Matriks Sederhana Menggunakan Rangkaian Fotonik

EL4062 Penelitian Rekayasa

13221044 Taufiq Hidayat

Pertanyaan Riset
"**Dapatkah** operasi matriks sederhana dilakukan dengan rangkaian fotonik?"

Hipotesis
Menggunakan rangkaian fotonik, dapat dirancang suatu sistem yang mampu menerima input matriks, melakukan pemrosesan matriks, dan menghasilkan output matriks yang sesuai.

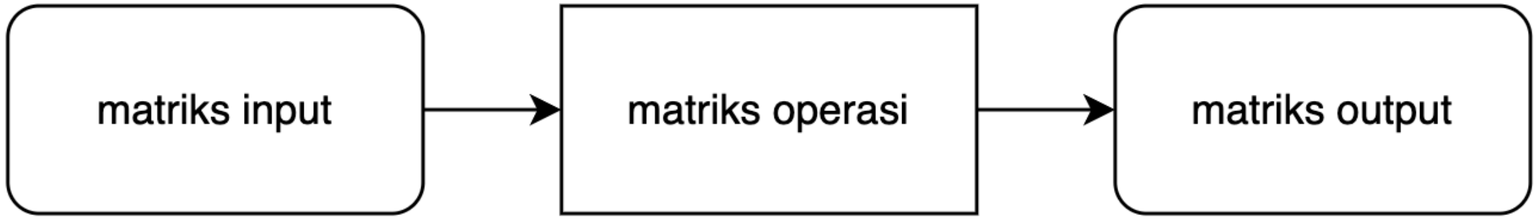
Metodologi
(1) Studi literatur publikasi yang terkait; (2) Pembelajaran *tools* untuk mendefinisikan devais dan rangkaian fotonik; (3) Simulasi sirkuit fotonik dengan menggunakan *tools* yang disediakan; (4) Verifikasi proses perhitungan matriks.

***Tools* yang Disediakan**
(1) GDSFactory (pemodelan); (2) KLayout (simulasi, verifikasi).

Deliverables
(1) Laporan Akhir;
(2) Script (source code) dari pemodelan rangkaian fotonik;
(3) Netlist rangkaian fotonik untuk operasi matriks sederhana.

Hipotesis

Menggunakan rangkaian fotonik, **dapat dirancang** suatu sistem yang mampu menerima input matriks, melakukan pemrosesan matriks, dan menghasilkan output matriks yang sesuai.



contoh :

$$\begin{bmatrix} a \\ b \end{bmatrix} \cdot \textit{matriks operasi} = \begin{bmatrix} b \\ a \end{bmatrix}$$

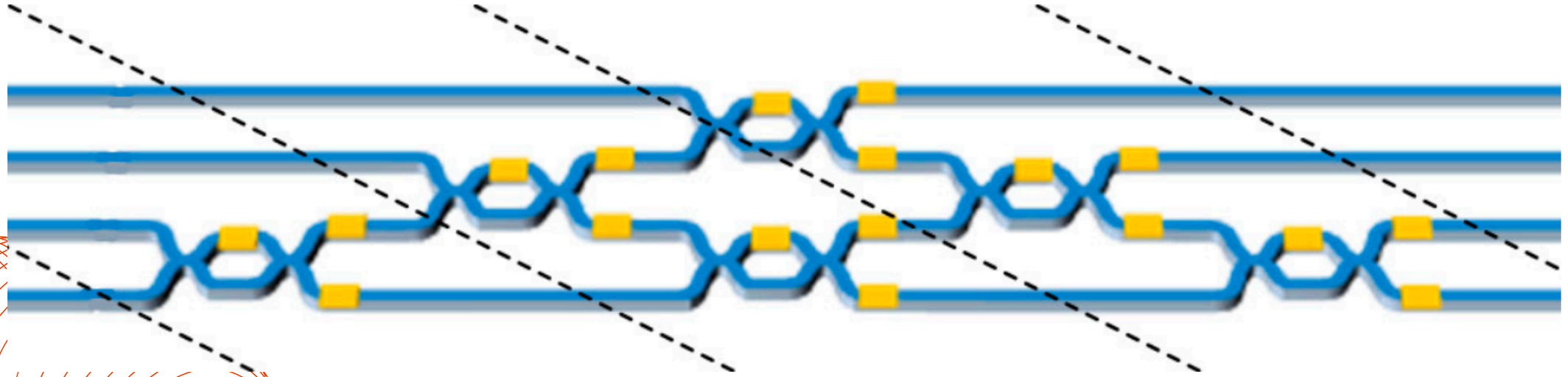
$$\begin{bmatrix} a \\ b \end{bmatrix} \cdot \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} = \begin{bmatrix} b \\ a \end{bmatrix}$$

(swap matrix)

Hasil Studi Literatur

"Dengan rangkaian fotonik, untuk matriks input N-komponen, **dapat dirancang** sistem matriks NxN yang mampu menghasilkan output matriks N-komponen"

$$\begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_N \end{bmatrix} \cdot \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1N} \\ w_{21} & w_{22} & \dots & w_{2N} \\ \dots & \dots & \dots & \dots \\ w_{N1} & w_{N2} & \dots & w_{NN} \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_N \end{bmatrix}$$



