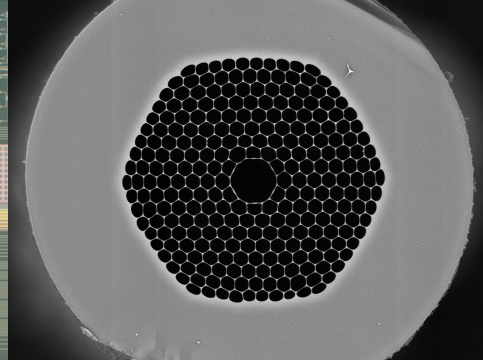
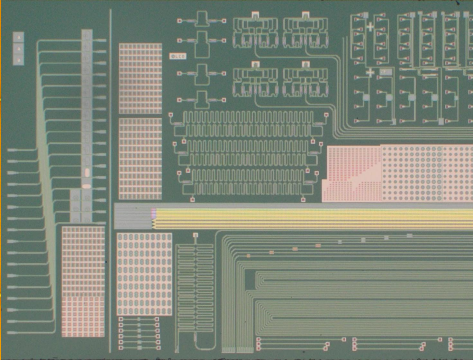
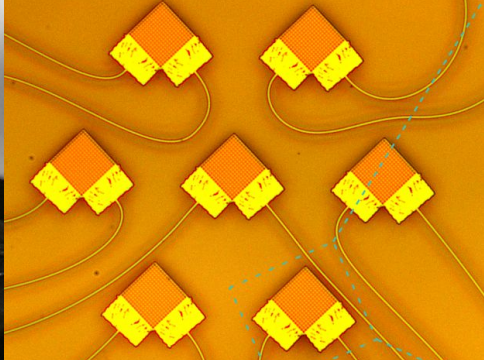
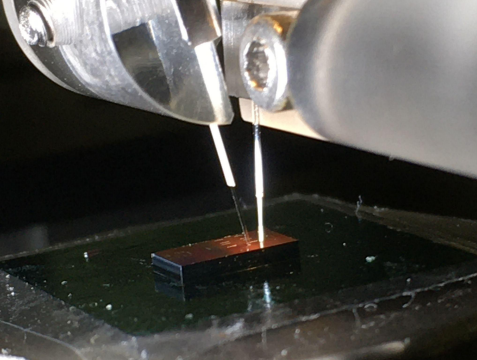




Óptica Integrada: Projeto, Fabricação e Aplicações

Prof. Lucas Heitzmann Gabrielli

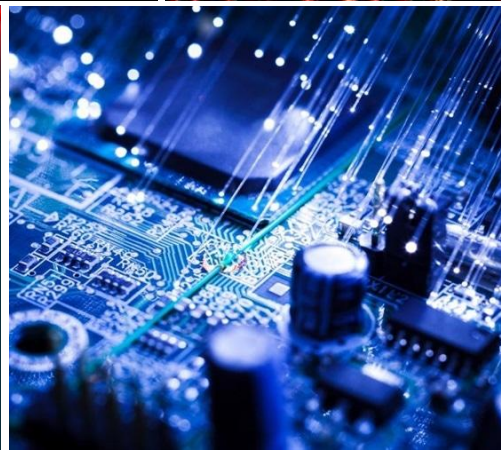
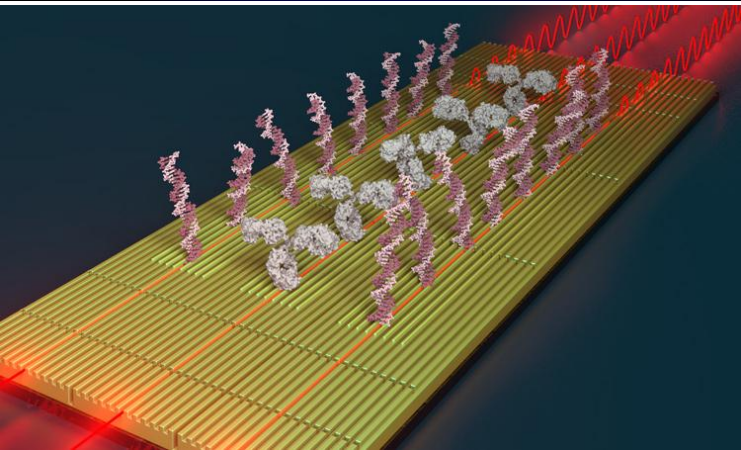
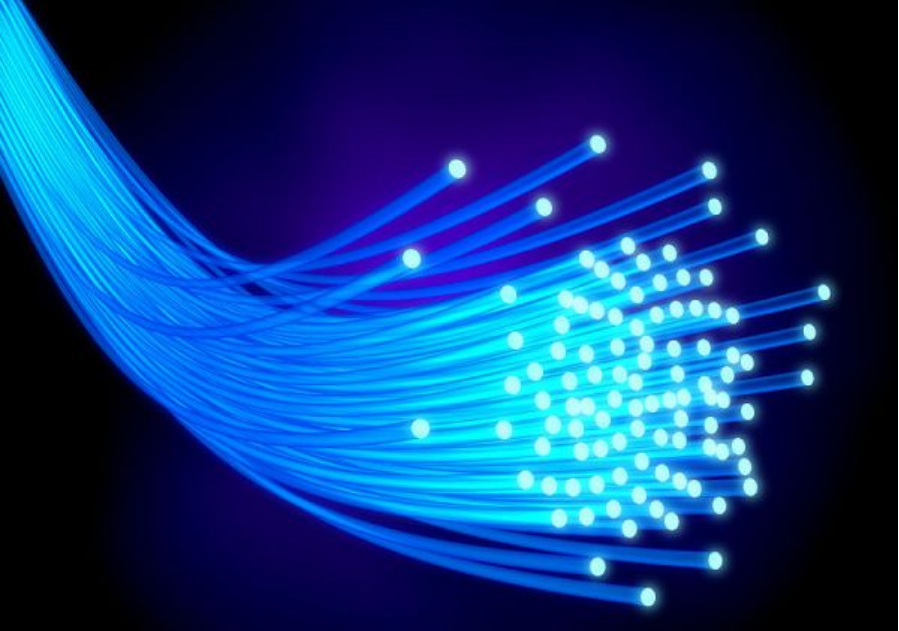
Applied and Computational Electromagnetism Group

