Design of Si/poly-Si microrings

with complex waveguide cross-sections and minimal non-linearity

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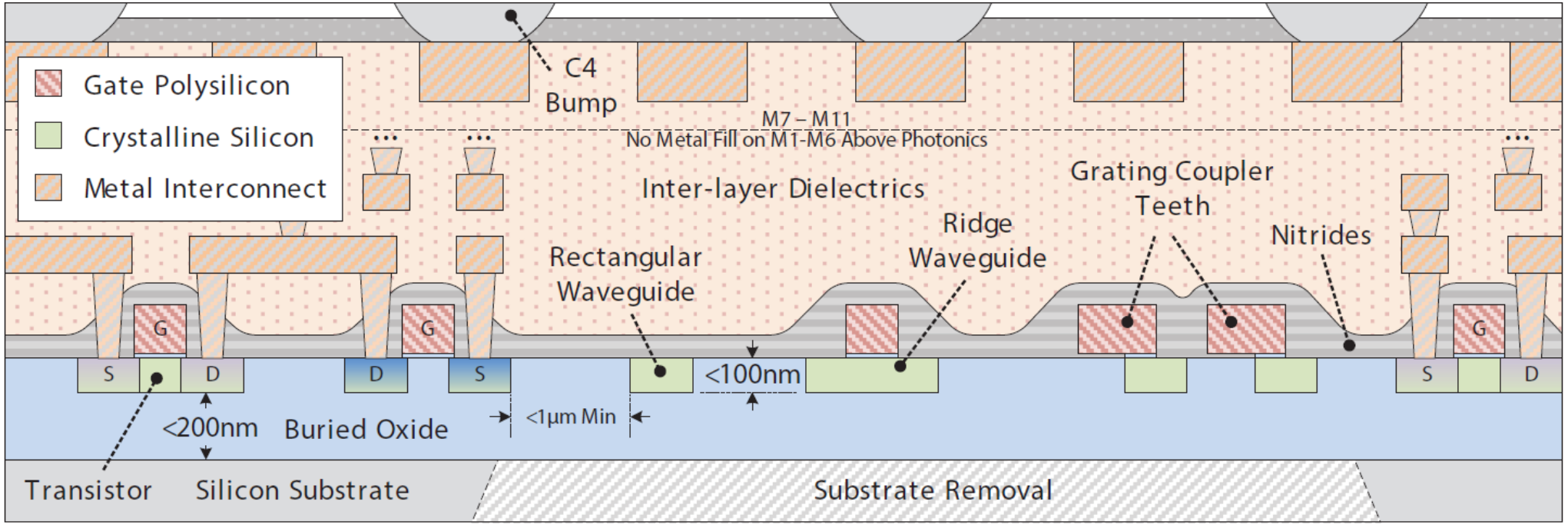
Silicon Photonics

