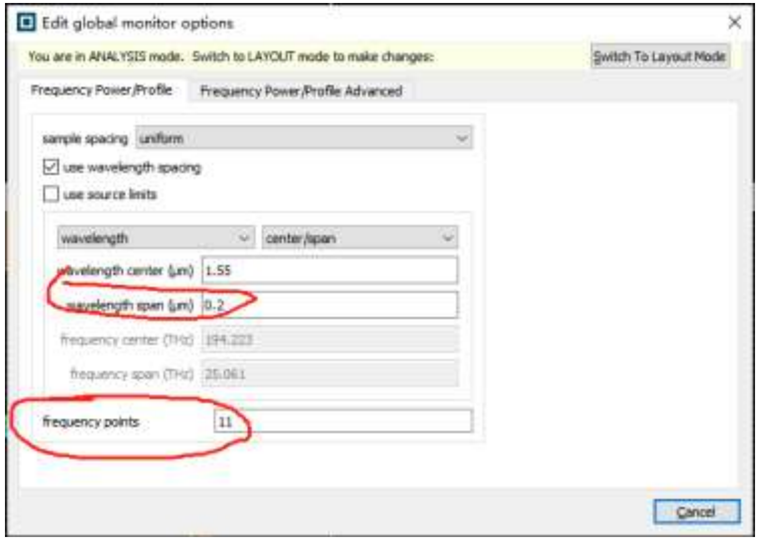
2. Some Extra Knowledge

About the Wavelength Dependence / Bandwidth

To evaluate the performance of a coupler across different wavelengths — that is, to study its **bandwidth** — you can define a specific **wavelength span** at the source. Then, under **Global Properties**, set the number of **frequency points** to determine how many wavelengths will be sampled in each simulation run. This will automatically generate a response curve (e.g., coupling efficiency vs. wavelength).

