Ph.D. in Information Technology
Thesis Defense

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at 12:00
Room Beta

Fabio TOSO – XXXIV Cycle

Scalable integrated electronics for closed-loop control of large reconfigurable photonic circuits

Supervisor: Prof. **Giorgio Ferrari**

Abstract:

Technological advances in integrated photonics have made the realization of complex photonic architectures possible. Several applications benefit from this progress, from the implementation of complex optical networks functionalities, to artificial intelligence, all-optical information processing and innovative light-based sensing. A key factor in enabling the successful operation of complex and dense photonic circuits is the implementation of a real-time electronic control layer, able to configure and stabilize the functionalities of optical devices against their intrinsic sensitivity to temperature fluctuations and fabrication tolerances. In this work, solutions for closed-loop control of complex photonic circuits scalable on a large number of devices are proposed and analyzed.

A first approach is represented by the miniaturization of the control electronics. In this context, an application-specific integrated circuit (ASIC) in CMOS technology was developed to control meshes of integrated Mach-Zehnder interferometers. The ASIC is able to automatically set and stabilize the working point of four interferometers in parallel, without any external control electronics. Optical power on the photonic chip is monitored through integrated non-invasive CLIPP detectors to minimize losses, thus allowing the use of the controller in a wide range of applications. Each interferometer is independently configured in 10ms, with a power consumption of 20mW, comparable to the dissipation of thermo-optical phase shifters. The controller was successfully used to control a 4-inputs binary-tree mesh of Mach-Zehnder interferometers, demonstrating its ability to compensate for input phase perturbations up to 50Hz. The compactness and low cost given by the CMOS technology make the proposed system a scalable solution to control large programmable photonic integrated circuits.

One of the main limits to the implementation of large photonic circuits is posed by the high number of electrical input and output connections necessary between the photonic circuit and the control electronics. In this thesis, the problem was approached innovatively by introducing the idea of on-chip time-multiplexing of electrical I/Os. This was made possible by adding the implementation of electron devices to a standard active silicon photonics platform. After a careful analysis of the selected silicon photonic technology, MOSFET transistors, logic gates and analog switches were designed with a zero-change approach, in order to preserve the full photonic performances of the technology and to avoid cost penalties. The realized devices were successfully used to design a 16-

to-1 analog multiplexer for integrated photo-diodes, which was used to feedback-control and stabilize a 16-to-1 optical router in real-time through a single output monitoring port. The time-multiplexing approach was also explored for the driving of actuators. In order to keep each actuator active during the multiplexing phase without the external stimulus, a new kind of gated thermal actuator was introduced. The new device has a linear voltage-power characteristic and requires zero DC current from the actuation port, thus allowing a low-frequency refresh of its driving voltage.

PhD Committee

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