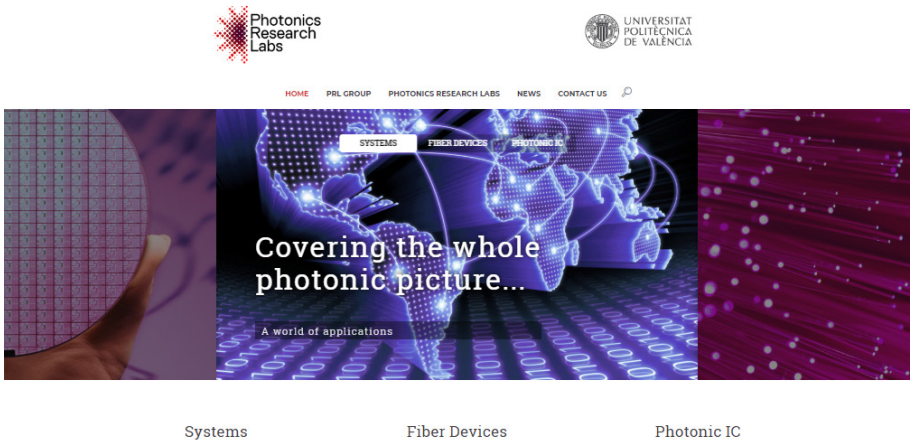


PRL web site

PHOTONICS RESEARCH LABS

PROF. DR. DR. JOSÉ CAPMANY – GROUP LEADER – PHOTONICS RESEARCH LABS

The Photonics Research Labs (PRL) are currently formed by more than 40 telecom engineers and physicists. The PRL mission is to produce high-quality scientific knowledge in the field of optics, quantum optics and photonics, through research projects, R&D contracts and collaboration agreements with the private sector. The PRL research activity is focused on several applications of photonics, mainly on optical communications of analog and digital signals, radio-over-fiber systems and photonic integrated circuits. Part of the research is also performed in the field of fiber optic sensor and industrial photonics. Among others, PRL has been granted two Excellent Projects by the European Research Council (ERC).

PRL Twitter

MAIN ACTIVITIES

Microwave Photonics

Among the most productive research lines, PRL is considered a world-leading group in Microwave Photonics (MWP), principally due to its contributions to the field of microwave photonic signal processing, a fundamental technology for the convergence of fixed and wireless telecommunication networks. The research is focused in tunable and reconfigurable microwave filters based in fiber gratings and delay lines for the processing of radiofrequency, microwave and millimetric signals, directly in the optical domain, Remote antenna array feeders by means of optical delay lines (beamforming and beam steering), Signal processing and distribution over space-division multiplexing (SDM) optical fibers, Slow and Fast Light (SFL) Effects applied to Microwave Photonics. Implementation of tunable broadband microwave phase shifting and true time delay functionalities by means of different SFL technologies as Coherent Population Oscillations in Semiconductor Optical Amplifiers and stimulated Brillouin scattering in optical fibers, RADAR and Ultra-Wide Band (UWB) applications and Optical Frequency Division Multiplexing (OFDM) techniques.

Photonic integrated circuits

Design of integrated photonic devices for multiple applications (optical telecom, optical signal processing, sensing, bio-photonics): Silica or PLC (SiO_2), Silicon-on-Insulator (SOI), Silicon Nitride (Si_3N_4), active devices in InP.

Cryptography and quantum information

The research line is focused on the applications of Quantum Mechanic principles to information processing in optical telecommunication systems (Entanglement, Quantum state teleportation and Encryption).

Fibre Bragg Gratings

Design and fabrication of Fibre Bragg Gratings for communication networks (Dispersion compensation and optical filters) and Sensing applications (high temperature, stress, pressure, chemical, bio).

Optical Networks

Optical links conform a large part of the current global communication network, and the trend is growing with the latest deployments of Fiber-to-the-Home networks and fiber backhauling of mobile and radio networks. PRL currently develops an active line on the development of novel architectures and technologies as well as providing reasonable cost solutions for access networks with high capacity and upgraded reconfigurable features towards the convergence with 5G upcoming standards.