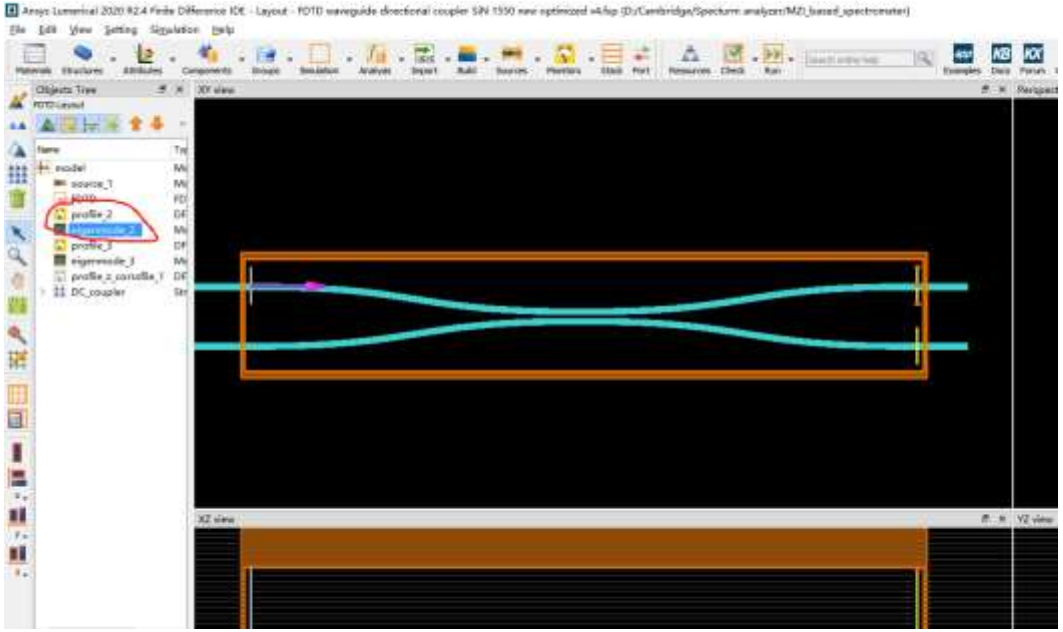


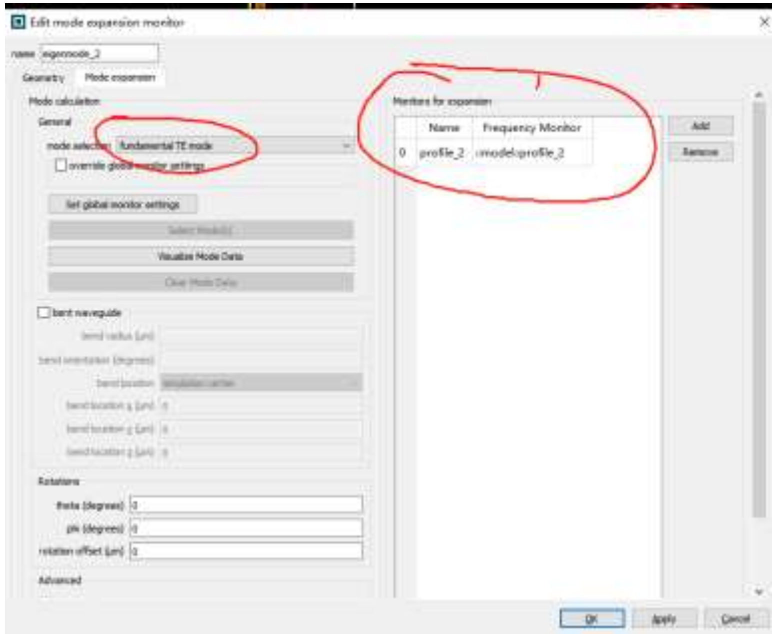




How to Use the Mode Expansion Monitor

Mode expansion monitor allow you to analyze the **fraction of power transmitted into any mode(s)** of a waveguide.





1. Alien this mode expansion monitor with the Field/Power monitor
2. Select the target mode for expansion (e.g. TE0 mode)
3. Check with the T_net (i.e. the fraction of TE0 mode)

https://optics.ansys.com/hc/en-us/articles/360034902433-Using-and-understanding-Mode-Expansion-Monitors

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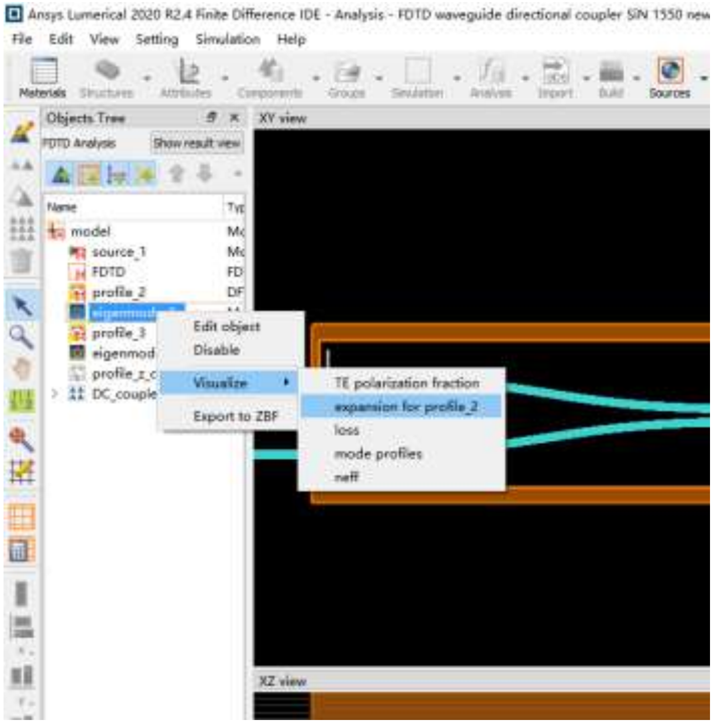