Cheng, J., Zhou, H., & Dong, J. (2021). Photonic Matrix Computing: From Fundamentals to Applications. Nanomaterials, 11(7), 1683. https://doi.org/10.3390/nano11071683

Tools yang Disediakan

GDS FACTORY

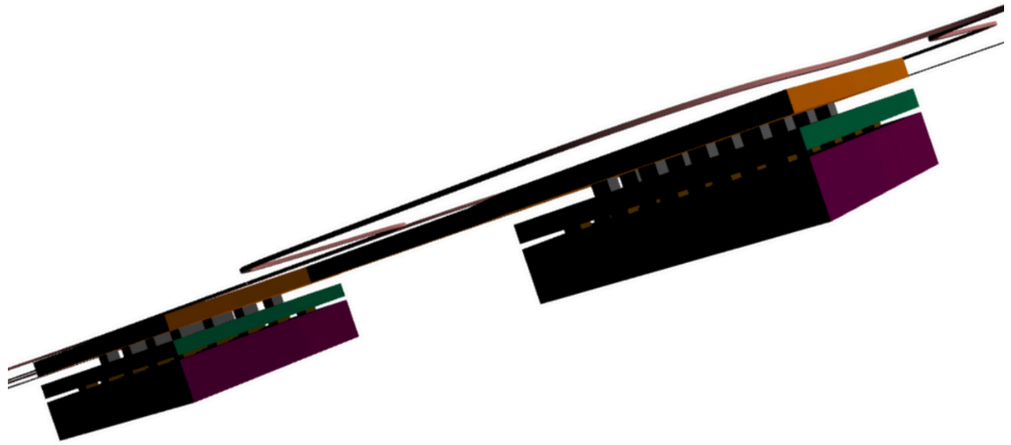
- **Layouting**
- **Schematic**
- **PDK**
- Sim. & Verifikasi

```python
bendS = gf.components.bend_euler_s(radius=20,p=0.5,
with_arc_floorplan=True, cross_section='strip',
allow_min_radius_violation=False, port1='o1', port2='o2').copy()

bendS.plot()
```

KLayout

- Layouting
- Schematic
- PDK
- **Sim. & Verifikasi**



Deliverables

(1) Laporan Akhir;

(2) Script (source code) dari pemodelan rangkaian fotonik;

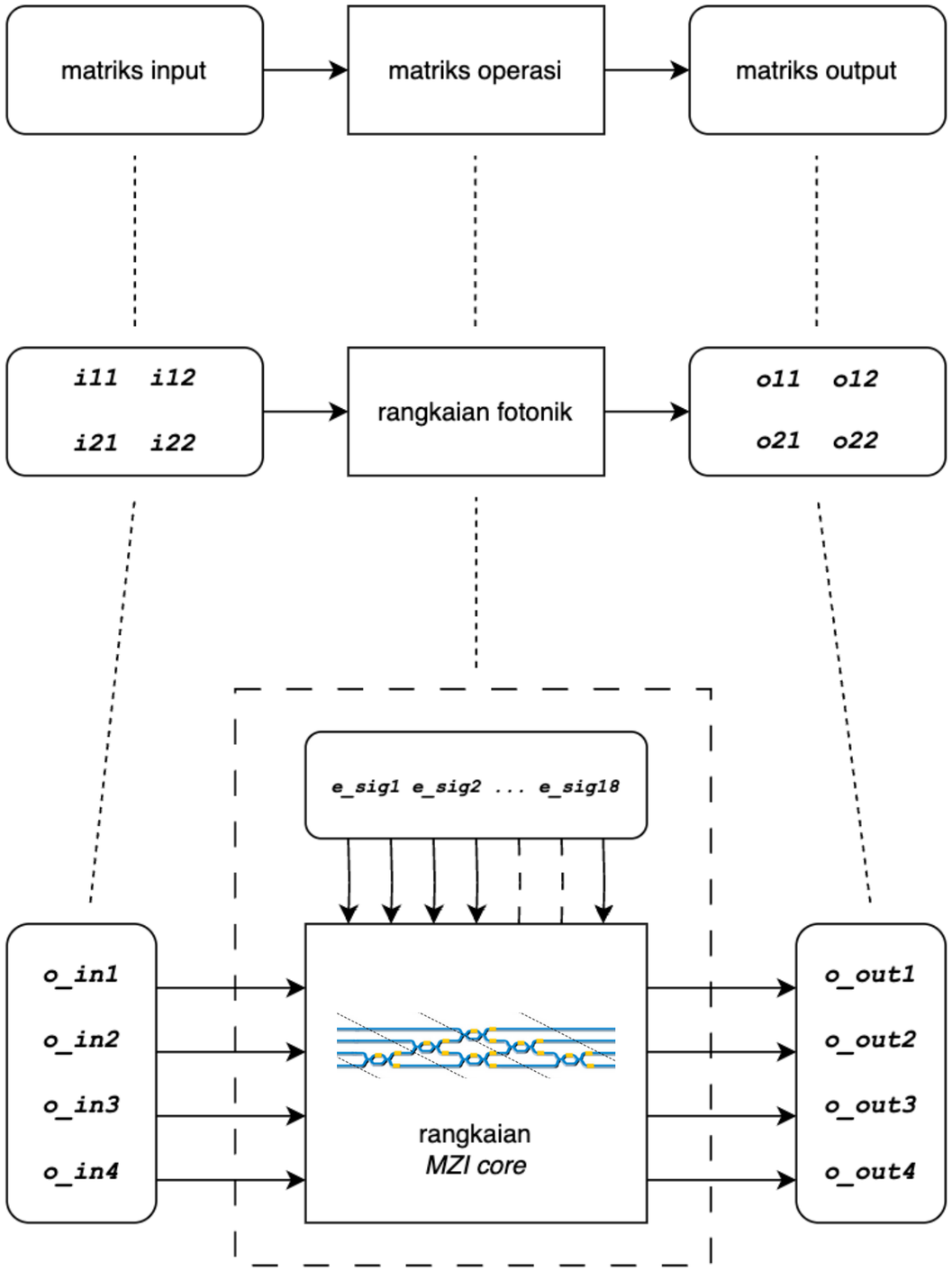
- script komponen-komponen penyusun **(✓)**
- script rangkaian operasi matriks **(✓)**

