Fourth European Workshop on Optical Fibre Sensors

Agenda of Sessions

Tuesday, September 7th (Arrival day)

17:00-20:00	Registration Open
20:00-22:00	Welcome Cocktail

Wednesday, September 8th (Morning)

08:00-13:00	Registration
09:00-9:30	EWOFS2010 Opening
Special Session "*Optical Fibre Sensors for Sustainable Environment*"	
09:30-10:00	**Dr. Manuela Soares**
10:00-10:30	**Dr. Mercè Griera Fisa**
10:30-11:00	Coffee Break
11:00-11:30	**Dr. Thomas Bosselmann**
11:30-12:00	**Dr. Mikko Jaaskelainen**
12:00-12:30	**Dr. Glynn Lloyd**
12:30:13:00	Discussion
13:00-14:00	Lunch

Wednesday, September 8th (Afternoon)

14:00-14:45	EWOFS2010 Introdutory Overview **Prof. Brian Culshaw**
Session I "Physical and Mechanical Sensors"	
14:45-15:15	**Dr. Fabien Sorin**
15:15-15:45	**Prof. Paulo Freitas**
15:45-16:05	Poster I Presentation ***(Prof. John Dakin)***
16:05-17:00	Posters I View
17:00--17:15	Coffee Break/Posters I View
17:20-17:55	Posters I (Group Discussion)
17:55-18:30	Posters I Plenary
19:15-20:15	Douro River Cruise
20:30	Regional Dinner at *Ferreirinha's* Port Winery

Thursday, September 9th (Morning)

Session II "Chemical, Environmental, Biomechanical, and Medical Sensors"	
08:30-09:00	**Prof. Xingde Li**
09:00- 09:30	**Prof. Hypolito Kalinowski**
09:30-10:00	Poster II Presentation (***Dr. Francesco Baldini)***
10:00-10:45	Posters II View
10:45-11:15	Coffee Break/Posters II View
11:20-12:00	Posters II (Groups Discussion)
12:05-12:45	Posters II Plenary
12:45-14:00	Lunch

Thursday, September 9th (Afternoon)

Session III "Electromagnetic, Interferometric, Polarimetric, New Concepts and Devices for Sensors"	
14:00-14:30	**Prof. Niek van Hulst**
14:30-15:00	**Prof. Michel Digonnet**
15:00-15:30	Poster III Presentation ***(Prof. Wolfgang Ecke)***
15:30-16:30	Posters III View
16:30-17:00	Coffee Break/Posters III View*
17:05-17:45	Posters III (Groups Discussion)
17:50-18:30	Posters III Plenary
19:30	Gala Dinner at *Bolsa* Palace

*Includes the view of the postdeadline papers

Friday, September 10th (Morning)

Session IV "Distributed, Multiplexing, System Applications, and Field Trials"	
08:30-09:00	**Prof. Luc Thévenaz**
09:00- 09:30	**Dr. Katerina Krebber**
09:30-10:00	Posters IV Presentation ***(Prof. Luc Thévenaz)***
10:00-10:45	Posters IV View
10:45-11:15	Coffee Break/Posters IV View
11:20-12:00	Posters IV (Groups Discussion)
12:05-12:45	Posters IV Plenary
12:50-13:00	EWOFS2010 Closing
13:00-14:30	Lunch

Friday, September 10th (Afternoon)

Introduction

Welcome to Porto and to the Fourth European Workshop on Optical Fibre Sensors. Following the successful meetings in Peebles (1998), Santander (2004) and Napoli (2007), we have the privilege of organizing the 2010 meeting, EWOFS'2010.

The Workshop Series aims to promote a scientific meeting with a high level of interaction between participants, enabling an open debate and the assessment of new concepts, technologies and applications in the domain of optical fibre sensors, as well as the establishment of new collaborations and networks.

Addressing scientific achievements, technological applications and commercial exploitation, our goal was to create a programme that would be attractive to both academics and professionals working in this area.

We have tried to incorporate a number of high-level invited talks addressing not only topics related to optical fibre sensors, but also other scientific domains that may be relevant to the future of this R&D field. Also, we looked for strengthening of the Workshops' unique features, including the discussion of technical contributions, identifying and highlighting the most significant achievements. Because everyone's active participation is important, we planned a Workshop with an invigorating and appealing Social Programme that could encourage a true scientific socialisation

EWOFS'2010 will take place a decade after the beginning of this new century, of this new millennium. Humankind is currently facing great challenges in the search for a future characterised by global justice, fair and sustainable progress, as well as economic and social wealth. This is a demanding, yet necessary purpose, and Science and Technology create opportunities so that Society may evolve in that direction.

A Special Session was organised on "Optical Fibre Sensors for Sustainable Environment" which reflects our commitment to one of the big challenges Humankind currently faces.

EWOFS'2010 aims to encourage scientific and technological advances, and provide a forum where young and experienced researchers and entrepreneurs may interact in a mutually profitable relationship oriented towards the development of optical fibre sensors and its impact on Society. Pursuing this central objective, we hope to create a technically and socially invigorating atmosphere and our best wish is that you will enjoy your visit to the metropolitan area of Porto, Portugal, in September 2010.

José Luís Santos
Brian Culshaw
José López-Higuera
William MacPherson

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Sofia Santos, INESC Porto (Portugal)
Luísa Mendonça, INESC Porto (Portugal)

EWOFS 2010 Format

Special Section *Optical Fibre Sensors for Sustainable Environment*

In the morning of the first Workshop day, a Special Session on "OPTICAL FIBRE SENSORS FOR SUSTAINABLE ENVIRONMENT" will address the advances and perspectives of future developments in optical fibre sensing and related fields, connected with the current challenge of social welfare and progress compatible with a sustainable healthy environment.
Five selected invited speakers will share with the audience their knowledge and experience on the subject.

EWOFS2010 Introductory Overview

The main programme of EWOFS2010 opens with the talk of Prof Brian Culshaw "*Fibre Optic Sensor Technology – an Engineering Reality or a Scientific Opportunity?*"

All the regular papers (139 papers) will be presented and discussed in FOUR POSTER SESSIONS:

Session I. **Physical and Mechanical Sensors**
Session II. **Chemical, Environmental, Biomechanical, and Medical Sensors**
Session III. **Electromagnetic, Interferometric, Polarimetric, New Concepts, and Devices for Sensors**
Session IV. **Distributed, Multiplexing, System Applications, and Field Trials**

Each session will have the following format:

a) **Invited Talks:** *Each Session will be introduced by two invited talks by accomplished speakers in the field.*

b) **Posters Presentation:** *The regular papers of each Session will be introduced by an well-known researcher whom acts as Session Chairman.*

c) **Coffee Breaks**

d) **Posters View:** *Individual discussion in regular poster session.*

e) **Discussion Groups:** *The participants will be organized in Discussion-Groups, coordinated by a Group Chair that will conduct the analysis of the papers presented in the Poster Session.*

f) **Session Remarks:** *Conclusions from each Discussion Group will be presented and discussed in a Plenary Session.*

EWOFS 2010 Session Chairs

Special Session

Brian Culshaw, University of Strathclyde (United Kingdom)
José López-Higuera, University of Cantabria (Spain)

EWOFS2010 Introductory Overview

Bishnu Pal, Indian Institute of Technology Delhi (India)

Session I

John Dakin, University of Southampton (United Kingdom)

Session II

Francesco Baldini, IFAC-CNR (Italy)

Session III

Wolfgang Ecke, IPHT-Jena (Germany)

Session IV

Luc Thévenaz, EPFL (Switzerland)

Discussion Group 1

Andrea Cusano, University of Sannio-Benevento (Italy)

Discussion Group 2

António Lobo Ribeiro, University Fernando Pessoa (Portugal)

Discussion Group 3

Leszek Jaroszewicz, Military University of Technology (Poland)

Discussion Group 4

Hypolito José Kalinowski, Federal University of Technology – Paraná (Brazil)

Discussion Group 5

Marco Petrovich, University of Southampton (United Kingdom)

Discussion Group 6

Manuel López-Amo, Public University of Navarra (Spain)

Discussion Group 7

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Discussion Group 8

Reinhardt Willsch, IPHT-Jena (Germany)

Discussion Group 9

Stephen James, Cranfield University (United Kingdom)

Discussion Group 10

Tong Sun, City University London (United Kingdom)

EWOFS 2010 Complete Programme

Wednesday, September 8th, 09:00 - 9:30

EWOFS2010 OPENING

Wednesday, September 8th, 09:30 - 13:00

Special Session
"Optical Fibre Sensors for Sustainable Environment"

Chairs:

Prof Brian Culshaw, *University of Strathclyde (United Kingdom)*

José López-Higuera, *University of Cantabria (Spain)*

09:30-10:00 **Dr. Manuela Soares**
European Commission (Belgium)

SS-01 **EU Strategy on Environmental R&D**

The challenges facing today's society are serious and complex, including: climate change; the depletion of natural resources; the loss of biodiversity; the emergence and spread of new diseases; the impact of natural and man-made disasters; etc. The need for new technologies, better knowledge and more detailed information to address these challenges arises at all levels, from that of senior decision-makers at national and international levels, to the individual citizen at the grass-roots level. The objective of the Environment Theme of the 7th EU Research Framework programme (FP7) is to help meet these needs by promoting the sustainable management of the natural and human environment and its resources by advancing our knowledge on the interactions between the biosphere, ecosystems and human activities, and developing new technologies, tools and services, in order to address, in an integrated way, global environmental issues. Emphasis is put on the prediction of climate, ecological, earth and ocean systems changes, and on tools and technologies for the monitoring, prevention and mitigation of environmental pressures.