Photonic Instrumentation and Advanced Techniques for Metrology

Research and development of innovative photonic instrumentation focuses on photons or optical fields and the light-matter interaction for a wide range of scientific and industrial applications. Our main target is to design, implement and demonstrate the feasibility of photonic instruments with advanced functionalities featuring unique properties beyond the current state of the art.

FLAGSHIP PROJECTS

ERC Advanced Grant awarded to Prof. José Capmany – UMWP-Chip: Universal microwave photonics programmable processor for seamlessly interfacing wireless and optical ICT systems.

ERC Consolidator Grant awarded to Dr. Ivana Gasulla – InnoSpace: Revolutionizing fibre-wireless communications through space-division multiplexed photonics.

ERC Proof of Concept awarded to Prof. José Capmany – FPPAs: Field Programmable Photonic Arrays.

H2020-ICT project led by Prof. José Capmany – NEoteRIC: NEuromorphic Reconfigurable Integrated Photonic Circuits as artificial image processor.

SPIN-OFF COMPANIES

VLC Photonics (2011)

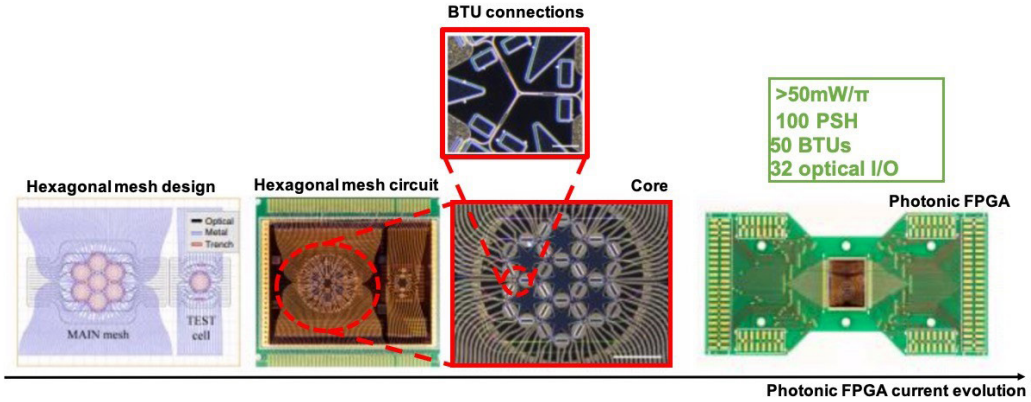
VLC Photonics' mission is to provide engineering solutions that allow our customers to harness the benefits of photonic integration, as well as to build up on our providers technologies. The mission spans from the initial work of drafting high-level optical system architectures to the final part of specifying its deepest technical details, all the while under a customized approach to the specific application domain at hand.

CalSENS (2013)

Cálculo y Estructuras Sensadas, CALSENS S.L., offers services of monitoring of processes and structures, of advice in the evaluation of its security and of decision making to guarantee its correct operation. It was born from the union of telecommunications engineering professionals and of roads, channels and ports that collaborate since 2004 in photonic technology research projects applied to the monitoring of processes and structures. This allows us to offer the customer an optimal solution adapted to their needs in the fields of civil engineering, aerospace, transportation and energy.

ePHOOX Engineering (2016)

EPHOOX Technology S.L. (founded in 2016) continues its activities towards the development of novel solutions based on Microwave Photonics technology for specific environments such as 5G.



ERC Proof of Concept Grant: Field Programmable Photonic Arrays

The module OVNA-P100X has been designed and manufactured as an advanced instrumentation for characterization and monitorization of photonic devices and hybrid RoF systems. Ongoing activities will provide soon an upgraded version with improved performance and new functionalities.

iPRONICS (2019)

The recently created company iPRONICS Programmable Photonics S.L. aims to turn programmable integrated photonic chips development into a commercial valuable proposition.

1. PROJECT ACTIVITIES

1.1. ONGOING PROJECTS

ERC Proof of Concept Grant: Field Programmable Photonic Arrays

***IP**: José Capmany Francoy*

2019-2021. European Funding - European Research Council (ERC).

