WIRTUSCC

Centro de Competência Embrapii em Hardware Inteligente para a Indústria

CURSOS, CAPACITAÇÃO E TREINAMENTOS



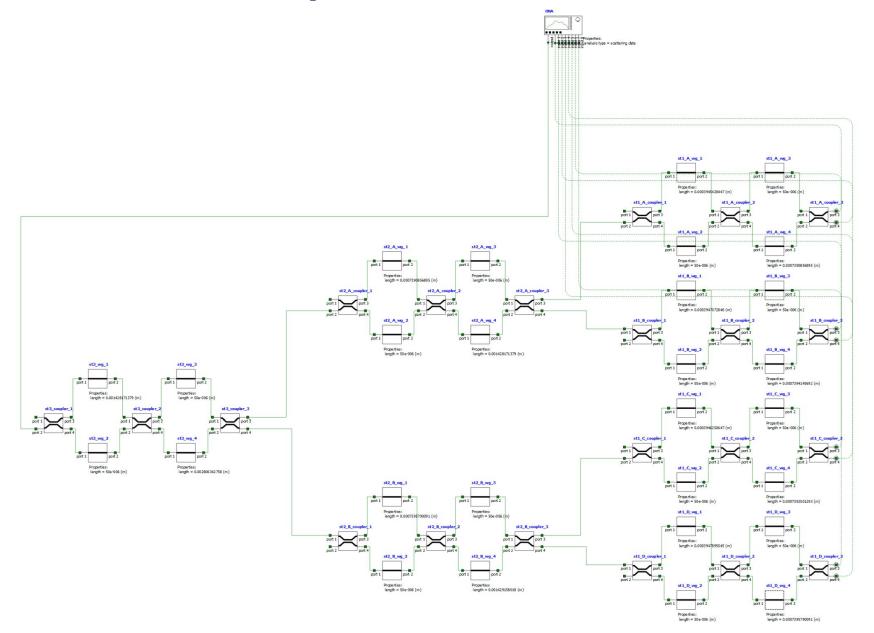
Projeto de Circuitos Fotônicos Integrados

Projeto de Filtro CDWM Baseado em MZI

Luiz Felipe Barros Alves

Layout Interconnect





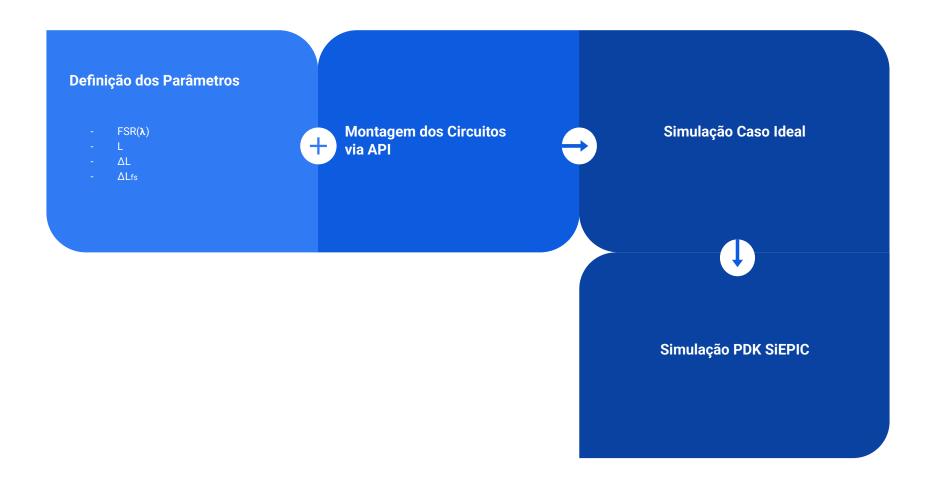
Pré-requisitos



- 1. Número de entradas: 1;
- 2. Número de saídas: 8;
- 3. Espaçamento entre canais: 50, 100 e 200 GHz;
- 4. Banda de operação: banca C (1530 1565 nm);
- O filtro deve estar alinhado com os canais definidos pelo padrão ITU da banda C (https://www.fiberdyne.com/products/pdf/Fiberdyne-ITU-Grid-C-Band-100GHz.pdf);
- 6. Uso de filtros de, no mínimo, segunda ordem;
- 7. Use acopladores de grade;
- 8. Tamanho máximo do circuito: 500 x 400 um;
- 9. PDK SiePIC (https://github.com/SiEPIC)

