



Universidade Federal
de Campina Grande

Projeto de circuitos fotônicos em silício

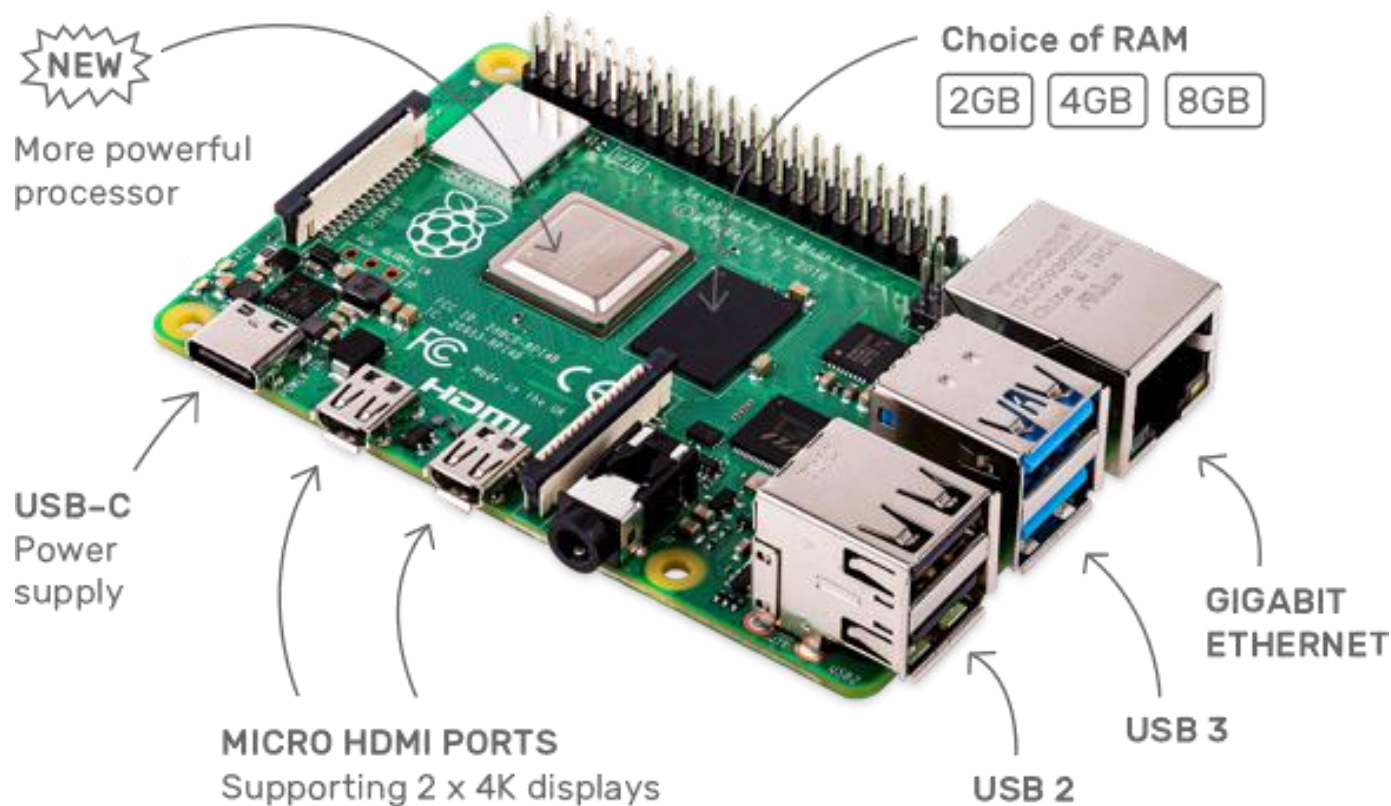
Aula 1: introdução ao conteúdo da disciplina

Prof. Adolfo Fernandes Herbster

Introdução

- O que é um circuito?
 - Conjunto de componentes correlacionados de maneira à desempenhar uma funcionalidade desejada;
 - Exemplos: circuito elétrico (quais componentes?)
- O que é um circuito integrado?
 - Conjunto de componentes discretos e blocos individuais que resultam em um circuito com funcionalidade global;
 - Exemplo: circuito elétrico integrado