In the domain of Earth monitoring, the European Commission actively supports the Group on Earth Observations (GEO) in its efforts to meet the urgent need for coordinated Earth observations relating to the state of our Planet, in order to support decision-making in the increasingly complex and inter-connected world in which we live today. The Global Earth Observation System of Systems (GEOSS) aspires to encompass all areas of the World, and to cover in situ, airborne, and space-based observations. One of the tasks being undertaken by the GEO in implementing GEOSS focuses on sensor web enablement for in-situ observing networks, looking to advances in communication technology and ground-based in-situ technologies to create webs of sensors on all types of platforms with rapid access to observations. Having acquired the relevant observations and processed this to provide the required information, there is a recognised need to circulate and distribute the data and products available within the GEOSS via suitable communication networks in response to users and providers needs, in order to provide innovative solutions to the grand environmental challenges facing today's global society.

10:00-10:30 **Dr. Mercè Griera i Fisa**
European Commission (Belgium)

SS-02 **ICT for Energy Efficiency - EU Strategy and Research Support**

Energy Security and Climate Change is becoming more and more prominent on political agendas worldwide and across all sectors of the economy, so that it ranks highest among the EU's priorities.

There is also consensus on that reorienting research and technological innovation towards the challenges of energy-efficient and low-carbon growth will help Europe emerge from the economic crisis on a more sustainable footing.

Information and Communication Technologies (ICTs) have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy. The European Commission has acknowledged that ICT based innovations can provide one of the most cost-effective means to help Member States achieving the agreed energy targets for 2020. ICTs will also stimulate the development of a large leading-edge market for ICT enabled energy-services that will foster the competitiveness of European industry and create new business opportunities.

The use of ICT equipment in the delivery of services represents about 1.75% of carbon emissions in Europe; a further 0.25% of carbon emissions come from the production of ICT and consumer electronic equipment. As the range and penetration of ICTs increase, their overall energy use is growing. The other sectors of the economy and of society are responsible for the remaining 98% of carbon emissions. This is where the enabling capacity of ICTs is expected to make the greatest contribution to reducing emissions - up to 15% by 2020 according to some reports - as well as cost savings.

The European Commission is:

- Firstly, accompanying the ICT sector to reduce its carbon footprint. The ICT sector has created the ICT4EE Forum to set itself targets and reach a collective agreement on measurement methodologies that focus on accuracy, transparency and verifiability of the energy consumption and carbon emissions of its processes, at company and sector level;

- Secondly, encouraging the establishment of partnerships between the ICT sector and other major energy-using sectors (notably, building and construction, energy and transport and logistics) to identify where and how ICTs can play a role in improving efficiency and reducing emissions in these sectors and thus accelerate the delivery of tools to assess and to optimise energy performance on a comparable basis;

- Thirdly, calling Member States national and local authorities to enable the EU-wide roll-out of ICT tools likely to trigger a shift towards a low carbon economy. In particular, the European Commission is supporting the Green Digital Charter initiated by Manchester City Council and Eurocities and signed by more than 20 Mayors of major European cities.

In this context it has emerged that it is essential for governments to embed long term visionary measures in their short term responses to the economic crisis. This makes it necessary to invest in research and innovation into novel ICT-based solutions for energy intensive sectors. To reinforce this vision, the Commission is planning, in the two coming years, Calls for Proposals on the following topics:

- ICT for energy efficient buildings and spaces of public use. The focus is on building energy management systems integrating diverse energy-efficient components and validating the resulting system in real user conditions to measure energy savings and recovery of investment. Examples of spaces of public use are sports centres, university campus and shopping malls. The expected funding is 20 M€ and the closing date is 2nd December 2010;

- ICT systems for energy efficiency. The focus is on the research and development of energy efficient components and its incorporation into decision support and/or operational systems. Examples are simulation and design tools, decision support systems for urban planning or data centre management systems. The expected funding is 35 M€ and the closing date is January 2011;

- ICT for energy-positive neighbourhoods. The focus is on both Management and Control and Decision Support systems addressing the dynamics of energy supply and demand in neighbourhoods and extended rural/urban areas. The expected funding is 30 M€ and the plan is to open the Call on July 2011 with a closing date on December 2011;

- Smart Energy Grids. The focus is on ICT systems for the management of the electricity distribution networks covering: control systems, decision support tools, power electronics building blocs, and integration with home networks. The expected funding is 30M€ and the plan is to open the call on September 2011;

- ICT for water resources management control. The focus is on Control and Decision Support systems for data management and real-time demand forecasting. The expected funding is 15M€ and the plan is to open the call on September 2011.

Optical fibre sensors are an essential component in the system we are planning to support. I invite the optical fibre sensors research community to address the challenge of energy-efficiency, a promising and exciting application research domain.

10:30-11:00 **Coffee Break**

11:00-11:30 **Dr. Thomas Bosselmann**
Siemens AG (Germany)

SS-03 **A Paradigm Change in Energy: The New Electricity Age**

Electric energy will become the backbone of future industrial development. Fossil fuel resources are still available, but the exploration will become increasingly costly. The share of renewable sources in power generation will increase significantly. Focusing on energy efficiency, condition monitoring systems will be implemented along the complete power generation and distribution chain. Smart sensors will function as the eyes for controlling the smart grid.

11:30-12:00 **Dr. Mikko Jaaskelainen**
SensorTran, Inc. (United States of America)

SS-04 **Temperature Monitoring of Geothermal Energy Wells**

Fiber optic sensing, and specifically Distributed Temperature Sensing (DTS), are powerful technologies extremely well suited for monitoring of geothermal wells and geothermal energy production facilities. This paper will discuss fiber optic technologies for high temperature sensing and monitoring applications in geothermal energy plants.

12:00-12:30 **Dr. Glynn Lloyd**
Insensys Ltd. (United Kingdom)

SS-05 **Maximising Wind Turbine Performance: How Optical Fibre Sensors Help to Provide Low Cost, Predicable Green Energy**

Wind Energy is now globally accepted as a key technology for helping to deliver clean and efficient renewable energy for the 21st century. But delivering clean electricity in a cost-competitive energy market has required many technology innovations in the design and operation of the new generation of multi-megawatt Wind Turbine Generators (WTG), which require rotors in excess of 100m and that must operate, unattended, in harsh offshore environments.

This talk show how Fibre Bragg Grating (FBG) based sensor systems provide a key enabling technology for real-time monitoring and control of WTG rotor loading, for optimizing the operating strategy during periods of blade icing and for adjustment of the turbine alignment to provide maximum energy capture.

It begins by looking at how embedding FBG sensors into the composite laminates of WTG blades provides a fatigue resilient, lightning immune method of monitoring localized strains in the blade structure, but in doing so it also highlights some of the engineering challenges that were overcome to ensure that the sensors and interrogator hardware are suitable for 20 year operation in the harsh climatic, electrically charged, vibrating environment of the WTG rotor.

It then shows how real-time blade load data is used by the WTG control system to dynamically manage the pitch settings of each blade and so respond to the constantly changing wind conditions and minimize structural overloading.

Finally the talk concludes with a look at how further advanced signal processing of optical sensor blade load data provides real-time health and diagnostics. This enables a remotely located Wind Farm Operator to detect the onset of damaging blade ice, to optimize the orientation of the turbine for maximum energy return and to schedule maintenance activities for times when their offshore turbines are most accessible.

12:30-13:00 **Open Discussion**

13:00-14:00 **Lunch**

Wednesday, September 8th, 14:00 - 14:45

EWOFS2010 Introductory Overview

Chair:

Prof. Bishnu Pal, *Indian Institute of Technology Delhi (India)*

14:00-14:45 **Prof. Brian Culshaw**
University of Strathclyde (United Kingdom)

IO-01 **Fibre Optic Sensor Technology – An Engineering Reality or a Scientific Opportunity?**

Optical fibre sensors have been established now for approaching half a century during which time they have stimulated a great deal of research and some useful practical engineering outcomes. Over the same period we have seen in parallel considerable changes in the photonic tool box of technologies and concepts.

The aims of this paper are to take a critical look at the engineering development which we have seen, to assess their contribution and potential for the future, and to speculate on the possibilities which the emerging photonics took box enable for future research and applications. We shall see that whilst the current engineering systems are based upon well established optical principles, both the scientific and technical prospects currently emerging offer significant interest for future research, development and application.

Wednesday, September 8th, 14:45 - 18:30

Session I: Physical and Mechanical Sensors

Chair:

Prof. John Dakin, *University of Southampton (United Kingdom)*

Invited Talks

14:45-15:15 **Dr. Fabien Sorin,** Y. Fink
MIT (United States of America)

SI-I1 **Multimaterial Fiber Sensors**

Recent discoveries have enabled the integration of metals, insulators and semiconductors structures into extended length of polymer fibers. This has heralded a novel path and platform towards sensing of different physical quantities such as temperature, chemicals, acoustic waves, and optical signals. The challenges and opportunities associated with this new class of fiber devices will be presented. In particular, we will discuss the materials and fabrication approach of multimaterial fibers. We will then present the latest results on photodetecting fiber sensors patterning to their performance and use in novel sensing designs. We will also introduce the recent development of active fiber devices that integrate a thin ferroelectric polymer layer for acoustic sensing applications. Finally, some aspects of the coming innovation and future prospect of the multimaterial fiber sensing technology will be discussed.

15:15-15:45 F. A. Cardoso, V. C. Martins, INESC MN (Portugal); L. P. Fonseca, IBB (Portugal); J. Germano, L. A. Sousa, M. S. Piedade, IST (Portugal), **Prof. Paulo Freitas**
INESC-MN (Portugal)

SI-I2 **Spintronic Microfluidic Platform for Biomedical and Environmental Applications**

This work reports the integration of a magnetoresistive biochip with a microfluidic system inside a portable and autonomous electronic platform aiming for a fully integrated device.