Fluxo de Atividades

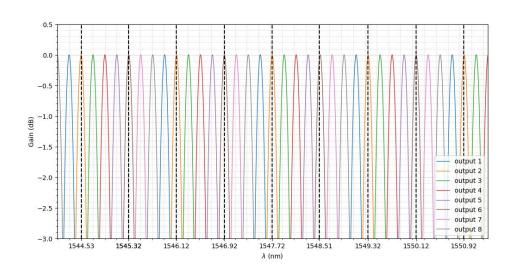




CDWM - Filtros de 1 estágio (Caso Ideal)



 Picos significativamente menos planos em comparação aos os resultados de para os filtros de 2 e 3 estágios.



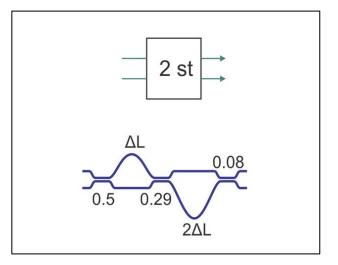
CDWM - Filtros de 2 estágios (Caso Ideal)



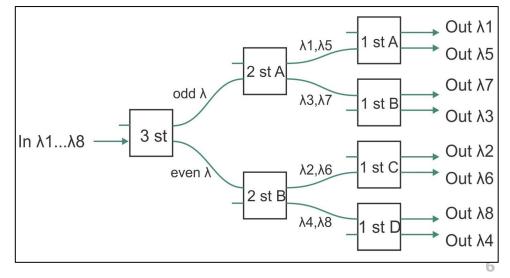


Parâmetros de Simulação:

- $\circ FSR = \lambda / n_{gr} \Delta L_{FSR}$
- $\bigcirc \Delta L_{FS} = \lambda^2 / n_{eff}$
- \bigcirc $\triangle L = \triangle L_{FSR} + \triangle L_{shift}$



Fonte: [1]

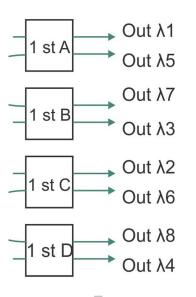






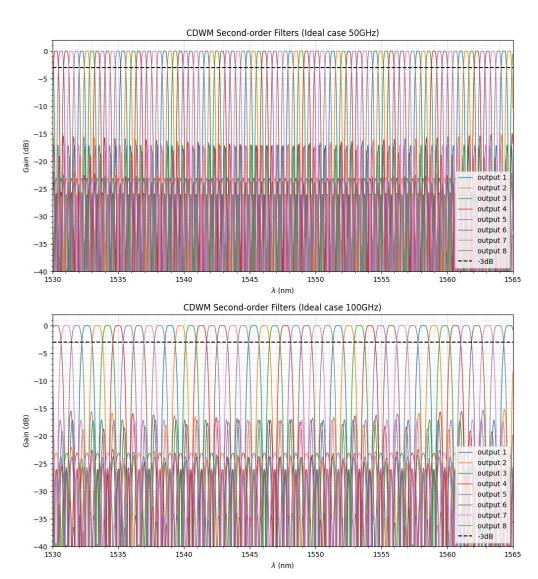
| Splitter | ΔL_{FSR} | ΔL_{Shift} |
|----------|---------------------|-----------------------|
| 3 st | ΔL_{Base} | 0 |
| 2 st A | $\Delta L_{Base}/2$ | 0 |
| 2 st B | $\Delta L_{Base}/2$ | $0.75 \Delta L_{FS}$ |
| 1 st A | $\Delta L_{Base}/4$ | 0 |
| 1 st B | $\Delta L_{Base}/4$ | $0.25 \Delta L_{FS}$ |
| 1 st C | $\Delta L_{Base}/4$ | $0.125 \Delta L_{FS}$ |
| 1 st D | $\Delta L_{Base}/4$ | $0.375 \Delta L_{FS}$ |

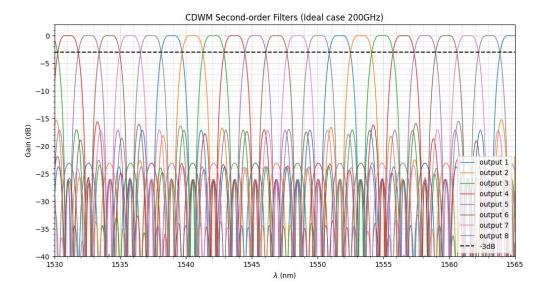
Fonte: [1]