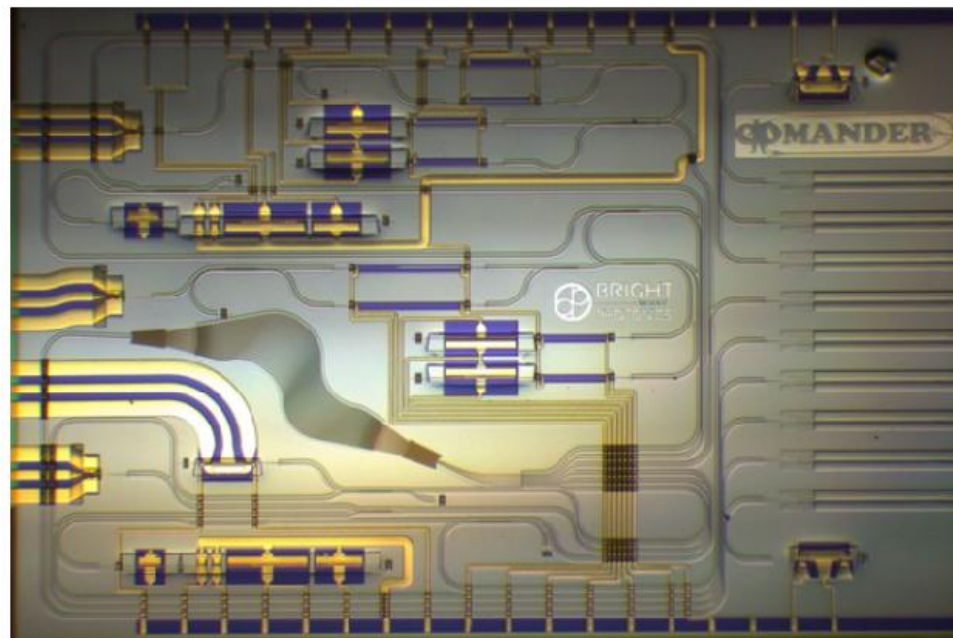
Introdução



Fonte: <https://www.raspberrypi.com/>

Introdução

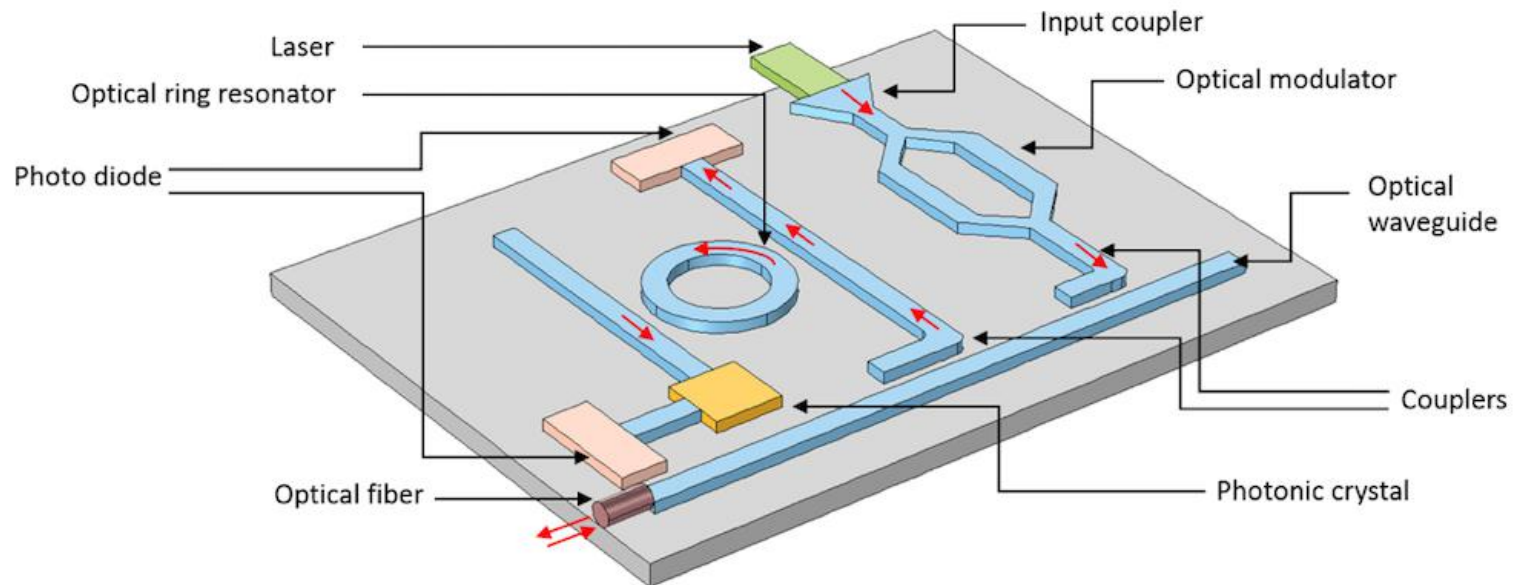
- O que é um circuito fotônico integrado?
 - Conjunto de componentes discretos e blocos individuais que resultam em um circuito com funcionalidade global;



Fonte: <https://brightphotonics.eu/>

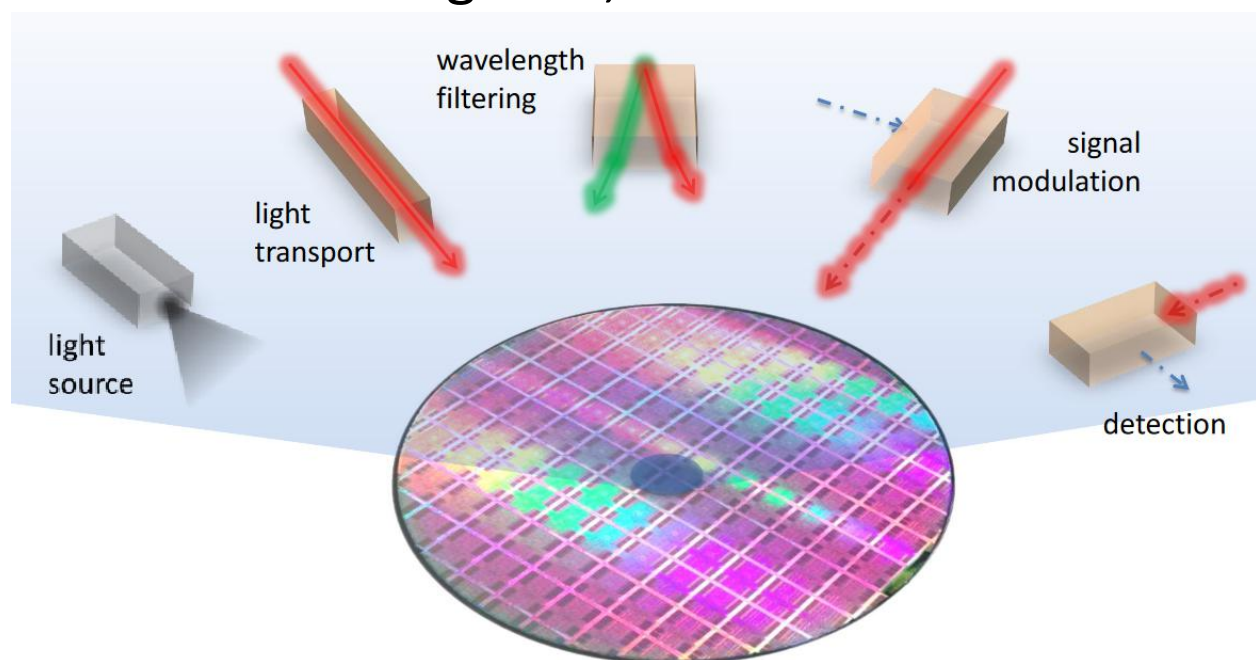
Introdução

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 - Conjunto de **componentes discretos** e **blocos individuais** que resultam em um circuito com funcionalidade global;



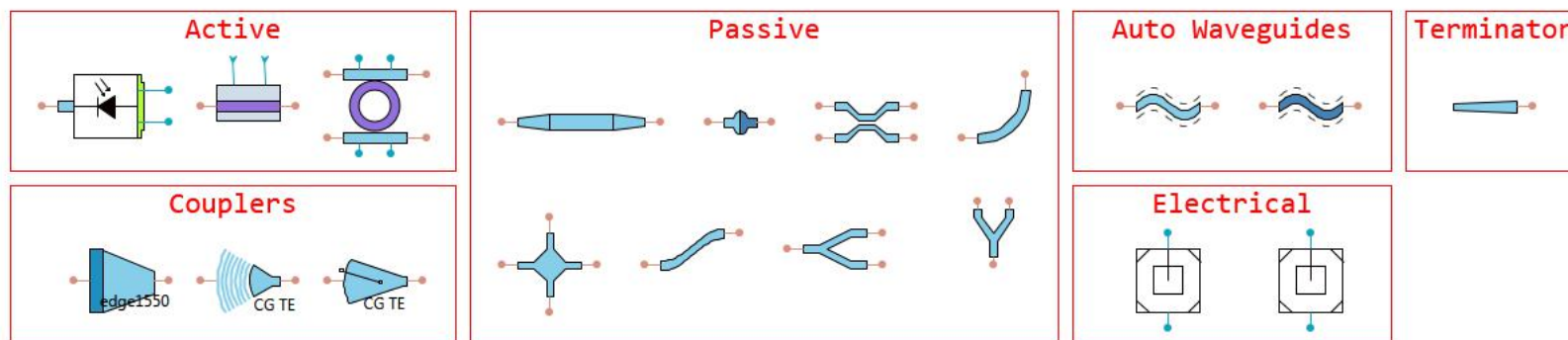
Introdução

- O que é um circuito fotônico integrado?
 - Conjunto de **componentes discretos** e **blocos individuais** que resultam em um circuito com funcionalidade global;



