Design of optical fiber sensors and interrogation schemes

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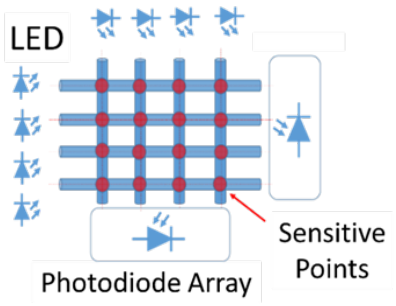
Defended on 01,14,2021

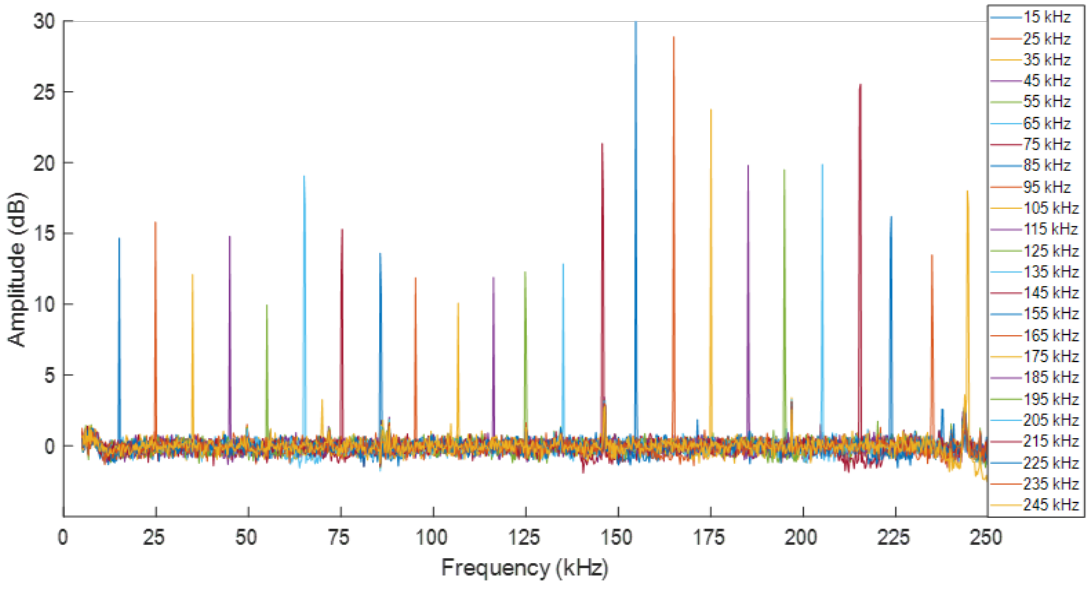
SUMMARY

Optical fibers are devices largely used in telecommunication field since their discovery. In the last decades, optical fibers started to be used as photonic sensors. The first works were focused on the measurement of physical dimensions to a specific point. Afterward, emerged the possibility to measure the optical fiber properties at different locations along the fiber. These kinds of sensors are defined as distributed sensors. The optoelectronic components were developed and investigated for telecommunications. The progress in telecommunication made possible the development of optical fiber sensors interrogation systems, growing in parallel with the advances of telecommunications.

Optical fiber interrogation systems were developed to use a single standard monomode optical fiber as a sensor that can monitor tens of thousands of sensing points at the same



Plastic optical fibers sensor matrix for 2D pressure sensing



Response for a wide range of vibration frequencies of the FBG-based vibration sensor

time. The methods that extract the sensing information from the backscattered signal in the optical fiber are widely employed because of the easiness of access to the sensor element and the flexibility of these systems. The most studied are the reflectometry in time and frequency domains. The optical time domain reflectometry (OTDR) was the first technique used to detect the position of the failures in the optical fiber communication networks. Using phase sensitive OTDR it is possible to sense strain and temperature at a specific position. In parallel, fiber Bragg gratings (FBGs) became the most widely used devices to implement discrete optical fiber sensors. Multiplexing techniques were developed to perform multi points sensing using these gratings. The reflectometry performed interrogating weak FBGs arrays demonstrate to improve the performance of the system employing a single mode fiber.

