1. Purpose and deliverables

This project will determine the group index n_g of a 220 nm silicon-on-insulator (SOI) strip waveguide by measuring the spectral interference fringes of unbalanced Mach–Zehnder interferometers (MZIs).

Deliverables

- Measured transmission spectra of multiple unbalanced MZIs
- Extracted FSR for each device near 1550 nm (and optionally across a wavelength band)
- Computed n_g (single value near 1550 nm or $n_g(\lambda)$)
- Brief comparison against simulation and/or literature expectations

2. Background and principle

An MZI splits input light into two arms and recombines them, producing constructive/destructive interference at the output. If the arms have a length mismatch ΔL, the output intensity varies periodically with wavelength because the relative phase changes with λ.

A common form for the normalized output intensity is:

$$\frac{I_{\text{out}}}{I_{\text{in}}} \propto 1 + \cos(\Delta\phi)$$

where the phase difference can be written as:

$$\Delta\phi(\lambda) = \beta(\lambda)\Delta L, \beta(\lambda) = \frac{2\pi n_{\text{eff}}(\lambda)}{\lambda}$$

The periodicity in wavelength is the free spectral range (FSR). For small wavelength spacing around a center wavelength λ, the FSR is related to group index by:

$$FSR(\lambda) = \frac{\lambda^2}{n_g(\lambda)\,\Delta L} \Rightarrow n_g(\lambda) = \frac{\lambda^2}{FSR(\lambda)\,\Delta L}$$

So once FSR is measured and ΔL is known from the layout, n_g follows directly.

3. Device plan and design choices

3.1 Platform and geometry

- SOI device layer thickness: 220 nm
- Waveguide type: strip waveguide
- Nominal waveguide width: 500 nm (TE operation assumed)
- Cladding: as provided by the process (oxide/air depending on the kit)

3.2 MZI set (multiple ΔLvalues)

Using several unbalanced MZIs improves robustness: if all devices produce consistent n_g, confidence increases; if one device is noisy or has poor visibility, others can still be used.

I will fabricate/simulate five MZIs with small variations in ΔL:

Table 1 – Interferometer naming and length difference

Interferometer ID	Length Difference (\Delta L) (μm)
MZI-A	24
MZI-B	29
MZI-C	34
MZI-D	39
MZI-E	44

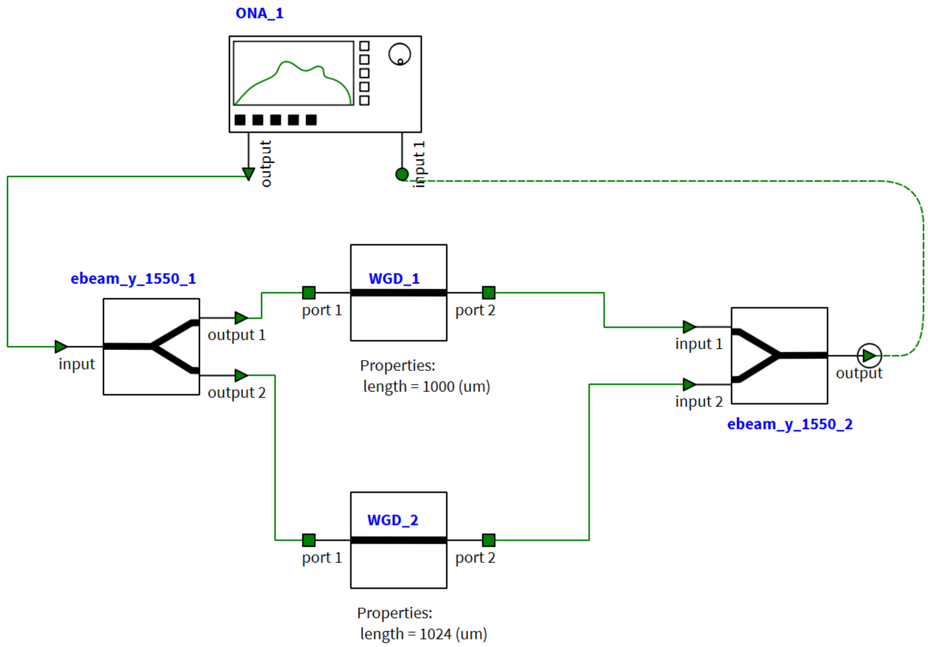

Figure 1 – Lumerical INTERCONNECT schematic of the unbalanced Mach–Zehnder interferometer (MZI-A) with $\Delta L = 24\ \mu m$ for transmission analysis.