Introdução

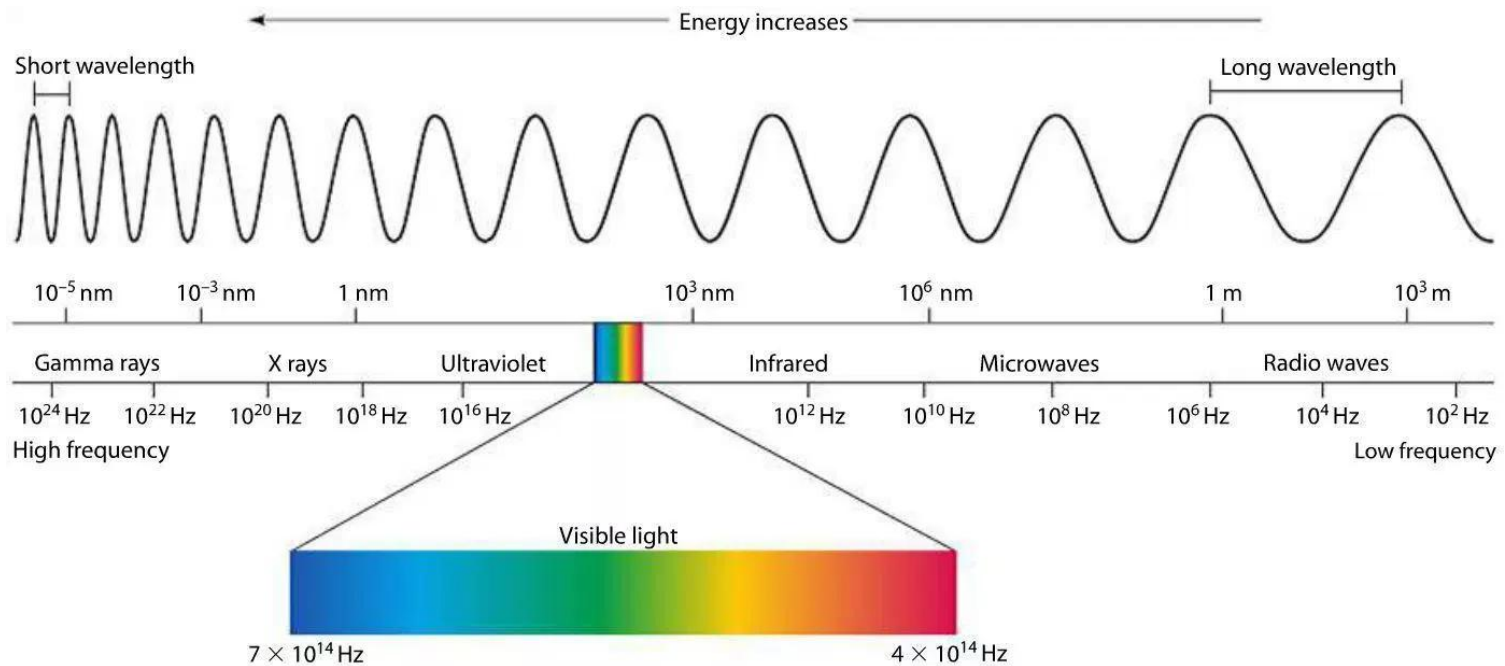
- O que é um circuito fotônico integrado?
 - Conjunto de **componentes discretos** e **blocos individuais** que resultam em um circuito com funcionalidade global;



Overview of building blocks available in VPItoolkit PDK GPIC

Introdução

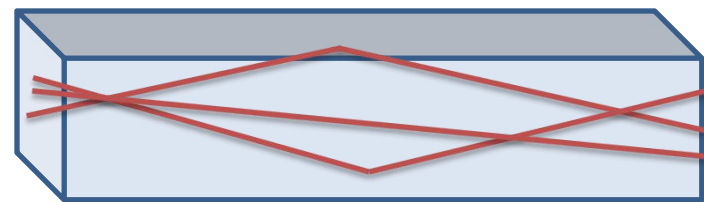
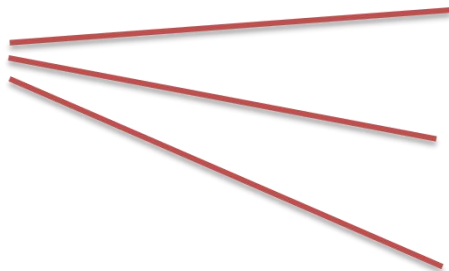
- O espectro eletromagnético



$$\lambda f = c \rightarrow \lambda = c/f$$

Introdução

- Condição básica do guiamento: reflexão interna total
- Condições:
 - guia sem perdas (ou baixa perdas);
 - Índice de refração do meio menor que o índice do guia;



Introdução

- Por qual motivo utilizar Silício?
 - **Compatível com a tecnologia CMOS (alta escala);**
 - **Transparente na região de 1.3 - 1.6 μm ;**
 - **Alto contraste de índice - menor *footprint*;**
 - **Baixo custo;**
 - **Sem detecção na região 1.3 - 1.6 μm ;**
 - **Sem efeito eletro-óptico;**
 - **Alto contraste de índice - acoplamento;**
 - **Falhas na emissão de luz (eficiência);**

Introdução

– Por qual motivo utilizar Silício?

- Ti
- C
- B
- A
- S
- S
- A
- F

ala);