School of Electrical and Computer Engineering

University of Campinas – Brazil

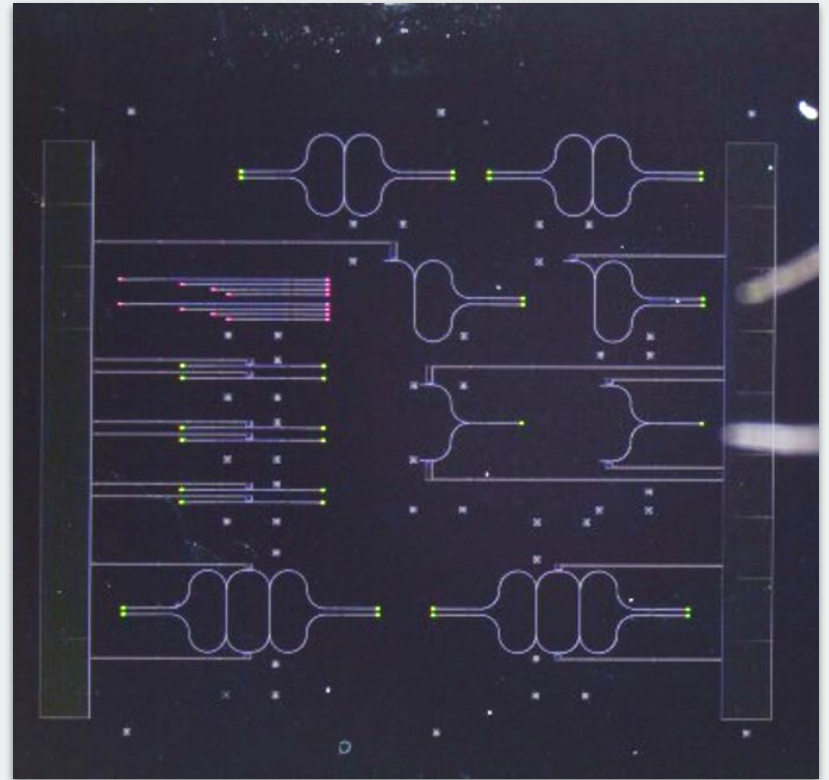
<http://www.decom.fee.unicamp.br/gemac>





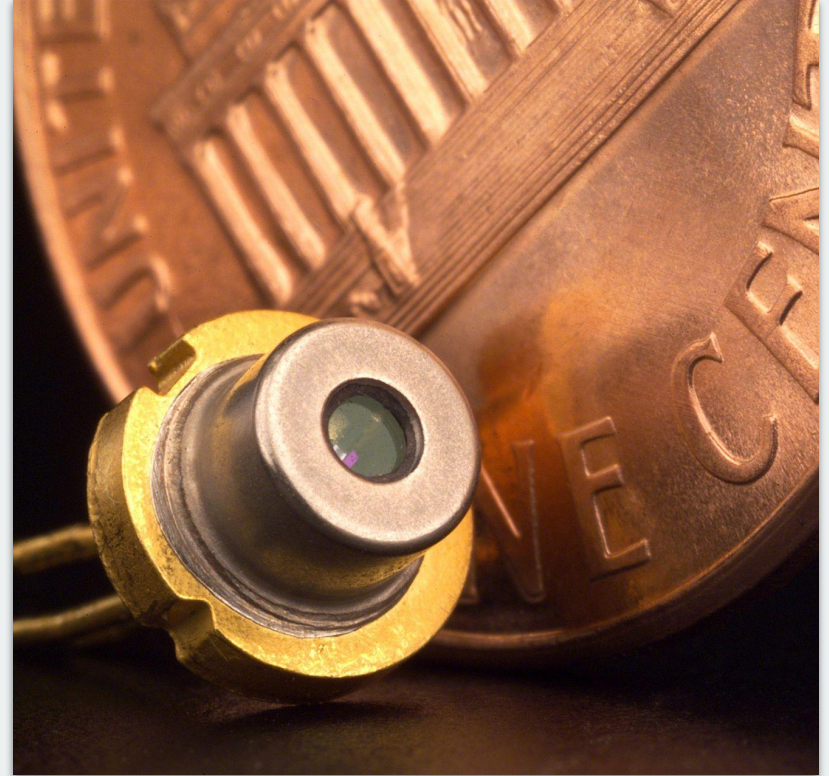


Componentes discretos



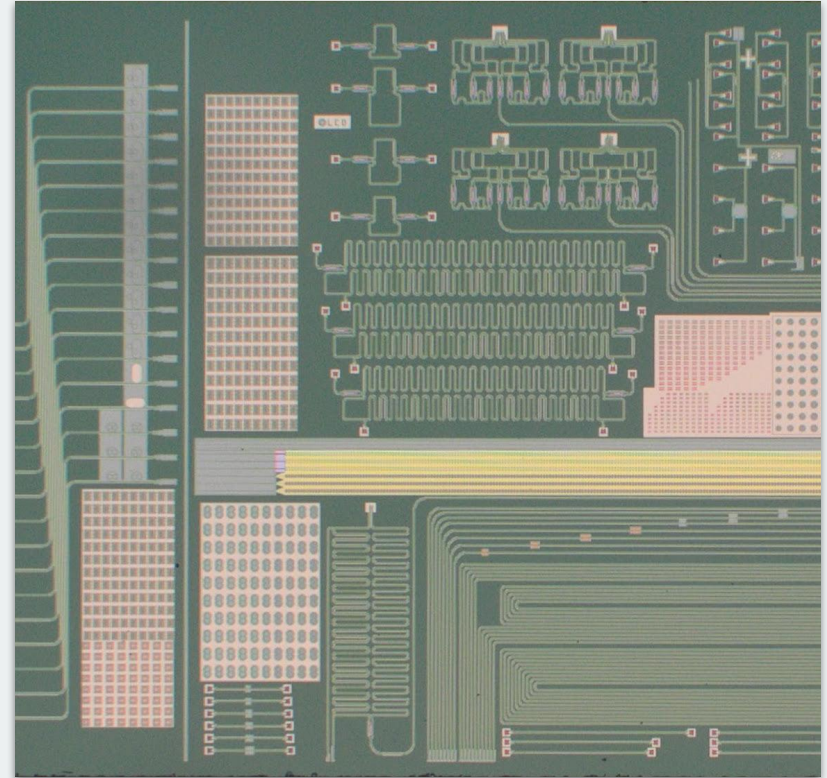
GaAs, InP

Dispositivos ativos



Si, SiO₂, Si₃N₄

Compatibilidade CMOS



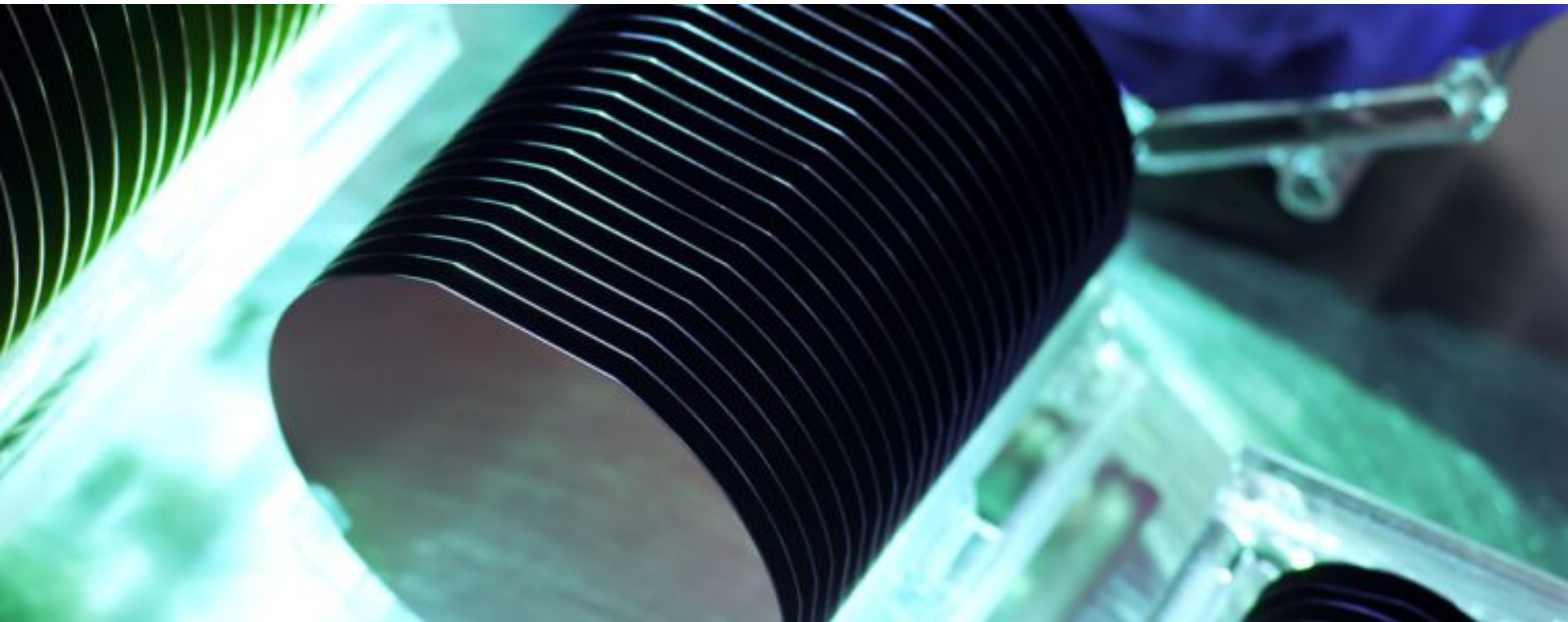
Sala Limpa

Processos de fabricação:

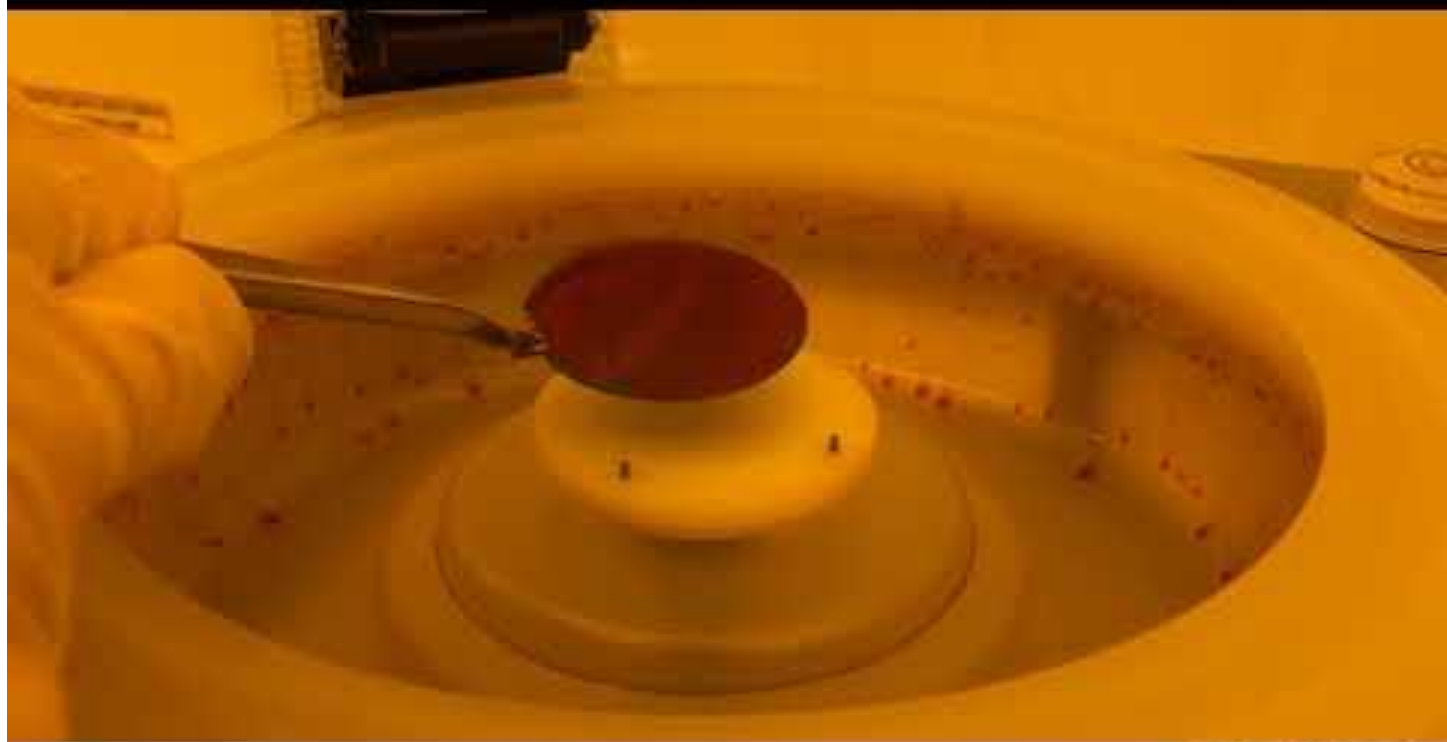
- Limpeza
- *Spin-coating*
- Deposição
- Litografia
- Revelação
- Corrosão
- *Lift-off*
- Implantação
- Polimento

Caracterização: microscopia,
varredura, interferometria, etc.