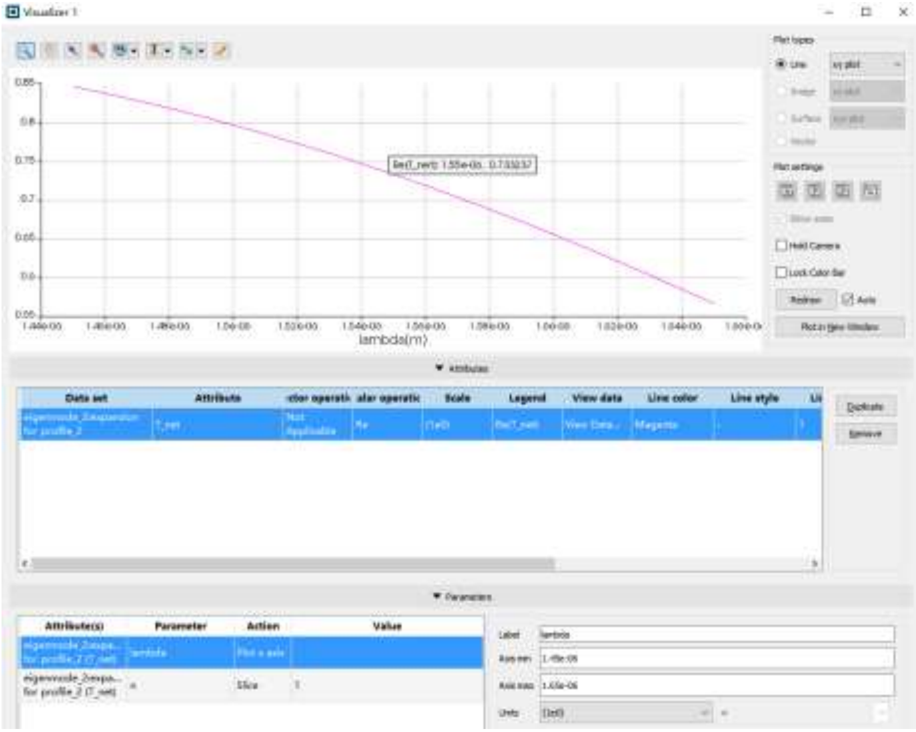

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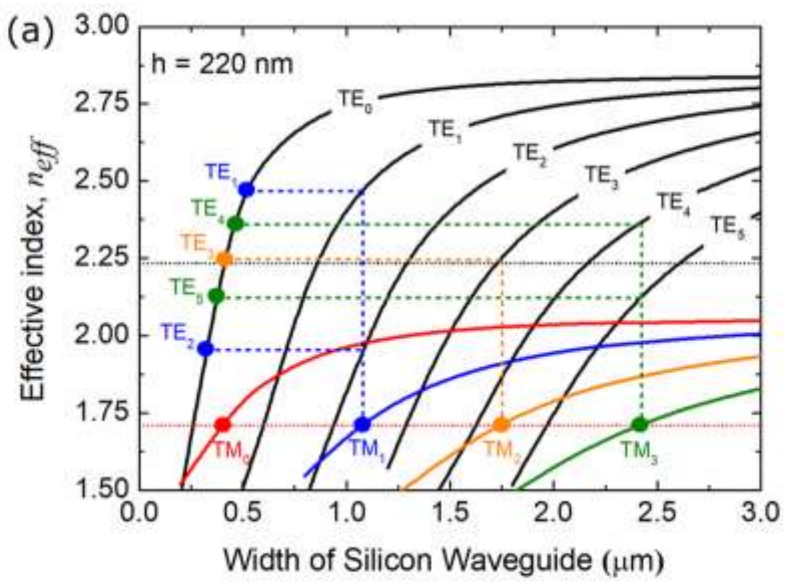
Coupling between asymmetrical waveguides