The interrogation systems nowadays have some drawbacks. Some of them are limited speed of interrogation, bulkiness, and high cost. New interrogation systems and optical fiber sensors were developed in this doctoral thesis to overcome some of these drawbacks. Plastic optical fiber sensors demonstrate to be an innovative platform to develop both new sensors and low cost, easy to implement interrogation systems for commercial plastic fibers. Reflectometry in time domain and microwave photonic techniques were investigated for the interrogation of weak gratings array allowed to simplify the interrogation system for the sensing of temperature and vibration.

Integrated spectroscopic sensor fabricated in a novel Si3N4 platform

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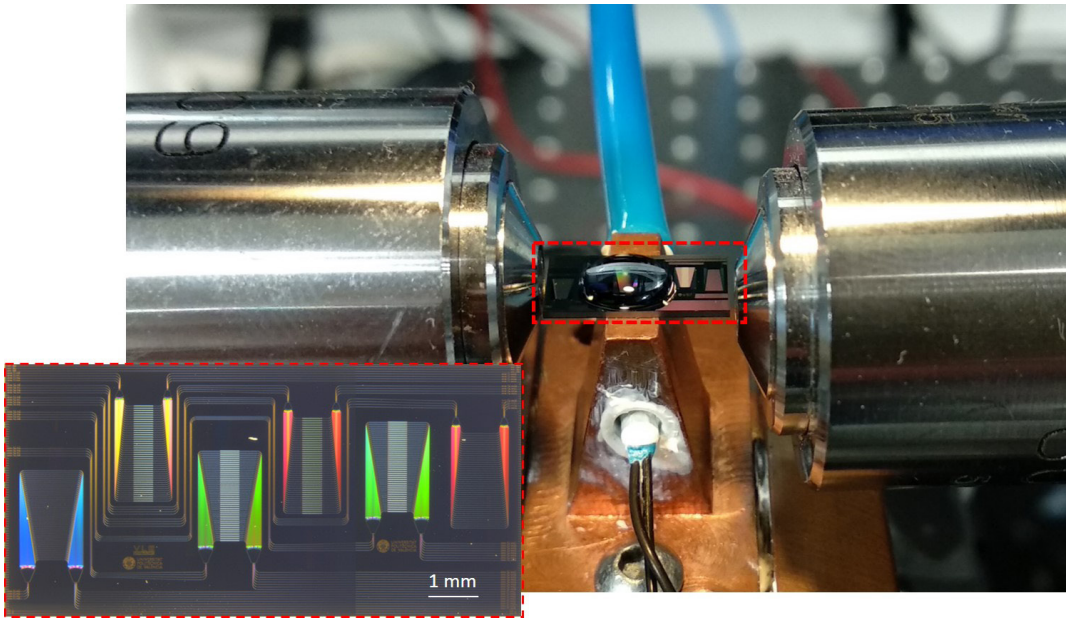
Defended on December, 16th, 2020

SUMMARY

This thesis is focused on the model, design and experimental demonstration of an integrated spectroscopic sensor based on a modified Arrayed Waveguide Grating (AWG). The device has been designed and fabricated in a new silicon nitride (Si3N4) on silicon oxide (SiO2) platform developed in Spain. The work performed for this thesis can be then divided into two main sections. In the first part, an overview of the existing Si3N4 platforms and their state of art is described, along with the report on the fabrication and characterization of our 300 nm guiding film height Si3N4 platform. On the second part, the device named Integrated Optical Spectroscopic Sensor (IOSS) is presented. The IOSS consists of an AWG which arrayed waveguides are divided into two sub-sets engineered to replicate the AWG channels. The waveguides of one of the sub-sets contain sensing windows, defined as waveguides sections which core is in contact with the surrounding media. Thus, the sensing is performed through evanescent field interaction with the sample deposited. The waveguides from the second sub-set remain isolated. Therefore, the device provides both sensing and reference spectra. The IOSS mathematical model, design procedure and proof of concept configured for absorption spectroscopy are reported in this thesis.