CDWM - Filtros de 2 estágios (Caso Ideal)

Alinhamento dos canais definidos pelo padrão ITU para C

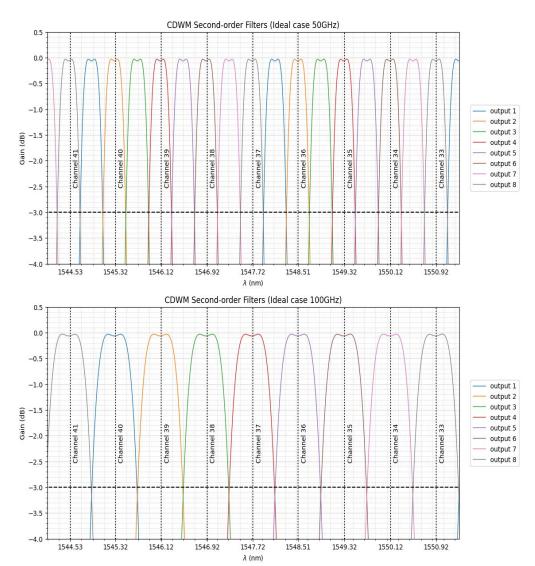


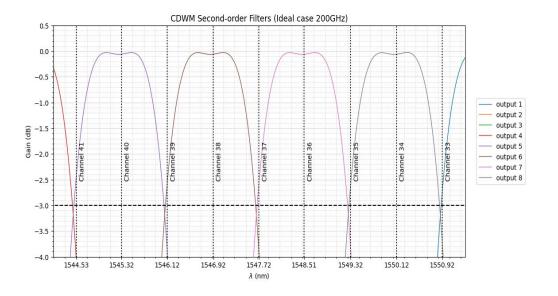


| Channel (#) | Frequency (GHz) | Wavelength (nm) | Channel (#) | Frequency (GHz) | Wavelength (nm) |
|-------------|-----------------|-----------------|-------------|-----------------|-----------------|
| 1 | 190100 | 1577.03 | 37 | 193700 | 1547.72 |
| 2 | 190200 | 1576.03 | 38 | 193800 | 1546.92 |
| 3 | 190300 | 1575.37 | 39 | 193900 | 1546.12 |
| 4 | 190400 | 1574.54 | 40 | 194000 | 1545.32 |
| 5 | 190500 | 1573.71 | 41 | 194100 | 1544.53 |
| 6 | 190600 | 1572.89 | 42 | 194200 | 1543.73 |
| 7 | 190700 | 1572.06 | 43 | 194300 | 1542.94 |
| 8 | 190800 | 1571.24 | 44 | 194400 | 1542.14 |
| 9 | 190900 | 1570.42 | 45 | 194500 | 1541.35 |
| 10 | 191000 | 1569.59 | 46 | 194600 | 1540.56 |
| 11 | 191100 | 1568.77 | 47 | 194700 | 1539.77 |
| 12 | 191200 | 1567.95 | 48 | 194800 | 1538.98 |
| 13 | 191300 | 1567.13 | 49 | 194900 | 1538.19 |
| 14 | 191400 | 1566.31 | 50 | 195000 | 1537.40 |
| 15 | 191500 | 1565.50 | 51 | 195100 | 1536.61 |
| 16 | 191600 | 1564.68 | 52 | 195200 | 1535.82 |
| 17 | 191700 | 1563.86 | 53 | 195300 | 1535.04 |
| 18 | 191800 | 1563.05 | 54 | 195400 | 1534.25 |
| 19 | 191900 | 1562.23 | 55 | 195500 | 1533.47 |
| 20 | 192000 | 1561.41 | 56 | 195600 | 1532.68 |
| 21 | 192100 | 1560.61 | 57 | 195700 | 1531.90 |
| 22 | 192200 | 1559.79 | 58 | 195800 | 1531.12 |
| 23 | 192300 | 1558.98 | 59 | 195900 | 1530.33 |
| 24 | 192400 | 1558.17 | 60 | 196000 | 1529.55 |
| 25 | 192500 | 1557.36 | 61 | 196100 | 1528.77 |
| 26 | 192600 | 1556.55 | 62 | 196200 | 1527.99 |
| 27 | 192700 | 1555.75 | 63 | 196300 | 1527.22 |
| 28 | 192800 | 1554.94 | 64 | 196400 | 1526.44 |
| 29 | 192900 | 1554.13 | 65 | 196500 | 1525.66 |
| 30 | 19300 | 1553.33 | 66 | 196600 | 1524.89 |
| 31 | 193100 | 1552.52 | 67 | 196700 | 1524.11 |
| 32 | 193200 | 1551.72 | 68 | 196800 | 1523.34 |
| 33 | 193300 | 1550.92 | 69 | 196900 | 1522.56 |
| 34 | 193400 | 1550.12 | 70 | 197000 | 1521.79 |
| 35 | 193500 | 1549.32 | 71 | 197100 | 1521.02 |
| 36 | 193600 | 1548.51 | 72 | 197200 | 1520.25 |