***Summary:** The core concept behind this project spins-off from the activity of the Advanced Grant ERC-ADG-2016-741415 UMWPCHIP. The aim of that project is to develop a generic universal signal processor for microwave photonics applications. The central part of such processor is a reconfigurable waveguide mesh circuit.*

The waveguide mesh circuit can enable a much more powerful concept with a considerable wider scope of applications. This new paradigm, which we call programmable photonics is radically different from the so-far dominant Application Specific Photonic Circuit paradigm. Furthermore, we expect that, as it happened in electronics, programmable circuits will play a key role in photonics.

In programmable electronics, the key device is the Field Programmable Gate Array (FPGA). For photonics we have proposed a novel device, the Field Programmable Photonic Array (FPPA). The FPPA has a similar rationale as the FPGA in electronics: A common hardware is designed to provide several resources that can be employed to implement different functionalities by means of programming. However, the FPPA is different from the FPGA in the sense that it does not carry digital logic operations but rather exploits optical interference to perform very high-speed analog operations acting over the phase and amplitudes of optical signals in a controlled environment provided by the chip's reduced footprint. Now that we have demonstrated the potential of developing FPPA, the challenge is to demonstrate its innovation potential, developing the first steps towards its technical and commercial viability and launching a spin-off company based on this concept.

ERC Advanced Grant: Universal microwave photonics programmable processor for seamlessly interfacing wireless and optical ICT systems (UMWP-Chip)

***IP:** José Capmany Francoy*

2017-2022. European Funding - European Research Council (ERC)

***Summary:** Information and communication technology (ICT) systems are expanding at an awesome pace in terms of capacity demand, number of connected end-users and required infrastructure. To cope with these rapidly increasing growth rates there is a need for a flexible, scalable and future-proof solution for seamlessly interfacing the wireless and photonic segments of communication networks. RF or Microwave photonics (MWP), is the best positioned technology to provide the required flexible, adaptive and future-proof physical layer with unrivalled characteristics. Its widespread use is however limited by the high-cost, non-compact and heavy nature of its systems. Integrated Microwave Photonics (IMWP) targets the incorporation of MWP functionalities in photonic chips to obtain cost-effective and reduced space, weight and power consumption systems. IMWP has demonstrated some functionalities in through application specific photonic circuits (ASPICs), yielding almost as many technologies as applications and preventing cost-effective industrial manufacturing processes. A radically different approach is based on a universal or general-purpose programmable photonic integrated circuit (PIC) capable of performing with the same hardware architecture the main required functionalities. The aim of this project is the design, implementation and validation of such a processor based on the novel concept of photonic waveguide mesh optical core and its integration in a Silicon Photonics chip.*

ERC Consolidator Grant: Revolutionizing fibrewireless communications through spacedivision multiplexed photonics (InnoSpace)

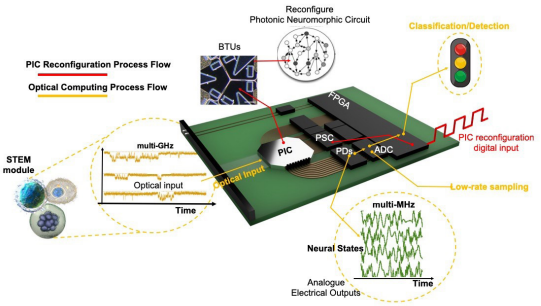
***IP:** Ivana Gasulla Mestre*

2017-2022. European Funding - European Research Council (ERC)

***Summary:** InnoSpace aims to revolutionize next generation fiber-wireless communication paradigms, such as 5G systems and Internet of Things, by pioneering the use of the photonic Space dimension. The present fiber-wireless landscape is characterized by radio-over-fiber distribution architectures that are static and inefficient, (with a replication of bundles of optical fibers) as well as by radiofrequency signal processing systems, such as antenna beam-steering or signal generation, which are nowadays bulky, heavy and power consuming. To overcome these limitations, we propose the*

application of Space-Division multiplexing to fiber-wireless scenarios where we provide "simultaneously" in a single optical fiber, a compact approach for both distribution and processing functionalities. This leads to the novel concept of "fiber distributed signal processing".

H2020 NEoteRIC: NEuromorphic Reconfigurable Integrated Photonic Circuits as artificial image processor



H2020-ICT: NEuromorphic Reconfigurable Integrated Photonic Circuits as artificial image processor

IP: *José Capmany Francoy*

2020-2022. European Funding - European Commission.