Poster Session I

15:45-16:05 **Poster Presentation by the Session Chair Prof. John Dakin**

16:05-17:00 **Posters I View**

17:00-17:15 **Coffee Break/ Posters I View**

17:20-17:55 **Posters I (Group Discussion)**

17:55-18:30 **Posters I Plenary**

19:15-20:15 **Douro River Cruise (Departure from Conference Hotel)**

20:30 **Regional Dinner at *Ferreirinha*'s Port Winery**

Poster Session I (36 Regular Papers)

SI-1 **Fibre optic hot-wire flowmeter based on a metallic coated hybrid LPG-FBG structure**

P. Caldas, P. A. S. Jorge, G. Rego, O. Frazão, J. L. Santos, L. A. Ferreira, F. Araújo, INESC Porto (Portugal)

In this work an all optical hot-wire flowmeter based on a silver coated fibre incorporating a long period grating and a Bragg grating is demonstrated. Optical energy at 1480 nm propagating down the fibre is coupled by the long period grating into the fibre cladding and absorbed by the metallic coating deposited on the fibre surface over the Bragg grating position. This absorption acts like a hot-wire raising locally the fibre temperature, which is effectively detected by the FBG resonance shift. The temperature raise depends on the flow speed of the surrounding air that has the effect to cool the fibre. In this way, the FBG Bragg wavelength shift can be related with the flow speed. Results obtained demonstrate the working principle and a flow speed resolution of 0.08 m/s is demonstrated.

SI-2 **Drift in high-temperature FBG sensors**

A. Busboom, H. Xia, GE Global Research (Germany); B. K. Lee, G. P. Koste, GE Global Research (United States of America)

Fiber Bragg gratings are reported that are optimized for low wavelength drift, making them suitable for high–accuracy temperature measurements over extended periods of time. Our gratings show drift in the order of a few 10's of pm over 1,300 h at up to 650°.

SI-3 Polarimetric sensitivity to hydrostatic pressure and temperature in birefringent dual-core microstructured polymer fiber

M. K. Szczurowski, T. Martynkien, G. Statkiewicz-Barabach, W. Urbanczyk, Wroclaw University of Technology (Poland); D. J. Webb, Aston University (United Kingdom)

We experimentally characterized a birefringent microstructured polymer fiber of specific construction, which allows for single mode propagation in two cores separated by a pair of large holes. The fiber exhibits high birefringence in each of the cores as well as relatively weak coupling between the cores. Spectral dependence of the group and the phase modal birefringence was measured using an interferometric method. We have also measured the sensing characteristics of the fiber such as the polarimetric sensitivity to hydrostatic pressure and temperature.

SI-4 Wavelength encoded fiber sensor for extreme temperature range

D. Barrera, Polytechnic University of Valencia (Spain); V. Finazzi, G. Coviello, ICFO (Spain); A. Bueno, S. Sales, Polytechnic University of Valencia (Spain); V. Pruneri, ICFO (Spain)

We have successfully created Chemical Composition Gratings (CCGs) into two different types of optical fiber: standard telecommunications Germanium doped fibers and photosensitive Germanium/Boron co-doped fibers. We have performed temperature cycles for analyzing the sensing properties and degradation or hysteresis with respect to the CCG sensors. The results show that CCG sensors based on Germanium/Boron co-doped photosensitive fiber have an almost linear response and negligible hysteresis effects, with a response of almost 100°C/s.

SI-5 Strain calibration of optical FBG-based strain sensors

J. Roths, A. Wilfert, P. Kratzer, F. Jülich, R. Kuttler, Munich University of Applied Sciences (Germany)

A facility for strain sensitivity calibration of optical FBG-based strain sensors according to the German VDI/VDE 2660 guideline was established and characterized. Statistical analysis of several calibration measurement series performed with one single type of FBG strain sensor and application technique showed a reproducibility of 0.15%. Strain sensitivities for FBGs inscribed in two different types of optical fibres (GF1B and PR2008) showed significantly different strain sensitivities of $k = 0.7885 \pm 0.0026$ and $k = 0.7758 \pm 0.0024$, respectively.

SI-6 Investigation of long term stability of arc-induced gratings heat treated at high temperatures

G. Rego, P. Caldas, ESTG-IPVC (Portugal); O. Ivanov, Ulyanovsk Branch of Kotel'nikov Institute of Radio Engineering and Electronics of Russian Academy of Sciences (Russia); J. L. Santos, INESC Porto (Portugal)

A long-period grating written in the SMF-28 fiber was heat treated at 1000°C for 15 days. The spectrum of the grating shifted to longer wavelengths and the amplitude of the cladding mode resonances decreased as a result of structural relaxation. The background loss increased considerably for time longer than 200 h, and this loss is caused by devitrification of the fiber.

SI-7 Temperature independent bend measurement using a pi-phase shifted FBG at twice the Bragg wavelength

H. K. Bal, F. Sidiroglou, Z. Brodzeli, Victoria University (Australia); S. A. Wade, Swinburne University of Technology (Australia); G. W. Baxter, S. F. Collins, Victoria University (Australia)

The effect of bending on the twin peaks of an alternative type of pi-phase shifted fibre Bragg grating (FBG) (embedded in a resin) at twice the Bragg wavelength, has been investigated. Variation of the direction of bending resulted in corresponding changes in the relative intensity of these peaks. Temperature independent bend measurements were realised by monitoring the change of ratio of the reflected intensities of these peaks.

SI-8 Investigation of sensing properties of long period gratings based on microstructured polymer optical fibres

J. Witt, M. Steffen, M. Schukar, K. Krebber, BAM (Germany)

We investigated the sensing properties of a single mode Poly Methyl Methacrylate (PMMA) Microstructured Polymer Optical Fibre (MPOF) with mechanically imprinted Long Period Grating (LPG). We measured the influence of strain to the LPG wavelength which showed the viscoelastic nature of PMMA. We also measured the influence of temperature and humidity to the LPG wavelength.

SI-9 Optical inclinometer based on fibre-taper-modal Michelson interferometer

L. Amaral, O. Frazão, J. L. Santos, INESC Porto (Portugal); A. L. Ribeiro, University Fernando Pessoa (Portugal)

An inclinometer sensor based on optical fibre-taper-modal Michelson interferometer is demonstrated. The magnitude of the tilt (bending angle of the fibre taper interferometer) is obtained by passive interferometric interrogation based on the generation of two quadrature phase-shifted signals from two fibre Bragg gratings. Optical phase-to-rotation sensitivity of 1.13 rad/degree with a 14 mrad/√Hz resolution is achieved.

SI-10 Photonic crystal fiber sensor for magnetic field detection

S. M. M. Quintero, University of Rio de Janeiro (Brazil); C. Martelli, Federal University of Technology - Paraná (Brazil); C. C. Kato, L. C. G. Valente, A. M. B. Braga, University of Rio de Janeiro (Brazil)

A magnetic field sensor comprised of a high birefringence photonic crystal fiber coated by a Terfenol-D/Epoxy composite layer is proposed. Magnetic fields induce strains in the magnetostrictive composite that are transferred to the fiber interfering with light propagation. The sensitivity of the developed sensor with magnetic fields is measured to be 6 pm mT-1.

SI-11 Optimized conditions for gas light interaction in photonic crystal fibres

I. Dicaire, J-C. Beugnot, L. Thévenaz, EPFL (Switzerland)

This paper presents helpful expressions predicting the filling time of gaseous species inside photonic crystal fibres. Based on the theory of diffusion, our gas-filling model can be applied to any given fibre geometry or length by calculating diffusion coefficients. This was experimentally validated by monitoring the filling process of acetylene gas in several fibre samples of various geometries and lengths. The measured filling times agree well within ±15% with the predicted values for all fibre samples. In addition the pressure dependence of the diffusion coefficient was experimentally verified by filling a given fibre sample with acetylene gas at various pressures. Finally ideal conditions for gas light interaction are determined to ensure optimal efficiency of the sensor by considering the gas flow dynamics in the design of microstructured fibres for gas detection and all-fibre gas cell applications.

SI-12 Fibre loop mirror using a small core microstructured fibre for the simultaneous measurement of strain and temperature

R. M. André, M. B. Marques, INESC Porto (Portugal); P. Roy, University of Limoges (France); O. Frazão, INESC Porto (Portugal)

In this work, a fibre loop mirror for the simultaneous measurement of strain and temperature is presented. The loop mirror contains a section of a small core microstructured fibre characterized for strain and temperature sensing. Due to the small core geometry and using a small section length, the structure presents high birefringence and also intermodal interference. The spectral response of this configuration shows the presence of three interferometers. One of them corresponds to the interference of light that propagates in the fast and slow axes (group birefringence) and the others are associated with the interference of light in the two lowest order spatial modes in each of the fibre eigenaxis. These interferometers present distinct sensitivities to strain and temperature for

different wavelengths.

SI-13 H2 sensing performance of optical fibers coated with WO3 film

J. Ou, M. H. Yaacob, M. Breedon, K. Kalantar-zadeh, W. Wlodarski, RMIT University (Australia)

Optical gas sensing performance of optical fibers coated with sputtered Pd/WO3 films was investigated for low concentration H2 sensing. This optical fiber H2 sensor was prepared by RF sputtering of WO3 on the tip of the multimode fiber at 260°C and subsequently depositing a Pd catalytic layer. Highly uniform nanotextured film, with individual crystallites having diameters in the range of 35-50 nm was observed. The sensing mechanism was based on the reflectance change of Pd/WO3 layers towards H2 reliant on the gasochromic effect. Under the conditions of different sensing layer thicknesses and different operating temperatures, full Vis-NIR spectra investigations were carried out during the sensor testing. It was found that the optical fiber H2 sensor coated with Pd/WO3 film show a remarkable optical reflectance response towards H2 concentrations as low as 0.06%. The optimum sensing layer thickness was 200 nm and the optimum operating temperature was found to be 100°C.