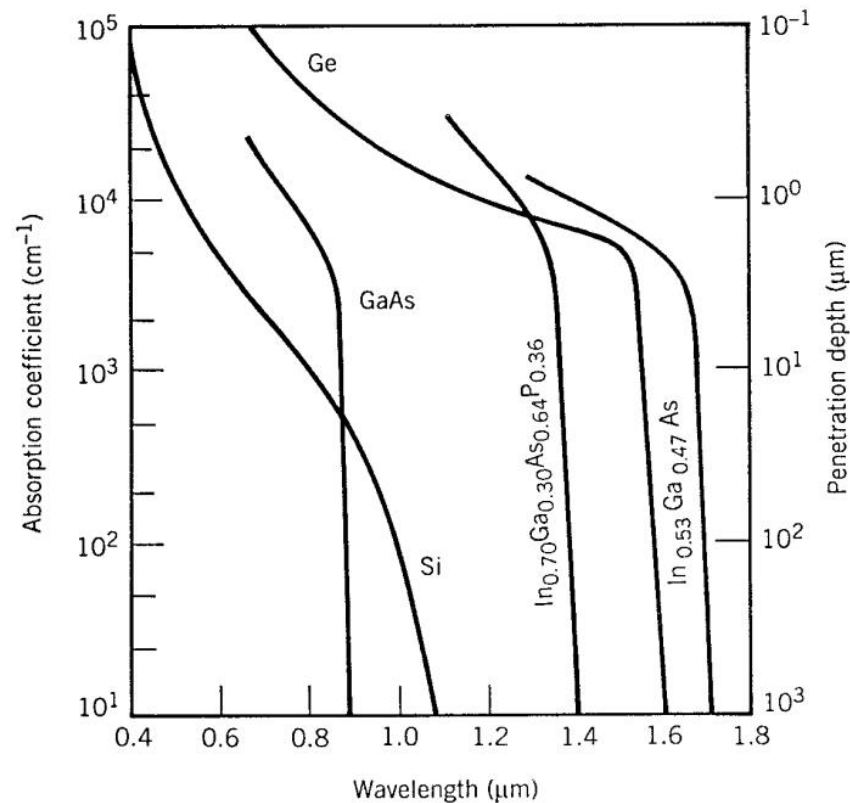
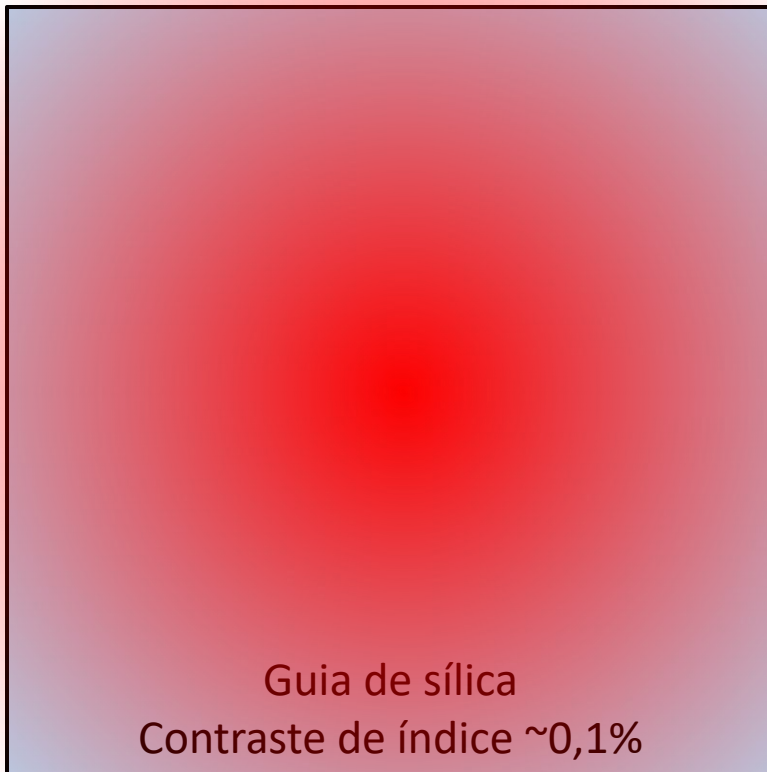
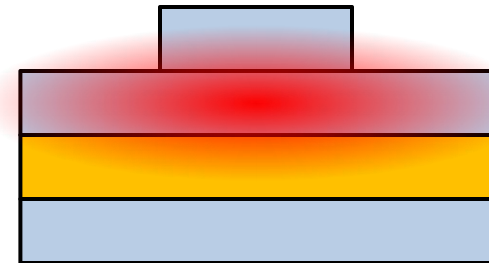


Figure 4.2: Wavelength dependence of the absorption coefficient for several semiconductor materials. (After Ref. [2]; ©1979 Academic Press; reprinted with permission.)

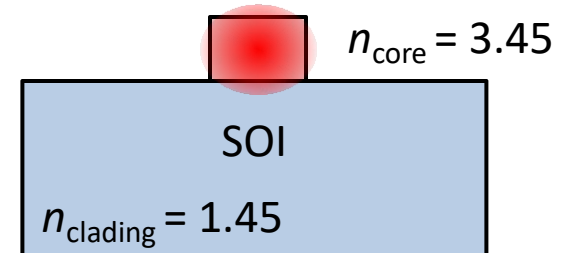
Contraste de índice



III-V Semicondutores
Contraste $\sim 10\%$



Guia de silício
Contraste $\sim 200\%$

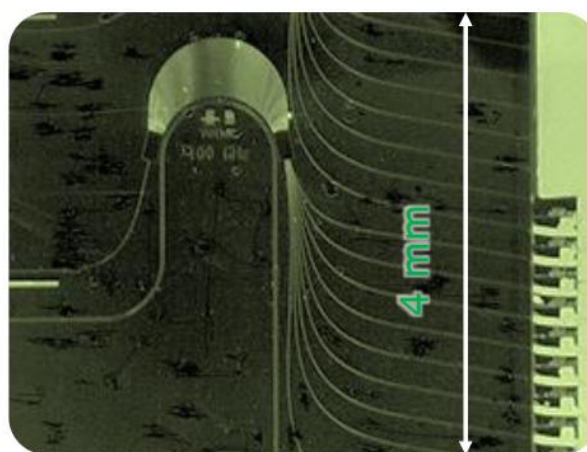


Contraste de índice



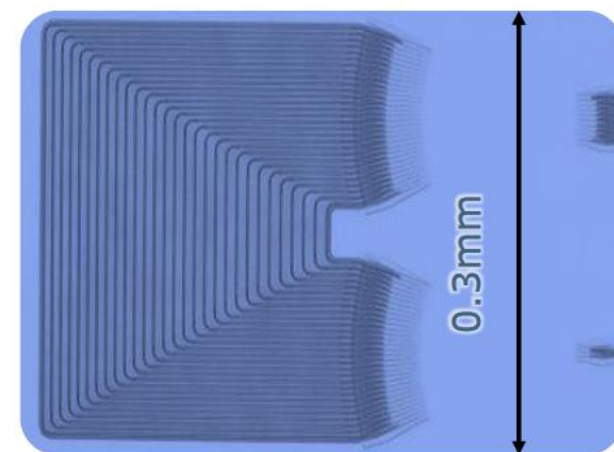
Sílica em sílica

Contraste $\sim 0,01 - 0,1$
Diâmetro do modo $\sim 8 \mu\text{m}$
Curvatura $\sim 5 \text{ mm}$
Tamanho $\sim 10 \text{ cm}^2$



Fosfato de índio (InP)

Contraste $\sim 0,2 - 0,5$
Diâmetro do modo $\sim 2 \mu\text{m}$
Curvatura $\sim 0,5 \text{ mm}$
Tamanho $\sim 10 \text{ mm}^2$



Silicon on insulator (SOI)

Contraste $\sim 1,0 - 2,5$
Diâmetro do modo $\sim 0,4 \mu\text{m}$
Curvatura $\sim 5 \mu\text{m}$
Tamanho $\sim 0,1 \text{ mm}^2$

Adaptado de http://www.photonics.intec.ugent.be/download/pub_4128.pdf

Redução de dimensão (10000x)



Aumento de complexidade - circuitos (10000x)