Design of communication systems based on broadband sources for fiber and free space optical links

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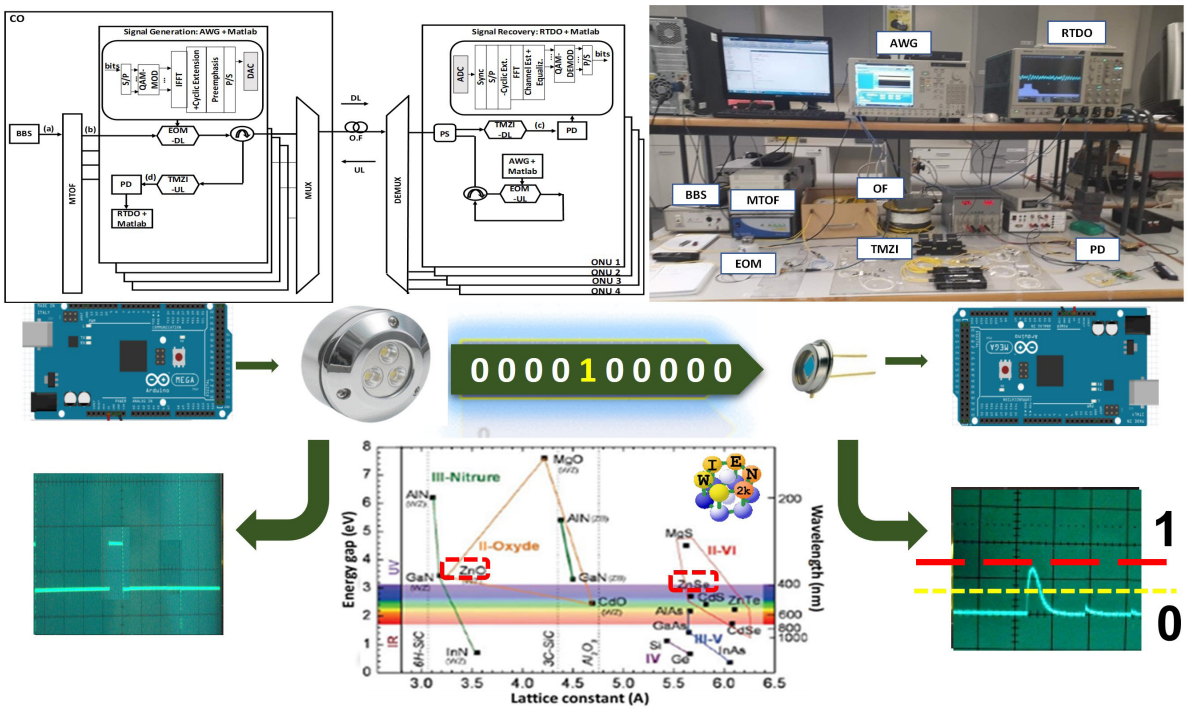
Supervisor: Dr. Beatriz Ortega and Dr. Benoudnine Hadjira

Defended on June, 28, 2021

SUMMARY

Optical wireless communication (OWC) is a very promising technology for future wireless communications developments. It has attracted increasing interest from researchers and several companies around the world are currently working on the development of very high-speed wireless networks. The scientific and industrial communities believe that OWC will be a complementary technology in its various forms: Free Space Optical communications (FSO), Visible Light Communications (VLC), Light Fidelity (Li-Fi). In fact, the optical spectrum has been considered for many years as a great opportunity for wireless communications especially due to the saturation of the radio frequency (RF) spectrum. This dissertation deals with the use of broadband sources in visible light transmission systems (VLC) as well as fiber optic systems. To carry out the research, three parts can be distinguished: In the first part, we consider the study and simulation of Light Emitting Diode (LED) components with the WIEN2k software by focusing on the optical and electrical properties of elements II-VI. The second part deals with the design, implementation and testing of different VLC communication prototypes for analogue and digital transmission in simplex and half-duplex mode. We have demonstrated that an OWC system using a broadband source (i.e., an LED)