Summary: *NEoteRIC's primary objective is the generation of holistic photonic machine learning paradigms that will address demanding imaging applications in an unconventional approach providing paramount frame rate increase, classification performance enhancement and orders of magnitude lower power consumption compared to the state-of-the-art machine learning approaches. NEoteRIC's implementation stratagem incorporates multiple innovations spanning from the photonic "transistor" level and extending up to the system architectural level, thus paving new, unconventional routes to neuromorphic performance enhancement. The technological cornerstone of NEoteRIC relies on the development and upscaling of a highspeed reconfigurable photonic FPGA-like circuit that will incorporate highly dense and fully reconfigurable key silicon photonic components (ring resonators, MZIs, etc.). High-speed reconfigurability will unlock the ability to restructure the photonic components and rewire inter-component connections. Through NEoteRIC the integrated photonic FPGAs will be strengthened by the incorporation of novel marginal-power consuming non-volatile high-speed phase shifters that will push the boundaries of energy consumption. NEoteRIC's "unconventional" chips will be utilized as a proliferating neuromorphic computational platform that will merge the merits of photonic and electronic technology and will allow the all-optical implementation of powerful non-von Neumann architectures such as Reservoir Computing, Recurrent Neural Networks, Deep Neural Networks and Convolutional Neural Networks simultaneously by the same photonic chip. The in-project excellence will be tested through demanding high impact application such as high frame-rate image analysis and in particular single-pixel time-stretch modalities thus pushing the boundaries of state-of-the-art; exhibiting simultaneous high spatial resolution and Gframe/sec processing rate.*

H2020 BlueSPACE: Building on the Use of Spatial Multiplexing 5G Networks Infrastructures and Showcasing Advanced technologies and Networking Capabilities

IP: *Salvador Sales Maicas*

2017 - 2020. European Funding – H2020

Summary: *The core concept of BLUESPACE is to exploit the added value of Spatial Division Multiplexing (SDM) in the Radio Access Network (RAN) with efficient optical beamforming interface for the pragmatic Ka wireless transmission band. Both being seamlessly integrable in next generation optical access networks infrastructures with massive beam steering capabilities and with flexible network management control. The main objectives targeted by the BLUESPACE project are: to develop a truly viable and efficient path for 5G wireless communications with a 1000-fold increase in capacity, connectivity for over 1 billion users, strict latency control, and network software programming. BlueSPACE targets a disruptive yet pragmatic approach for the deployment of scalable, reconfigurable and future-proof fronthaul solutions for 5G communications, offering unrivalled characteristics that include: a) increased bandwidth provision by naturally enabling and supporting massive multiple Input Multiple Output (MIMO) transmission starting/ending in the fiber medium by enabling space diversity in the RF domain by supporting RF beam steering in the photonic domain, b) compact infrastructure that is reconfigurable by means of Software Defined (SDN) and Network Function Virtualization (NFV) paradigms and c) the possibility of providing full integration with other existing approaches for the implementation of access networks, such as Passive Optical Networks (PONs). This approach relies on the core concept of this project, which is the introduction of Spatial Division Multiplexing (SDM) in the fronthaul of the mobile access network.*

COST Action EUIMWP: European Network for High Performance Integrated Microwave Photonics

IP: *José Capmany Francoy*

2017 - 2020. European Funding – H2020

Summary: *This Action aims to shape and bring the relevant integrated Microwave Photonics community, supporting coordination and networking actions to consolidate this new ecosystem. EUIMWP is providing exchange of knowledge, ideas and, equally important, delivering a portfolio of technological benchmarkings to establish performance*

indicators and define future technological requirements in high-performance scenarios, mainly radar, 5G, Internet of Things, automotive and aerospace technologies. Over 40 partners from academia, industry and public organizations are founding members of the Action.

MSCA-ITN MICROCOMB: Applications and Fundamentals of Microresonator Frequency Combs (MSCA-ITN- 2018-ETN)

IP: *Pascual Muñoz Muñoz*

2019-2022. European Funding - European Commission.