Cross-sectional view

V.Stojanovic et al., Opt. Express, 26 (13106-13121), 2018

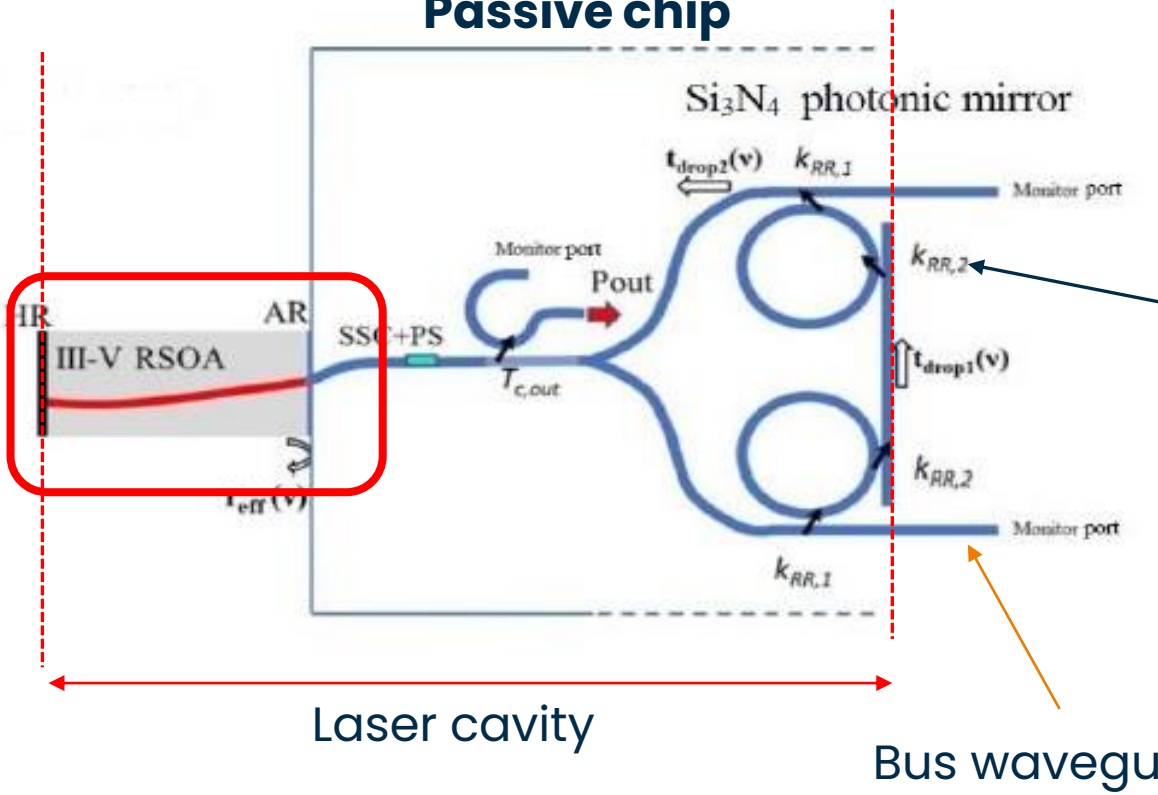


- A technology that allows creating photonic devices that use silicon as an optical medium, with the final goal of integrating photonic and electronic devices on the same silicon chip
- Main problem: efficient laser sources, monolithically integrated on Si, are still missing

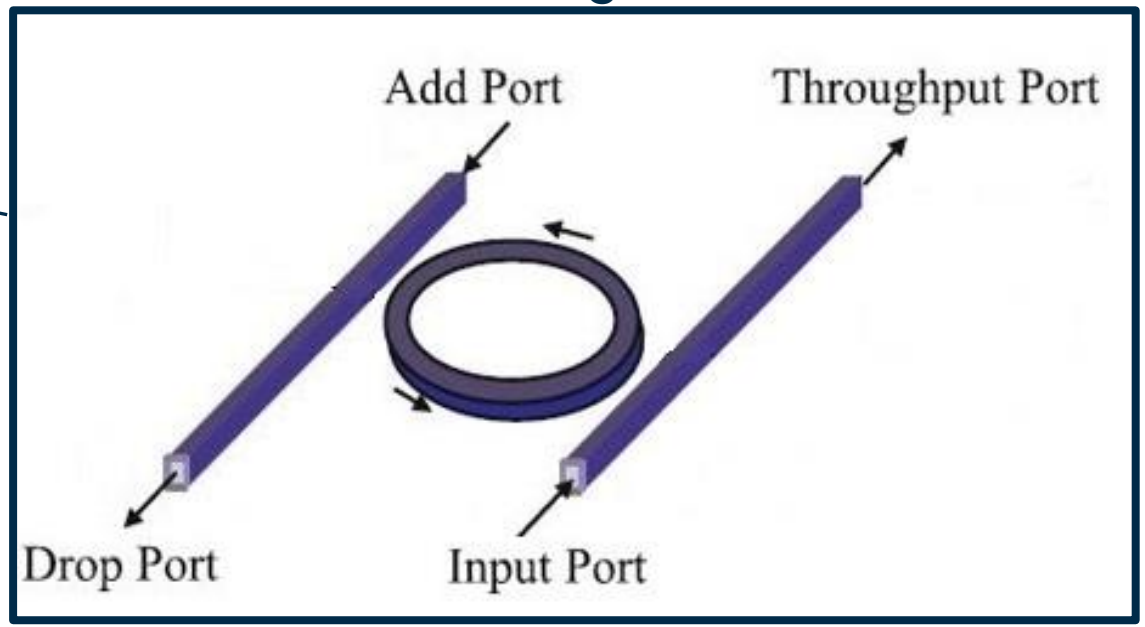
Tunable Hybrid laser

Lorenzo Columbo et al., ''Efficient and Optical Feedback Tolerant Hybrid Laser Design for Silicon Photonics Applications'' IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS.

