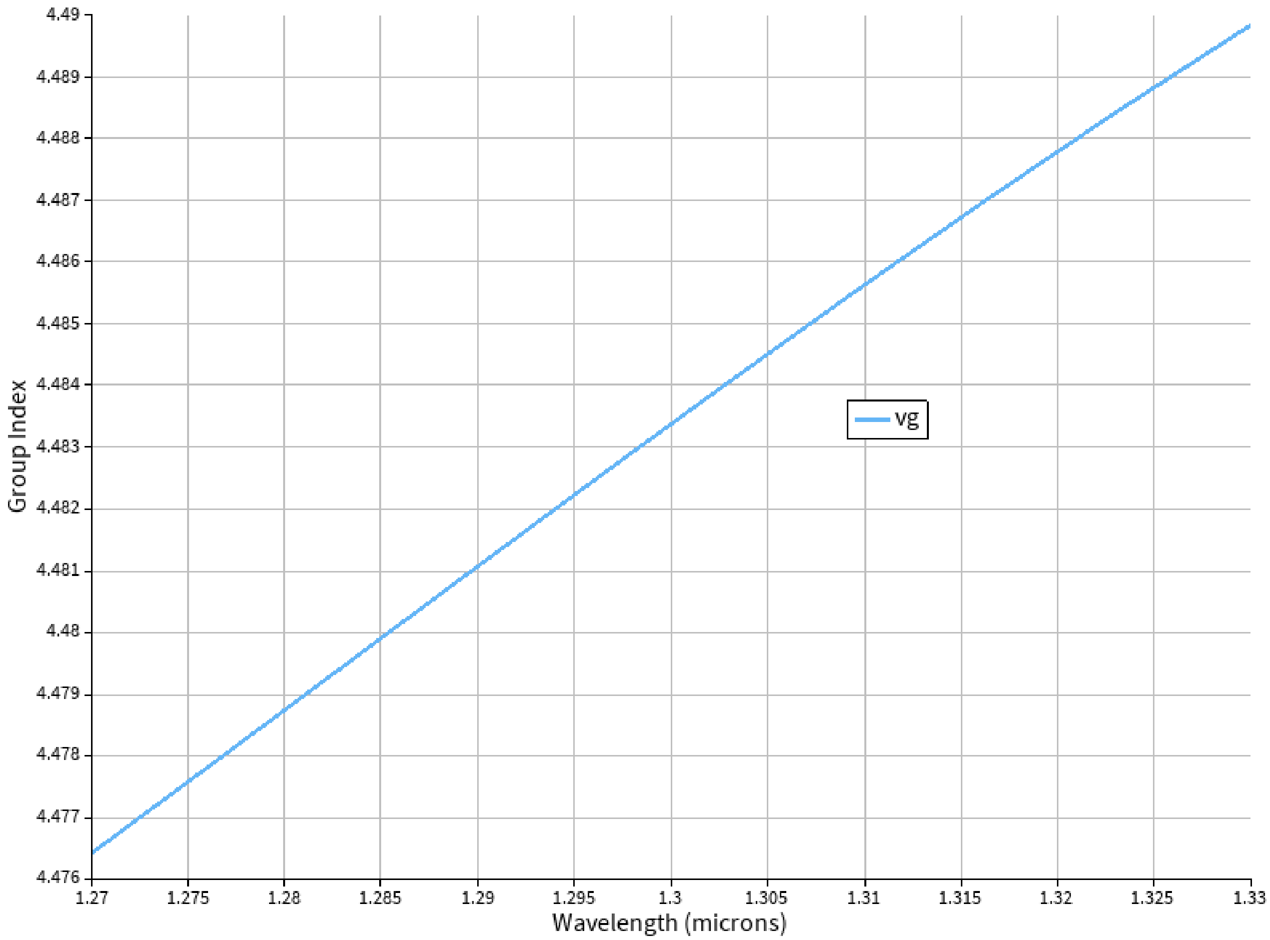
ELEC 413 - Chip 1 and 2 Design Document

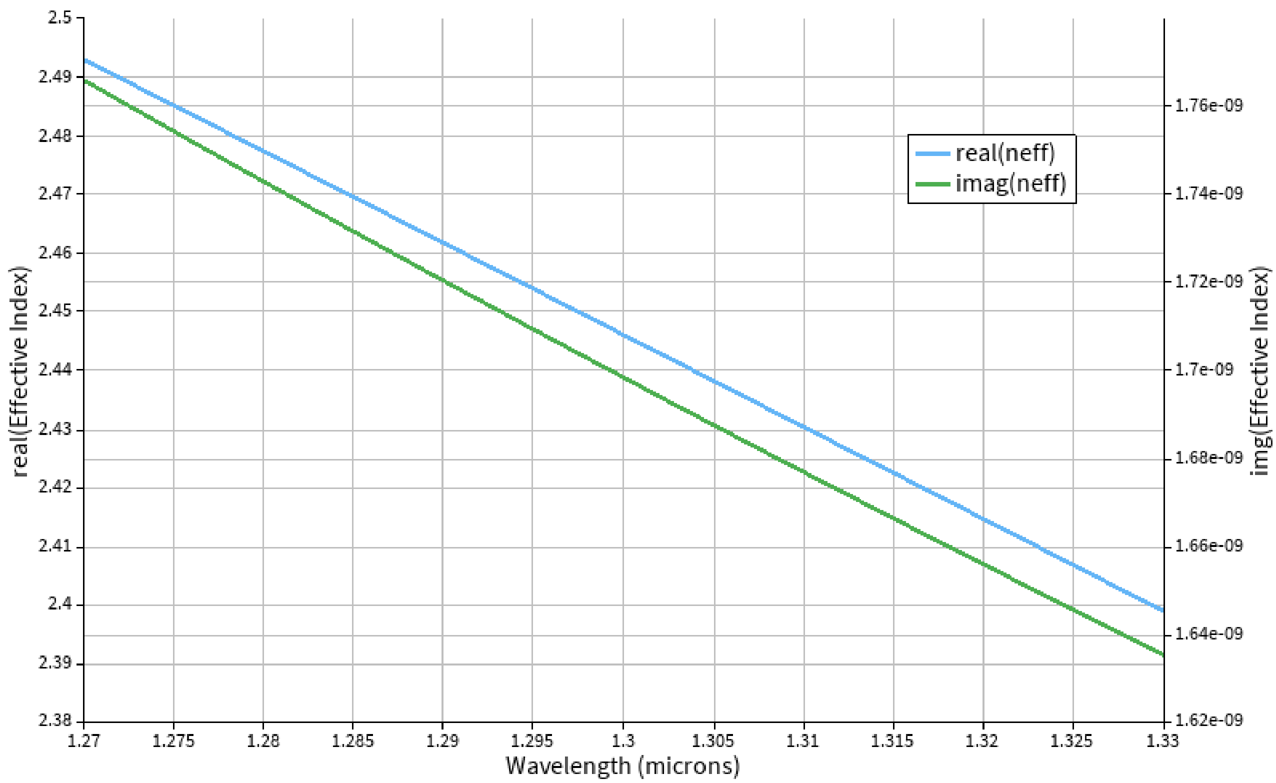
Abstract

This document outlines the design of an demux interferometer. It includes design details for both the multiplexer and demultiplexer circuits. This is a work in progress.

Lumerical MODE and Python Modelling

- A silicon waveguide with width $350\,\mu\mathrm{m}$ and thickness $220\,\mu\mathrm{m}$ was modelled in Lumerical MODE. Using a frequency sweep from 1270 to $1330\,\mathrm{nm}$, data on the effective and group indices was collected:





- Compact model of a waveguide:

$$n_{\mathrm{eff}}(\lambda) = n_1 + n_2(\lambda - \lambda_0) + n_3(\lambda - \lambda_0)^2$$

- The compact model is used to determine the propagation constant of the waveguide, as a function of frequency:

$$\beta(\lambda) = \frac{2\pi n_{\text{eff}}(\lambda)}{\lambda} + i\frac{\alpha(\lambda)}{2}$$