Summary: *MICROCOMB is a collaborative research and training network, gathering together 17 European universities, research centers and industrial partners with complementary expertise on microresonator technology and the observation and exploitation of the microresonator frequency combs. Microcombs are emerging as a disruptive technology for realizing precision metrology, frequency and waveform synthesis and optical processing of information on a chip-scale platform. A typical microcomb setting is a microring resonator evanescently coupled with a waveguide mode, which is pumped by a continuous wave laser by means of a non-linear process like four-wave mixing (Kerr nonlinearity). Applications of microcombs for processing information with terabit rates, take advantage of the smaller resonator length and therefore being compatible with higher data transmission rates and also of the broad spectral coverage extending over C, L and U optical transmission bands. Other applications are: astronomical research, molecular spectroscopy, arbitrary wave form generators and RF and THz signal processing and generation.*

Website: https://www.microcomb-eu.org/

MSCA-ITN FINESSE: Fibre Nervous Sensing Systems (MSCA-ITN- 2016-ETN)

IP: *Salvador Sales Maicas*

2016-2020. European Funding - European Commission.

Summary: *FINESSE (FIbre NErvous Sensing SystEms) is a collaborative research and training network, gathering together 26 European universities, research centers and industrial partners with complementary expertise with the ultimate vision of a widespread implementation of distributed optical fibre sensor systems for a safer society.*

The objective behind FINESSE (FIbre Nervous Sensing SystEms) is to mimic the nervous system of living bodies by turning man-made and natural structures into objects that are sensitive to external stimuli owing to advanced distributed fibre-optic sensor technology, with the objective to either give early warning in case of possible danger or occurrence of damage, or to optimise the operation of the structure to allow for a sustainable use of natural resources and assets. Enabling such functionalities will greatly contribute to realizing a safe, secure and energy efficient Europe, which is an identified societal concern. http://itn-finesse.eu/

H2020 PICS4ALL: Photonic integrated circuits accessible to everyone

IP: *Pascual Muñoz Muñoz*

2016 - 2019. Public Funding - European Commission

Summary: *The aim of the PICs4All CSA is to establish a European network of Application Support Centres (ASC's) in the field of Photonic Integrated Circuits (PICs) technology. The main task of these ASC's is to lower the barrier to Researchers and SMEs for applying advanced Photonic IC technology, in particular InP and TriPleX based, and thus to increase the awareness of the existence of this worldwide unique facility. Website: http://pics4all.jeppix.eu/*

FOCAL: Energy eFficient hybrid Optical networks for indoor Communications And Lighting (RTI2018-101658-B-I00-AR)

IP: *Beatriz Ortega Tamarit, Vicenç Almenar Terre*

2019 - 2021. Public Funding - Ministerio de Ciencia, Innovación y Universidades (MICINN)

Summary: *The Project consists on the definition of the architecture of an indoor hybrid wired and wireless optical network based on VLC communications (Fi2VLC) to provide coverage and 5G services in residences and offices. Full characterization of hybrid POF and VLC links with improved capacity and flexibility, also including different multiplexing techniques will be addressed. Electro-optical transceivers based on low cost commercially available LEDs will be designed to transmit digital modulation formats such as OFDM, QPSK, CAP, 16QAM, etc. and adaptive modulations to adjust the transmission capacity to the actual demand in a multiuser scenario. The Project also includes the experimental characterization of the networks (QoS, BER, SNR) using the developed technologies (multiplexing, adaptive modulations and multiuser access) for service transmission and the implementation of software-defined Fi2VLC networks for energy efficient operation. Finally the techno-economical evaluation of the implemented solutions will assess their viability in short term 5G networks.*

CARÁCTER: Desarrollo de sistemas de caracterización y monitorizacion basados en fotonica de microondas de aplicacion en el mercado emergente de redes 5G (RTC-2016-5343-7)

IP: *José Mora Almerich*

2017 - 2019. Public Funding - Ministerio de Economía y Competitividad (MINECO)

Summary: *The main objective of the project is to develop a family of characterization systems based*

on the advanced control of high-performance microwave photonic components and a competitive price determinant for the implementation of new generation networks. The interest of the consortium in the present project is to analyze the feasibility of the Microwave Photonic technology for the development and implementation of an advanced performance analyzer for the characterization of devices and monitoring of hybrid radio-fiber systems that is capable of operating until the 70 GHz.