(3) Netlist rangkaian fotonik untuk operasi matriks sederhana.

- netlist rangkaian **(✓)**
- model 3d **(✓)**
- verifikasi
  - verifikasi desain **(✓)** *(verifikasi interkoneksi)*
  - verifikasi fungsi **(X)** *(verifikasi i/o)*

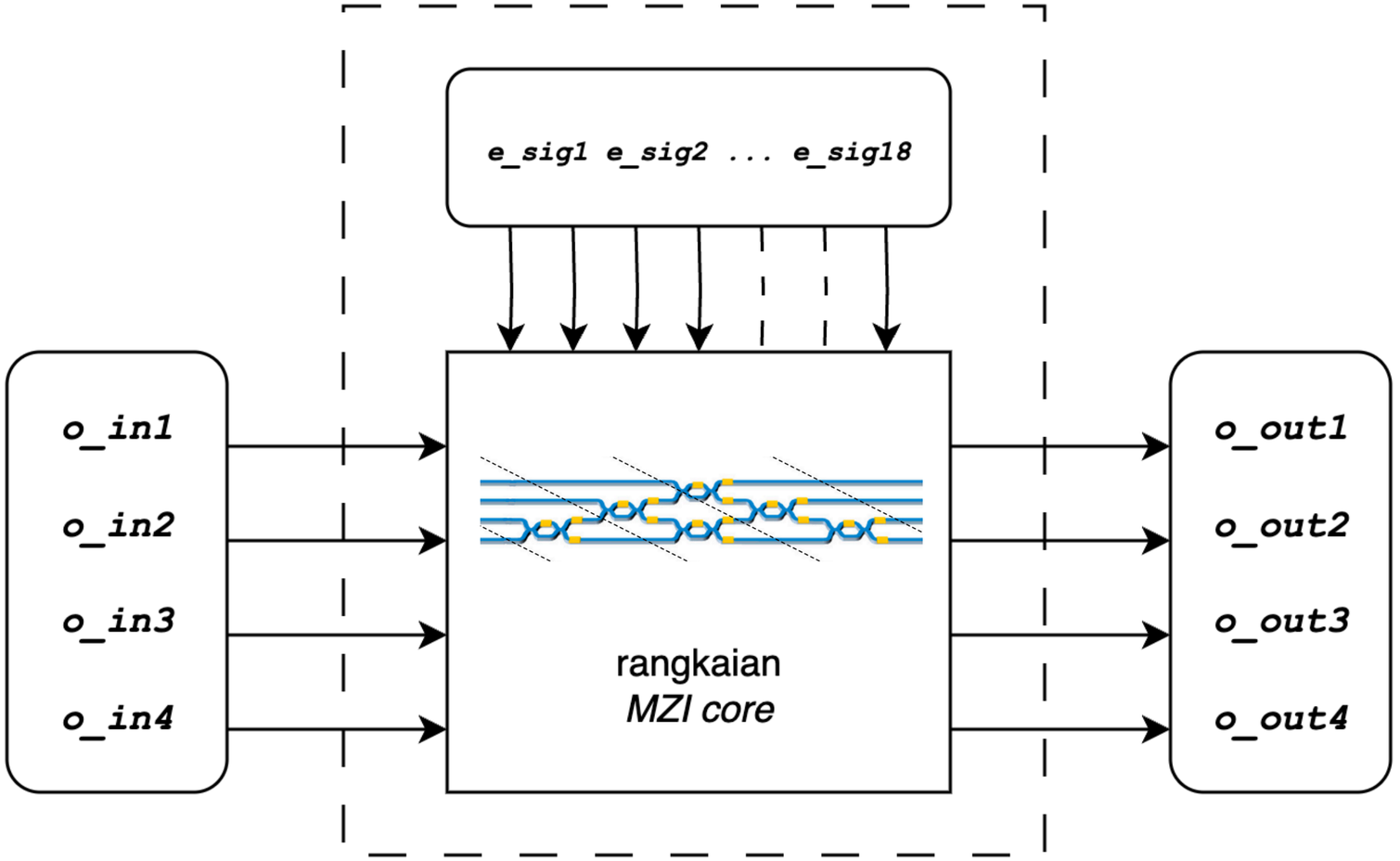
Deliverables: bagian laporan

pengembangan hipotesis

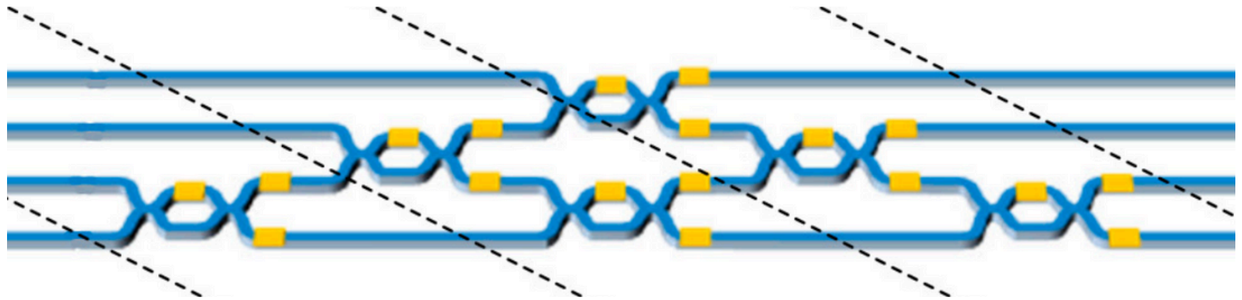


Deliverables:
bagian laporan

trace hasil
