PHOTONICS AND RADIOFREQUENCY LABORATORY

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Keywords

Integrated optics, silicon photonics, photonic bionsensors, all-dielectric metamaterial waveguides, optical communications, radiofrequency devices and subsystems

Research Lines

- ✓ Highly sensitive integrated photonic biosensors
- ✓ Nanostructured metamaterial waveguide components
- ✓ Integrated photonic waveguides and components for the mid-infrared
- ✓ Optical coherent sensors with phase and polarization diversity

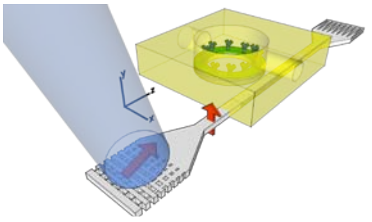
Scientific Activity

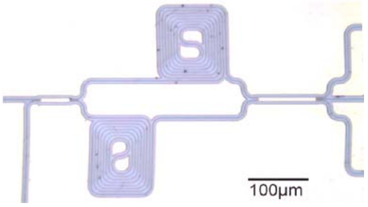
Our research group has a strong background in radiofrequency and integrated optics for optical communications. We specialize in high performance components for the silicon and indium phosphide platforms, with applications to high speed telecom receivers. We apply this extensive knowledge to novel photonic sensing techniques, based on the interaction of the evanescent field of a waveguide mode with an analyte deposited on the waveguide surface. This technique enables sensitivities on par with surface plasmon resonance (SPR), but with the potential of multiplexing tens or hundreds of different test on a single chip.

Research lines:

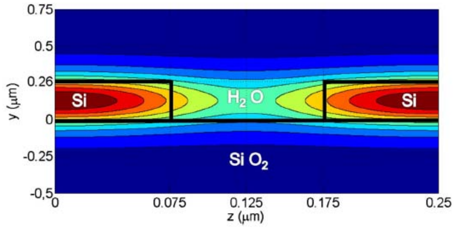
✓ Highly sensitive integrated photonic biosensors

Based on our expertise on coherent (amplitude and phase) optical phase detection techniques for optical communications we develop highly sensitive evanescent field optical biosensors. These sensors aim to: a) detect very low concentrations of drugs and pathogens and b) monitor molecular reactions in real-time for early diagnosis of diseases and drug discovery. The key advantage of photonic biosensors is that they enable label-free monitoring and detection, obviating intermediate labelling steps that can hamper detection reliability. Photonic biosensors based on integrated optics can be fabricated on a large scale, and, as opposed to surface plasmon resonance, their sensitivity is not limited by reduced propagation distances. The Silicon-on-Insulator platform offers increased sensitivity for evanescent field sensors, and a high degree of miniaturization and integration, enabling parallelized probing. Parallelization allows for several different reactions to be monitored simultaneously, while at the same time performing redundancy checks to reduce false positive/negatives. We are currently working with colleagues from the Catalan Institute of Nanoscience in Barcelona to test these our sensor designs.





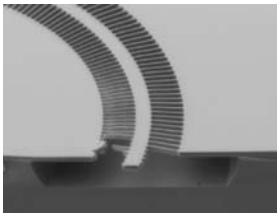
✓ Nanostructured metamaterial waveguide components

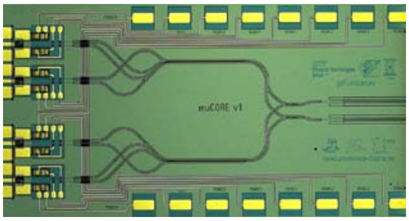


All-dielectric waveguides segmented at a sub-wavelength scale suppress diffraction effects, and behave as equivalent homogenous metamaterials whose refractive index and other optical properties can be engineered. This enables the design of photonic components with unprecedented performance, for applications in both (bio)sensing and communications. Our group has developed in-house simulation tools for these structures and has pioneered, together with our colleagues from the National Research Council of Canada, a variety of high performance devices, ranging from high efficiency grating couplers, to ultra-broadband waveguide couplers and high-sensitivity photonic biosensors.