can be used not only for data transmission, but also for wireless power transmission. Moreover, the synchronization problem and the detection of level “1” or “0” of a bit often arise in the optical wireless communication systems. This is a result of the attenuation nature of the light over the distance and the problem of Non-Line-Of-Sight (NLOS) between the emitter and the receiver. To deal with this problem, a communication protocol ensuring reliable digital data transmission with an adaptive bit level detection algorithm has been provided and its effectiveness has been demonstrated by the transmission of texts and images. In addition, this thesis provides a solution for the implementation of wavelength division multiplexed - orthogonal frequency division multiplexed (WDM-OFDM) transmitters based on the use of broadband sources in the infrared spectrum for centralized bidirectional fiber networks. Despite the chromatic dispersion that avoids the use of this type of optical sources, the inclusion of certain structures before detection allows the transmission of OFDM signals in optical links. Carrier reuse, dynamic bandwidth allocation and multiband OFDM signals transmission will be experimentally demonstrated by using optical broadband sources in WDM networks. The main results obtained during this thesis work demonstrate the study procedures, for each part, the effectiveness of the proposed solutions as well as the constraints encountered.

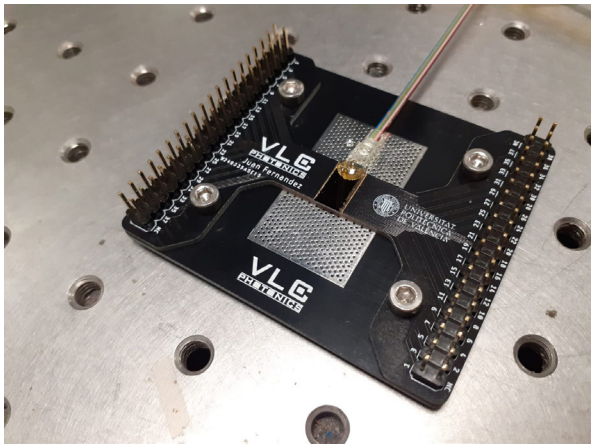
Reconfigurable reflective arrayed waveguide grating on silicon nitride

Author: Juan Fernández Vicente
Supervisor: Dr. Pascual Muñoz and Dr. José David Doménech

Defended on March, 26, 2021

SUMMARY

This thesis is focused on the modelling, design and experimental demonstration for the first time of Reconfigurable Reflective Arrayed Waveguide Grating (R-RAWG) device. In order to build this device, that can be employed in spectrometry, a silicon nitride platform termed CNM-VLC has been chosen since this material allows to operate in broad range of wavelengths. This platform has the necessary elements, but some limitations because the operation of this device had a low performance. Therefore, a methodology has been developed and validated, which has allowed to obtain better splitters. Also an inverted taper has been designed, which has considerably improved the coupling of light to the chip. This has been possible thanks to an exhaustive analysis of existing options in the literature, that has allowed choosing the best option to make a reconfigurable mirror on the platform without changing or adding new manufacturing steps. Reconfigurable mirrors have been demonstrated by using feedback splitters. Furthermore, codes have been developed to predict the behaviour of the actual device. With all the work done, a R-RAWG has been designed by using certain considerations so that it can operate over a broad wavelength range and the phase actuators are not in danger of being damaged. A code has also been



developed for the modelling of the R-RAWG, which allows manufacturing imperfections to be considered, thanks to this, a method or algorithm called DPASTOR has been developed. DPASTOR resembles machine learning to optimise the response by just using the optical output power. Finally, a PCB and an assembly with the chip interconnected to it have been made and designed. Moreover, a measurement method has been developed, which has made it possible to have a stable response and to demonstrate a multitude of optical filter responses with the same device.