studi literatur

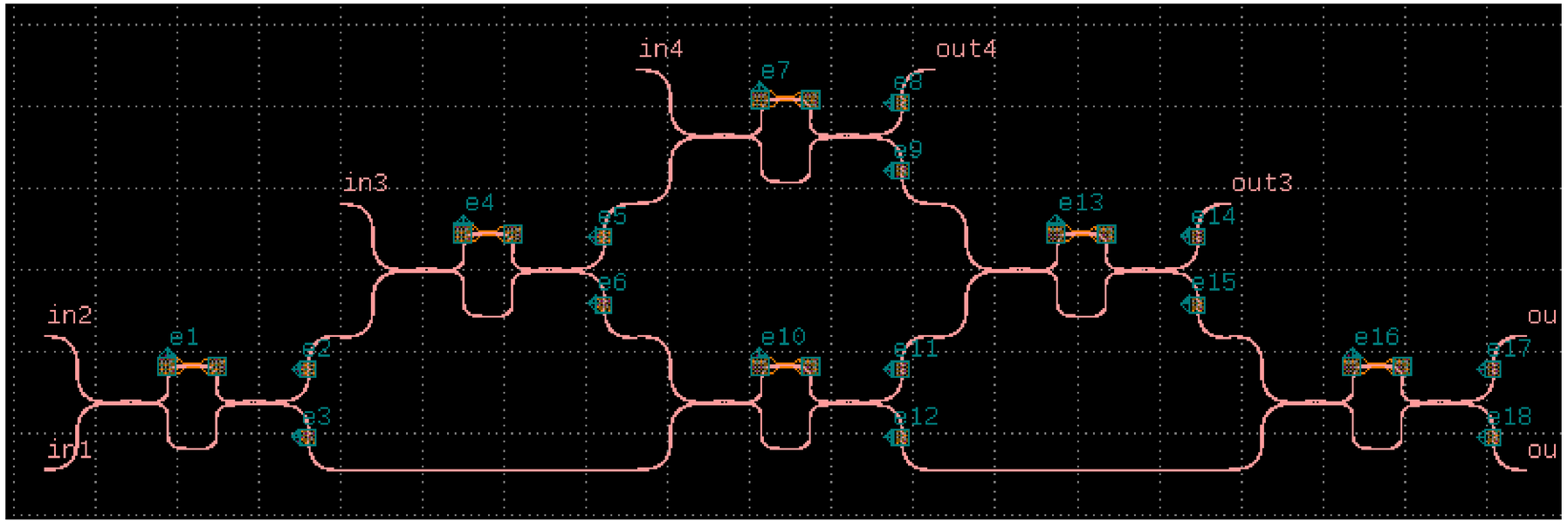


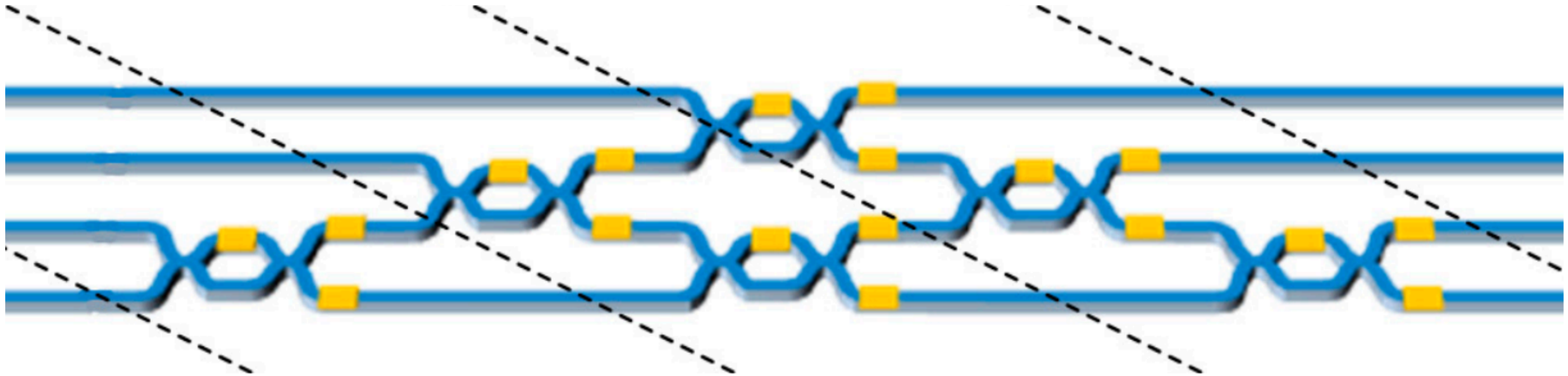
$$\begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_N \end{bmatrix} \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1N} \\ w_{21} & w_{22} & \dots & w_{2N} \\ \dots & \dots & \dots & \dots \\ w_{N1} & w_{N2} & \dots & w_{NN} \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_N \end{bmatrix}$$