Bolacha de silício sobre isolante (SOI)

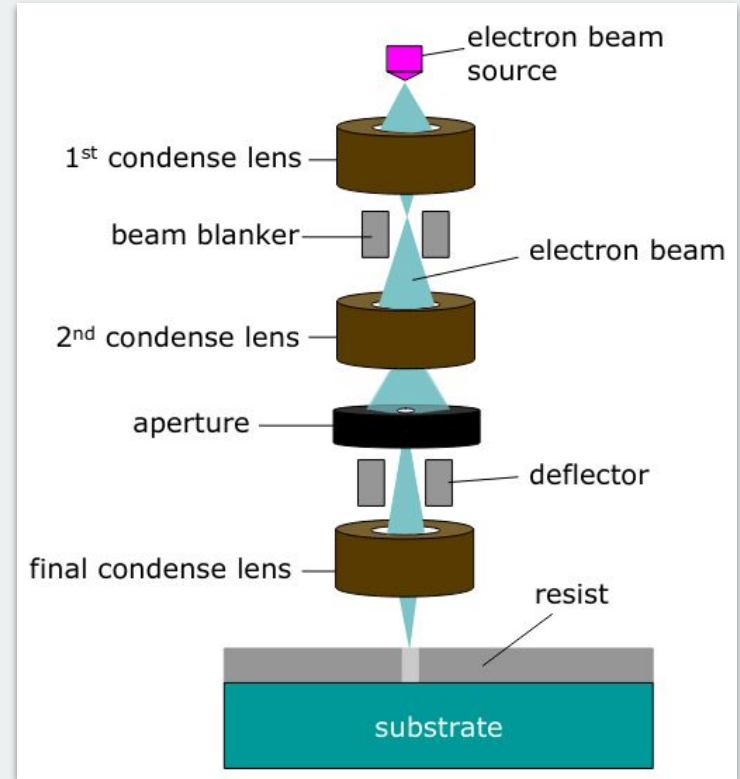


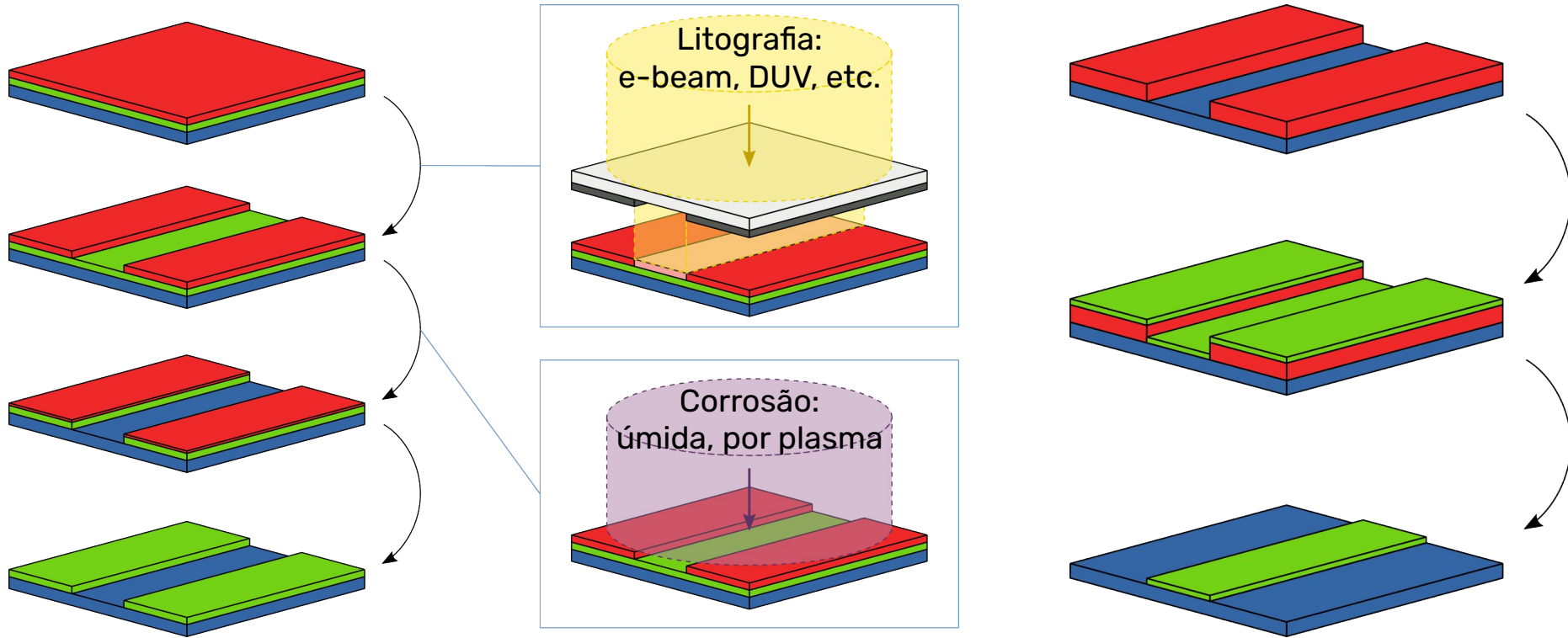
Inspect

 NTNU

Litografia por e-beam

Prototipagem em alta
resolução





Visão geral: corrosão e *lift-off*

Bloco Básico: Guia de Ondas

Modos guiados:

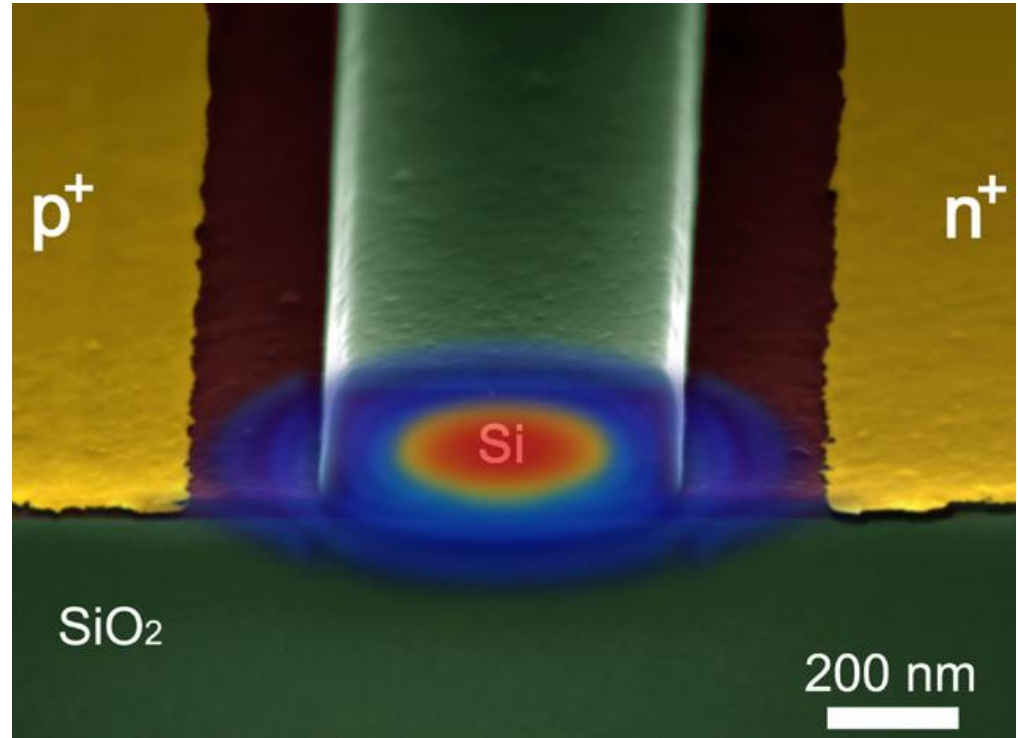
$$E(x, y, z) = E_0(x, y)e^{-i\beta z}$$

$$\beta = k_0 n_{\text{eff}} = \frac{2\pi}{\lambda} n_{\text{eff}}$$

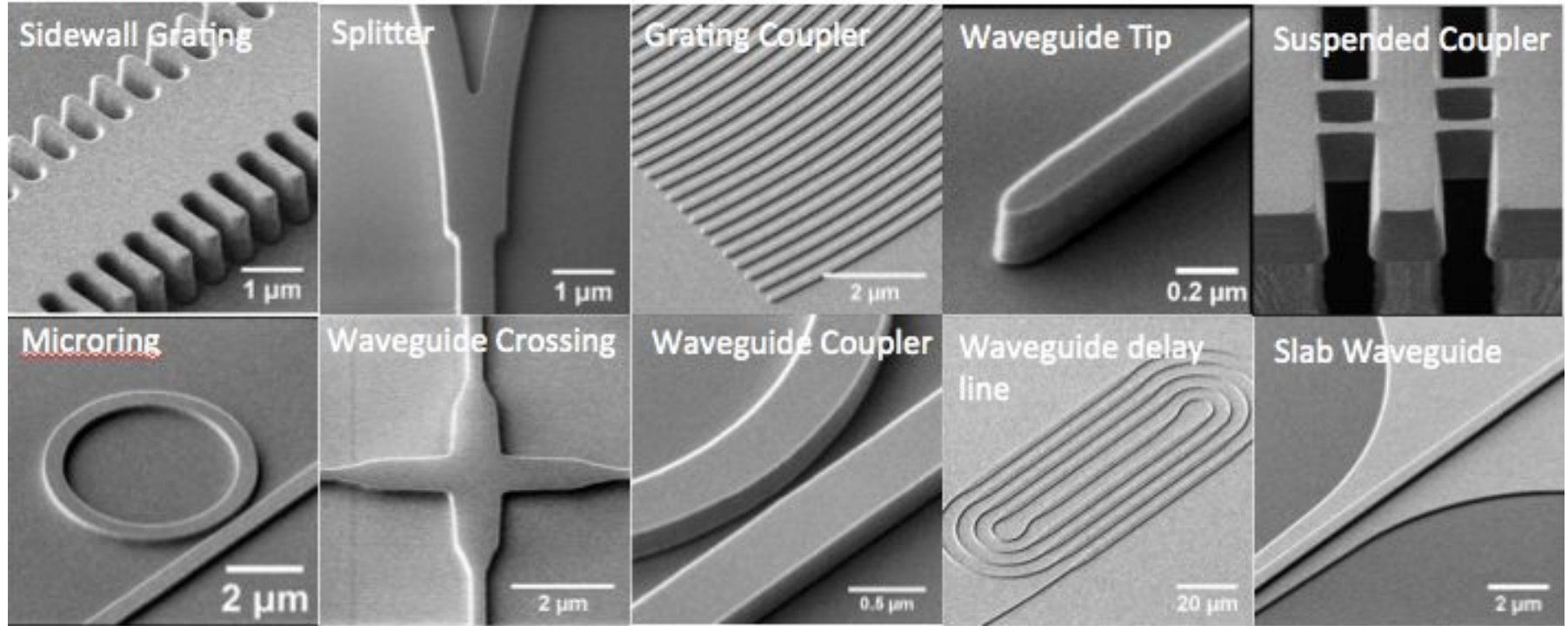
Modos fundamentais:

- quasi-TE
- quasi-TM

DEMO!



Dispositivos



Interferômetros

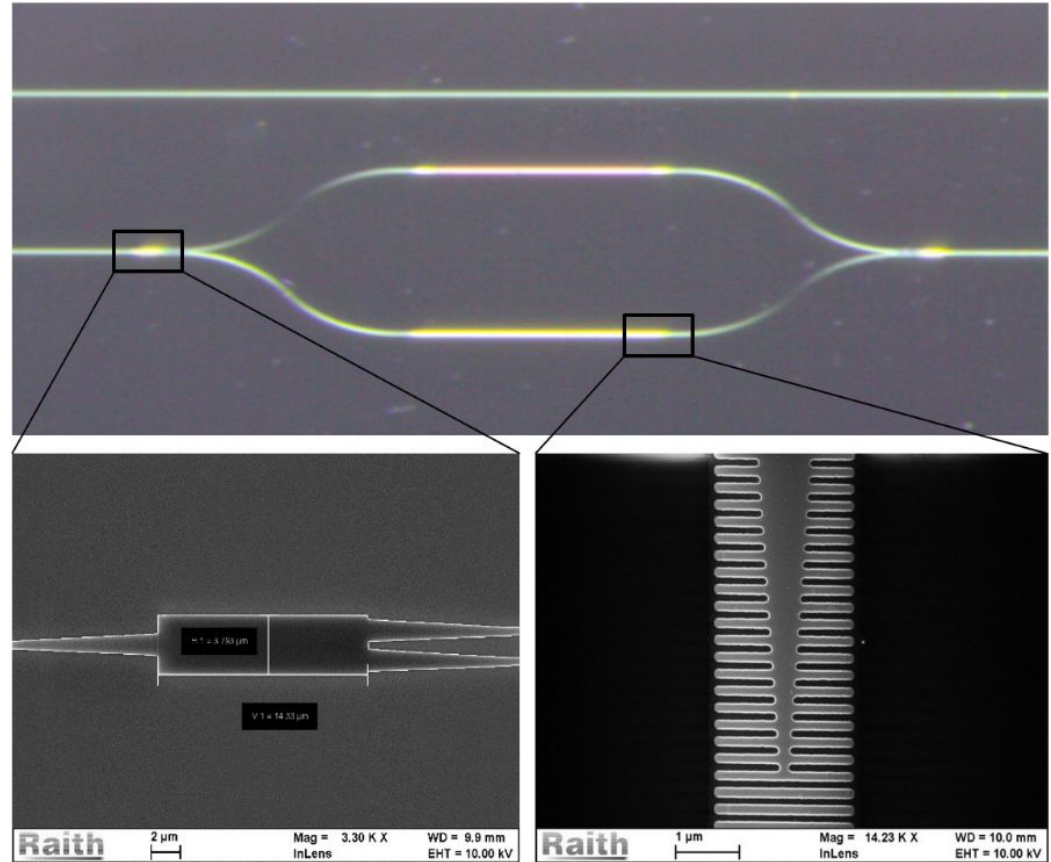
Propagação em cada braço:

$$E_{\text{out},1} = \frac{E_{\text{in}}}{\sqrt{2}} e^{-i\beta_1 \ell_1}$$

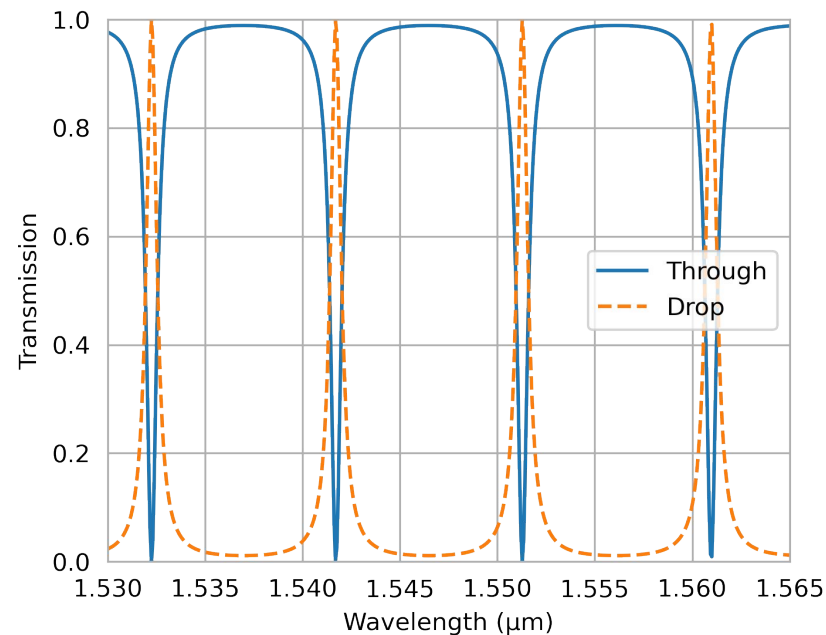
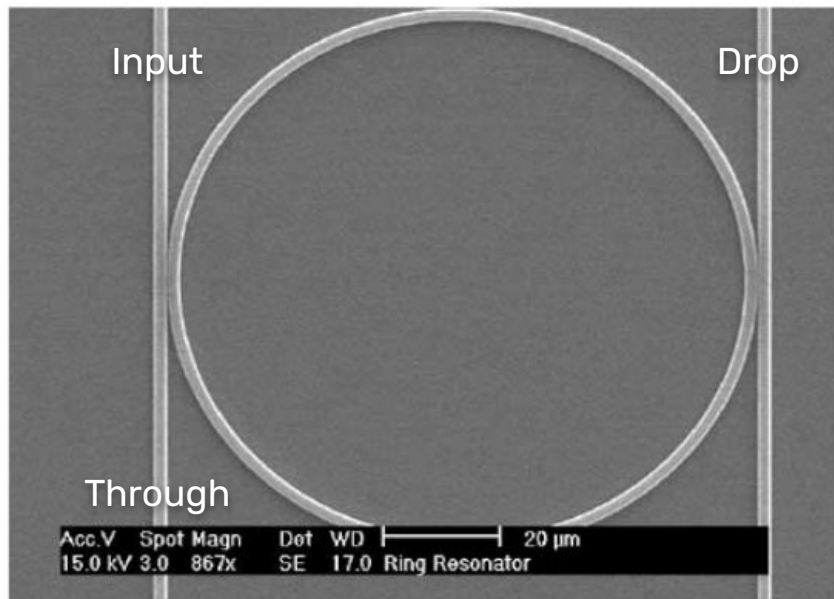
$$E_{\text{out},2} = \frac{E_{\text{in}}}{\sqrt{2}} e^{-i\beta_2 \ell_2}$$

Modulação de amplitude e fase:

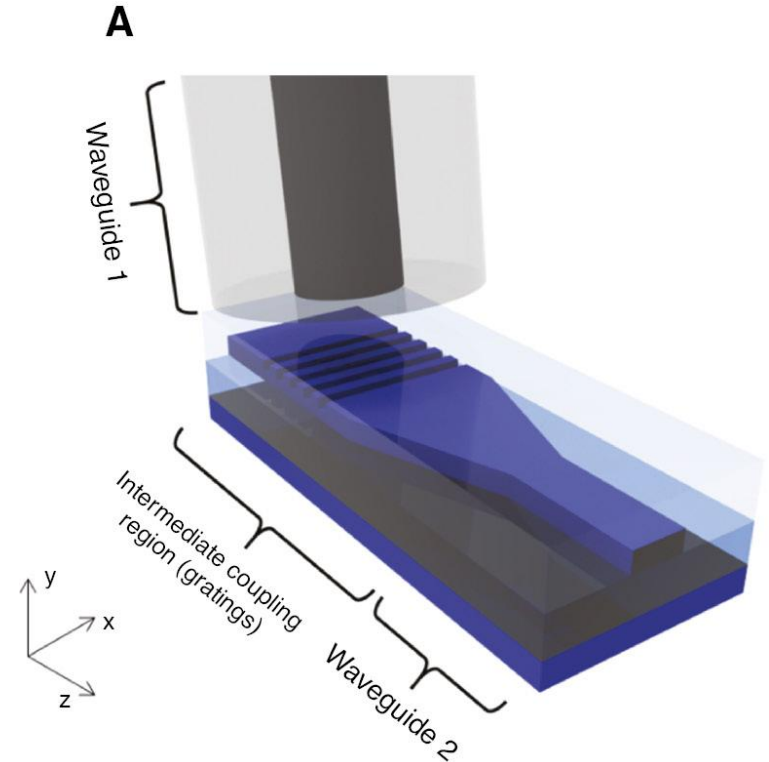
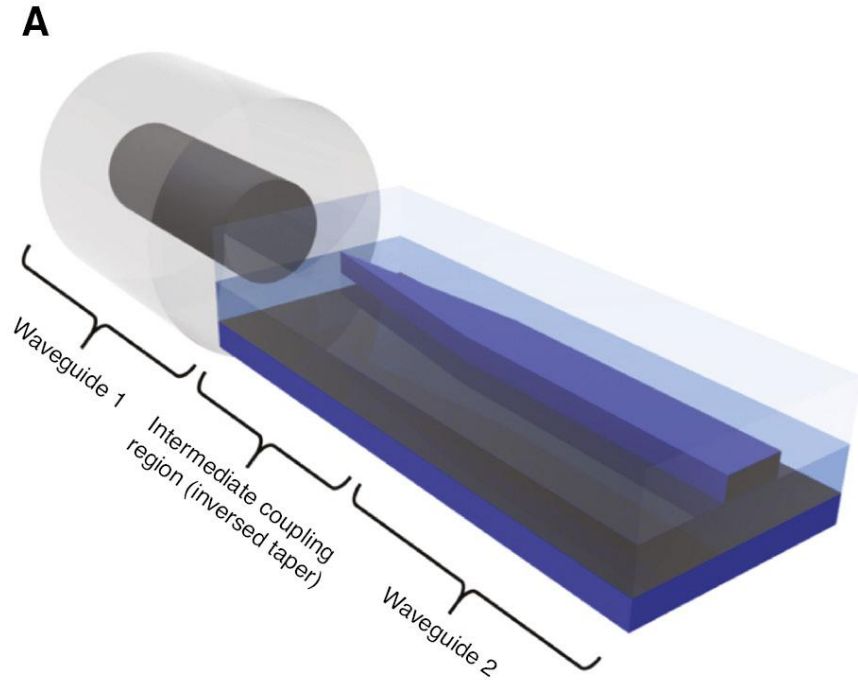
$$\frac{E_{\text{out}}}{E_{\text{in}}} = \cos\left(\frac{\beta_1 \ell_1 - \beta_2 \ell_2}{2}\right) e^{-i\frac{\beta_1 \ell_1 + \beta_2 \ell_2}{2}}$$



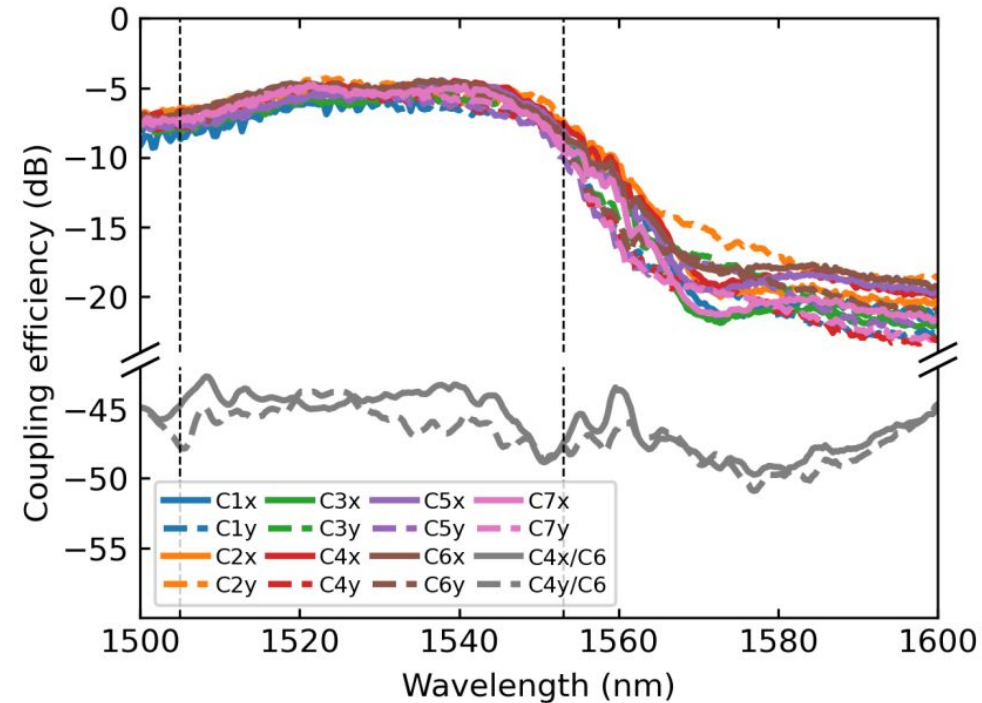
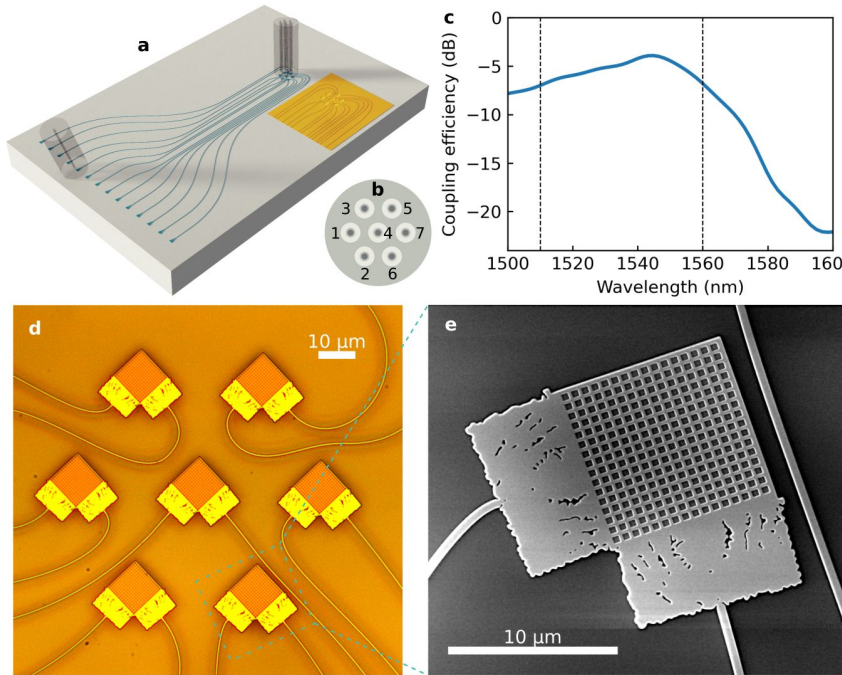
Ressonadores em Anel



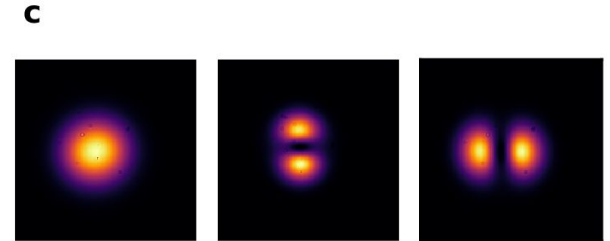
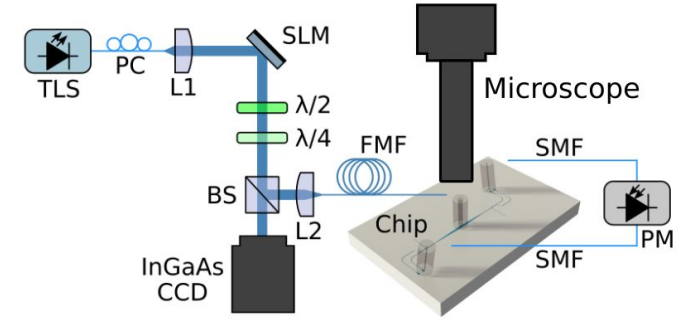
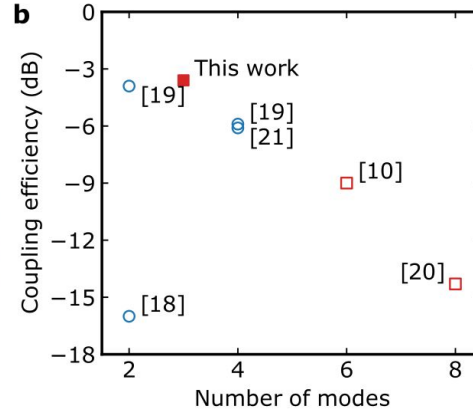
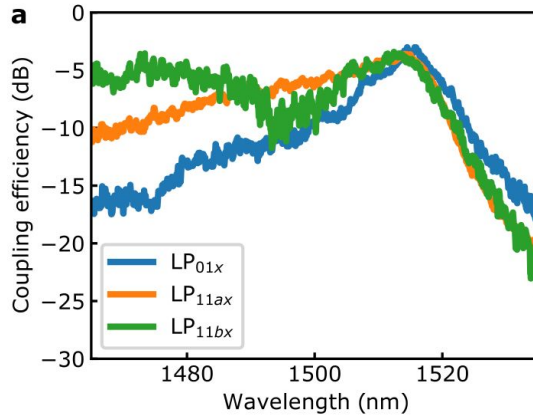
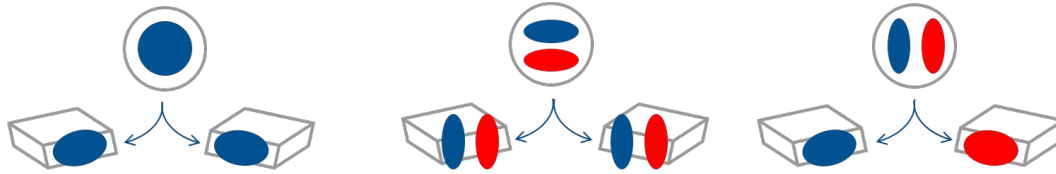
Acopladores