Improving DASH video streaming with variable bitrate encoding through the Look Ahead algorithm and playback coordination mechanisms, and proposal of new metrics for QoE assessment

Author: Román Belda Ortega
Supervisor: Dr. Juan Carlos Guerri Cebollada and Dr. Ismael de Fez Lava

Defended on 07,17,2021

SUMMARY

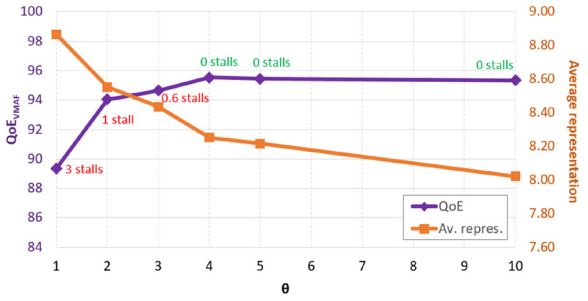
This thesis presents several proposals aimed at improving video transmission through the DASH (Dynamic Adaptive Streaming over HTTP) standard.

This research work studies the DASH transmission protocol and its characteristics. At the same time, this work proposes the use of encoding with constant quality and variable bitrate as the most suitable video content encoding mode for on-demand content transmission through the DASH standard.

Based on the proposal to use the constant quality encoding mode, the role played by adaptation algorithms in the user experience when consuming multimedia content becomes more important. In this sense, this thesis presents an adaptation algorithm called Look Ahead which, without modifying the standard, allows the use of the information on the sizes of the video segments included in the multimedia containers to avoid making adaptation decisions that lead to undesirable stalls during the playback of multimedia content.

Comparison of the VMAF value of each segment of the "Elephants Dream" video encoded at constant quality (CRF 45) and constant bitrate (1.13 Mbps)

In order to evaluate the improvements of the presented adaptation algorithm, three models of objective QoE evaluation are proposed. These models allow to predict in a simple way the QoE that users would have in an objective way, using well-known parameters such as the average bitrate, the PSNR (Peak Signal-to-Noise Ratio) and the VMAF (Video Multimethod Assessment Fusion). All of them applied to each segment.



Evolution of the number of stalls, average representation, and the QoE with the number of future segments considered by Look Ahead (Θ)

Finally, the DASH behavior in Wi-Fi environments with high user density is analyzed. In this context, there could be a high number of stalls in the playback because of a bad estimation of the available transfer rate due to the ON/OFF pattern of DASH download and to the variability of the access to the Wi-Fi environment. To relieve this situation, a coordination service based on SAND (MPEG's Server and Network Assisted DASH) is proposed, which provides an estimation of the transfer rate based on the information of the state of the clients' players.

Setup of 36 tablets used to evaluate the proposed SAND based coordination mechanism

Advanced Techniques for the Design and Optimization of Multi-Band and Reconfigurable Microwave Waveguide Filters

Author: Juan Carlos Melgarejo Lermas
Supervisor: Dr. Vicente E. Boria Esbert and Dr. Santiago Cogollos Borrás