Deliverables: *script* rangkaian operasi matriks

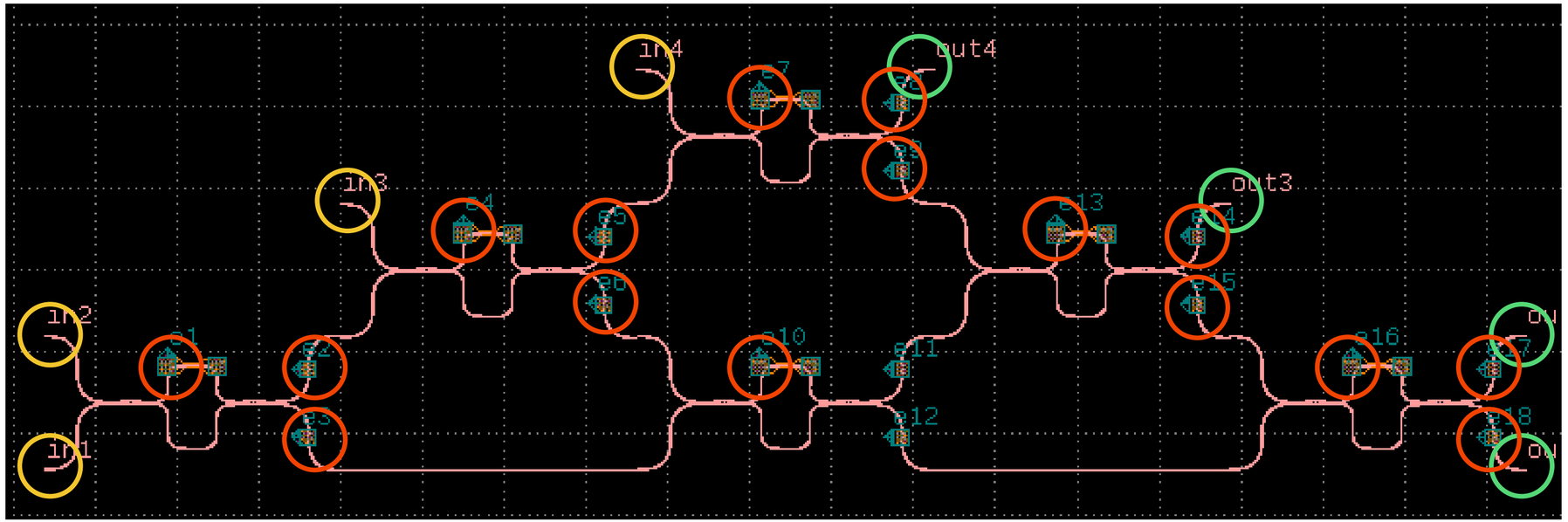
output compile script rangkaian (skematik)





Deliverables: *script* rangkaian operasi matriks

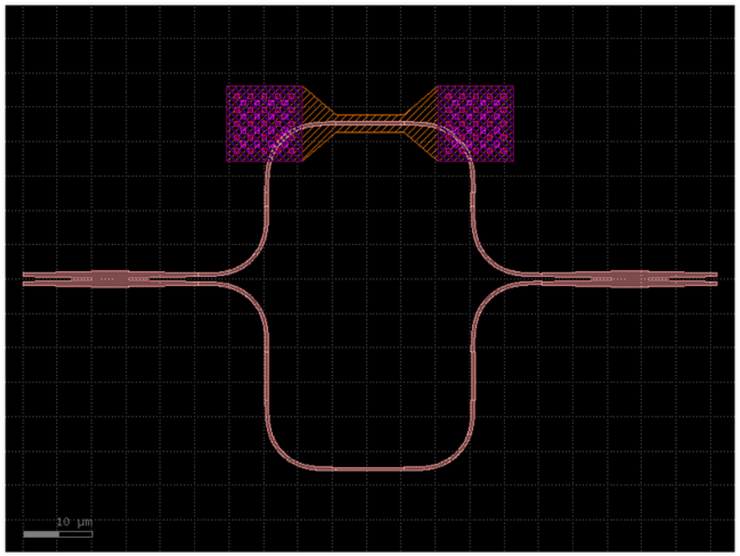
output compile script rangkaian (skematik)