Passive chip



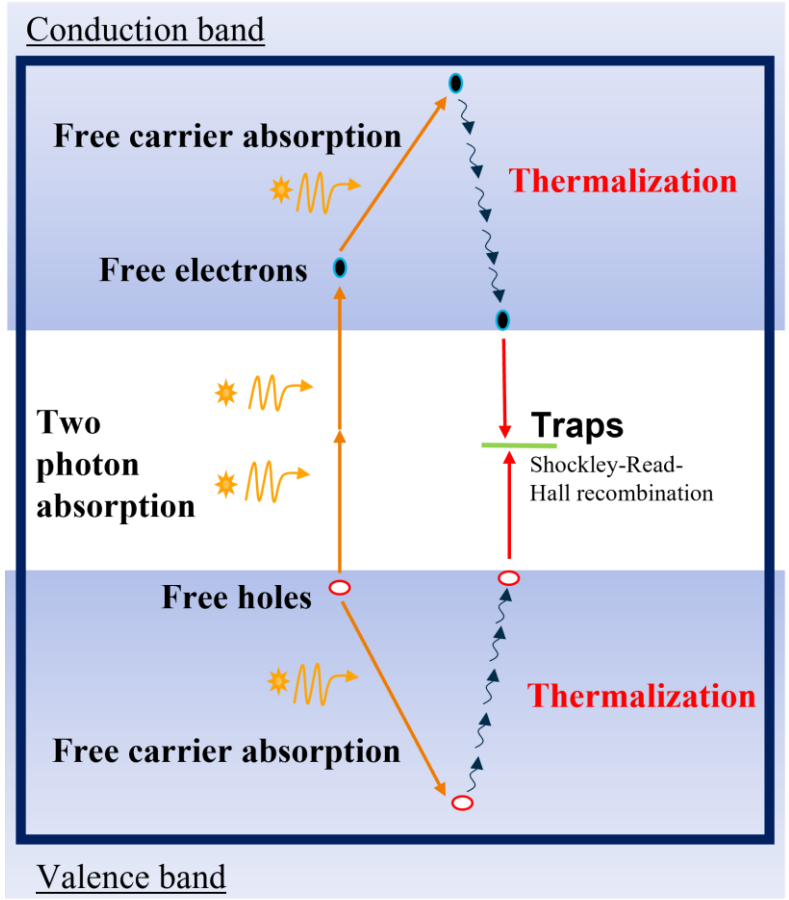
Microring resonators

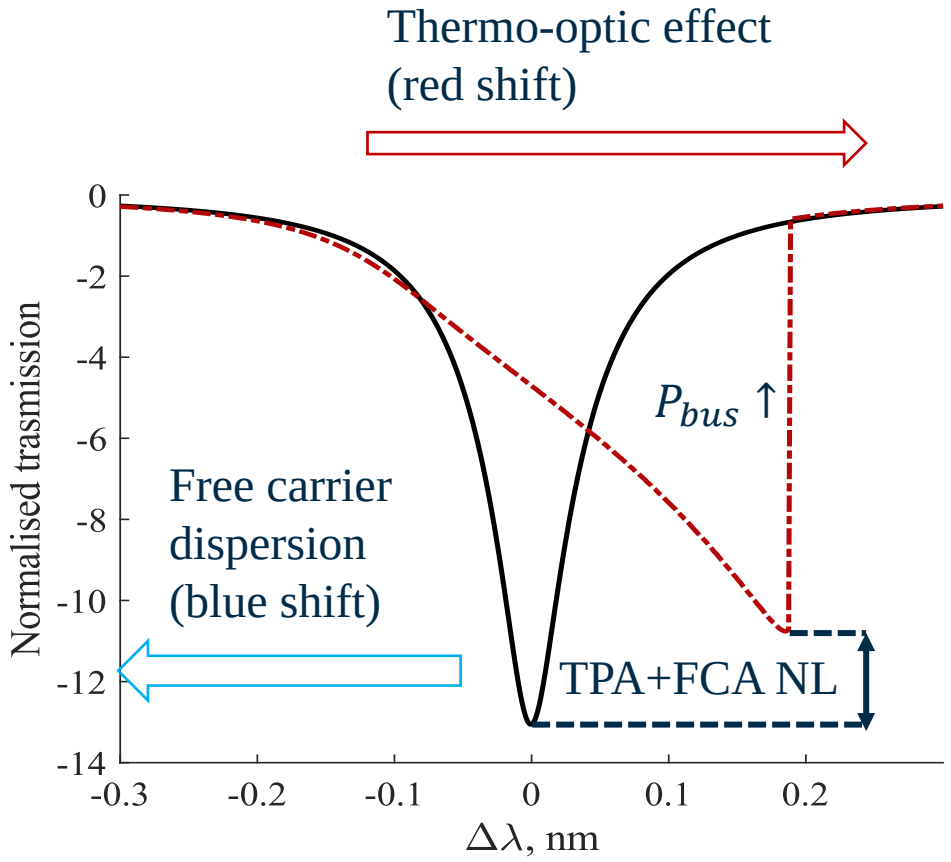


The design of the passive chip is crucial for improving the performances of these devices

Nonlinear effects in silicon

- The **SRH recombination** regulates the amount of free carriers, generated by **TPA,** that contribute to **nonlinear loss** and **free carrier dispersion**.





Models

Drift-diffusion equations