SI-14 Optical refractometer based on high birefringence Bragg grating Fabry-Perot cavity

C. Gouveia, O. Frazão, P. A. S. Jorge, J. M. Baptista, INESC Porto (Portugal)

An optical fibre sensor for simultaneous measurement of refractive index and temperature is presented. The refractive index measurement is based on the visibility variations of a Fabry-Perot interferometer with interfering waves generated in a low reflectivity Bragg grating inscribed on a Panda fibre and in the fibre tip (Fresnel reflection) in contact with the liquid. The temperature measurement is based on the wavelength shift of the FBG peaks. Results obtained show the feasibility of simultaneous measurement of refractive index and temperature and also the possibility of adjusting fringe visibility via polarization control.

SI-15 Transverse strain sensor based on etched phase-shifted fiber Bragg gratings

H. K. Bal, Z. Brodzeli, F. Sidiroglou, S. F. Collins, Victoria University (Australia)

The effect of transverse strain on a uniquely etched phase-shifted fiber Bragg grating (FBG) was investigated. The relevant phase-shifted FBG was fabricated by the application of a non-uniform wet chemical etching technique. The prospect of providing temperature independent transverse strain measurements is also explored using this FBG.

SI-16 Rapid disappearance of regenerated fibre Bragg gratins at temperatures approaching 1500°C in Boron-codoped Germano silicate optical fibre

M. L. Åslund, J. Canning, University of Sydney (Australia); H. Fu, H. Tam, The Hong Kong Polytechnic University (China)

Rapid annealing of Regenerated fibre Bragg gratings observed at temperatures approaching 1500°C. Simple packaging within a dry silica tube is found to resolve issue of brittleness of fibres at extreme temperatures.

SI-17 Two-dimensional fibre grating packaging design for simultaneous strain and temperature measurement

M. R. Mokhtar, T. Sun, K. T. V. Grattan, City University London (United Kingdom)

This paper demonstrates a novel two-dimensional sensor packaging design to facilitate the use of fibre grating-based sensors for simultaneous strain and temperature measurement. The width and height of a sensor package were optimized to induce dissimilar responses from two co-located fibre gratings within the sensor head. Through an appropriate calibration of both the strain and temperature coefficients of the individual fibre gratings used, both strain and temperature can be accurately determined and their individual components separated by measuring the shift in their respective Bragg wavelengths. This approach can not only ensure the robustness of the sensor

head, but also offer the necessary level of control over the differences between the coefficients, which allows for maximizing the accuracy of the strain and temperature values determined from the sensor itself.

SI-18 Frequency response of underwater ultrasonic transducers in the near field using polarimetric polarization maintaining fiber sensors

A. Bennecer, M. McGuire, G. M. H. Flockhart, S. G. Pierce, G. Hayward, B. Culshaw, University of Strathclyde (United Kingdom)

Near-field ultrasonic response (50-2000 kHz) of an underwater 1-3 piezocomposite transducer is experimentally investigated using a polarimetric polarization maintaining fiber sensor. Measured outputs from our sensor and a reference hydrophone are observed to be comparable.

SI-19 Dynamic studies of fibre Bragg gratings

D. A. Jackson, University of Kent (United Kingdom)

The dynamic performance of standard fibre Bragg gratings (FBGs) is assessed by 1) Straining the grating between two fixed points and subjecting it to a displacement corresponding to 1g over a frequency range of 100Hz to 1kHz. The induced strain on the grating is calculated and used in conjunction with the strained grating spectra to determine the minimum detectable length change of the grating as a function of frequency. 2) Studies were made where the FBG is wrapped under tension and modulated at frequencies up to 100 kHz. 3) Measuring large strains at low frequencies and high resolution is demonstrated by comparing the relative phase of a FBG subject to increasing strain to a reference FBG held under constant environmental conditions. The interrogating system used for all the reported measurements was a fibre optic Mach Zehnder interferometer used to generate an optical carrier at frequencies up to 2 MHz.

SI-20 Understanding the mode coupling process in a strong long period grating

L. Jin, W. Jin, J. Ju, The Hong Kong Polytechnic University (China)

The mode coupling process of a strong long period grating inscribed in a photonic crystal fiber is quantitatively analyzed based on coupled local-mode theory.

SI-21 Fiber-optic Bragg grating sensors at cryogenic temperatures

T. Habisreuther, W. Ecke, I. Latka, K. Schröder, R. Willsch, IPHT-Jena (Germany)

Advantages of optical fiber Bragg grating sensors at low temperatures, are electrical isolation, low electro-magnetic interference, low thermal conductivity to a large number of multiplexed sensors. They show negligible thermo-optic and magnetooptic effects in cryogenic environment. These properties make them attractive for temperature surveillance and structural health monitoring of cryogenic systems, or for the testing of material properties and system components at low temperatures.

SI-22 An ultra-high-resolution FBG static-strain sensor for geophysics applications

Q. Liu, Z. He, T. Tokunaga, K. Hotate, The University of Tokyo (Japan)

We report an ultra-high-resolution static-strain measurement with a pair of fiber Bragg gratings (FBGs), one for strain sensing and the other for compensating the error due to temperature disturbance and source drift. The difference between the two FBGs' Bragg wavelengths is evaluated by utilizing a cross-correlation algorithm. The mechanism of noise suppression by the cross-correlation algorithm is quantitatively analyzed and the factor that determines the ability of noise suppression of this algorithm is revealed. The temperature dependence is further subtracted by using a vector operation. When no strain is applied, an ultra-high wavelength resolution corresponding to 2.6 nε was obtained, which gives the ultimate performance of the measurement system. With a variable strain applied with a piezo-stage, a resolution of 17.6 nε was demonstrated. This is the first demonstration, to the best of our knowledge, that a real-static strain down to 10 nε is measured, providing a powerful technique for the measurement in geophysics application.

SI-23 Temperature and strain independent torsion sensor using a Sagnac interferometer based on a suspended twin-core fibre

R. M. Silva, INESC (Portugal); J. Kobelke, K. Schuster, IPHT-Jena (Germany); O. Frazão, INESC Porto (Portugal)

In this work, it is presented a Sagnac interferometric configuration based on a suspended twin-core fibre for sensing applications. Using the suspended twin-core fibre, the fringe pattern is due to the differential optical path of the light in the two cores associated with a refractive index difference of ~10-3, which indicates an advantage of this approach compared with those based on Hi-Bi fibres, namely the possibility to use a small length of suspended twin-core fibre. The sensing configuration was characterized for torsion, temperature and strain. Using the Fast Fourier Transform technique it is possible to obtain the measurand induced amplitude variations of the fringe pattern. The results obtained indicate the viability of a temperature and strain independent torsion sensor.

SI-24 Acoustically modulated long period grating sensor for simultaneous viscosity and density measurement

R. A. Oliveira, Federal University of Technology - Paraná (Brazil); M. Naqshbandi, K. Cook, J. Canning, University of Sydney (Australia); A. A. P. Pohl, Federal University of Technology - Paraná (Brazil)

Acoustic waves, generated by exploiting the acousto-optic effect within silica optical fibres, were used to enhance the sensitivity of a long period grating. Most of the physical parameters measured by using an LPG involve simple linear and passive transformations of spectral shifts. However, by adding a temporal element using acoustic waves, parameters that require dynamic assessment become accessible. In this work we demonstrate the measurement of fluid viscosity by measuring the rise time and acousto-optic efficiency. We show results of sensor characterization and suggest the possibility of monitoring a chemical reaction in real time.

SI-25 Dual polarization fiber grating laser accelerometer

B-O. Guan, Jinan University (China); X-S. Sun, Y-N. Tan, Dalian University of Technology (China)

A novel fiber optic accelerometer based on the integration of dual polarization fiber grating laser with cantilever-mass element is proposed and experimentally demonstrated. The applied acceleration is converted into a change in the beat frequency between the two polarization modes from the fiber laser. This new type of accelerometer has advantages of high sensitivity, absolute frequency encoding, capability to multiplex a number of sensors on a single fiber, and capability of separately tailoring the response sensitivity and natural frequency.

SI-26 Multi-parameter sensor using fiber in-line MZ interferometer embedded in fiber Bragg grating

C. R. Liao, Y. Wang, D. N. Wang, M. Yang, The Hong Kong Polytechnic University (China)

We propose an ultra compact optical fiber sensor integrating a Mach-Zehnder interferometer (MZI) in fiber Bragg grating (FBG) for simultaneous refractive index (RI) and temperature measurement. By use of the resonant wavelength of the FBG and the interference dip of the MZI, the RI and temperature of the surrounding medium can be unambiguously determined. The interesting properties of the sensor include good operation linearity, extremely high RI sensitivity up to ~9148 nm/RIU (RI unit) in the RI range between 1.30 and 1.325 and precise sensing location, determined by the MZI cavity created.

SI-27 Intrinsic Fabry-Pérot cavity sensor based on chemical etching of a multimode graded index fiber spliced to a single mode fiber

P. A. R. Tafulo, O. Frazão, P. A. S. Jorge, F. M. Araújo, INESC Porto (Portugal)

An intrinsic Fabry-Pérot cavity for high temperature and strain measurement is presented. The in-fibre cavity is formed by a chemical etched graded index optical fiber spliced to a single mode fiber. The intrinsic sensor obtained shows high sensitivity to strain (6.2 pm/με) and rather low sensitivity to temperature (0.9 pm/°C), being suitable for applications as a strain gauge at high temperature.

SI-28 Strongly regenerated Bragg gratings in standard single-mode fibres

V. Oliveira, H. J. Kalinowski, Federal University of Technology – Paraná (Brazil)

We report the formation of strongly regenerated Bragg gratings in standard, telecommunications grade, fibre optics. The fibres are Hydrogen loaded for several days and the inscription of the seed grating is done using 248 nm UV light. Seed gratings are not fully saturated. When heated to 800 °C-1000 °C the seed grating is regenerated; and the new grating presents strong reflection spectrum.