  - The propagation loss α is determined by the imaginary part of the effective index:

$$\alpha(\lambda) = \frac{4\pi}{\lambda}\text{Im}\{n_{\text{eff}}\}$$

- Mach-Zender interferometer transfer function:

$$T_{\text{MZI}}(\lambda) = \frac{1}{4}\left|1 + e^{-i\beta\Delta L}\right|^2$$

  - ΔL is the path length difference of the two arms of the interferometer
  - In decibels,

$$T_{\text{MZI-dB}}(\lambda) = 10\log_{10}(T_{\text{MZI}}(\lambda))$$

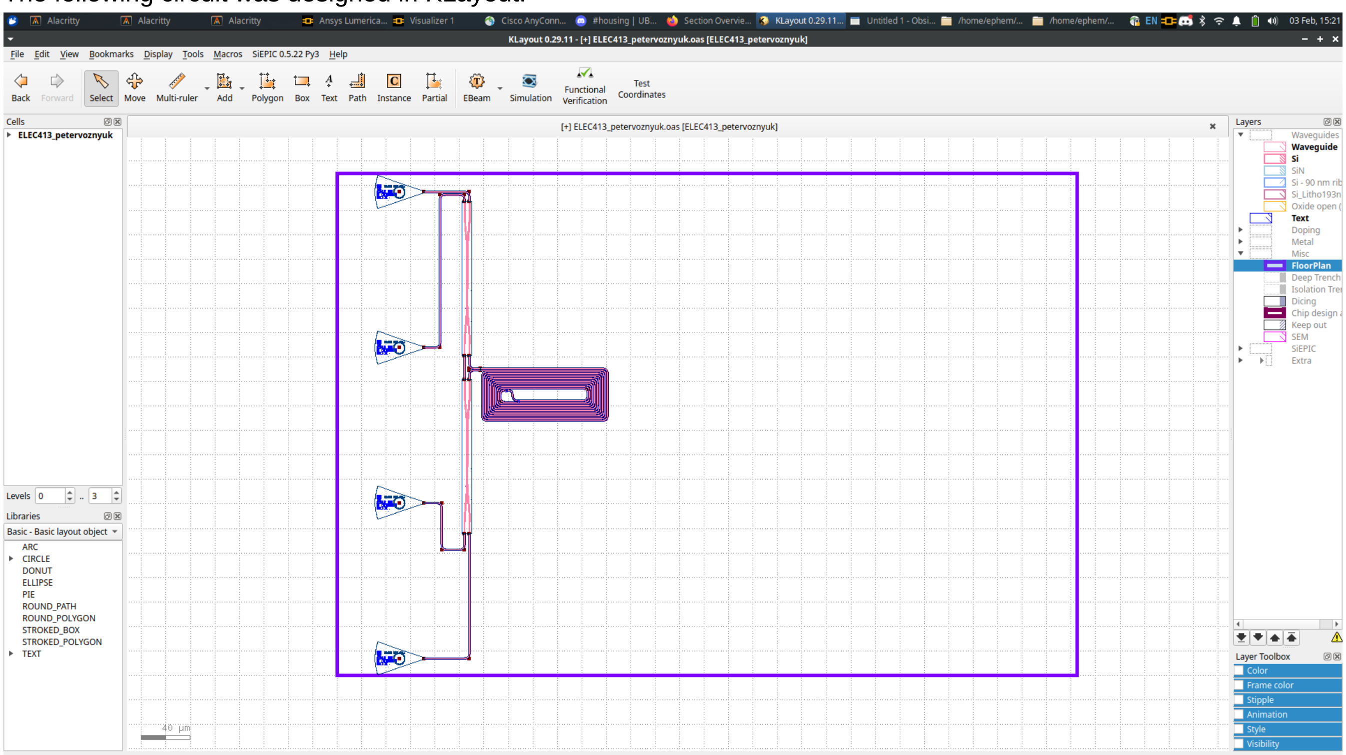
- TODO: implement transfer function in Python

Chip 1

- From Lumerical MODE modelling, the group index of the first mode of the waveguide was found to be 4.486 at $1310\,\text{nm}$. Thus, the required path length difference is:

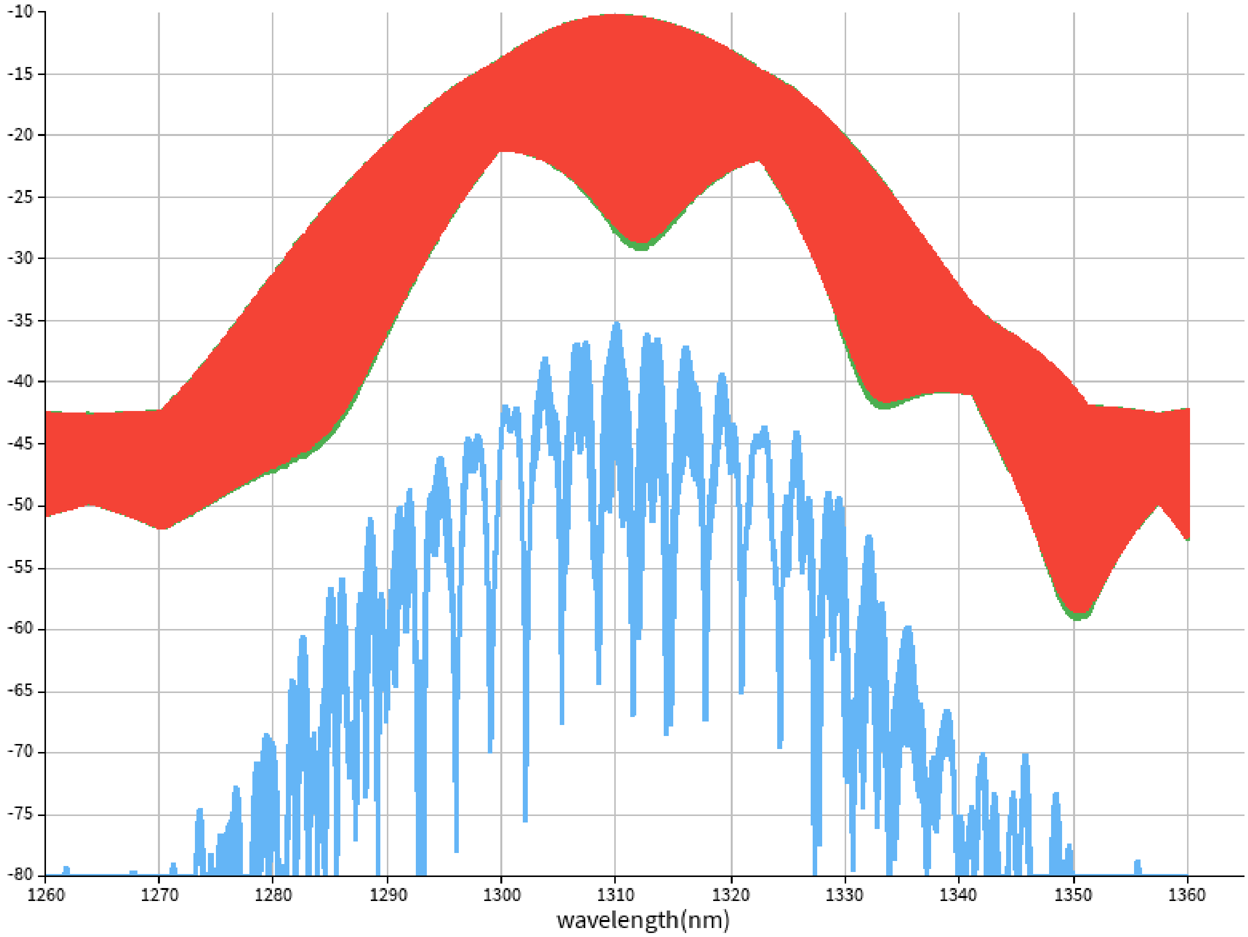
$$\Delta L = \frac{c}{n_g\Delta\nu} = 2666\,\mu\text{m}$$

- The following circuit was designed in KLayout:



  - There is sufficient room for additional designs that test the effectiveness of an additional waveguide width. These designs can be implemented using tapers.

- The circuit was modelled in Lumerical INTERCONNECT:

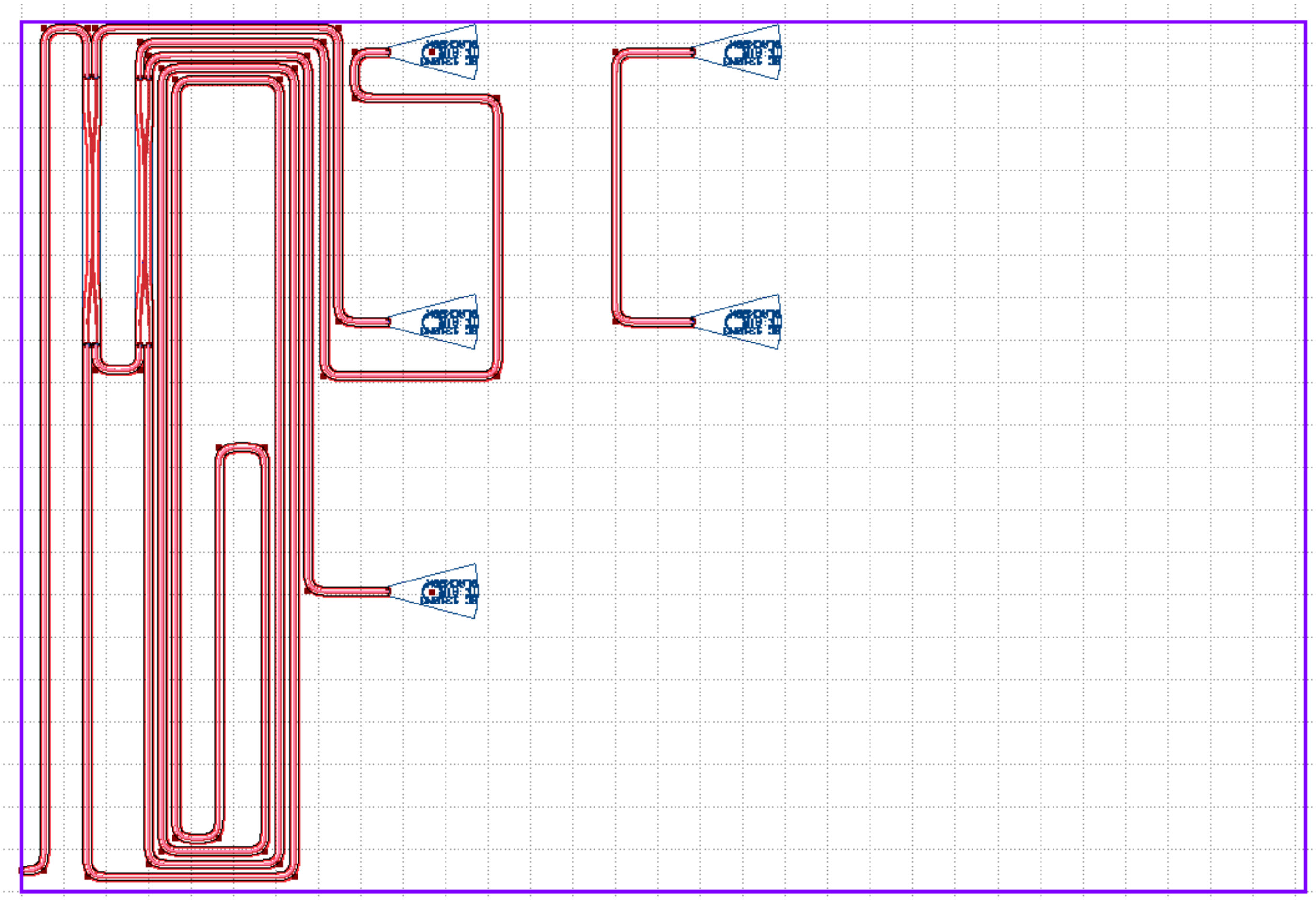


  - The blue plot shows the transmission at the first optical port, indicating that there is negligible backscatter.
  - The red and green plots show the transmission at the two outputs. At $1310\,\mathrm{nm}$, the free spectral range is $0.14\,\mathrm{nm}$, which corresponds to $25\,\mathrm{GHz}$.

TODO

- Calculate group index at corners (*i.e.* with some variation in waveguide width/thickness)
  - Add additional circuits with a path length difference that corresponds to these indices
- Rotate paperclip waveguide and extend to reduce number of bends
- Add variations
- Add de-embedding structure
- Account for process bias by increasing feature size by $15\,\mu\mathrm{m}$

Chip 2



- The circuit layout was designed to minimize differential mode error (by keeping waveguides close together, in the same vertical area) and propagation loss (by keeping the first interferometer path short and having as many straight waveguides as possible, while keeping the overall footprint small.)
- A small de-embedding circuit was included. The output from this circuit will be subtracted from the output of the interferometer to cancel-out insertion loss.
- The same path difference as Chip 1 was used ($2666\,\mu\mathrm{m}$); however, the process is different (air vs. oxide cladding), so this should be revised.
- The width of the waveguide cladding was reduced from 4.35 to $4.00\mu\mathrm{m}$, in order to avoid errors caused by overlapping waveguides at splitter inputs/outputs. This waveguide will be modelled in Lumerical MODE to recalculate the group index and estimate the magnitude of coupling.