Silicon Nitride Spectrometers (TEC2016-80385-P)

***IPs**: Pascual Muñoz, Daniel Pastor*

2017 - 2020. Public Funding - Ministerio de Economía y Competitividad (MINECO)

***Summary:** Spectrometric devices are employed in multitude of disciplines, as information technologies, analytical chemistry, bio/life sciences and safety & security. The wavelength range spanning the upper part of the Near Infra-Red (NIR), wavelengths in the range of 1.5-4.0 μm, has recently raised considerable interest both for telecom due to the fiber capacity crunch, and non-telecom applications, since inorganic and organic molecules of fluids, and gases, exhibit fingerprint vibrations in this part of the spectrum. Compact integrated optics spectrometers on photonic integrated circuits (PICs) are comparatively smaller, but to the date they have not achieved the reconfiguration capabilities of the conventional bulk instruments. Among the different PIC technologies, Silicon Nitride on Silicon Oxide waveguiding platforms have received considerable interest in the recent years, due to their broad wavelength range of operation, from visible to the lower part of the mid infrared (400-4000 nm), serving to photonic applications in multiple disciplines (physics, engineering, bio/life sciences, safety & security, to name a few).*

FITNESS: Multicore fibers for next-generation fiberwireless applications (TEC2016-80150-R)

***IP:** Ivana Gasulla Mestre*

2017 - 2020. Public Funding - Ministerio de Economía y Competitividad (MINECO)

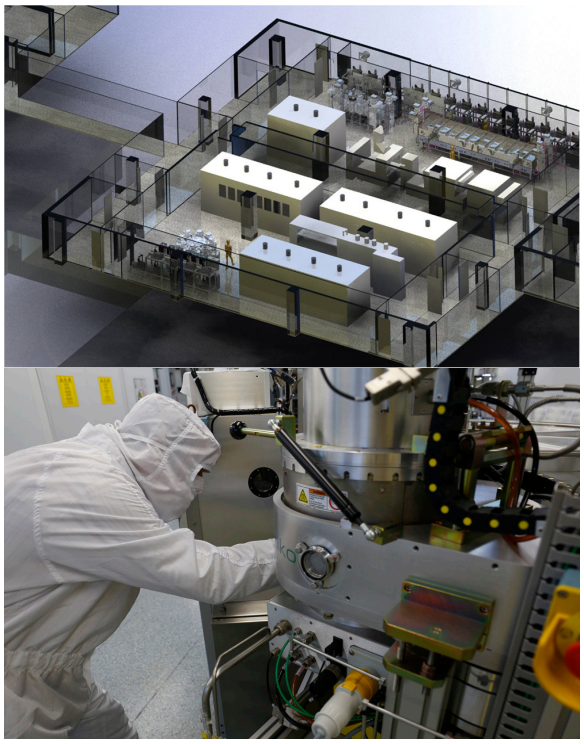
***Summary:** The pioneering idea of FITNESS is to develop a novel area of application for Space-Division Multiplexing by exploiting, for the first time, the inherent parallelism of multicore fibers to implement broadband delay lines for radiofrequency signals, which is the basis of multiple Microwave Photonics functionalities. More specifically, this project works on designing and fabricating group index variable delay line built upon the heterogeneous multicore fibers, where each one of the different cores that comprise it will feature an independent group delay.*

UPVFab: Micro-Fabricación para Fotónica, Electrónica y Química

***IP:** Pascual Muñoz Muñoz*

2017 - 2020. Public Funding - Generalitat Valenciana

***Summary:** Infrastructure acquisition project to upgrade and retrofit equipment at the class 100/10000 (ISO 5/7) 500 m² micro-fabrication pilot line / clean room www.fab.upv.es*



UPVfab

2. RESEARCH RESULTS

2.1. HIGHLIGHTED PUBLICATIONS

D. Pérez, I. Gasulla, J. Capmany, "Programmable multifunctional integrated nanophotonics" Nanophotonics 7 (8), 1351-1371, (2018)