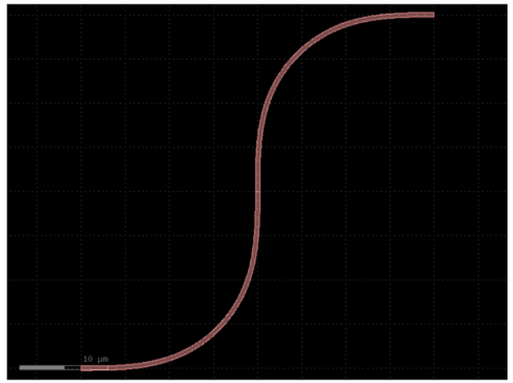


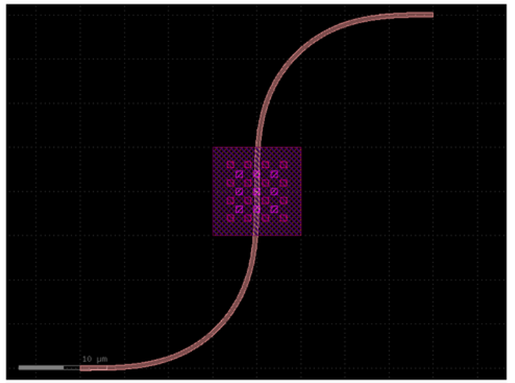
$$\begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_N \end{bmatrix} \quad \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1N} \\ w_{21} & w_{22} & \dots & w_{2N} \\ \dots & \dots & \dots & \dots \\ w_{N1} & w_{N2} & \dots & w_{NN} \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_N \end{bmatrix}$$