Acoplador para Fibra Multi-Núcleo



Acoplador para Fibra com Poucos Modos



Ferramentas de Projeto

Analíticas e semi-analíticas

- Difração, refração, reflexão
- Modos guiados
- Teoria de perturbação
- Teoria de modos acoplados

Simulação eletromagnética

- Modal (autovalores)
- Espalhamento e propagação
- Multifísica (térmica, mecânica, semicondutores, etc.)

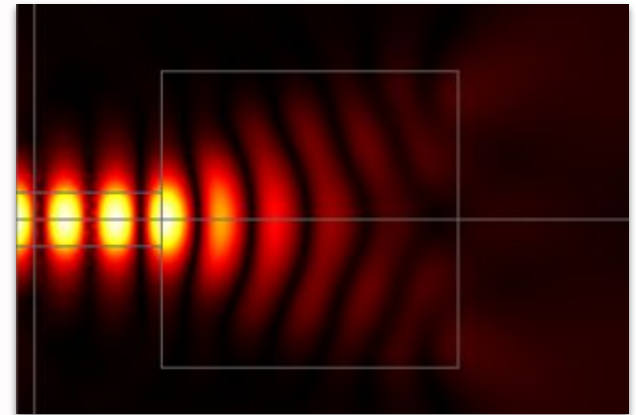
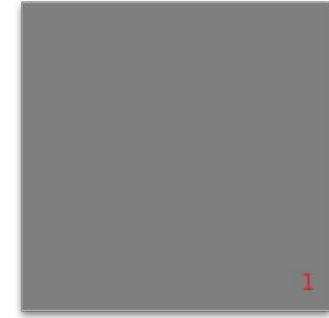
Métodos numéricos

- FEM
- FDTD
- BPM

Otimização numérica

- Varredura de parâmetros
- Otimização heurística (não-linear)
- Aprendizado de máquina
- Otimização topológica (métodos adjuntos)

Otimização Topológica



Transceptor Óptico Integrado

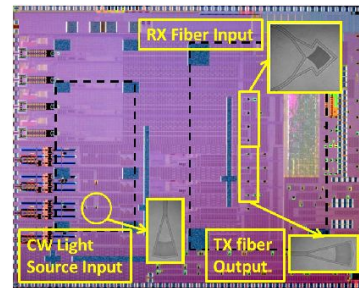
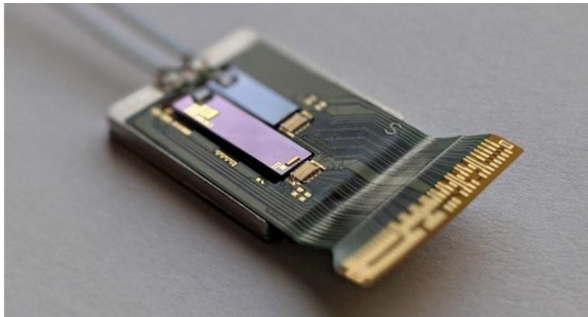
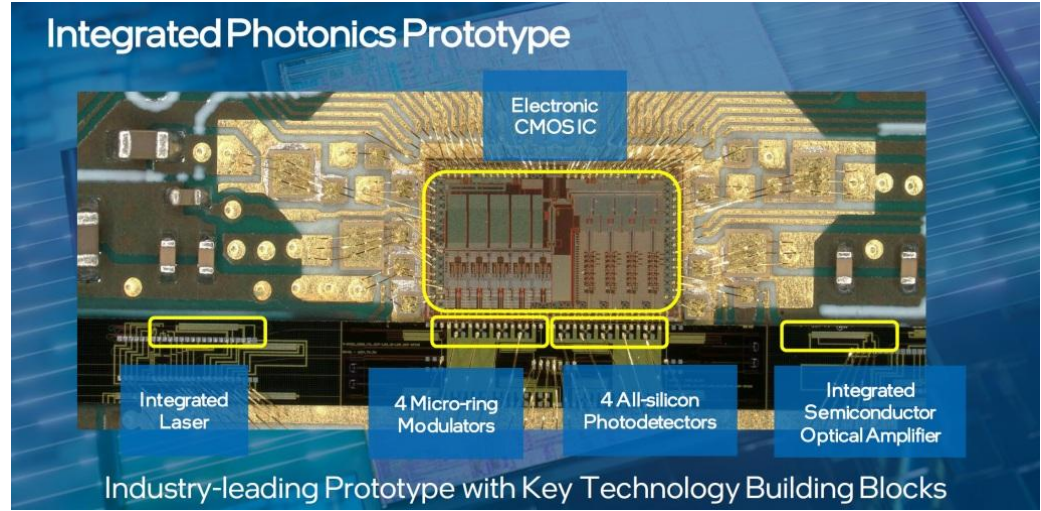


Fig. 7 Optical Interfaces to a 4x14 Gbps transceiver Si Photonics IC.