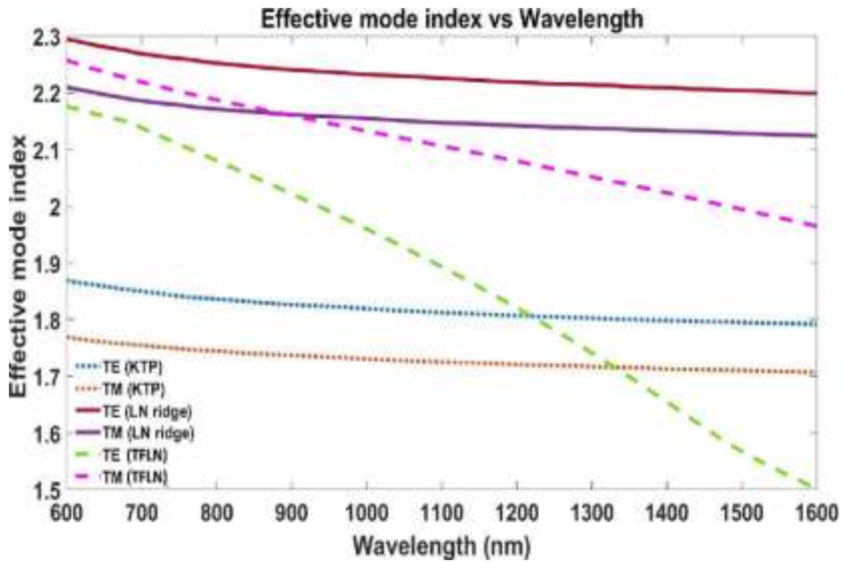
Mode Effective Index

$$\begin{cases} \dfrac{dA_0(z)}{dz} = -i\beta A_0(z) - i\kappa A_1(z) \\[2ex] \dfrac{dA_1(z)}{dz} = -i\beta A_1(z) - i\kappa A_0(z) \end{cases}$$

Effective refractive index experienced by the guided mode

where β is the propagation constant, $\beta = kn_{eff} = \omega n_{eff}/c$



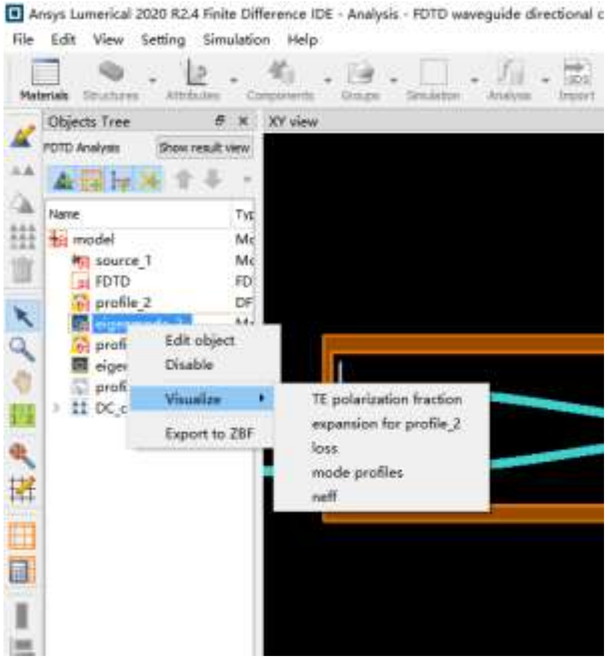


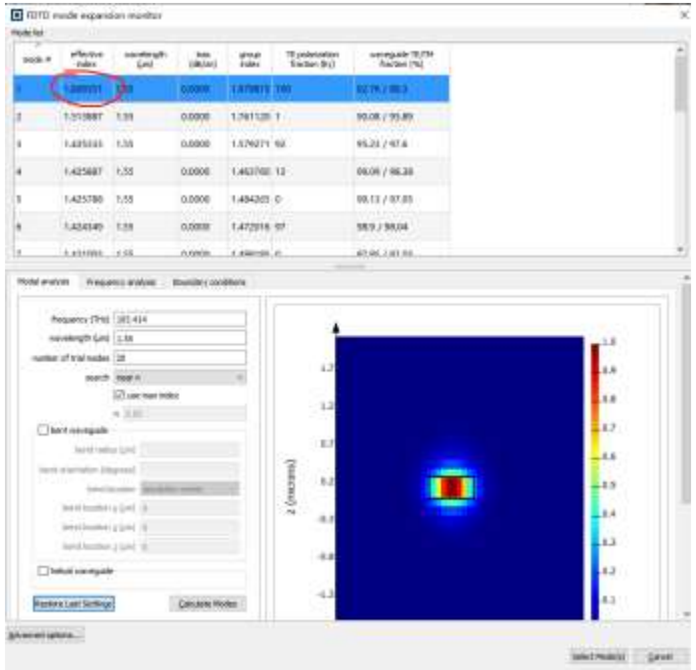
Varies over Mode Order, Waveguide geometry, Wavelength, etc…