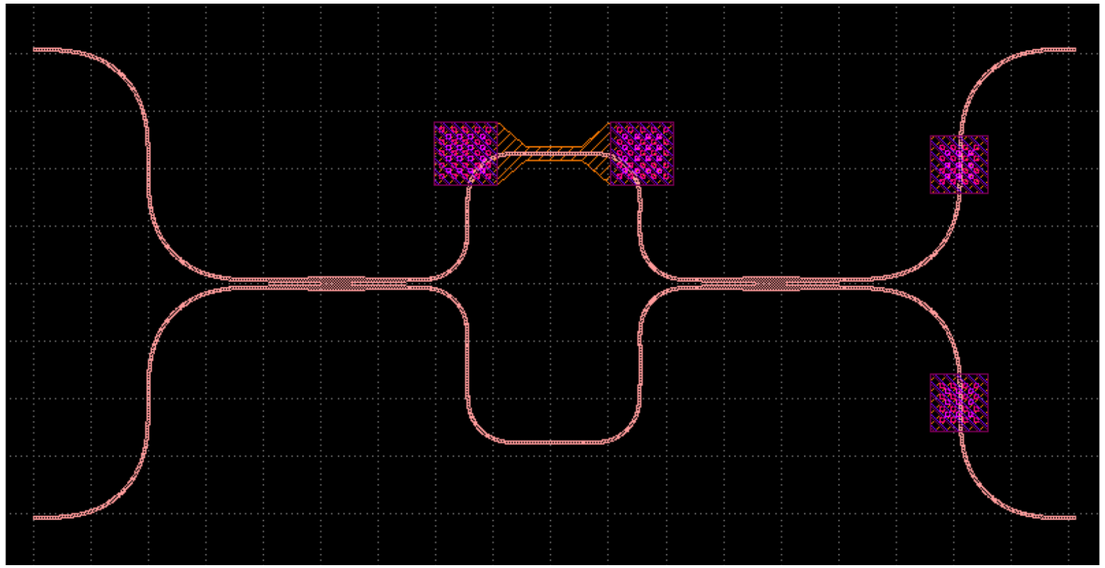
Deliverables:
***script* model**

output compile
script komponen



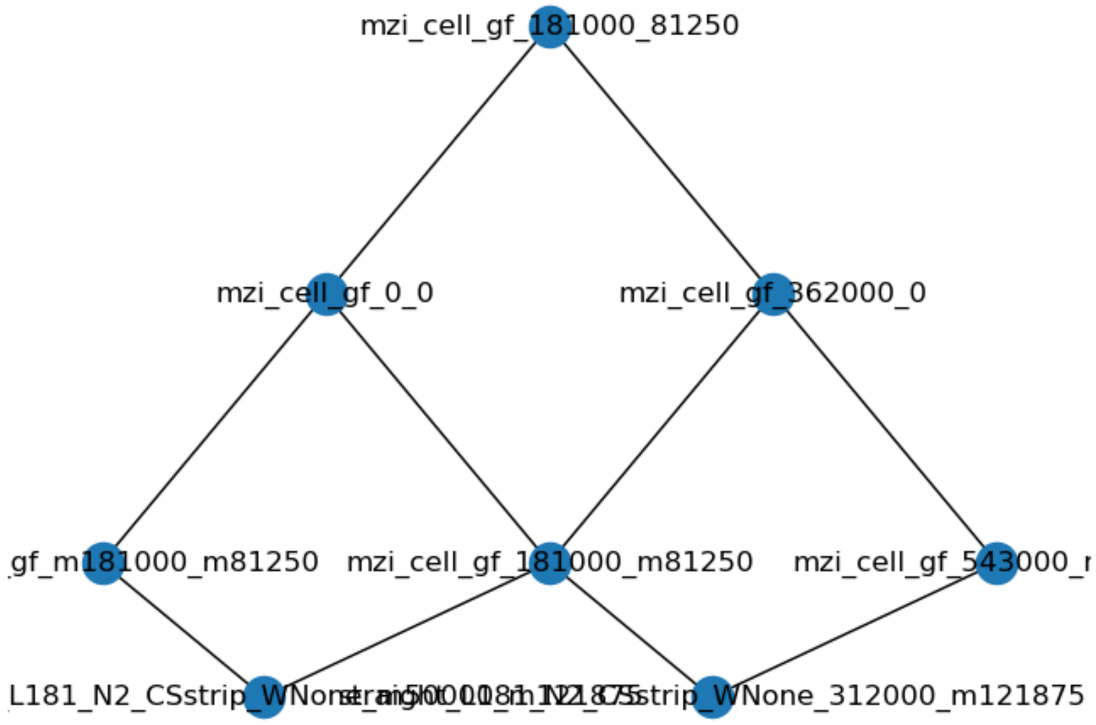




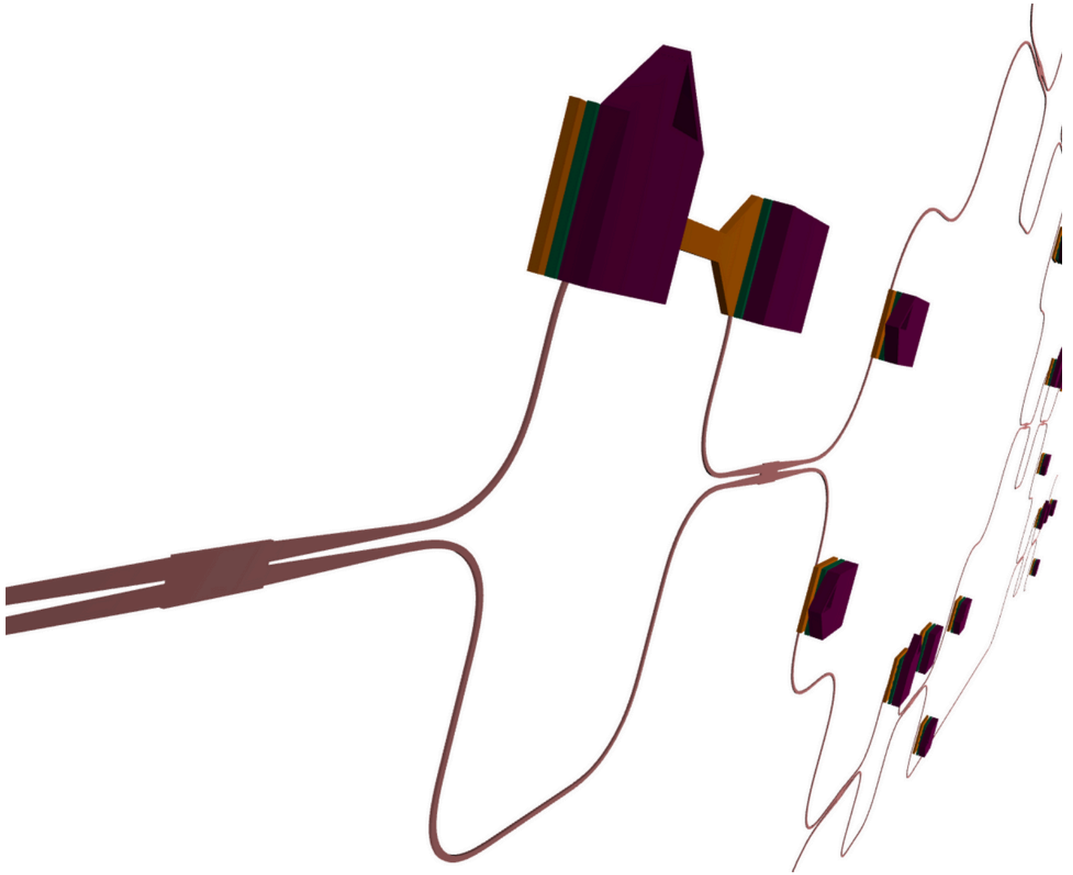


Deliverables: netlist rangkaian

netlist rangkaian



model 3d



Deliverables: netlist rangkaian

verifikasi desain

name	width	orientation	layer	center	port_type
in1	0.5	180.0	WG (1/0)	(-231.0, -121.875)	optical
in2	0.5	180.0	WG (1/0)	(-231.0, -40.625)	optical
in3	0.5	180.0	WG (1/0)	(-50.0, 40.625)	optical
in4	0.5	180.0	WG (1/0)	(131.0, 121.875)	optical
out4	0.5	0.0	WG (1/0)	(312.0, 121.875)	optical
out3	0.5	0.0	WG (1/0)	(493.0, 40.625)	optical
out2	0.5	0.0	WG (1/0)	(674.0, -40.625)	optical
out1	0.5	0.0	WG (1/0)	(674.0, -121.875)	optical
e1	11.0	90.0	MTOP (49/0)	(-155.9, -53.125)	electrical
e2	10.0	180.0	MTOP (49/0)	(-75.0, -60.625)	electrical
e3	10.0	180.0	MTOP (49/0)	(-75.0, -101.875)	electrical
e4	11.0	90.0	MTOP (49/0)	(25.1, 28.125)	electrical
e5	10.0	180.0	MTOP (49/0)	(106.0, 20.625)	electrical
e6	10.0	180.0	MTOP (49/0)	(106.0, -20.625)	electrical
e7	11.0	90.0	MTOP (49/0)	(206.1, 109.375)	electrical
e8	10.0	180.0	MTOP (49/0)	(287.0, 101.875)	electrical
e9	10.0	180.0	MTOP (49/0)	(287.0, 60.625)	electrical
e10	11.0	90.0	MTOP (49/0)	(206.1, -53.125)	electrical
e11	10.0	180.0	MTOP (49/0)	(287.0, -60.625)	electrical
e12	10.0	180.0	MTOP (49/0)	(287.0, -101.875)	electrical
e13	11.0	90.0	MTOP (49/0)	(387.1, 28.125)	electrical
e14	10.0	180.0	MTOP (49/0)	(468.0, 20.625)	electrical
e15	10.0	180.0	MTOP (49/0)	(468.0, -20.625)	electrical
e16	11.0	90.0	MTOP (49/0)	(568.1, -53.125)	electrical
e17	10.0	180.0	MTOP (49/0)	(649.0, -60.625)	electrical
e18	10.0	180.0	MTOP (49/0)	(649.0, -101.875)	electrical