CDWM - Filtros de 2 estágios (PDK SiEPIC)



- Atualização dos dados
 - \circ **n**eff
 - o **n**gr
- Parâmetros de Simulação:
 - $\circ FSR = \lambda / n_{gr} \Delta L_{FSR}$
 - $\circ \quad \Delta L_{FS} = \lambda^2 / n_{eff}$
 - \bigcirc $\triangle L = \triangle L_{FSR} + \triangle L_{shift}$





Função para determinar o comprimento de acoplamento ideal

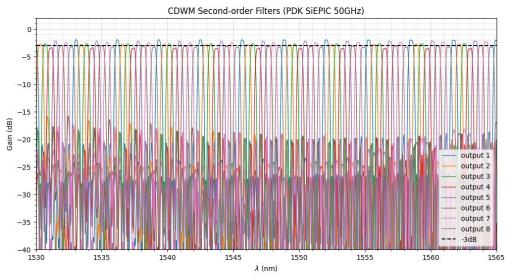
```
1 # Function to determine the correct coupling lengths for each D.C.
2 def coupling(length):
      L_array = np.array([])
       dif array 50 = np.array([])
       dif_array_29 = np.array([])
       dif_array_8 = np.array([])
       target_29 = 10*np.log10(0.29)
       target_8 = 10*np.log10(0.08)
11
       for L in length:
           interApi.switchtolayout()
13
           interApi.select('coupler')
           interApi.set('coupling_length', L)
           interApi.run()
17
           input_1 = interApi.getresult('ONA', 'input 1/mode 1/gain')
           input_2 = interApi.getresult('ONA', 'input 2/mode 1/gain')
           gain_1 = input_1["'TE' gain (dB)"]
           gain_2 = input_2["'TE' gain (dB)"]
23
           L array = np.append(L array, L)
           dif_array_50 = np.append(dif_array_50, np.mean(np.abs(gain_1-gain_2)))
           dif_array_29 = np.append(dif_array_29, np.mean(np.abs(gain_1-target_29)))
           dif_array_8 = np.append(dif_array_8, np.mean(np.abs(gain_1-target_8)))
28
29
30
       idx_50 = dif_array_50.argmin()
       idx_29 = dif_array_29.argmin()
       idx_8 = dif_array_8.argmin()
32
       print(f"Coupling length to 50% : {L_array[idx_50]/um}um\n"
               f"Coupling length to 29%: {L_array[idx_29]/um}um\n"
               f"Coupling length to 8%: {L_array[idx_8]/um}um")
```

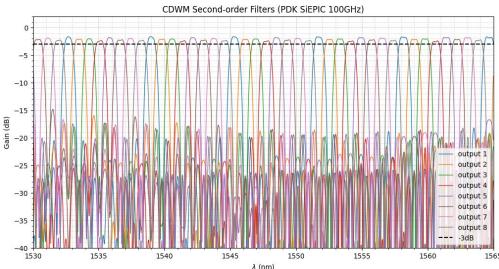
```
1 length = np.arange(0, 50, 2.5) * um
2 coupling(length)

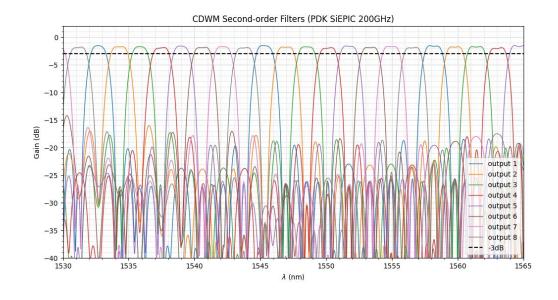
... Coupling length to 50%: 17.5um
Coupling length to 29%: 12.5um
Coupling length to 8%: 5.0um
```





