Ph.D. in Information Technology:

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An increasing research effort is being carried out to profit from the advantages of photonics not only in long-range telecommunications, where it has become the standard technology, but also at short distances, to implement board-to-board or even chip-to-chip interconnections. The performance scaling required by datacenter, automotive and telecommunication applications is in fact requiring very high data-rates achieved with reduced losses and power consumption, that are pushing copper-based connections close to their physical limitations even at short distance. In this context, Silicon Photonics emerged as a very promising technology, allowing to integrate many optical devices in a small silicon chip fabricated with the well-consolidated manufacturing processes of the microelectronics. However, the integration density made possible by Silicon Photonics revealed the difficulty of operating complex optical architectures in an open-loop way, due to their high sensitivity to fabrication parameters and temperature variations. Local light monitoring and active control of each photonic device thus emerged as strong requirements to correctly operate complex optical systems.

In this thesis, the true potential of integrated photonics was unlocked thanks to the design of a low-noise mixed-signal electronic platform implementing feedback control of complex optical architectures. The system exploits the innovative ContactLess Integrated Photonic Probe (CLIPP), a detector that senses light in silicon waveguides in a non-invasive way by measuring their electrical conductance and can thus be integrated in many points of an optical circuit without penalties. The electrical behaviour of waveguides was first investigated, to understand how to improve the structure and performance of the sensor. A new CLIPP layout was then proposed, allowing a 10-fold improvement of the sensitivity with reduced influence of environmental conditions. The resolution in the CLIPP readout was then maximized with the design of a custom impedance-sensing multichannel ASIC. The extremely low-noise performance of the ASIC allows to measure conductance variations well below 1 pS, that reflect in an accuracy in the detection of light around -50 dBm, outperforming the resolution of other transparent sensor found in literature. A mixed-signal FPGA-based motherboard completes the electronic system, acquiring the signals from the ASIC and closing in the digital domain the feedback loops to control multiple photonic devices with the most suitable algorithms. The dithering technique was in particular identified as a very effective strategy to stabilize the behaviour of optical architectures and an extension of the standard approach was proposed to allow easy control of many devices in parallel. The effectiveness of the designed system was finally demonstrated in several experiments of light routing at extremely high data-rates, reconfiguration of programmable circuits and thermal crosstalk compensation, both in datacenters applications and mid-range free-space optical communications.