$$\nabla(-D_n \cdot \nabla n(x,y) + \mu_n \cdot n(x,y) \cdot \nabla\phi(x,y)) = G_{ph}(x,y) - R_n(x,y)$$
$$\nabla(-D_p \cdot \nabla p(x,y) - \mu_p \cdot p(x,y) \cdot \nabla\phi(x,y)) = G_{ph}(x,y) - R_p(x,y)$$
$$\nabla^2\phi(x,y) = \frac{q}{\varepsilon}(p(x,y) - n(x,y) + N_a^- - f_t N_t)$$

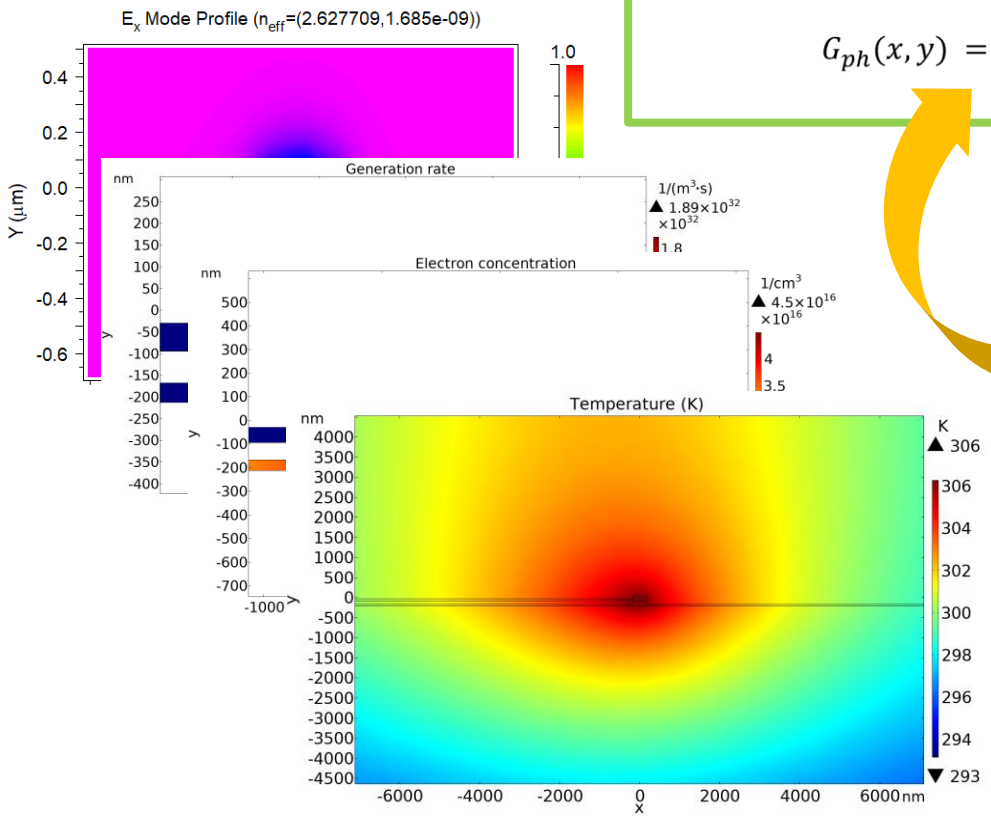
$$G_{ph}(x,y) = \frac{P_c^2}{\frac{hc}{\lambda}} \beta_{TPA} \frac{n^2}{Z_0^2 \ 8P_\mu^2} |E_\mu(x,y)|^4$$