Programmable multifunctional integrated nanophotonics (PMIN) is a new paradigm that aims at designing common integrated optical hardware configurations, which by suitable programming can implement a variety of functionalities that can be elaborated for basic or more complex operations in many application fields. The interest in PMIN is driven by the surge of a considerable number of emerging applications in the fields of telecommunications, quantum information processing, sensing and neurophotonics that will be calling for flexible, reconfigurable, low-cost, compact and low-power-consuming devices, much in the same way as how field programmable gate array (FPGA) devices operate in electronics. The success of PMIN relies on the research into suitable interconnection hardware architectures that can offer a very high spatial regularity as well as the possibility of independently setting (with a very low power consumption) the interconnection state of each connecting element. Integrated waveguide meshes provide regular and periodic geometries, formed by replicating a unit cell, which can take the

form of a square, hexagon or triangle, among other configurations. Each side of the cell is formed by two integrated waveguides connected by means of a Mach-Zehnder interferometer (MZI) or a tunable directional coupler that can be operated by means of an output control signal as a crossbar switch or as a variable coupler with independent power division ratio and phase shift. In this paper, we review the recent advances reported in the field of PMIN and, especially, in those based on integrated photonic waveguide meshes, both from the theoretical as well as from the experimental point of view. We pay special attention to outlining the design principles, material platforms, synthesis algorithms and practical constraints of these structures and discuss their applicability to different fields.

D. Barrera, J. Madrigal, S. Delepine-Lesoille, and S. Sales, "Multicore optical fiber shape sensors suitable for use under gamma radiation," Opt. Express 27, 29026-29033, (2019)

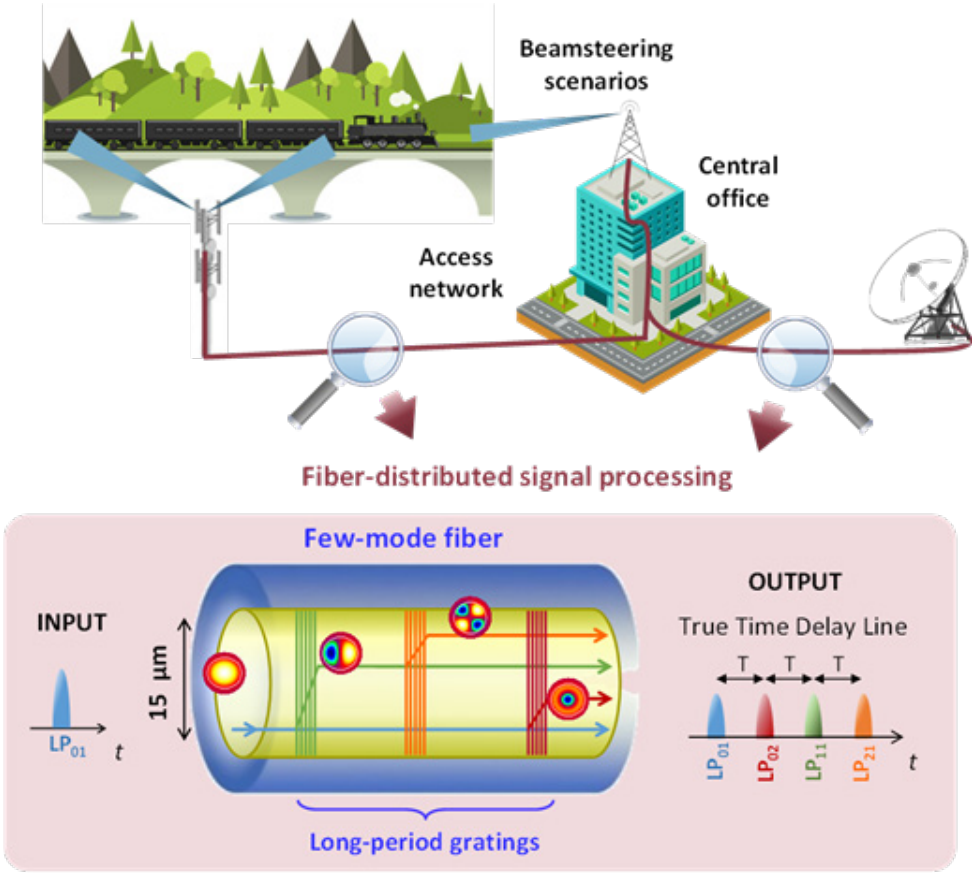
We have designed and implemented the first fiber optic shape sensor for nuclear radiation environments based on multicore optical fibers. We inscribed two fiber Bragg gratings arrays in a seven-core optical fiber. The radiation-induced Bragg wavelength shift (RI-BWS) produces errors. However, the use of the multiple cores permits to make these sensors immune to RI-BWS obtaining without modifying the composition of the fiber, pre-irradiation or thermal treatment.