verifikasi fungsi *(error simulasi)*

```
ERROR: Your simulation is aborted due to insufficient balance. You
can reduce the simulation cost with
'https://www.flexcompute.com/tidy3d/learning-center/faq/#how-can-i-
reduce-the-simulation-cost' or click
'https://tidy3d.simulation.cloud/account?tab=plan' to add more
credits.

[B Maximum FlexCredit cost: 111.592 for the whole batch.

   Use 'Batch.real_cost()' to get the billed FlexCredit cost after the
   Batch has completed.

_0: status = draft ──────────────────────────────────────── 100% 0:00:00
_0: status = draft ──────────────────────────────────────── 100% 0:00:00
_0: status = draft ──────────────────────────────────────── 100% 0:00:00
_0: status = draft ──────────────────────────────────────── 100% 0:00:00

[B Batch complete.
```

Deliverables: netlist rangkaian

verifikasi fungsi *(error simulasi)*

```
ERROR: Your simulation is aborted due to insufficient balance. You
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_0: status = draft ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100% 0:00:00
_0: status = draft ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100% 0:00:00
_0: status = draft ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100% 0:00:00
_0: status = draft ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 100% 0:00:00

[B Batch complete.
```
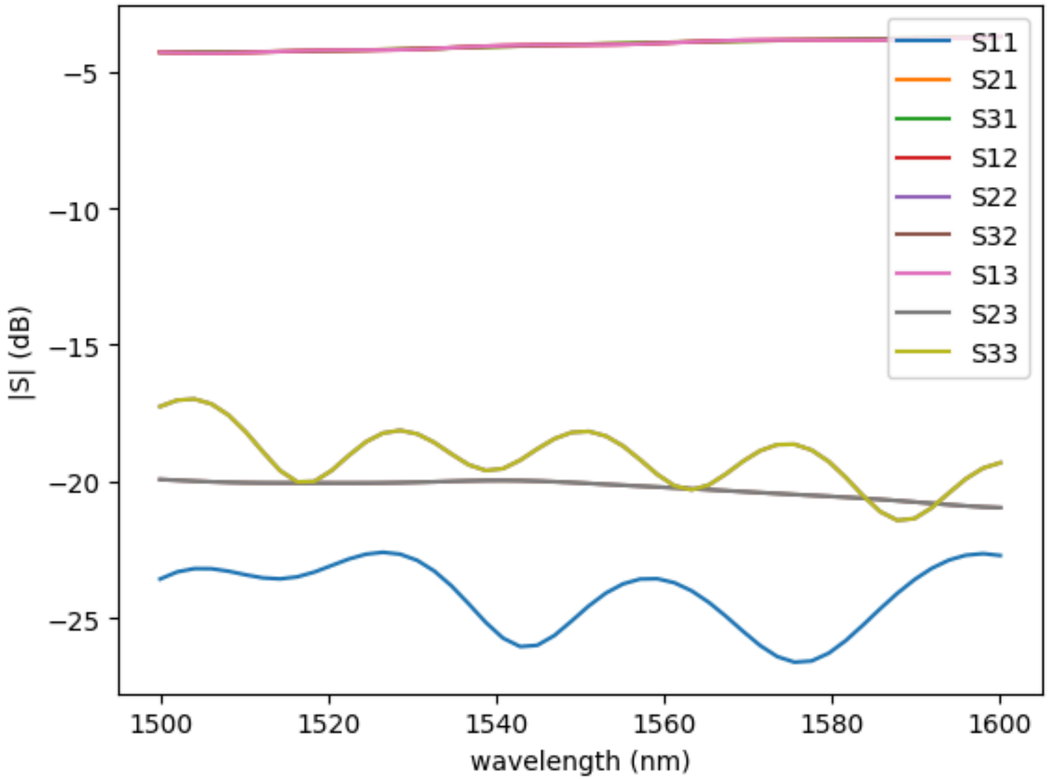

verifikasi fungsi *(ekspektasi output)*



$S(i, j)$ → rasio sinyal port-i (output) thd. port-j (input)

No	Kegiatan	Pekan																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Instalasi *tools* pendukung																			
2	Studi pustaka																			
3	Pembelajaran *tools*																			
4	Replikasi penelitian																			
5	Penyusunan laporan tengah semester																			
6	Eksperimen																			
7	Penyusunan hasil dan laporan akhir semester																			

planned

actual

Terima kasih