SI-29 Optical vibration sensor using FBG Fabry-Pérot interferometer with wavelength scanning and Fourier analysis

A. Wada, S. Tanaka, N. Takahashi, National Defense Academy (Japan)

An in-fiber Fabry-Perot interferometer with fiber Bragg grating mirrors (FBG-FPI) yields extremely narrow transmission peaks within the FBG reflection wavelength range. Periodical scanning of the laser light source wavelength produces a train of optical pulses and the occurrence time of the pulse is modulated as the FBG-FPI is under influence of strain. When dynamic strain due to mechanical vibration is applied to the FBG-FPI, the detected signal of the pulse train is Fourier transformed and processed to reproduce the waveform of the vibration-induced strain. A high signal-to-noise ratio interrogation is possible with high resolution and a wide range of vibration frequency can be analyzed since the laser wavelength can be easily scanned at high frequency. Furthermore, an inexpensive DFB laser can be utilized as a light source because the narrowness of the transmission peaks does not require broad wavelength scanning.

SI-30 A fibre Bragg grating based inclinometer system for ground movement measurement

J. Li, R. Correira, E. Chehura, S. Staines, S. W. James, R. P. Tatam, Cranfield University (United Kingdom)

The measurement of ground movement is an essential part of many geotechnical engineering operations. For decades, inclinometer systems have traditionally been used for this purpose to provide crucial information to engineers and researchers. However, conventional inclinometer systems have their limitations, such as high cost and poor durability. In this paper a fibre optic based inclinometer system is reported, which utilizes fibre Bragg grating sensors attached to the casing of a conventional inclinometer. The characterization of the sensor revealed good agreement with theory and conventional displacement measurements. For a casing of length 2.5 m, the minimum measureable deflection of the top of the casing was found to be 0.48 mm when the FBGs were interrogated with a 1 pm wavelength resolution system.

SI-31 High sensitivity inline fiber Mach-Zehnder interferometer bend sensor using a twin core fiber

A. Harhira, J. Lapointe, R. Kashyap, Polytechnic School of Montréal (Canada)

A novel Mach–Zehnder interferometer based on a multimode fiber combined with a twin-core fiber is proposed. The section of twin-core fiber is spliced between a section of multimode fiber and a single mode fiber. The curvature induced wavelength shifts on the interference fringes is experimentally monitored. A blue shift is observed. This device is simple to fabricate, and is used as a bend sensor with good sensitivity.

SI-32 Optical fibre sensor for measurement the large range of strain and frequency vibrations of flat diaphragm

H. Krisch, M. Lau, S. Tournillon, KROHNE Messtechnik GmbH (Germany)

The subject of this work is the use of a novel fibre optic sensor in industrial applications. In the presented investigation, the issue of accurate determination of a flat diaphragm frequency response has been studied. Here a special construction including a fibre optic interferometer is used to monitor the deformations on the diaphragm surface. Main advantage of fibre optic interferometer is the possibility of measurement of phase changes within the range of micro radian. The challenge of the implementation of such technology under hard industrial environment lays in the extremely difficult requirements like large temperature range, high pressure dynamics, chemical resistance, measuring range, demanded sensitivity, vibration immunity etc. It is also necessary to design an inexpensive system.

SI-33 Simulation of vibration induced changed in the fiber Bragg grating reflection spectrum

A. Aray, H. Saghafifar, Malek-e-Ashtar University of Technology (Iran)

This study investigates the vibration induced changes in the reflection spectrum of an optical Fiber Bragg Grating. In most cases the strain distribution associated with vibration through the Fiber Bragg Grating length is uniform and the vibration can be measured just by the observation of Bragg wavelength shift in time. But if the strain profile associated with the vibration is not uniform or if there is some primary strain gradient in FBG, not only the Bragg wavelength but also the shape of the reflection spectrum will change. Although the exact simulation of the Fiber Bragg Grating response can be obtained via the couple mode theory and the Runge-Kutta method but they usually require a long running time. Beside the fact that higher convergence speed can be obtained with implementation of transfer matrix method, neglecting the induced chirp created by the distribution field nonuniformities decrease the precision. A modified transfer matrix formulation used in this paper, provides a high accuracy and computationally efficient mean for simulation of a vibration induced change in FBGs reflection spectra.

SI-34 Angle transducer based on fiber Bragg gratings able for tunnel auscultation

A. Quintela, J. M. Lázaro, M. A. Quintela, J. Mirapeix, V. Muñoz-Berti, J. M. López-Higuera, University of Cantabria (Spain)

In this paper an angle transducer based on Fiber Bragg Grating (FBG) is presented. Two gratings are glued to a metallic platen, one in each side. It is insensitive to temperature changes, given that the temperature shifts affect equally to both FBG. When the platen is uniformly bent an uniform strain appears in both sides of the platen. It depends on the bend angle and the platen length and thickness. The transducer has been designed to be used in the auscultation of tunnels during their construction process and during their live time. The transducer design and its characterization are presented.

SI-35 Reflective polarimetric fiber-optic thermometer

R. Wüest, B. Gülenaltin, F. Buchter, T. Bühler, ABB Ltd. (Switzerland)

The design and the realization of a cost effective reflective polarimetric fiber optic thermometer are discussed for several applications. The temperature dependent birefringence of a polarization maintaining fiber is used to deduce the sensor head temperature from measured polarization intensities. Measurements from a fabricated and packaged prototype show that the sensor features a non-ambiguous temperature range of >160°C and an accuracy of ±2°C.

SI-36 Dynamic response of optical fiber Bragg grating temperature sensors

G. E. Silva, J. C. Santos, University of São Paulo (Brazil); V. R. Almeida, R. M. Caso, Institute of Advanced Studies (Brazil)

This paper presents the results of thermal tests performed with commercial optical fiber Bragg grating (FBG) temperature sensors and raw FBGs fabricated by Photonics Division of IEAv. Test results show significant differences on dynamic response behavior among all sensors and gratings under fast variations of environmental temperature. This effect may suggest a limitation on the use of sensors based on this technique in applications requiring fast and precise response.

Thursday, September 9th, 08:30 - 12:45

Session II: Chemical, Environmental, Biomechanical, and Medical Sensors

Chair:

Dr. Francesco Baldini, *IFAC-CNR (Italy)*

Invited Talks

08:30-09:00 J. Xi, Y. Zhang, L. Huo, Y. Chen, T. Jabbour, Johns Hopkins University (United States of America); M-J. Li, Corning Inc. (United States of America), **Prof. Xingde Li**
Johns Hopkins University (United States of America)

SII-I1 **Emerging Fiber-optic Endomicroscopy Technologies towards Noninvasive Real-time Visualization of Histology *in situ***

This paper reviews our recent developments of ultrathin fiber-optic endomicroscopy technologies for transforming high-resolution noninvasive optical imaging techniques to *in vivo* and clinical applications such as early disease detection and guidance of interventions. Specifically we describe an all-fiber-optic scanning endomicroscopy technology, which miniaturizes a conventional bench-top scanning laser microscope down to a flexible fiber-optic probe of a small footprint (i.e. ~2-2.5 mm in diameter), capable of performing two-photon fluorescence and second harmonic generation microscopy in real time. This technology aims to enable realtime visualization of histology *in situ* without the need for tissue removal. We will also present a balloon OCT endoscopy technology which permits high-resolution 3D imaging of the entire esophagus for detection of neoplasia, guidance of biopsy and assessment of therapeutic outcome. In addition we will discuss the development of functional polymeric fluorescent nanocapsules, which use only FAD approved materials and potentially enable fast track clinical translation of optical molecular imaging and targeted therapy.

09:00-09:30 M. Muller, J. L. Fabris, **Prof. Hypolito José Kalinowski**
Federal University of Technology – Paraná (Brazil)

SII-I2 **Fibre Optic Grating Sensors for Biofuels**

Biofuels will have more intense impact on the energetic grid of the planet, because known fossil fuels reserves are being exhausted. The biofuel production relies on the transformation process of some organic material in the desired hydrocarbon product. Because of the natural characteristics of the related processes, fibre optic sensors appear to be adequate candidates to be used.

Poster Session II

09:30-10:00 **Poster Presentation by the Session Chair Dr. Francesco Baldini**

10:00-10:45 **Posters II View**

10:45-11:15 **Coffee Break/ Posters II View**

11:20-12:00 **Posters II (Group Discussion)**

12:05-12:45 **Posters II Plenary**

12:45-14:00 **Lunch**

Poster Session II (35 Regular Papers)

SII-37 **Microstructured optical fiber with homogeneous monolayer of plasmonic nanoparticles for bioanalysis**

K. Schröder, A. Csaki, I. Latka, T. Henkel, D. Malsch, K. Shuster, T. Schneider, D. Zopf, IPHT-Jena (Germany)

Microstructured optical fibers (MOFs) represent a promising platform technology for fully integrated, next generation plasmonic devices. This paper details the use of a dynamic chemical deposition technique to demonstrate the wet chemical deposition of gold and silver nanoparticles (NP) within MOFs with longitudinal, homogenously-distributed particle densities. The plasmonic structures were realized on the internal capillary walls of a three-hole suspended core fiber. The population density of the NP on the surface, which directly influences the usable / necessary sensor length, can be tailored via the controlled pre-treatment of the fiber. With the proposed procedure we can coat several meters of fiber and, afterwards, cut the fiber into the desired lengths. Accordingly, this procedure is highly productive and makes the resulting MOF-based sensors potentially very cheap. Electron microscope micrographs, taken of the inside of the fiber holes, confirm the even distribution of the NP. A transversal through-light setup was used for the non-destructive layer characterization. In proof-of-principle experiments with liquids of different refractive indices, the LSPR dependence on the surroundings was confirmed and compared with Mie-theory based calculations.