D. Pérez, I. Gasulla, J. Capmany, "Field-programmable photonic arrays" Optics Express 26 (21), 27265-27278, (2018)

We propose a new programmable integrated photonic device, the Field Programmable Photonic Array, which follows a similar rationale as that of Field Programmable Gate Arrays and Field Programmable Analog Arrays in electronics. This high-level concept, basic photonic building blocks, design principles, and technology and physical implementation are discussed. Experimental evidence of its feasibility is also provided.

S. García, R. Guillem, J. Madrigal, D. Barrera, S. Sales and I. Gasulla, "Sampled true time delay line operation by inscription of long period gratings in few-mode fibers" Optics Express 27(16), 27(16), 27(15), 22787-22793, (2019).

We propose and experimentally demonstrate distributed microwave photonics signal processing over a few-mode fiber link by implementing 4-sample true time delay line operation. The inscription of a set of long period gratings at specific locations along the few-mode fiber allows the excitation of the higher-order modes while adjusting the individual sample group delays and amplitudes that are required for sampled true time delay line behavior.



Sampled true time delay line operation by inscription of long period gratings in few-mode fibers

We experimentally validate the performance of the implemented true time delay line when applied a typical signal processing system in fiber-wireless communications scenarios: radiofrequency signal filtering.

R. Min, B. Ortega, C. Broadway, C. Caucheteur, G. Woyessa, O. Bang, P. Antunes, C. Marques, "Hot water-assisted fabrication of chirped polymer optical fiber Bragg gratings", Optics Express, 26, 34655 – 34664, (2018)

We obtained chirped gratings by performing hot water gradient thermal annealing of uniform poly (methylmethacrylate) (PMMA) microstructured polymer optical fiber Bragg gratings (POFBGs). The proposed method's simplicity is one of its main advantages because no special phase mask or additional etching are needed. It not only enables easy control tuning of the central wavelength and chirp characteristics, but it also leads to obtain flexible grating response, compared with tapered chirped POFBGs. Therefore, a flexible and low-cost chirped POFBG devices fabrication technique has been presented by using a single uniform phase mask.

P. Muñoz et al. "Foundry developments towards silicon nitride photonics from visible to the mid-infrared" IEEE J. of Selected Topics in Quantum Electronics, 25 (5), 1-13, (2019).

Photonic integration technologies have spread in the past decade by means of foundry models that mirror the electronic-integrated circuit industry developments of the past century. Several monolithic technologies exist, based on silicon and III-V semiconductors. In this paper, we discuss the current state and forthcoming developments of open access photonic foundries whose technology platforms are based on silicon nitride material. The paper presents various silicon nitride technologies and foundries, alongside with access models supported by generic integration and process design kits. Technical features, enabled by different micro-fabrication processes and tools are summarized. Application examples and developments of forthcoming incorporation into these platforms are outlined.

2.2. PATENTS

J. Capmany, I. Gasulla y D. Pérez, "Método de configuración y optimización de dispositivos fotonicos programables basados en estructuras malladas de guiaondas opticas integradas", Application no. P201831118, Publication date: 2018. Priority country: Spain.

J. Capmany, I. Gasulla y D. Pérez, "Acoplador direccional fotofónico con sintonización independiente de factor de acoplo y desfase" Application no. P201831055, Publication date: 2018. Priority country: Spain.

J. Capmany, I. Gasulla y D. Pérez, "Photonic chip, Field Programmable Photonic Array and Programmable Circuit", Application no. 6/235,056, Publication date: 2018. Priority country: United States of America.

J. Capmany, I. Gasulla y D. Pérez, "Photonic chip, Field Programmable Photonic Array and Programmable Circuit," Application no. JP1598.79 Publication date: 2019. Priority country: Japan.

D. Pastor, P. Muñoz; et. al, "Dispositivo difractivo de análisis químico y biológico," Application no. P201930661. Publication date: 2019. Priority country: Spain.

D. Pastor, P. Muñoz; et. al, "Dispositivo difractivo de análisis químico y biológico," Application no. P201930661. Publication date: 2019. Priority country: Spain.