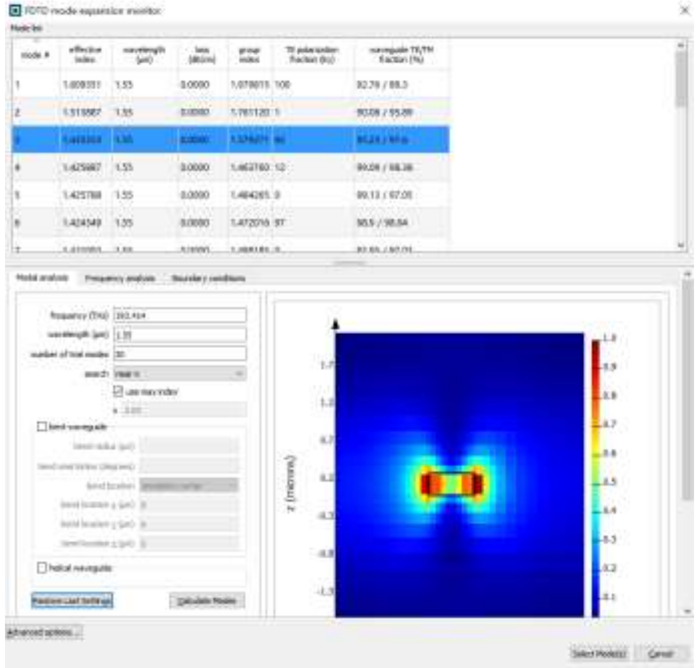
Coupling Between Asymmetrical Waveguides

The key to designing an asymmetrical directional couplers is to **identify matching effective indices** across different modes — i.e., to find the waveguide widths *where different mode orders have approximately the same effective index.*

In Lumerical, you can use the **mode solver** embedded in the **source** or the **mode expansion monitor:**





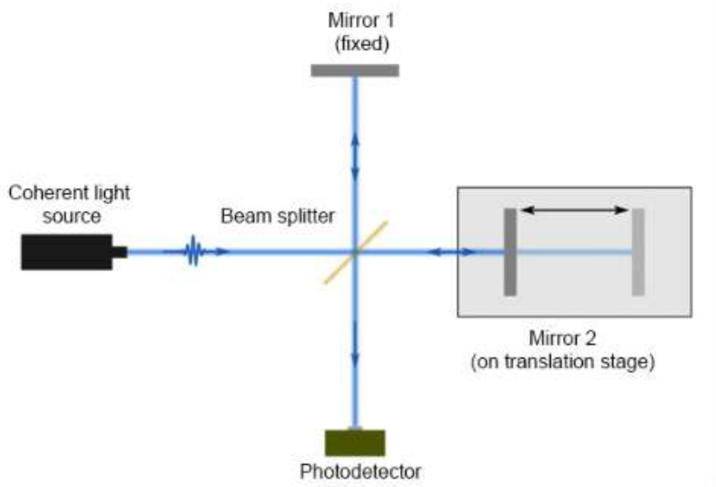


Application Scenario of Directional Couplers – MZI

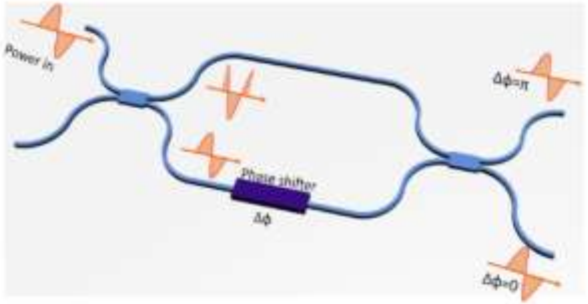
Directional couplers (DCs) fundamentally **split and combine light**. This simple function makes them key elements in building everything from diverse waveguide components to large-scale photonic integrated circuits.