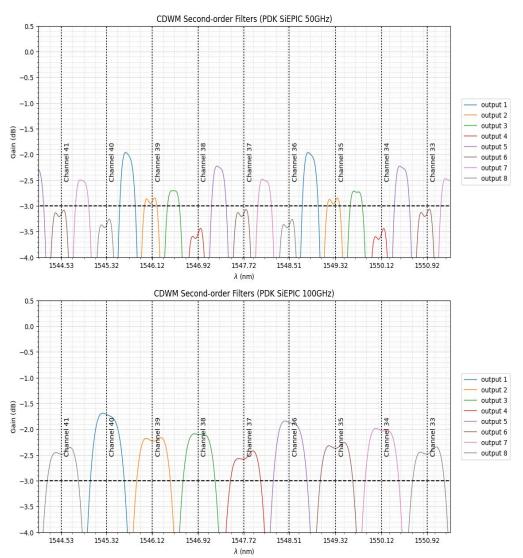


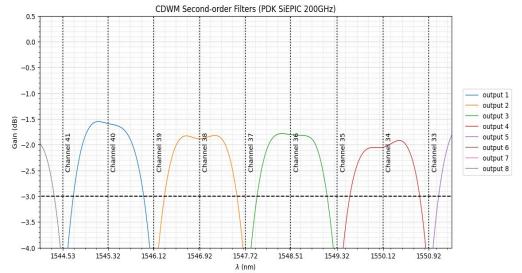


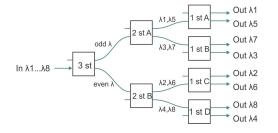


CDWM - Filtros de 2 estágios (PDK SiEPIC)





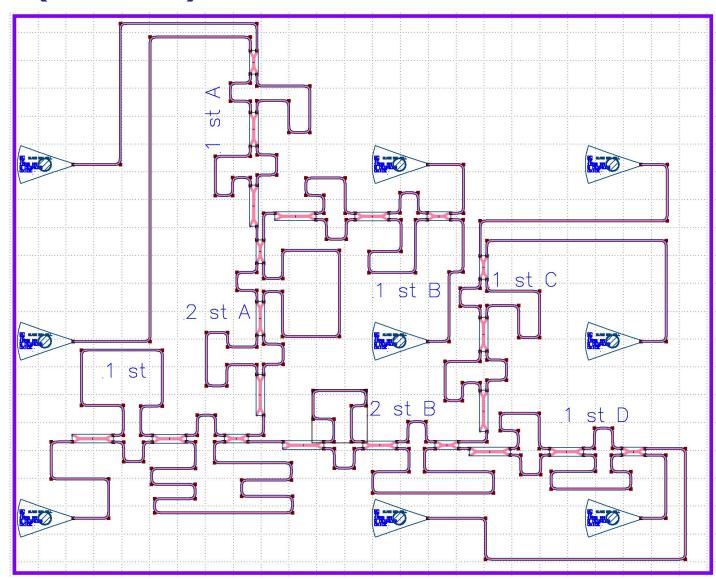








CDWM - KLayout (200 GHz)



Referências



- [1] Folkert Horst, William M.J. Green, Solomon Assefa, Steven M. Shank, Yurii A. Vlasov, and Bert Jan Offrein, "Cascaded Mach-Zehnder wavelength filters in silicon photonics for low loss and flat pass-band WDM (de-)multiplexing," Opt. Express 21, 11652-11658 (2013).
- [2] Luceda Photonics. "CWDM based on cascaded MZI lattice filters". Link: <u>2. CWDM based on cascaded MZI lattice filters Luceda Academy 2025.03 documentation</u>. Acessado em: 20/04/2025
- [3] FiberDyne. "Dense Wave Division Multiplexing (DWDM) ITU Grid: C-Band, 100 GHz Spacing". Link: *Fiberdyne-ITU-Grid-C-Band-100GHz.pdf*. Acessado em: 20/04/2025

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