Abstract

The aim of this PhD thesis is to develop tools for understanding and describing the behaviour of silicon in the context of hybrid tunable lasers developed in the Silicon Photonics platform. These lasers incorporate a III-V Reflective Semiconductor Optical Amplifier (RSOA) as an active component coupled with a passive mirror made of ring resonators, which act as filters and determine the laser's output frequency.

However, when propagating in the silicon ring waveguide, the optical field experiences significant absorption due to non-linear (NL) effects such as Two Photon Absorption (TPA) and Free Carrier Absorption (FCA). These effects result in the accumulation of free carriers within the silicon core waveguide, which can adversely affect the performance of the ring resonators, even with input powers of just a few milliwatts. This thesis has two primary objectives: first to develop a compact model that describes the impact of NL effects on the performance of ring resonators; second to establish an experimental setup designed for the characterization of microrings resonators in steady-state regime (as in the case of the hybrid tunable laser) or in switching applications where a good knowledge on the ring response in time is crucial.

Within this framework, I have numerically solved the non-linear problem associated with the variation of silicon refractive index and optical losses coupled with the Shockley-Read-Hall recombination (SRH) theory for trap-assisted recombination processes of free carriers.

Furthermore, the developed theory has been effectively generalised to incorporate more complex waveguide cross sections, such as rib waveguides. This extension allows for a comprehensive description of the diffusion of free carriers in silicon, resulting in an non-uniform distribution within the ring core cross section. In contrast, strip waveguides maintain a uniform distribution of free carriers throughout the silicon core.

To validate our approach, I have developed a flexible experimental setup that supports

the characterization of various types of ring resonators using continuous input power and pump-probe experiments.

In the pump-probe experiment, high power pulsed input light is introduced into the ring to analyse the impact of free carriers on the ring's response and extract the free carrier lifetimes in ring resonators. The experimental results are found to be in good agreement with the developed theory.

Finally, I conclude this work by introducing the theoretical formalism that extend our model beyond the simple ring resonator to incorporate the description of the hybrid tunable laser composed of the RSOA and the passive mirror with non-linear silicon microrings.