Shockley-Read-Hall recombination

$$R_n(x,y) = C_n \cdot N_t \cdot n(x,y)(1 - f_t)\left(1 - e^{\frac{E_{ft} - E_{fn}}{k_b T}}\right)$$

$$R_p(x,y) = C_p \cdot N_t \cdot p(x,y) f_t \left(1 - e^{\frac{E_{fp} - E_{ft}}{k_b T}}\right)$$

$$f_t = \frac{1}{1 + g_D \cdot e^{\frac{E_t - E_{ft}}{k_b T}}}$$



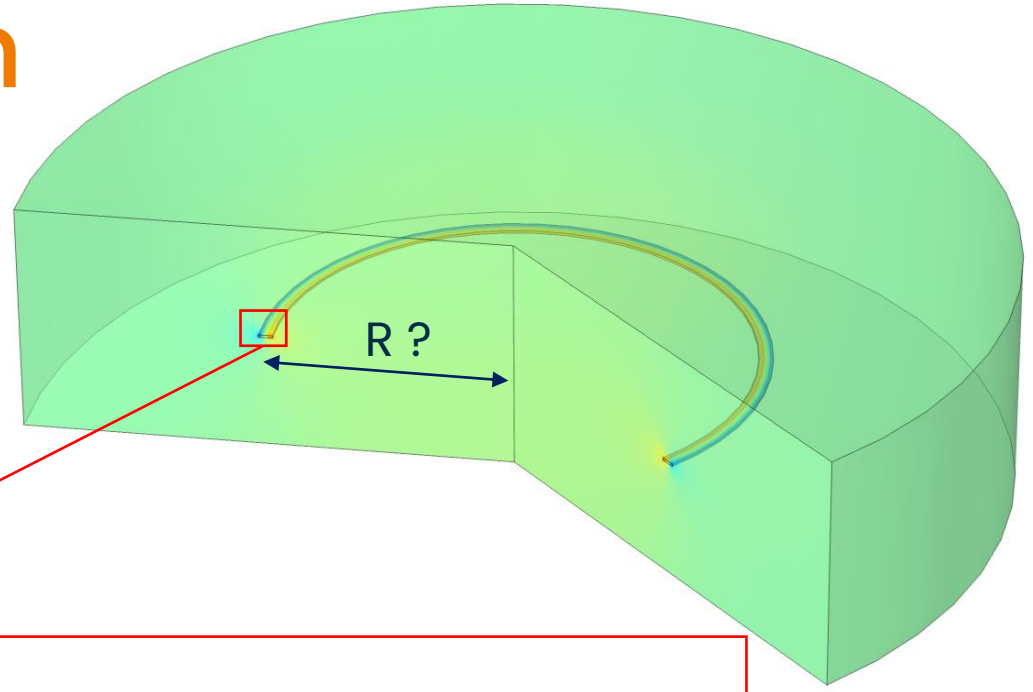
Thermal model

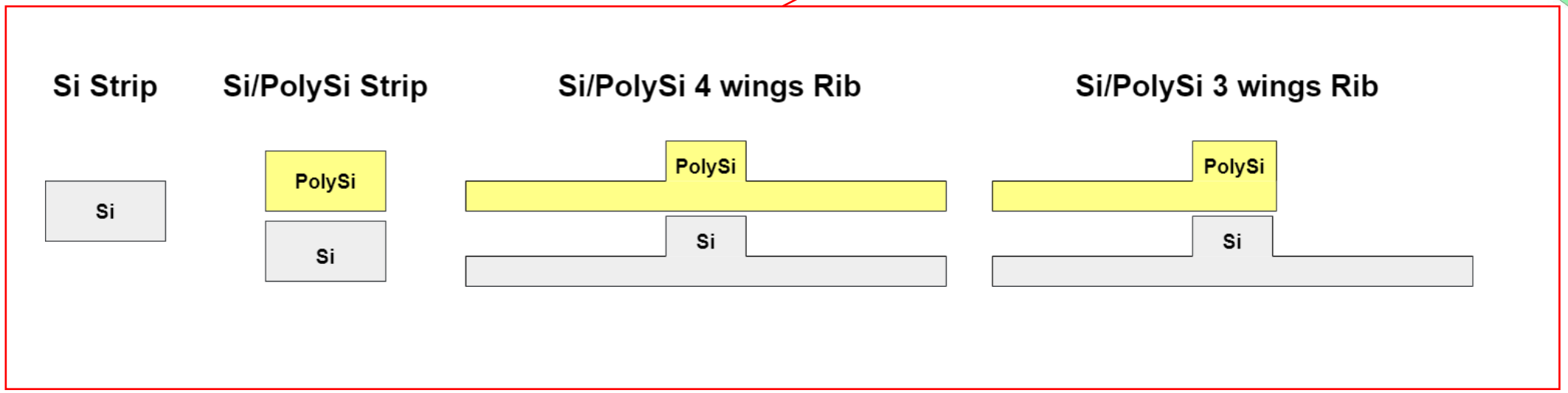
$$d_z \cdot \rho \cdot C_p \cdot u \cdot \nabla T - \nabla(d_z \cdot k \nabla T) = d_z Q(x,y)$$