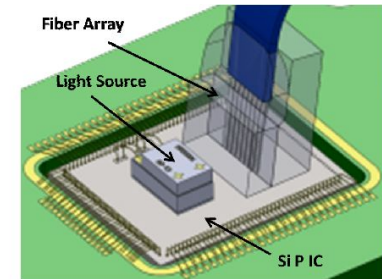
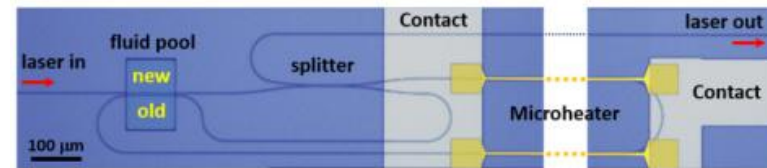
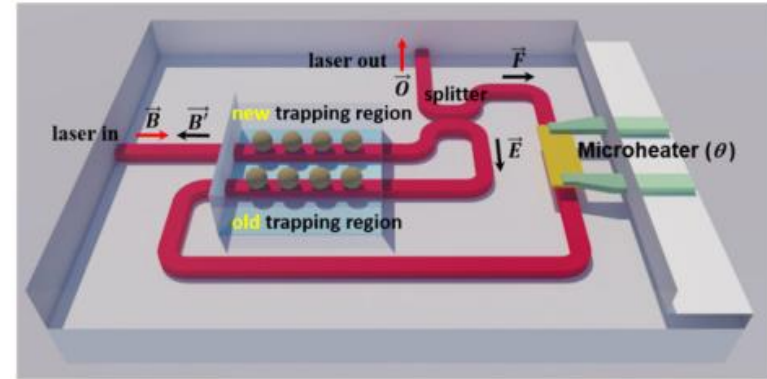
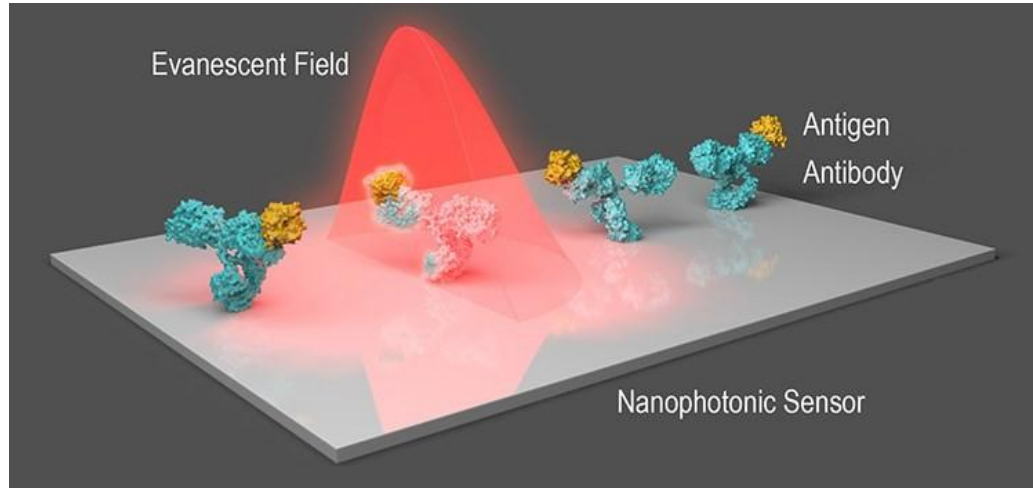
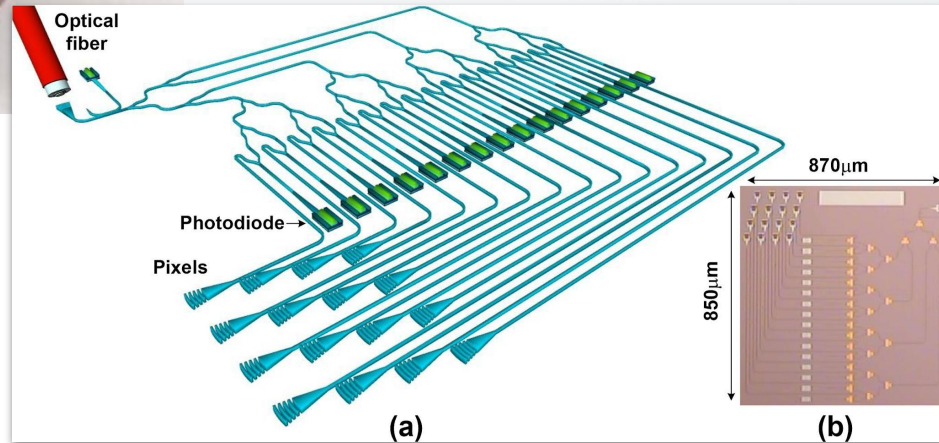
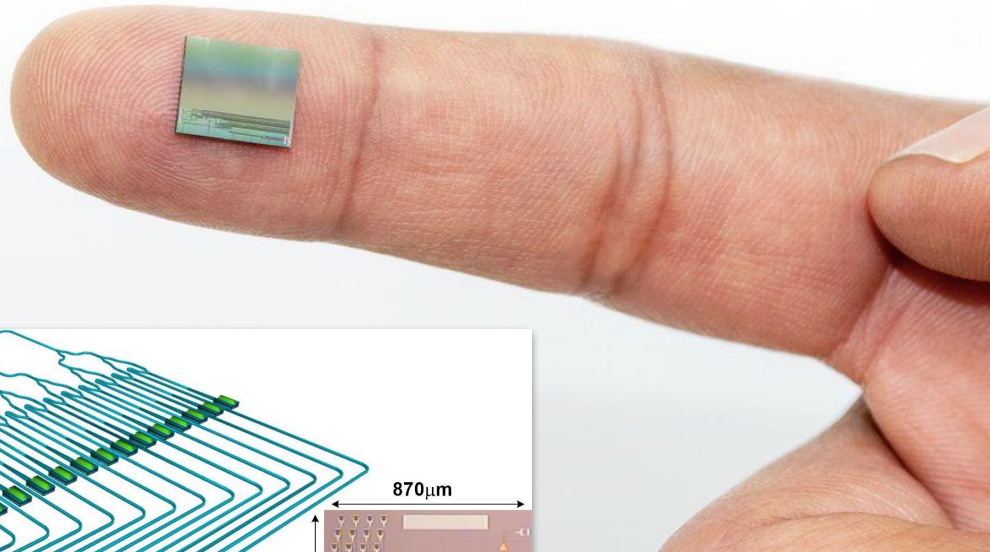
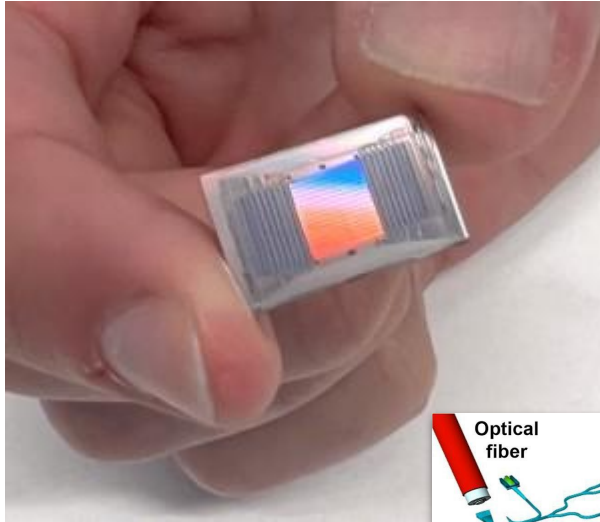


Fig. 8 Assembly of Si Photonic transceiver system: Si Photonics IC, light source and fiber interface.

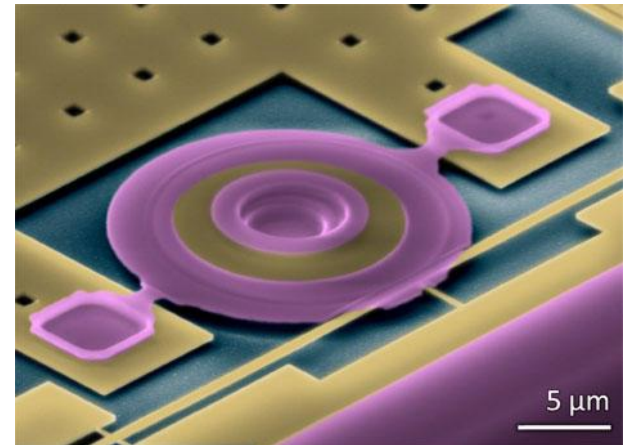
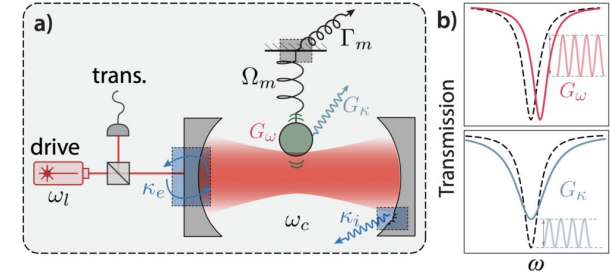
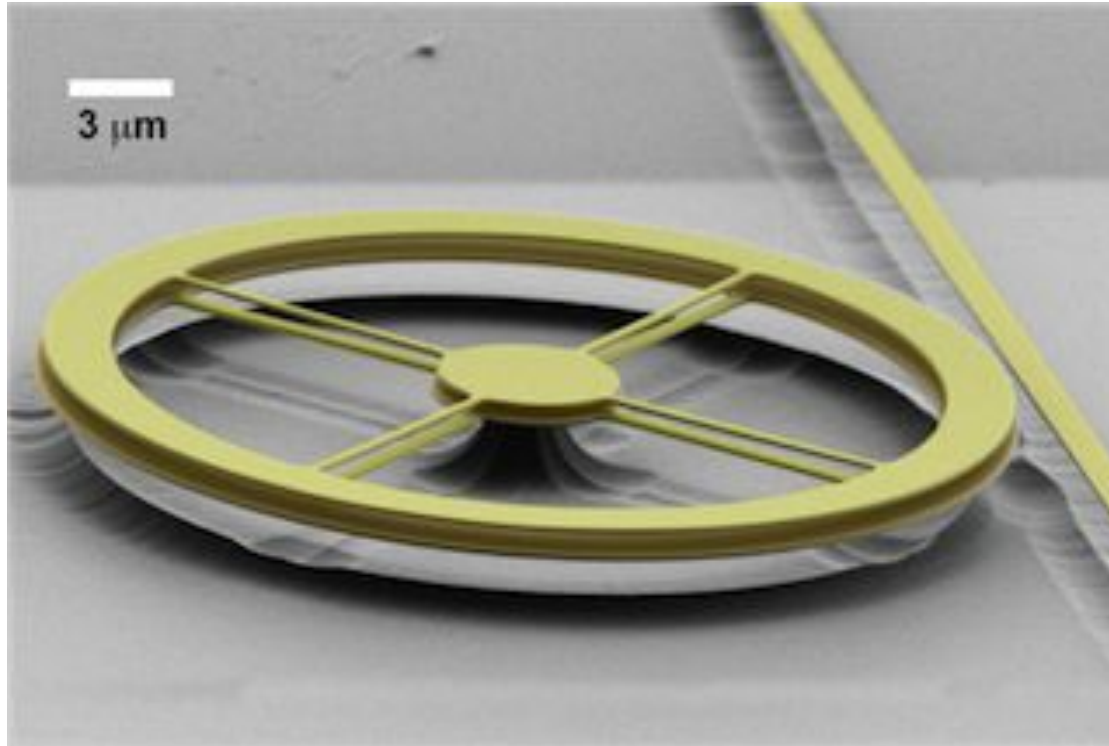
Biosensores