3.3 Expected FSR

Using a typical SOI group index baseline $n_g \approx 4.2$ and $\lambda = 1550\text{nm}$:

$$FSR \approx \frac{(1.55\ \mu m)^2}{4.2\ \Delta L}$$

Table 2- Simulated FSR values at 1550 nm (computed by $n_g = 4.2$).

Interferometer	(\Delta L) (µm)	Calculated FSR (nm)	Simulated FSR (nm)
MZI-A	24	223.8	24
MZI-B	29	19.7	20
MZI-C	34	16.8	16.8
MZI-D	39	14.6	15
MZI-E	44	13.0	13

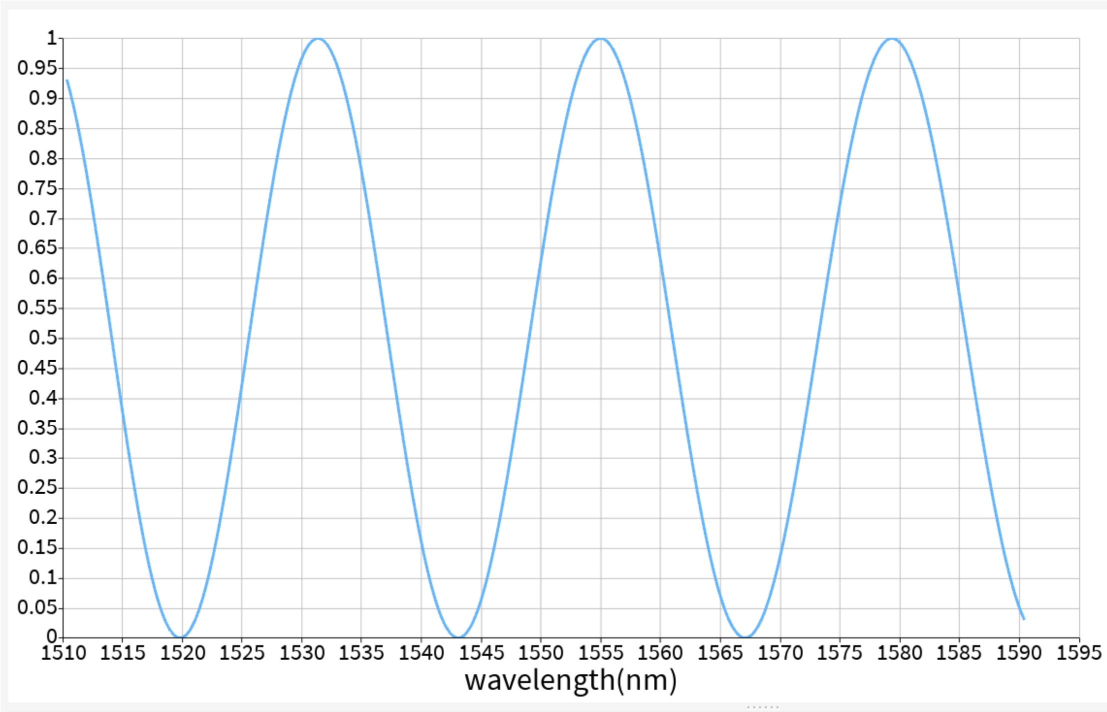

Figure 2 – Simulated TE transmission spectrum of the unbalanced Mach–Zehnder interferometer (MZI-A) with $\Delta L = 24\ \mu$m, showing periodic interference fringes used to extract the free spectral range (FSR).

This check is mainly to confirm the fringes will be resolvable with a typical laser sweep step size.

4. Simulation and modeling workflow

Simulation will be used to (1) validate that the designed ΔLproduces the expected fringe spacing and (2) estimate visibility and insertion loss trends.

Tool: Lumerical Interconnect (system-level) and optionally MODE/FDTD for waveguide effective/group index inputs.

Procedure

1. Build an MZI schematic using:
   - 2×2 couplers (or Y-splitters) with realistic insertion loss if available
   - Two waveguide arms with lengths $L$and $L + \Delta L$
2. Sweep wavelength
3. Extract transmission spectrum at the output

4. Compute simulated FSR using the same algorithm intended for measured data (peak spacing / fitting)

Simulation outputs

- Transmission vs wavelength for each device
- Simulated FSR near 1550 nm

5. References

- Lukas Chrostowski, Michael Hochberg, *Silicon Photonics Design*, Cambridge University Press, 2015.
- UBC Course/lab notes

6. Acknowledgments

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