✓ Integrated photonic waveguides and components for the mid-infrared

The mid-infrared (MIR) wavelength region (2-20 micrometers) is key for spectroscopic sensing because many compounds of interest (e.g. Methane, Carbon monoxide, Benzene) exhibit specific absorption spectra ("fingerprints") in this region. With applications ranging from explosive detections to medical diagnosis the marked for MIR sensor is expected to reach $7 billion by 2019. Integrated photonic devices operating in the MIR hold potential for measurement equipment with higher performance and reliability, while reducing size, weight and cost. We work with colleagues from the Optoelectronics Research Center at Southampton University to develop waveguides and devices that will enable photonic sensors in this fingerprint region.





✓ **Optical coherent sensors with phase and polarization diversity**

We continue to push the envelope of telecom optical receivers, advancing in the complete monolithical integration of these devices, with a particular focus on polarization control. This concept, which is of fundamental importance in optical communications, has not yet been widely explored for integrated sensing, where it has the potential to provide further enhancements in sensitivity and selectivity.

Collaborations

❖ **National Research Council of Canada**, Dr. Pavel Cheben, Sub-wavelength metamaterial silicon waveguide devices.

❖ **Catalan Institute of Nanoscience and Nanotechnology** (Spain), Prof. Laura Lechuga, Photonic biosensors.

❖ **Optoelectronics Research Center at Southampton University** (United Kingdom), Prof. Goran Mashanovich, Mid-infrared photonics.

❖ **Instituto de Telecomunicaciones y Aplicaciones Multimedia, Politechnic University of Valencia** (Spain), Dr. Pascual Muñoz, Photonic Integrated circuits for Telecom and Bio.

❖ **University of Zaragoza** (Spain), Prof. Ignacio Garcés, Polarization diversity coherent telecom receivers.

❖ **Czech Academy of Sciences** (Czech Republic), Prof. Jiri Ctzeroky, Numerical modelling of sub-wavelength structures.

❖ **Leibniz Institute for Astrophysics** (Germany), Jose Boggio, Dispersion engineered waveguides for supercontinuum generation.

❖ **State Key Laboratory of Modern Optical Instrumentation, Zhejiang University** (China), Prof. Dr. Jian-Jun He, Efficient light coupling to SiN photonic platforms

Research Projects in the last 5 years

- “Subwavelength engineering of photonic integrated circuits for near and mid-infrared applications (SENMIRA)”, TEC2016-80718-R, 2017-2019, Ministerio de Economía y Competitividad, IP: Iñigo Molina-Fernández, Alejandro Ortega-Moñux

- “Photonic Integrated Circuits for Telecom and Bio (PIC4TB)”, TEC2015-69787-REDT, 2016-2018, Ministerio de Economía y Competitividad, Coordinator: Pascual Muñoz, IP: Alejandro Ortega-Moñux

- “Coherent multiport receivers”, TEC2013-46917-C2-1-R, Ministerio de Economía y Competitividad, 2014-2017, IP: Íñigo Molina Fernández

- “Monolithic InP-Based dual polarizaion QPSK Integrated Receiver and Transmitter for Coherent 100-400GB Ethernet”, FP7 2010 ID257980, European Union 7th framework programme, 2010-2013, Coordinator: Christophe Kazmierski, IP: Íñigo Molina Fernández

- “Technologies for designing components and new generation coherent optical communication systems”, TEC2009-10152, Ministerio de ciencia e innovación, 2010-2012, IP: Alejandro Ortega Moñux

- “Frequency locked loops for enhanced phase noise performance in radiofrequency instrumentation sources”, P09-TIC-5268, 2010-2014, Dirección General de Investigación, Tecnología y Empresa (Junta de Andalucía) P09-TIC-5268. Investigador Principal: Iñigo Molina Fernandez

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- “Highly Tolerant Tuneable Integrated Optical Polarization Rotator”, Carlos Alberto Alonso Ramos, Laurent Vivien, Pavel Cheben, Robert Halir, Delphine Marris Morini, Alejandro Ortega Moñux, Íñigo Molina Fernández, PCT/FR2012/051001
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