A typical example is **Mach-Zehnder Interferometer (MZI):**

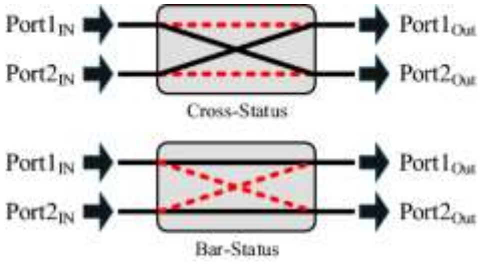
Michelson interferometer (free-space optics):

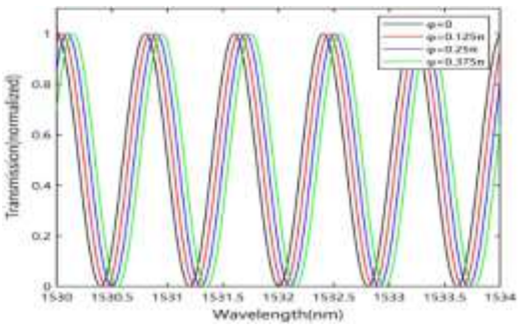


Integrated MZI with 50:50 DCs and phase shifters:



Transmission features:



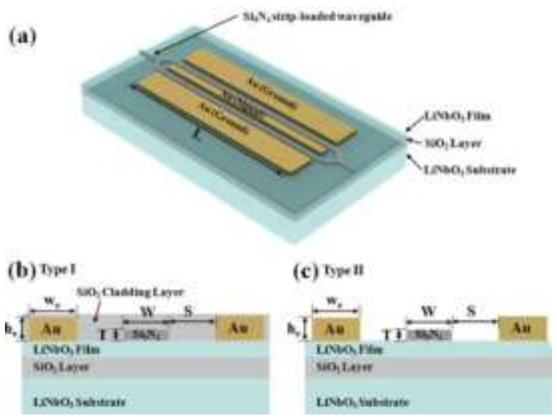


Application Scenario of Directional Couplers – MZI

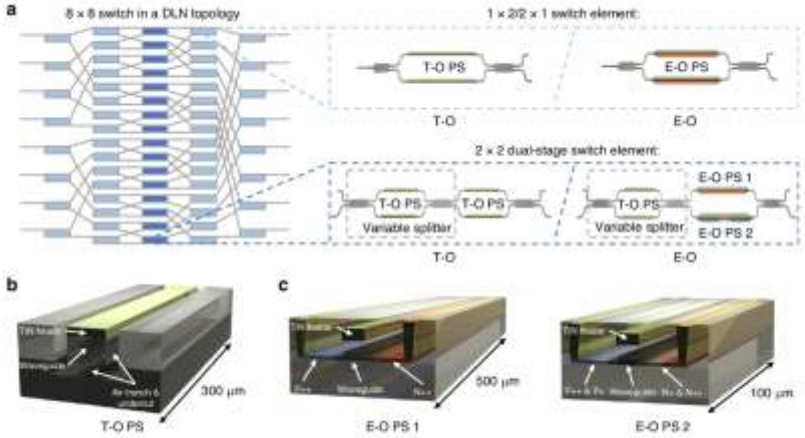
MZI structures that can be used to create:

1. ***Filters***: *by exploiting wavelength-dependent interference*
2. ***Modulators***: *by inserting phase shifters (e.g., based on thermo-optic or electro-optic effects) for high-speed modulation*
3. ***Switches***: by tuning the cross/bar condition of each MZI stage to reconfigure the entire switch network's connectivity
4. ***Programmable circuits*** *for optical computing and sensing applications*