$$Q(x,y) = \frac{|J_n|^2}{\sigma_n} + \frac{|J_p|^2}{\sigma_p} + \Delta\alpha_{FCD} \cdot I_{opt} + R_{n,p} \cdot 2\hbar\omega$$

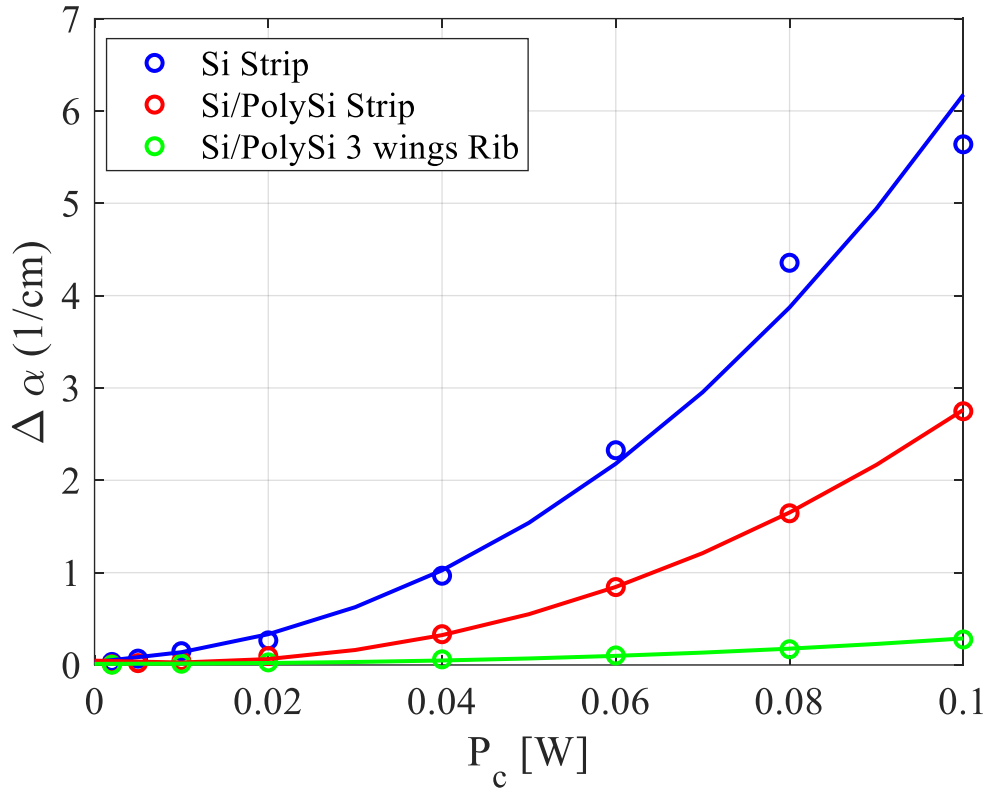
Design in SISCAP platform

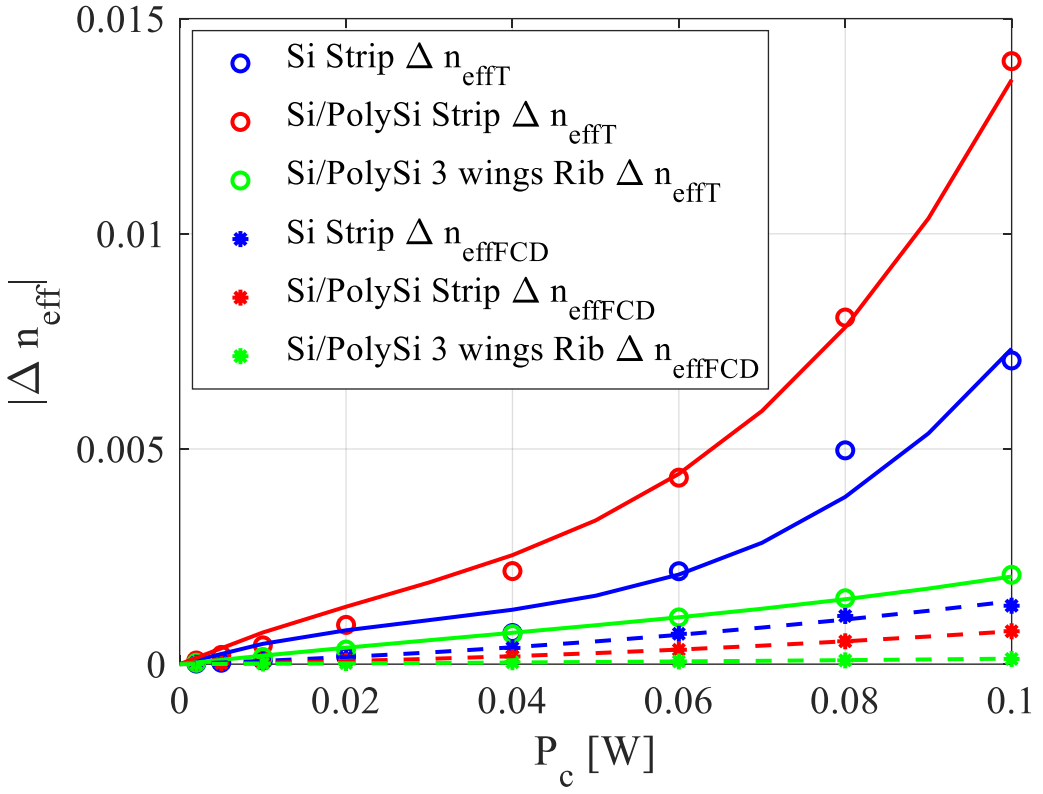
Silicon Insulator Silicon Capacitor





Data processing

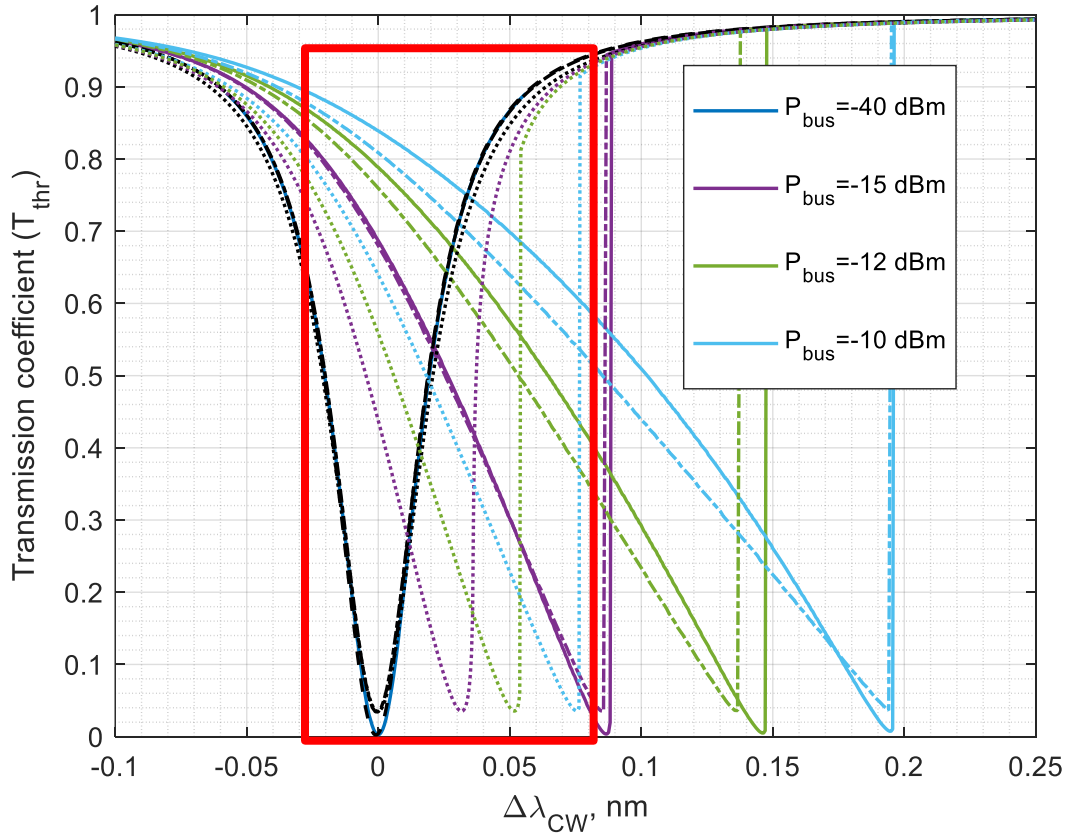