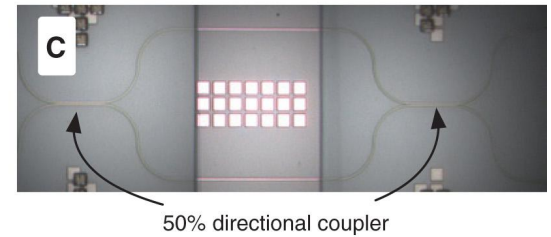
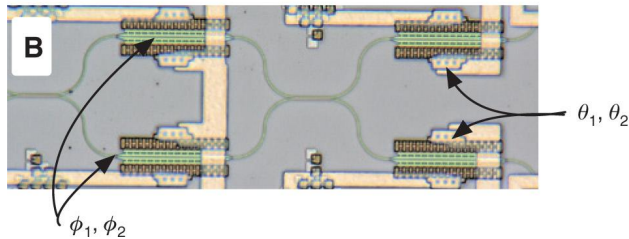
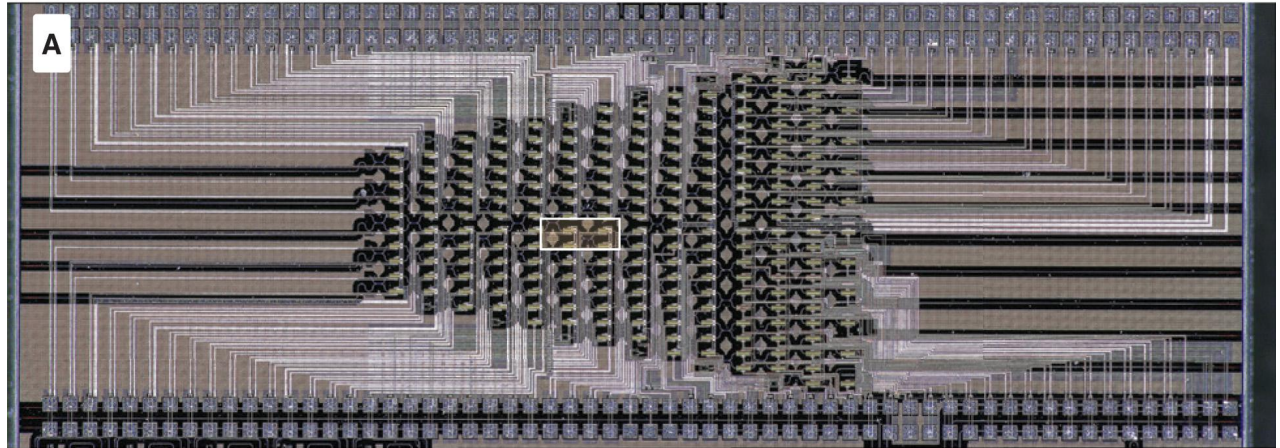
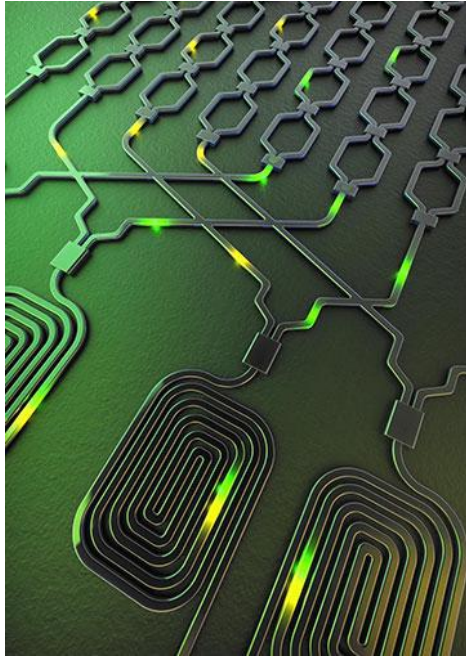
Veículos Autônomos: LIDAR

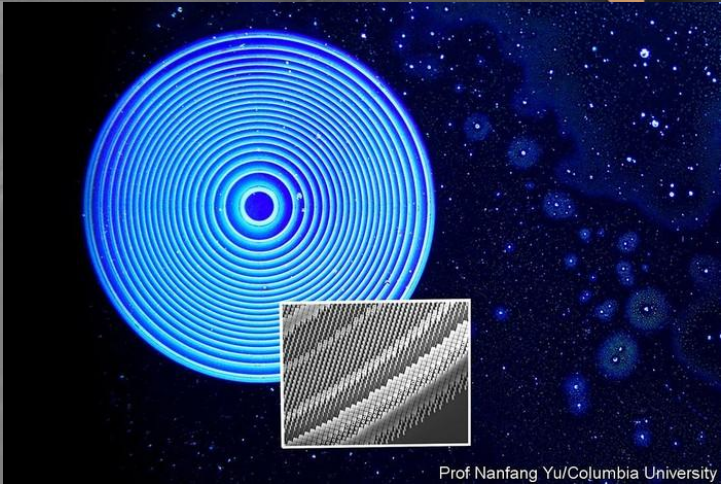
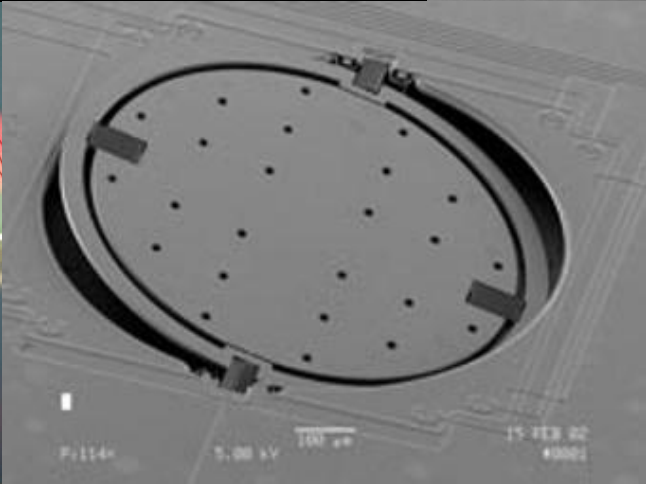
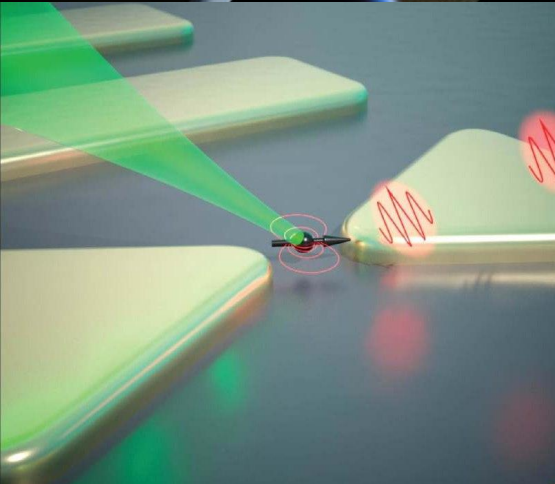
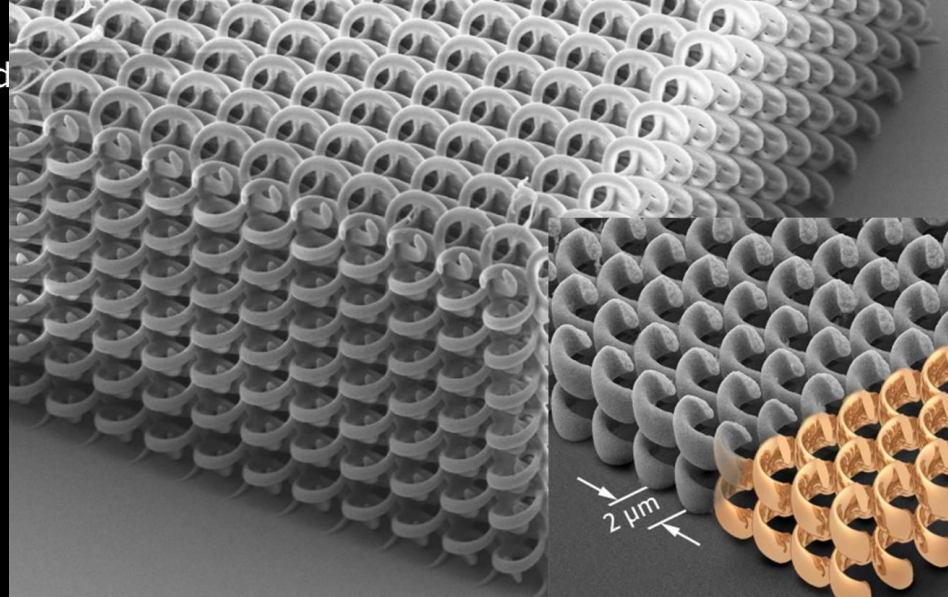
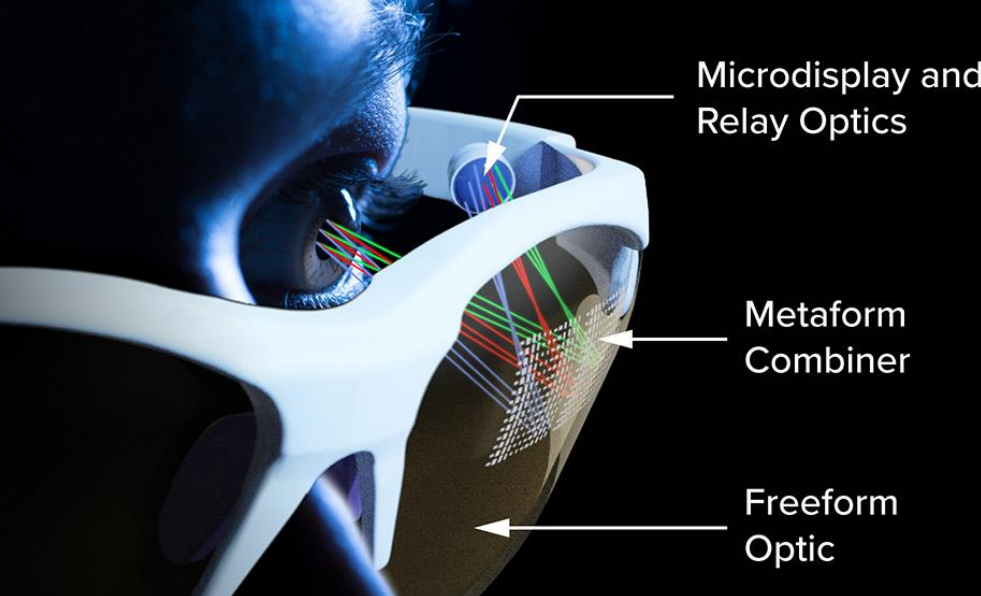


Optomecânica



Óptica Quântica





Desafios

Oportunidades de pesquisa

- Integração CMOS
- Estabilidade térmica
- Fontes e detectores
- Fontes de fótons únicos
- Projeto em larga escala