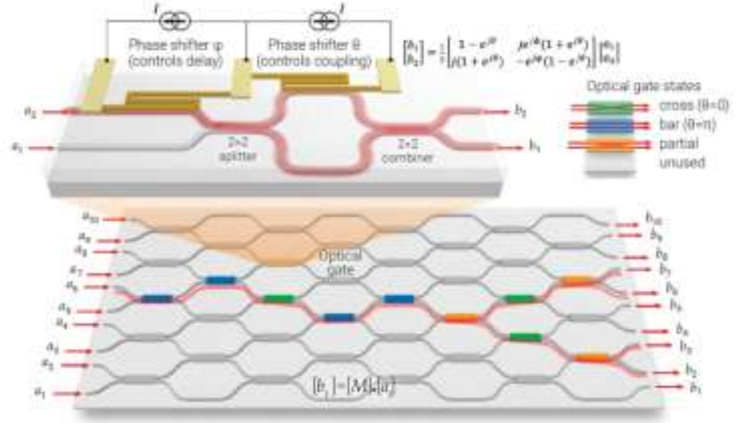
$LiNbO_3$ MZI modulator:



T-O/E-O MZI switches:

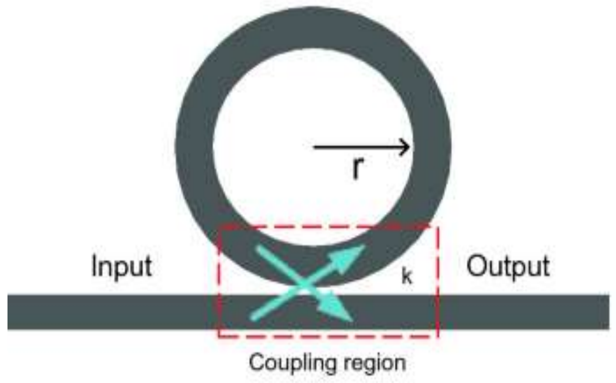


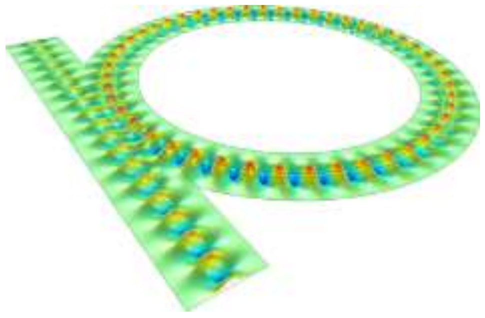
Programmable MZI network for optical computing:

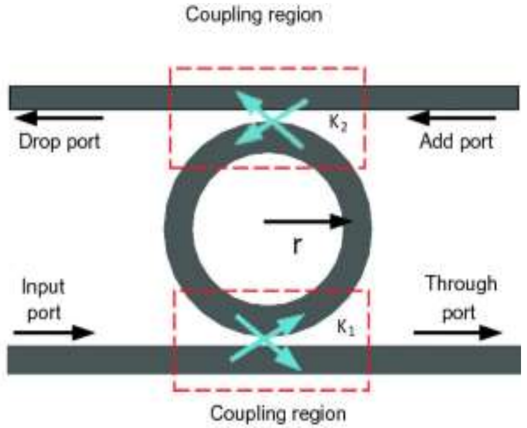


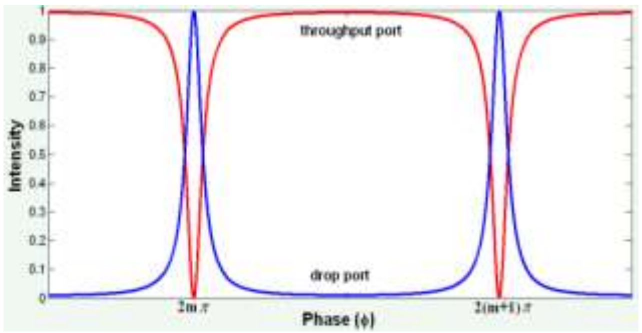
Application Scenario of Directional Couplers – MRR

Imagine looping the split light back onto itself, allowing it to interfere with itself — we got **Micro-ring Resonator (MRR)**









Typical Applications of MRRs include:

1. **Add/drop filters** for WDM systems
2. **Compact modulators** and switches
3. **Nonlinear optics** and **biosensors**
4. **Quantum photonic circuits**