SII-38 **Diffuse-light absorption spectroscopy by fiber optics for detecting and quantifying the adulteration of extra virgin olive oil**

A. G. Mignani, L. Ciaccheri, CNR-IFAC (Italy); H. Ottevaere, H. Thienpont, Vrije Universiteit Brussel (Belgium); L. Conte, M. Marega, University of Udine (Italy); A. Cichelli, G. D'Annunzio University (Italy); C. Attilio, A. Cimato, CNR-IVALSA (Italy)

A fiber optic setup for diffuse-light absorption spectroscopy in the wide 400-1700 nm spectral range is experimented for detecting and quantifying the adulteration of extra virgin olive oil caused by lower-grade olive oils. Absorption measurements provide spectral fingerprints of authentic and adulterated oils. A multivariate processing of spectroscopic data is applied for discriminating the type of adulterant and for predicting its fraction.

SII-39 **Ammonia sensing using a fibre optic long period grating with a porous nanostructured coating formed from silica nanospheres**

S. Korposh, W. Batty, Cranfield University at Kitakyushu (Japan); S. Kodaira, S-W. Lee, The University of Kitakyushu (Japan); S. W. James, S. M. Topliss, R. P. Tatam, Cranfield University (United Kingdom)

The transmission spectrum of a fibre optic long period grating (LPG) coated with a porous multilayer coating of thickness of order 400 nm formed from silica nanospheres is shown to exhibit a strong sensitivity to the infusion of a functional, chemically sensitive material into the coating. Subsequently, the transmission spectrum of the LPG shows sensitivity to changes in the properties of the functional material when exposed to a particular chemical species in an aqueous solution. The

operation of such a device as an ammonia sensor is demonstrated, exhibiting 1 ppm sensitivity. The sensing mechanisms are discussed.

SII-40 Lab-on-a-fiber: building a fiber-optic sensing platform for low-cost and high-performance trace vapor TNT detection

J. Ma, A. Kos, W. J. Bock, University of Québec in Outaouais (Canada); X. Li, H. Nguyen, Z. Y. Wang, Carleton University (Canada); A. Cusano, University of Sannio (Italy)

By depositing an amplifying fluorescent polymer (AFP) directly onto the core side wall of an optical fiber near the fiber tip, a functional fiber-optic sensing platform is created at a scale of a mere 0.8×0.8×1.6 mm3, including the second fiber tip for excitation light delivery. The device integrates several functional optical components, a chemical sensory film and the necessary laboratory procedures on a minute scale. Here the Lab-on-a-Fiber (LOF) platform is conceptually introduced and proven to be a high-performance and low-cost approach to detection of trace vapors of TNT explosives. The low-cost potential is achieved by straightforward system construction and simple procedures for the AFP film deposition. The high performance is achieved by a dramatic increase of fluorescence emission signal collection, virtually complete suppression of excitation stray light and the fast response to the presence of TNT vapor, which is illustrated by 30% of quenching percentage occurring within 10 seconds.

SII-41 Moving the wavelength detection range in surface Plasmon resonance sensors based on tapered optical fibres

N. Díaz-Herrera, A. González-Cano, Complutense University of Madrid (Spain); D. Viegas, J. L. Santos, University of Porto (Portugal); M-C. Navarrete, Complutense University of Madrid (Spain); O. Esteban, University of Alcalá (Spain)

It is shown how the design possibilities offered by double-layer uniform-waist tapered optical fibers (DLUWTs) permit to move the wavelength detection range to adapt the response of the sensors to varied conditions. In particular, we have obtained very good experimental curves showing that we can achieve plasmon resonances in the C-band of the optical communications, around 1.5 μm, for the range of refractive indices of aqueous media, highly interesting in the biosensors field. Also, we show results for other interesting wavelength region, around 500 nm, where we can take advantage of the absorption peaks of the analytes. Finally, we explore the possibilities of using InN as a dielectric material for the second layer of the deposition. These results contribute to considerably expand the applicability and performance of SPR fiber sensors.

SII-42 Evanescent-wave LPFG in D-fiber by periodically patterned overlay

G. Quero, A. Crescitelli, D. Paladino, M. Consales, University of Sannio (Italy); A. Buosciolo, M. Giordano, CNR-IMCB (Italy); A. Cusano, University of Sannio (Italy)

Long-period fiber gratings (LPFGs) represent an attractive fiber grating-based technological platform because of their selective spectral features together with the intrinsic sensitivity to surrounding refractive index (SRI). Unfortunately, their main limitation relies on the necessity to opportunely coat the glass substrate when sensitivity enhancement and/or specific functionalization are required. Here, we investigate the possibility to realize a self-functionalized and highsensitivity LPFG by evanescent-wave interaction of the propagating light with a periodically patterned overlay. In particular, a D-shaped optical fiber is considered because of its peculiar geometrical features. First chemical etching is used to allow the evanescent-wave interaction of the propagating light with the surroundings with the desired sensitivity. Successively a uniform atactic polystyrene overlay is deposited onto the flat surface of the structure by dip-coating technique. Finally the overlay is opportunely patterned by laser-micromachining techniques in order to create a LPFGlike structure. The reported results demonstrate the spectral features of the realized device and confirm the LPFG-like behavior with high SRI-sensitivity. The flexibility of the adopted fabrication method could allow the realization of innovative LPFGs to be adopted for a multitude of sensing applications, depending on the nature of the material deposited onto the flat surface of the etched D-fiber.

SII-43 A portable instrument for the optical interrogation of a novel biochip

F. Baldini, CNR-IFAC (Italy); L. Bolzoni, Datamed s.r.l. (Italy); A. Giannetti, CNR-IFAC

(Italy); G. Porro, Datamed s.r.l. (Italy); C. Trono, CNR-IFAC (Italy)

A simple and flexible sensing configuration for discrimination of temperature and strain is investigated by implementing a PM-PCF-based Sagnac fiber loop mirror incorporating an EDF. The integration of an optical source and the sensing probe can obviously simplify the overall system configuration without requiring any additional broadband light source. Since the ASE of the EDF was reduced by the increase of temperature, the transmission peak power of the proposed sensor decreased as the temperature increased. The temperature sensitivity of the transmission peak power was estimated to be –0.04 dB/oC. When the strain was applied to the proposed sensing head, the transmission peak power was not changed by the applied strain because the ASE power of the EDF was independent of the strain. However, the peak wavelength shifted into the longer wavelength because the variation of the peak wavelength was directly proportional to the applied strain. The strain sensitivity was measured to be 1.3 pm/με.

SII-44 Optical fiber biosensor based on enzymatic coating matrix for catecholamines assessment in human urine

L. I. B. Silva, A. C. Freitas, T. A. P. Rocha-Santos, Piaget Institute (Portugal); M. E. Pereira, A. C. Duarte, University of Aveiro (Portugal)

An optical fiber (OF) biosensor has been developed and applied for simultaneous determination of catecholamines (dopamine, norepinephrine and epinephrine) in human urine. The developed analytical device shows a high potential for catecholamines quantification with a detection limit of 2.1, 2.6 and 3.4 pg mL-1 for dopamine, norepinephrine and epinephrine, respectively. The analytical performance of the OF biosensor was found to be similar to that of the High Performance Liquid Chromatography - Electrochemical Detector (HPLC-ED) regarding catecholamines determination in samples of human urine.

SII-45 Spectral marks for qualitative discriminant analysis

O. M. Conde, L. Uriarte, P. B. García-Allende, A. M. Cubillas, F. Anabitarte, J. M. López-Higuera, University of Cantabria (Spain)

In this paper, a method for the automatic qualitative discrimination of liquid samples based on their absorption spectrum in the ultraviolet, visible and near-infrared regions is presented. An alternative implementation of conventional spectrum matching methodologies is proposed working towards the improvement of the response time of the discrimination system. The method takes advantage of not making assumptions on the probability density function of the data and it is also capable of automatic outlier removal. Preliminary discrimination results have been evaluated on the classification of different oil samples from seeds and olives. The system here proposed could be easily and efficiently implemented in hardware platforms, improving in this way the system performance.

SII-46 Comparison of 2-D planar approximation and rigorous 3-D theoretical analysis of a fiber optic surface Plasmon resonance sensor utilizing a Bragg grating

B. Špačková, J. Homola, Institute of Photonics and Electronics AS CR (Czech Republic)

We present theoretical analysis of a fiber optic surface plasmon resonance (SPR) sensor utilizing a Bragg grating using the rigorous 3-D numerical modeling and the approximation of the equivalent planar (2-D) waveguide. It is demonstrated that the 2-D approach provides a good estimate of sensitivity of the sensor; however, it fails to describe the complex behavior of the spectral transmission.

SII-47 Regenerated Bragg gratings in high birefringence optical fibers

I. Abe, University of Aveiro (Portugal); V. Oliveira, H. J. Kalinowski, Federal University of Technology - Paraná (Brazil); J. L. Pinto, University of Aveiro (Portugal)

Experimental results of the thermal regeneration of Bragg gratings recorded in hydrogen loaded high birefringence fibers are presented. The thermal characterization of saturated and non saturated recorded gratings is described, as well as results of the changes in the birefringence of these types of fibers when subjected to temperature variations.

SII-48 Fabrication of dual analyte luminescent optrodes by photo-polymerization

P. A. S. Jorge, C. Maule, INESC Porto (Portugal); O. Soppera, Institute for Materials Science of Mulhouse (France); P. V. S. Marques, INESC Porto (Portugal)

A technique for the fabrication of luminescence based fiber optic optrodes with multiple analyte sensitivity is proposed. Combination of photosensitive polymers doped with different luminescent indicators was used to produce fiber probes, by self-guiding photopolymerization, having different geometries and sensing capabilities. Results demonstrating the method flexibility are shown with luminescent probes doped with CdSe/ZnS quantum dots and an organometalic ruthenium complex for simultaneous detection of oxygen and temperature.