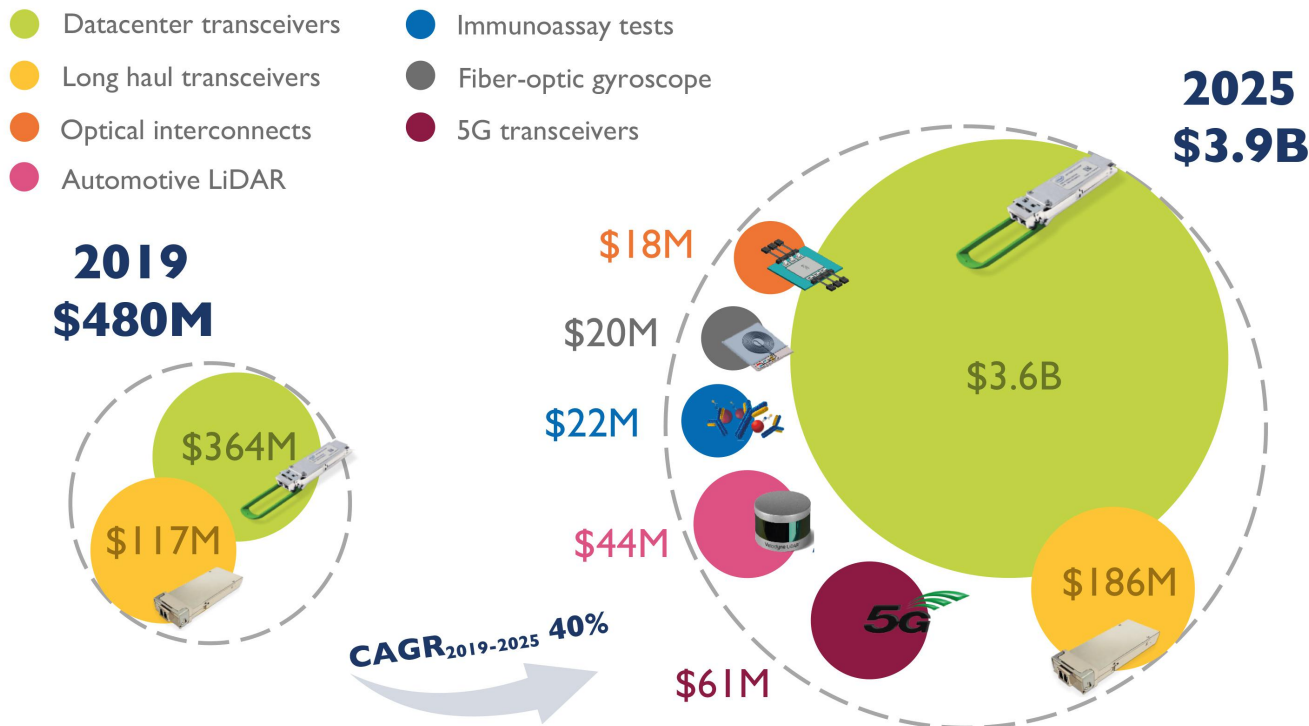
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Silicon photonic 2019-2025 market forecast by application

(Source: Silicon Photonics 2020 report, Yole Développement, 2020)



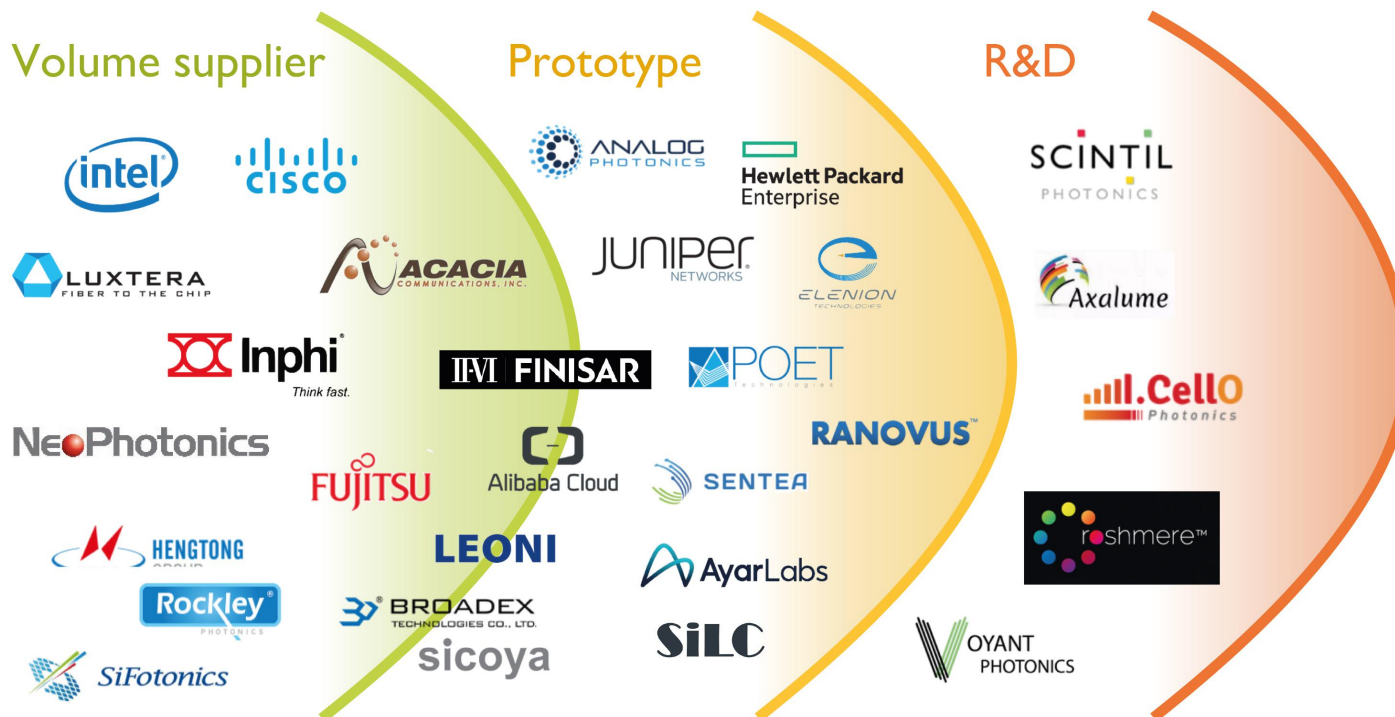
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Readiness of silicon photonic players

(Source: Silicon Photonics 2020 report, Yole Développement, 2020)