Defended on: 07/30/2021

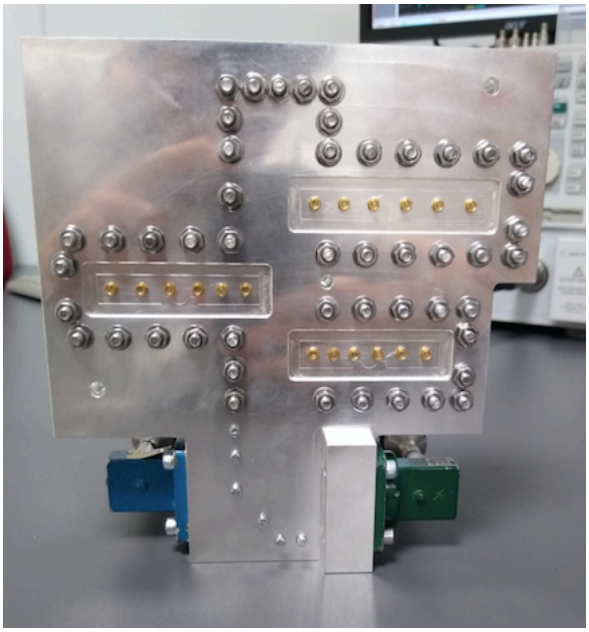
SUMMARY

The need for ever increasing data rate of modern communication systems has motivated companies in the space sector to exploit higher frequency bands, such as Ku, K and Ka, in order to offer wider bandwidths to their customers. However, as the frequency increases, the wavelength decreases, and all waveguide hardware becomes smaller and more sensitive to deviations from the ideal dimensions that normally occur when manufacturing the devices. In order to compensate for these deviations (or errors), tuning elements must then be added to the hardware and included in the design process.

In this context, therefore, we focus on the investigation of novel design strategies for filters and multiplexers with the objective of including all necessary non ideal factors in the design process.

It is important to note in this context that, once the filters are manufactured, the tuning elements are usually adjusted manually until the desired target performance has been achieved. However, successfully performing this task requires a considerable amount of time and very significant previous experience in tuning microwave filters. Consequently, an additional goal of our research work is to propose efficient and systematic tuning procedures so that anyone, regardless of their previous tuning experience, can successfully perform this difficult task.

In addition to the increasing data rates, another current challenge of advanced communication systems is the ability to be reconfigured remotely to adjust to changes in customer demands. The use of multi-function or reconfigurable devices is then an attractive possible solution. In this context, therefore, we also investigate new families of multi-band waveguide filters that can be used to accommodate several pass bands in the same filtering device. Furthermore, we also propose a new family of reconfigurable devices with several discrete states that can be easily controlled remotely.



Development of New Tunable Passive Microwave Components in Waveguide Technology

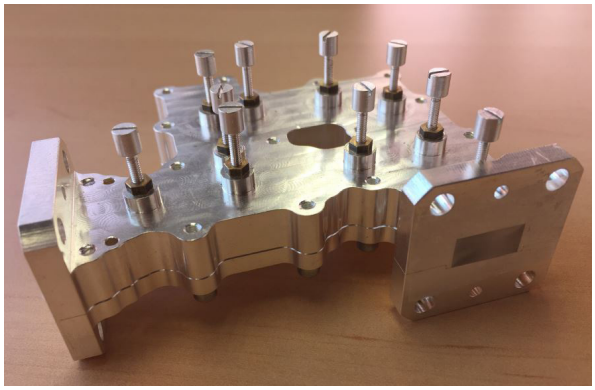
Author: Javier Ossorio García
Supervisor: Dr. Vicente E. Boria Esbert

Defended on April, 7, 2021

SUMMARY

The main objective of this doctoral thesis is the study, development, design and manufacture of new passive microwave components in waveguide technology, such as filters and multiplexers, that operate in the high frequency bands of current and future telecommunication satellite payloads between 12 and 40 GHz (Ku, K and Ka bands). The new solutions developed must offer both classic and advanced (elliptical) responses, as well as the possibility of being reconfigured both in terms of center frequency and bandwidth. The motivation for this research is to address the current and future needs of space communication systems which require a higher data transmission rate (that is larger bandwidths), as well as flexibility with respect to the operating frequency to dynamic adaptation to possible changes in user demands.

In this context, we propose in this thesis alternative microwave filter structures in metallic waveguide, as well as novel solutions. We explore different approaches to adjust the filter performance, using both traditional metallic tuning screws as well as tuning elements made with different dielectric materials. We also advance the state-of-the-art by developing higher performing Space Mapping procedures for the design, optimization and tuning of the



filter structures that we propose. The objective is to improve the response of the devices and reduce, at the same time, their manufacturing time and costs.

As a fundamental element of our work, in addition to theoretical developments, we also apply the findings of our research to the design, manufacture and measurement of a number of more complex components, such as diplexers and integrated switches and filters. They are practical devices to demonstrate the ability of the novel filters that we propose to satisfy the requirements of current and future advanced satellite payloads.