_An_alog _Ph_otonic _In_formation _Pro_cessing _Mo_dules (ANAPHI-PRO)

1. FINAL PUBLISHABLE SUMMARY REPORT

The objective of this research project is the study, design and implementation of **Ana**log **Ph**otonic **I**nformation **Pro**cessing **Mo**dules (ANAPHI-PRO) for signal processing applications. The many advantages of photonics compared to electronics give the potential to realize solutions that offer low loss, high bandwidth modules with immunity to electromagnetic interference (EMI), high speed, parallel processing (e.g., through wavelength division multiplexing or spatial multiplexing), which greatly increase the channel count and the available system functionality. The project goal is to develop a mathematical and physical model to describe fibre-optic and integrated photonic based photonic filter designs for information processing in telecommunications, sensing and metrology.

Under the above context the project developed designs and architectures for of all optical tunable and programmable optical filters based on a combination of elemental photonic elements such as directional couplers and splitters, waveguides, phase shifters to build more complex building blocks such as Mach-Zehnder Interferometers and Ring Resonators to form larger complex devices.

The project addressed three main information processing functions: (a) Multifunctional photonic filters, (b) high linearity interferometric devices and (c) photonic delay lines.

(a) The multifunctional photonic filters were based on fibre-optic (FO) and photonic integrated circuit (PIC) Michelson-Gires-Tournois Interferometers (MGTI). The basic interferometric structure is that of a Michelson Interferometer (MI), where each arm is complimented by Gires-Tournois Resonator (GTR). The functionality of the module depends on the selection of appropriate path length and cavity lengths as well as tailored reflectivity for the reflectors. The reflectors are based on loop mirrors. A variety of intensity transfer functions (e.g., square like pass-band, notch, ramp and sinusoidal) have been achieved. The challenge has been to be able to achieve these different transfer function with the same platform. In FO based approaches the reflectivity is tuned by FO-polarization controllers, whereas in PIC designs the reflectivity is tuned by controlling the coupling coefficient of directional couplers that are building elements for the PIC loop mirrors. The FO based architectures helped us, through modeling and simulation, to develop the mathematical and physical models to study and analyze performance. However, PIC designs are far more stable as they are more compact and environmentally isolated, as well as they are based on mature fabrication techniques. An added feature of the multifunctional photonic filters is the potential for compensating manufacturing tolerance by means of adjusting the reflectivity

(b) The high linearity interferometric devices address the need for highly linear operation in telecommunication systems. Typical high linearity devices are based on a large number of components (e.g., MZI, RR), which eventually increase size, cost, and complexity of controls. The ANAPHI-PROMO devices are based on a low count approach based on a combination of MZI and RR components. In particular a 2 MZI matrix with an additional MZI nested in the second stage of the MZI matrix, provides linear response of the electric field. This photonic filter can be used in systems and links where frequency discrimination is required. The device was design, modeled and fabricated silicon/silicon dioxide platform. Important design and fabrication experience has been gained and we are proceeding with additional optimized designs.

(c) Switched photonic delay lines are important photonic information processing tools. A critical requirement for switched photonic delay lines is fast switching speed and low insertion loss. In the proposed architectures, switching is achieved using semiconductor optical amplifiers, which also provide insertion loss compensation. Delay lines are based on FO circuits and/or low loss waveguides. A single switched photonic delay line has been demonstrated for RF antenna signal beam-steering. The delay line was built with bulk components and serves as a proof of principle for the approach, which can be implemented in the future using PIC technology.

The project addresses the development of innovative photonic technology that will lead to low cost products of significant market horizon and social impact. The current industry trend is the reduction in size, weight and power (SWaP) for commercial devices. Photonic modules based on PIC platforms can address such a critical requirement for tomorrow’s applications. Reduction of SWaP can lead to widespread use of photonic modules for fast and low-cost information processing modules that can be integrated in larger systems in telecommunications, sensors, and metrology applications.

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