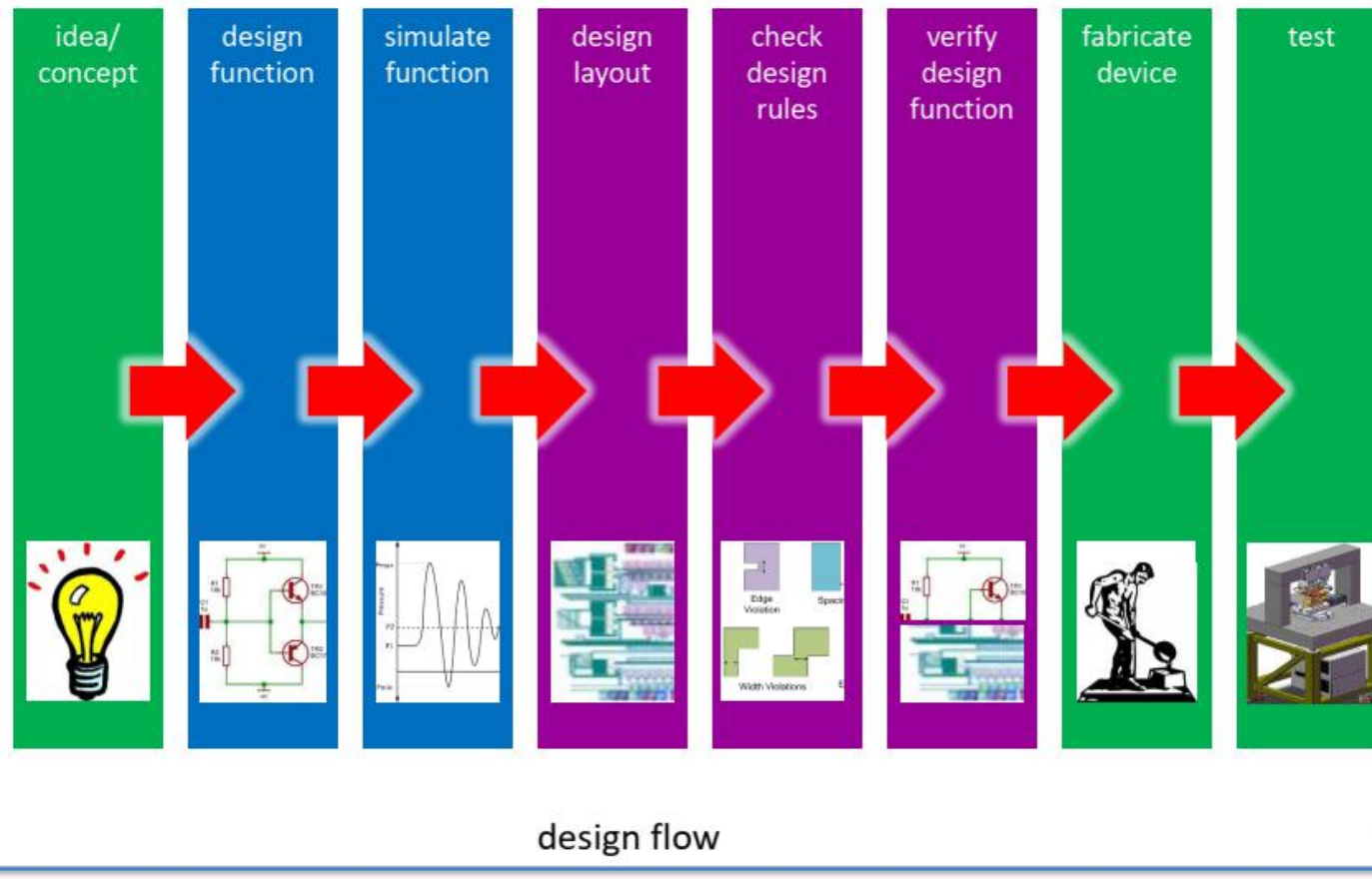


Introdução

Metodologia simples de projeto



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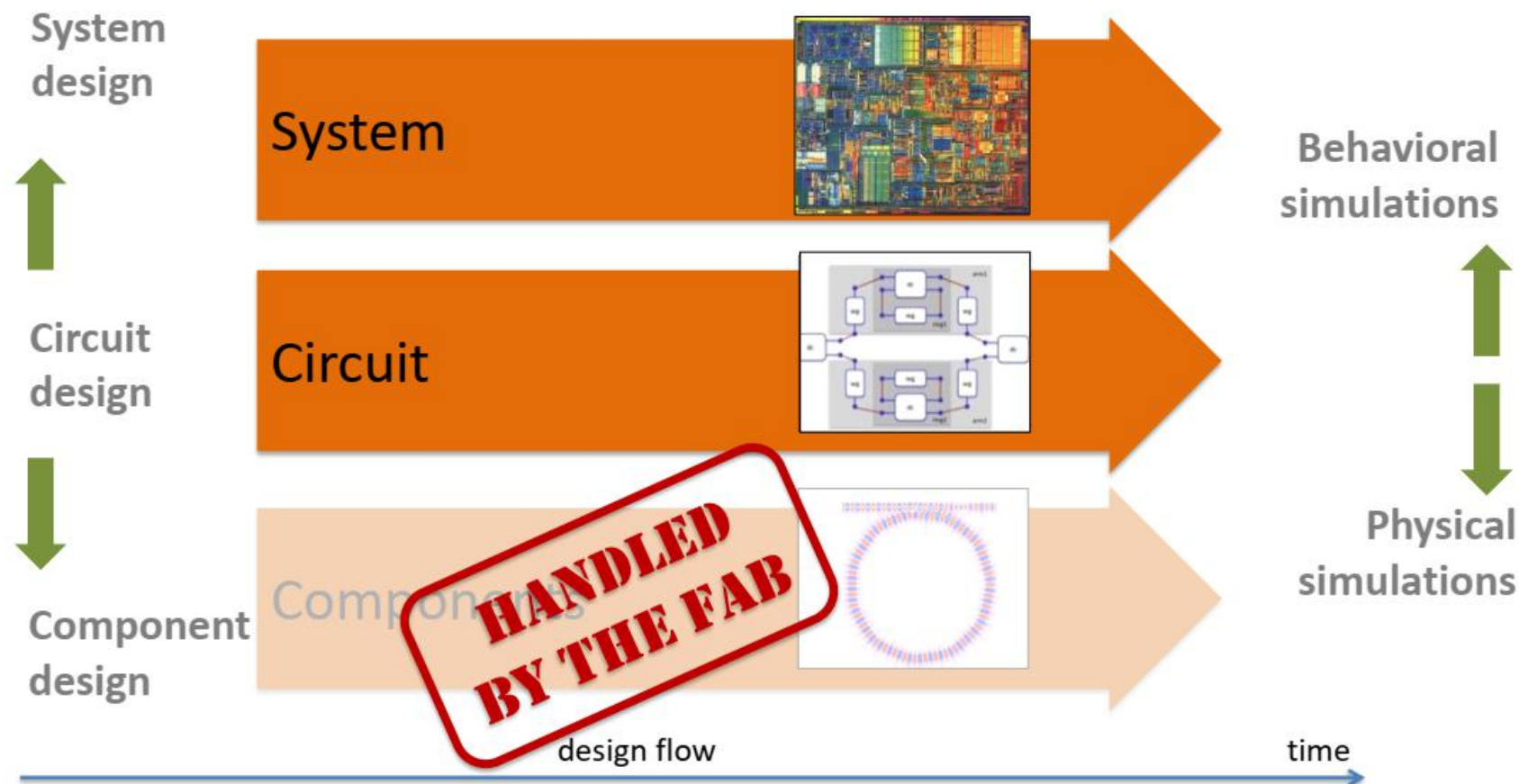
Adaptado de http://www.photonics.intec.ugent.be/download/pub_4128.pdf