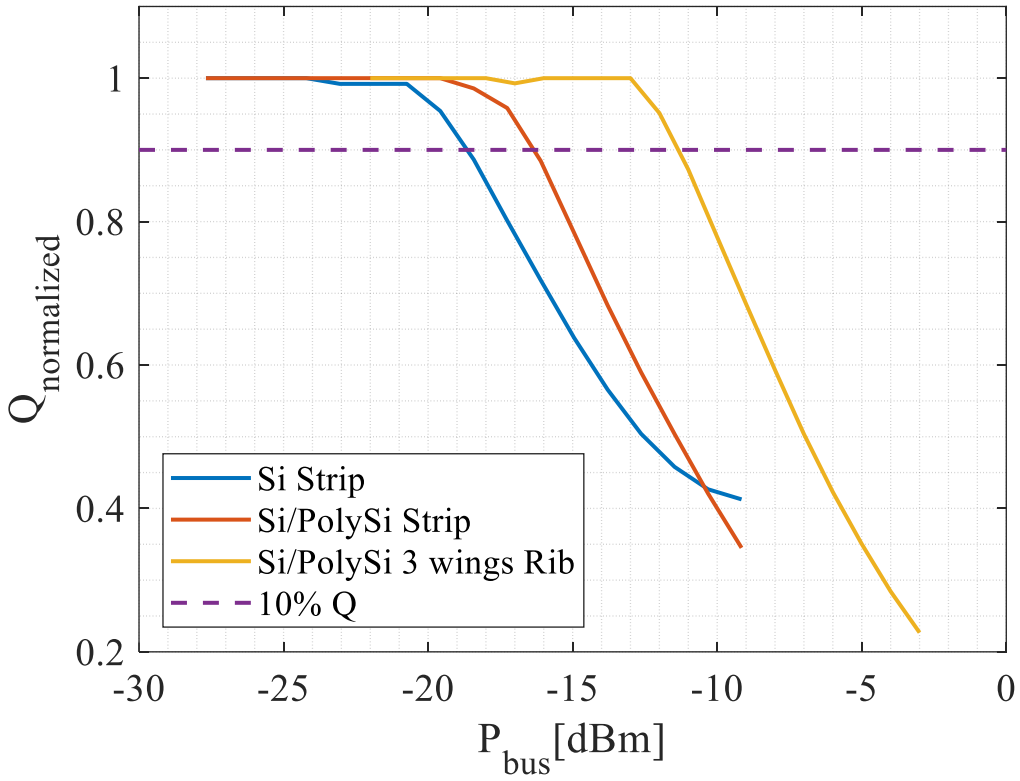


$$\Delta\alpha = \frac{2c \cdot \epsilon_0 \cdot n \int\int_{\infty} \frac{\Delta\ \alpha_{FC}(x,y)\lambda}{4\pi} \cdot |E(x,y)|^2 dxdy}{\int\int_{\infty} Re\{E(x,y)\mathrm{x}H(x,y)^*\} \cdot e_z dxdy}$$

$$\Delta n_{eff_{FCD,T}} = \frac{c \cdot \epsilon_0 \cdot n \int\int_{\infty} \Delta n_{FCD,T}(x,y) \cdot |E(x,y)|^2 dxdy}{\int\int_{\infty} Re\{E(x,y)\mathrm{x}H(x,y)^*\} \cdot e_z dxdy}$$

Final Results





Transmission spectra of the 3 MRRs at different bus input power:

- Si strip (continuos)
- Si/PolySi strip (dash-dotted)
- Si/PolySi 3 wings Rib guide (dotted)