SII-49 Optical cavity fibre sensor for detection of microcystin-LR in water

R. B. Queirós, S. O. Silva, INESC (Portugal); M. G. F. Sales, REQUIMTE/ISEP (Portugal); J. P. Noronha, REQUIMTE/FCT-UNL (Portugal); O. Frazão, P. A. S. Jorge, G. G. Aguilar, INESC Porto (Portugal)

The deterioration of water quality by Cyanobacteria causes outbreaks and epidemics associated with harmful diseases in Humans and animals because of the released toxins. Microcystin-LR (mcyst) is one of the most widely studied hepatotoxin and World Health Organization recommends a maximum value of 1 µg L-1 of mcyst in drinking-water. Therefore, there is a great demand for remote, real-time sensing techniques to detect and quantify the presence of mcyst. In this work a Fabry-Perot sensing probe based on a fibre tip coated with a mcyst sensitive thin film is presented. Highly specific recognition membranes, using sol-gel based Molecular Imprinted Polymers (MIPs), were developed to quantify microcystins in water, showing great potential in the analysis of this kind of samples. The fibre Fabry-Pérot MIP sensor shows a linear response to mcyst concentration with a sensitivity of -13.2 ± 0.4 nm L µg-1.

SII-50 Functional multilayer coated long period grating tuned in transition region for life science applications

P. Pilla, University of Sannio (Italy); V. Malachovská, A. Borriello, M. Giordano, L. Ambrosio, CNR-IMCB (Italy); A. Cutolo, A. Cusano, University of Sannio (Italy)

We report preliminary results on the development of multilayer coated long period gratings (LPGs) for life science applications. The dip-coating technique and a solvent/nonsolvent strategy were exploited to deposit double-layer polymeric film onto a LPG. A primary coating of atactic polystyrene was used as high refractive index layer to tune the working point of the device in the so-called transition region thus achieving remarkable surrounding medium refractive index sensitivity. A secondary layer of atactic poly(methyl methacrylate-co-methacrylic acid) containing functional carboxyl groups, characterized by a lower refractive index, was deposited onto the primary coating in order to have the desired functional groups on the surface of the device. Commonly used covalent immobilization procedure, NHS/EDC coupling method, was exploited to link streptavidin on the surface of the functionalized coated device. Finally, real-time detection of biotinylated bovine serum albumin affinity binding on immobilized streptavidin was performed by monitoring the shift of the LPG attenuation bands.

SII-51 Optical properties of hydrogel-filled hollow core photonic crystal fibres

M. Rutowska, P. Galvin, F. C. G. Gunning, University College Cork (Ireland)

In this paper we analyse the optical properties of a 3D hydrogel matrix integrated with a hollow core Photonic Crystal Fibre (HC-PCF). The overall refractive index was investigated with the aid of a spectroscopic ellipsometer. Moreover, a supercontinuum source was launched to the filled fibres, for spectrum and near-field analysis. We observe that when the fibres are filled with hydrogel, a clear shift in wavelength guidance occurs from 1060nm to approximately 700nm, and that the propagation occurs at the core. We will also discuss possible guidance mechanisms for such fibre scheme.

SII-52 Remote gaseous acid sensing within a porphyrin-doped TiO2 sol-gel layer inside a structured optical fibre

G. Huyang, J. Canning, M. L. Åslund, M. Naqshbandi, D. Stocks, M. J. Crossley, University of Sidney (Australia)

A porphyrin containing sol-gel layer has been deposited within the interior of the channels of a silica structured opticalfibre. Gaseous HCl detection based on protonation of the porphyrin and observed as a change in the spectrum is demonstrated. This system is compared to previous work based on an acid sensor within a liquid-core fibre. The signalto-noise of this type of fibre system shows a higher level of sensitivity than the liquid-core and has a forty-fold acid diffusion rate increase due to the different medium for acidification.

SII-53 Ambient index sensor using a Sagnac interferometer based on a D-shaped polarization maintaining fiber

O-J. Kwon, Y. B. Shim, R. K. Kim, Y-G. Han, Hanyang University (Korea)

A Sagnac loop interferometer based on a hybrid polarization maintaining fiber (PMF) is proposed and experimentally demonstrated for measurement of ambient index. The hybrid PMF consists of the PMF and the locally D-shaped PMF. The important key component is the locally D-shaped PMF. Since the core mode of the locally D-shaped PMF is directly interfaced to the external environment, the core mode is immediately changed by the variation of external index. The birefringence of the locally D-shaped PMF can generate the interference patterns. Consequently, the flexibility and simplicity in the sensing scheme can be provided by the ambient index change can be measured simply and flexibly since the peak wavelength shift is only monitored by changing the ambient index. The sensitivity of ambient index was measured to be -30 nm/RIU.

SII-54 Characterization of nanolayer LPG refractometer according surrounding refractive index

E. Simões, I. Abe, J. Oliveira, J. L. Pinto, University of Aveiro (Portugal); P. Caldas, O. Frazão, INESC Porto (Portugal)

In this work the behavior of an optical fiber Long Period Grating (LPG) refractometer with the variations of the surrounding refractive index is discussed. The objective is to characterize optical fiber refractometers sensitive to surrounding refractive index, higher and lower than the cladding. For values of surrounding refractive index higher than the cladding, the LPG does not show enough sensitivity. For this reason, a nanolayer of an organic material was coated onto the fiber, using the Langmuir-Blodgett technique. We characterized LPG covered with different nanolayers thickness (110 and 120 nm) relatively to changes in surrounding refractive index.

SII-55 POF metrology in physics medicine and rehabilitation

L. Bilro, University of Aveiro (Portugal); J. G. Oliveira, Hospital Inf. D. Pedro (Portugal); J. L. Pinto, University of Aveiro (Portugal); R. N. Nogueira, Telecommunications Institute (Portugal)

Three optical monitoring joint angle devices with the ability of real-time assessment of the knee, elbow and ankle movements are presented. All devices were tested in different selected tasks and its performance evaluated. Results have shown that these side-polished plastic optical fiber based systems are a valid technique and suitable to aid physicians in the diagnosis and rehabilitation of joint injuries, to monitor the performance of high competition athletes or even to quantify daily activities. The wearable sensor systems have properties such as low-cost, friendly operation and less effect to human which are important topics in biomechanics and clinical applications.

SII-56 A cylindrical-core fibre optic oxygen sensor based on Pt (II) complexes immobilized in a polymer matrix

R. Chen, A. D. Farmery, University of Oxford (United Kingdom); A. Obeid, Oxford

Optronix (United Kingdom); C. E. W. Hahn, University of Oxford (United Kingdom)

The development of a cylindrical-core fiber optic oxygen sensor for fast measurement of oxygen partial pressure (pO2) is described. The fibre sensing element is based on a cylindrical-core waveguide structure formed by a polymer sensing film that contains immobilized Pt (II) complexes. The performance of the fibre optic oxygen sensor was evaluated using luminescence intensity measurement. To determine accurately the response time of the oxygen sensor, a test chamber was used to provide rapid changes in the partial pressure of oxygen. The result showed that the time response of this cylindrical-core fibre based optic oxygen sensor can be less than 0.2 second. The details of the sensor chemistry, experimental system and the results are reported.

SII-57 A fibre-optic chemical sensor for the detection of cocaine

T. H. Nguyen, T. Sun, K. T. V. Grattan, City University London (United Kingdom); S. A. Hardwick, Home Office Scientific Development Branch (United Kingdom)

A fibre-optic chemical sensor for the detection of cocaine has been developed, based on a molecularly imprinted polymer (MIP) containing a fluorescein moiety as the signalling group. The fluorescent MIP was formed and covalently attached to the distal end of an optical fibre. The sensor exhibited an increase in fluorescence intensity in response to cocaine in the concentration range of 0 – 500 μM in aqueous acetonitrile mixtures with good reproducibility over 24 h. Selectivity for cocaine over others drugs has also been demonstrated.

SII-58 Lossy-mode resonance based refractometers by means of indium oxide coatings fabricated onto optical fibers

C. R. Zamarreño, I. Villar, P. Sanchez, M. Hernaez, C. Fernandez, I. R. Matias, F. J. Arregui, Public University of Navarra (Spain)

In this work, lossy mode resonance (LMR) based optical fiber refractometers are fabricated by using a transparent coating (indium oxide), as the LMR supporting layer. The utilization of indium oxide coatings permits the fabrication of highly sensitive optical fiber refractometers and enables the tunability of the LMR by adjusting the fabrication parameters, such as the coating thickness. The detection technique is based on the wavelength shift of the LMR. In this work it has been studied the influence of the external refractive index, achieving a maximum sensitivity of 2.24e-4 refractive index units per nanometer. Moreover, by adequated parameterization, more than one LMR can be observed in the wavelength range analyzed in the experiments, which leads to a more accurate measurement of the refractive index.

SII-59 High sensitivity transition-tuned long period grating for label-free immunosensing

P. Pilla, University of Sannio (Italy); V. Malachovská, CNR-IMCB (Italy); A. Sandomenico, M. Ruvo, CNR-IBB (Italy); M. Giordano, CNR-IMCB (Italy); A. Cutolo, A. Cusano, University of Sannio (Italy)

We present real-time monitoring of multiple biomolecular interactions by means of high refractive index (HRI) coated long period grating (LPG) working in transition region. The coating was deposited by dip-coating as a thin layer of few hundreds nanometers of atactic polystyrene (PS). The HRI coating was used to enhance the LPG sensitivity to refractive index changes of the surrounding medium and its thickness was determined in order to tune the coated device at the desired working point. To allow immobilization of specific biomolecules, the PS overlay surface was functionalized through bovine serum albumin (BSA) and glutaraldehyde. In particular, BSA was directly adsorbed on PS through strong hydrophobic interactions, then glutaraldehyde was linked atop exploiting the lysines side chains. This intermediate layer allowed to covalently immobilize human IgG (antibody) on the device surface. To prove the immobilization method, the interaction between IgG and its proper anti-human IgG (antigen) was studied. The four binding interactions were on-line monitored following the shift of the LPG attenuation band. The experiment also suggests a novel and interesting biofunctionalization approach of unreactive synthetic polymers with applications in immunosensing.