Introdução

Abstração



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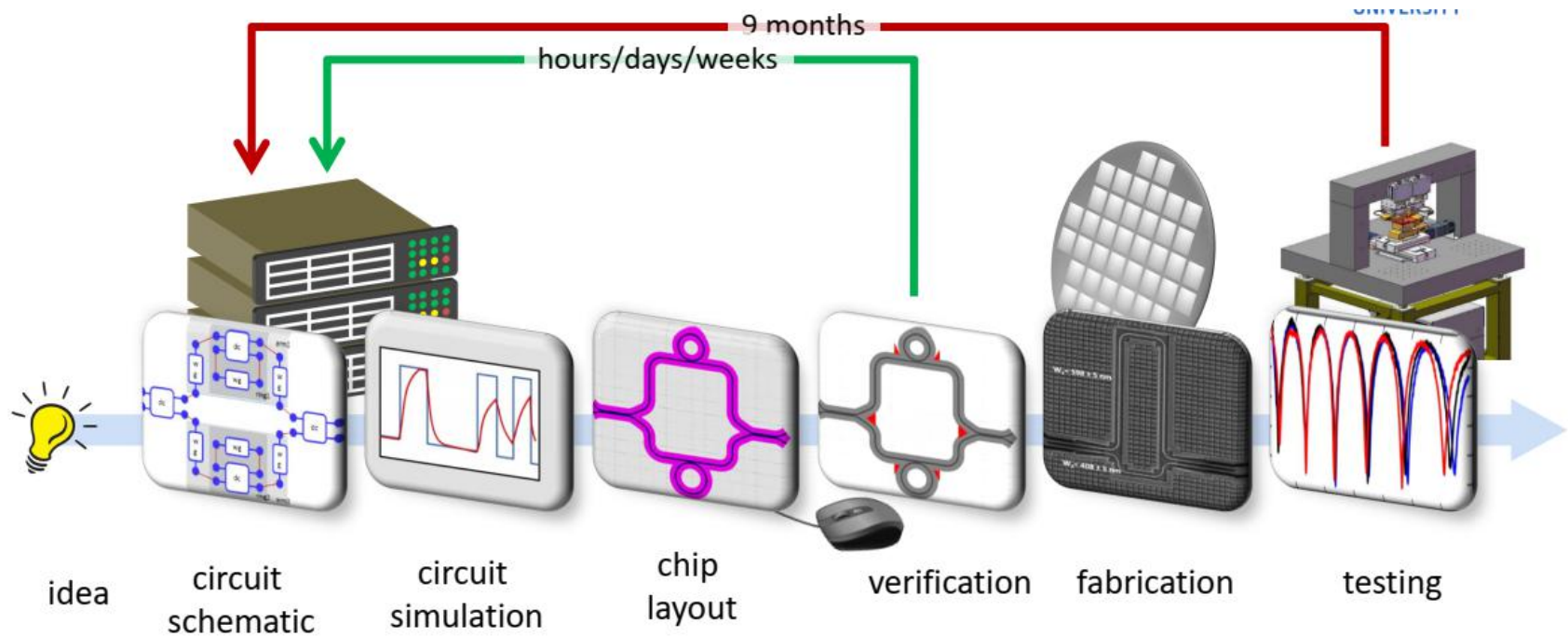
Adaptado de http://www.photonics.intec.ugent.be/download/pub_4128.pdf

Introdução

Abstração



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Ementa

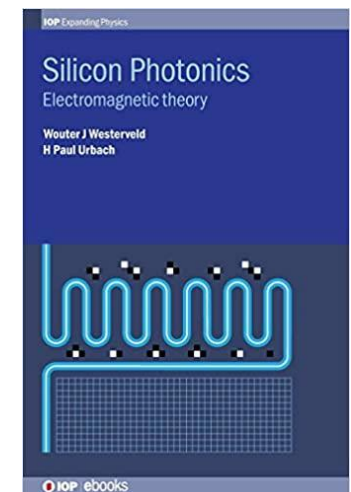
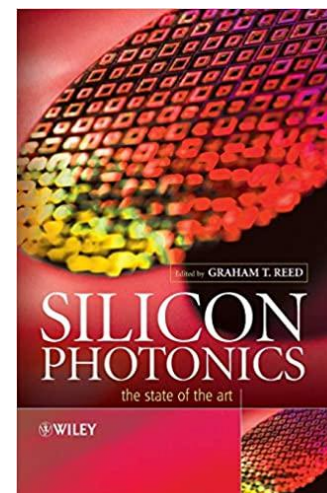
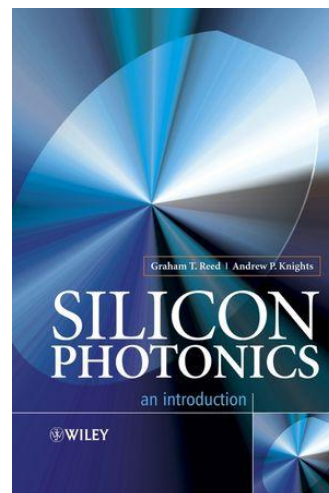
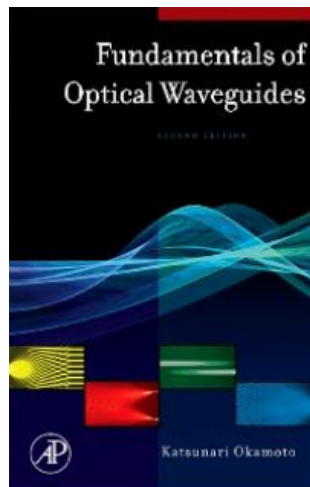
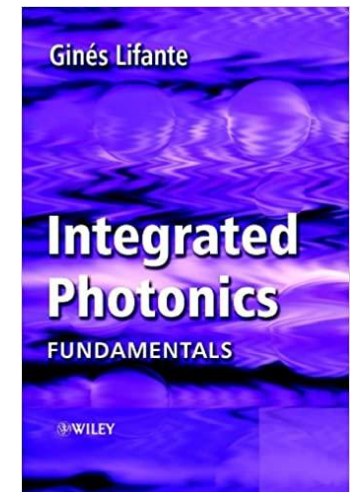
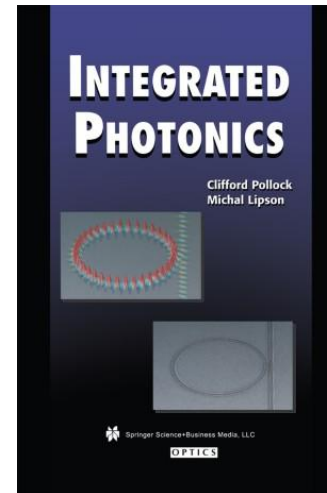
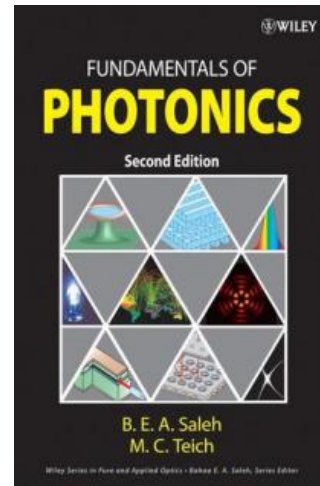
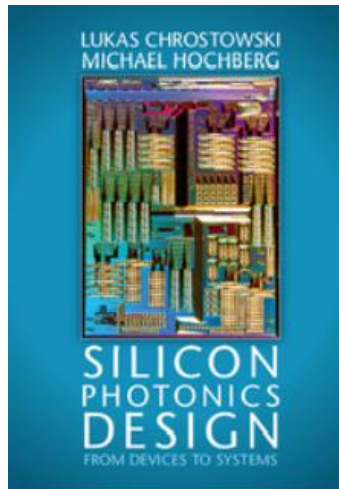
Item	Tema
1	Revisão - eletromagnetismo
2	Problema modal
3	Guia slab simétrico
4	Guia slab assimétrico
5	Guias retangulares
6	Acopladores de guias ópticos
7	Teoria dos modos acoplados
8	Acopladores ópticos
9	Interferômetros de Mach-Zehnder
10	Ressonadores ópticos em anel
11	Grades de Bragg
12	Layout de circuitos fotônicos
13	Modelos compactos de componentes

- Atividades de laboratório
 - Lumerical MODE
 - Lumerical FDTD
 - Lumerical Interconnect
 - Klayout
 - Lumerical CML
- Outras ferramentas:
 - Python
 - Matlab/Octave

Livros



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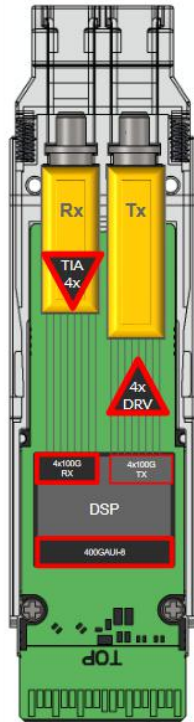


Aplicações

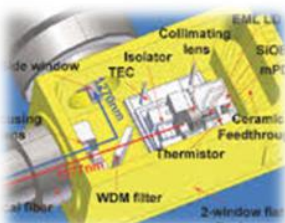
- Material processing;
- Displays and lighting;
- Optical communication;
- Sensing;
- High performance computing;
- LIDAR;

Optical communications

Conventional Optics



- Incumbent technology common in pluggable modules
- Discrete optical components

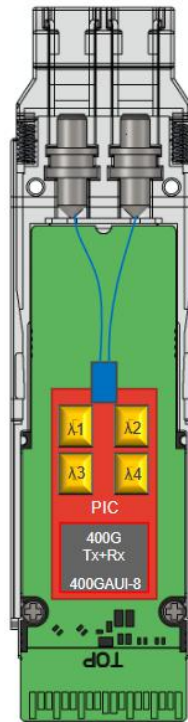


Transmitter Optical Subassembly



Labor Intensive

Silicon Photonics 1.0

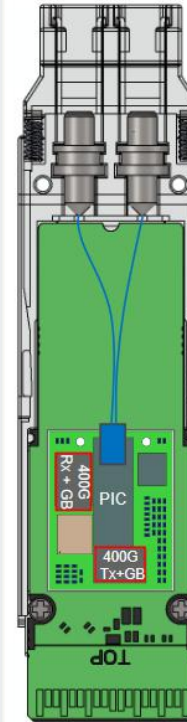


- Lasers are external to silicon photonics
- Most optical components integrated on silicon die



Si Photonics die with flip
chipped electronics and
external laser

Silicon Photonics 2.0



- Lasers integrated into the silicon die (**the holy grail!**)
- Only two companies capable of doing this.

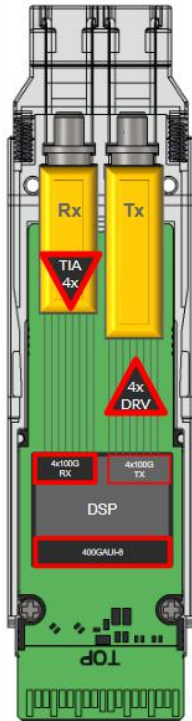


System in package
transceiver

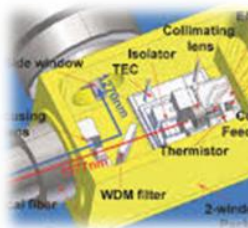
<https://www.juniper.net/assets/us/en/local/pdf/nxtwork/silicon-photonics.pdf>

Optical communications

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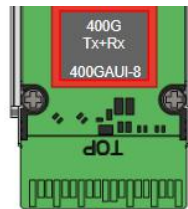
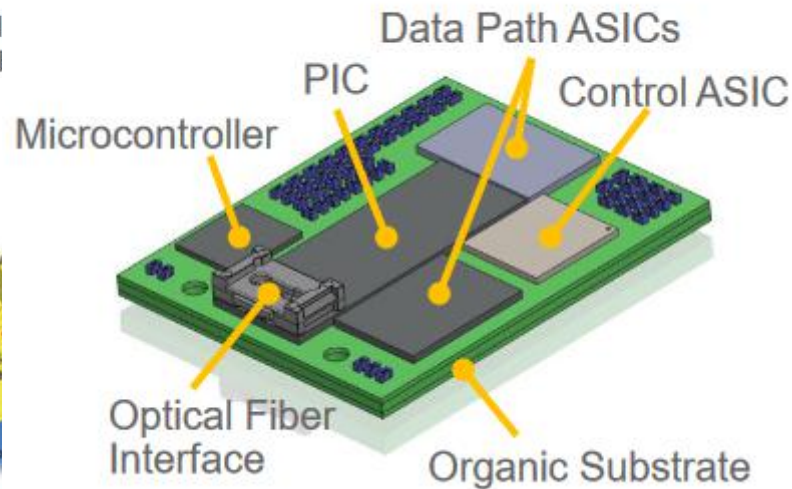


Transmitter Optical Subassembly

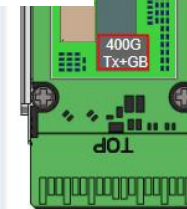


Labor Intensive

400Gbps



Si Photonics die with flip
chipped electronics and
external laser



Silicon Photonics 2.0



- Lasers integrated into the silicon die (the holy grail!)
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System in package
transceiver

<https://www.juniper.net/assets/us/en/local/pdf/nxtwork/silicon-photonics.pdf>

Optical communications

Example: A 100Gbps transceiver

PSM4: 4 parallel fibers

QAM16: coherent

WDM4: wavelength
channels