SII-60 Self assembling and coordination of water nano-layers on polymeric coated long period gratings as promising tool for cation detection

P. F. Manzillo, University of Naples "Parthenope" (Italy); P. Pilla, University of Sannio (Italy); S. Campopiano, University of Naples "Parthenope" (Italy); A. Borriello, M. Giordano, CNR-IMCB (Italy); A. Cusano, University of Sannio (Italy)

In this work, polymeric coated Long Period Gratings (LPGs) working in transition mode have been used to monitor the coordination and self assembling of water nano layers providing new scenarios in chemical sensing applications. In particular, nano-scale layers of syndiotactic and atactic polystyrene (sPS and aPS) have been deposited by dip - coating onto LPGs to tune the devices at the transition point. Experimental results demonstrate the polymers capability to orient water molecules in proximity of their surfaces. The sPS and aPS interactions with water have been compared. Moreover, the high sensitivity of the coated LPGs was used to monitor the effect of disorder induced by different cations depending on their size and electrical charge. Experimental results show for the first time that, thanks to the water - polymer interaction, sPS coated LPGs could be successfully employed as high sensitivity cation sensors.

SII-61 Femtosecond laser induced microfiber Bragg grating for refractive index sensing

C. R. Liao, X. Fang, D. N. Wang, The Hong Kong Polytechnic University (China)

Fiber Bragg grating (FBG) is fabricated in the microfiber by use of femtosecond laser pulse irradiation. Such a grating can be directly exposed to the surrounding medium without etching or thinning treatment of the fiber, thus possessing high refractive index sensitivity while maintaining superior reliability. The FBG was successfully inscribed on the tapered fiber with diameters ringing from 2 to 10 μm. Such a grating has high potential in various types of optical fiber sensor applications.

SII-62 Humidity sensor based on a long-period fiber grating coated with a hydrophobic thin film

A. Urrutia, P. J. Rivero, J. Goicoechea, F. J. Arregui, I. R. Matias, Public University of Navarra (Spain)

In this work it is proposed a novel fiber optic humidity sensor based on a functionally coated long-period fiber grating (LPG). The coating is composed of tetraorthosilicate matrix functionalized with perfluorooctyltriethoxysilane and its fabrication was performed by the sol-gel technique using a dip coating process using the LPG as substrate. This technique allows to fabricate sensitive films in a fast and simple way compared to other overlay fabrication techniques. The fabricated sensor was tested in a programmable temperature and climatic chamber. Relative humidity (RH) was varied in range from 20%RH to 80%RH at room temperature. The results showed a smooth exponential-like wavelength shift of the LPG attenuation band.

SII-63 Colloidal-core photonic crystal fiber incorporating CdSe quantum dots for temperature sensing

A. Bozolan, University of São Paulo (Brazil); C. J. S. de Matos, Mackenzie Presbyterian University (Brazil); M. A. Romero, University of São Paulo (Brazil)

We filled the hollow core of photonic crystal fibers with CdSe nanocrystals in oil for application as temperature sensors. A 65pm/°C spectral shift was obtained. The high light-CdSe overlap resulted in relatively high luminescence powers.

SII-64 Biconical tapered optical fiber biosensor for real-time monitoring of bovine serum albumin at femtogram/mL levels on antibody-immobilized tapered fibers

M. I. Zibaii, H. Latifi, M. Arabsorkhi, A. Kazemi, M. Gholami, M. K. Azar, S. M. Hosseini, Shahid Beheshti University (Iran)

A single-mode tapered fiber optics biosensor was utilized for the real-time attachment of model protein bovine serum albumin (BSA) to the antibody-immobilized surface of the taper. The applied fiber tapers were fabricated with waist diameter of 6-7μm and of 3mm waist length using heat-pulling method. The surfaces of the tapers were modified with an amine group to allow for the formation of a covalent bond between the amine and one of the carboxylic groups of the

antibody. The attachment of BSA to the antibody-immobilized surface of the taper at (20-25ºC) temperature was monitored by transmission of a 1558.17nm distributed feedback (DFB) laser through the tapered fiber. While cuvette measurements established that BSA was non-absorbing at 1558 nm showing no significant changes in optical throughput through the cuvette, tapered fibers with antibody-immobilized surfaces showed changes in optical throughput at bulk concentrations down to100 fg/mL of BSA. We postulate that the adsorption of the protein to the tapered fiber leads to changes in the optical characteristics of the taper. This affects the evanescent field leading to changes in optical throughput.

SII-65 Fiber optics biosensor fabricated for measuring the growth rate of Escherichia coli K-12 in the aqueous

M. I. Zibaii, A. Kazemi, H. Latifi, M. K. Azar, S. M. Hosseini, M. H. Ghezelaiagh, Shahid Beheshti University (Iran)

A single-mode tapered fiber optic biosensor was utilized for real-time monitoring of the Escherichia coli (E. coli K-1II) growth in an aqueous medium. The applied fiber tapers were fabricated using heat-pulling method with waist diameter and length of 6-7μm and 3mm, respectively. The bacteria were immobilized on the tapered surface using Poly-L-Lysine. By providing the proper condition, bacterial population growth on the tapered surface increases the average surface density of the cells and consequently the refractive index (RI) of the tapered region would increase. The adsorption of the cells on the tapered fiber leads to changes in the optical characteristics of the taper. This affects the evanescent field leading to changes in optical throughput. The bacterial growth rate was monitored at room temperature by transmission of a 1558.17nm distributed feedback (DFB) laser through the tapered fiber. At the same condition, after determining the growth rate of E. coli by means of colony counting method, we compared the results with that obtained from the fiber sensor measurements. This novel sensing method, promises new application such as rapid analysis of the presence of bacteria.

SII-66 Simultaneous strain and refractive index sensor based on a TFBG

N. J. Alberto, University of Aveiro (Portugal); C. A. Marques, Telecommunications Institute (Portugal); J. L. Pinto, University of Aveiro (Portugal); R. N. Nogueira, Telecommunications Institute (Portugal)

In this work, a dual sensor for simultaneous measurements of strain and refractive index (RI) is proposed. The sensor is based on a 4.5º tilted fibre Bragg grating (TFBG). Using two different demodulating techniques, namely monitoring the core mode wavelength and the normalized area of the transmission spectrum, it is possible to measure, strain and RI with a resolution of 2.5 με and 3 x 10-5, respectively.

SII-67 Optical fiber micro-analyzer for real-time monitoring of trimethylamine

L. I. B. Silva, A. C. Freitas, T. A. P. Rocha-Santos, Piaget Institute (Portugal); M. E. Pereira, A. C. Duarte, University of Aveiro (Portugal)

An analytical device based on optical fiber detection has been developed for monitoring of trimethylamine (TMA) in fish handling environments and for indirect assessment of fish quality. The fiber optic analyzer was firstly calibrated and then its analytical performance evaluated by correlating TMA levels in fish tissue and in air samples from an experimental chamber containing sardines.

SII-68 Operation of optical fiber sensors in hydrogen-rich atmosphere

C. Martelli, Federal University of Technology – Paraná (Brazil); A. L. C. Triques, Petrobras Research Center (Brazil); A. Braga, Pontifical Catholic University of Rio de Janeiro (Brazil); J. Canning, K. Cook, University of Sydney (Australia); R. Llerena, V. Takahashi, Pontifical Catholic University of Rio de Janeiro (Brazil)

The application of optical fiber sensors in hydrogen rich atmospheres and temperatures as high as 300°C is presented and discussed. Two well known optical fiber sensor technologies are evaluated: (1) distributed temperature sensing, based on Raman scattering, and (2) fiber Bragg gratings. Results show that a new generation of gratings and possibly of fibers that are more hydrogen

resistant, both optically and mechanically, are needed.

SII-69 Low cost plastic optical fiber sensor based on surface plasmon resonance

V. M. Muñoz-Berti, A. C. López-Pérez, B. Alén, J. L. Costa-Krämer, A. García-Martín, Microelectronics Institute of Madrid(Spain); M. Lomer, J. M. López-Higuera, University of Cantabria (Spain)

Surface plasmon excitation using a variation of Kretschmann method based on light guiding through an optical fiber has been extensively studied in the literature. But, due to its particularly bad propagation conditions, plastic optical fiber was not taken into account in documented experiments. We propose a low cost sensor using this type of fiber, in which we try to avoid the problems both through careful design and signal processing. First of all we discuss the sample fabrication and measurement in section 2; then the results obtained are discussed in section 3, including the problems faced because of the multimode character of the fiber, for which we propose alternative sample shapes as a mean of reducing them. As a conclusion we propose a roadmap to design a low cost sensor based in the structures studied in this paper.

SII-70 Low power signal processing for demodulation of wide dynamic range of interferometric optical fibre sensor signals

N. Fernandes, KROHNE Marshall Pvt Ltd., (India); L. Gossner, H. Krisch, KROHNE Messtechnik GmbH (Germany)

The linear phase demodulation of a signal from the detector of an interferometer, subjected to alternating elongation for large dynamic range crossing a number of fringes, with low power signal processing has been implemented using different schemes. These include phase generated carrier homodyne demodulation (PCHD), pseudo-heterodyne and finally a power optimized phase tracker.

SII-71 Sensing applications of U-optrodes

L. Kalvoda, J. Aubrecht, R. Klepáček, P. Lukášová, Czech Technical University in Prague (Czech Republic)

Preparation of refractometric, thermometric and chemo-optical sensing heads based on extremely curved optical fibers (U-optrodes) is described and their sensing properties demonstrated on obtained experimental results.

Thursday, September 9th, 14:00 - 18:30

Session III: Electromagnetic, Interferometric, Polarimetric, New Concepts and Devices for Sensors

Chair:

Prof. Wolfgang Ecke, *IPHT-Jena, Germany*

Invited Talks

14:00-14:30 **Prof. Niek van Hulst**
ICFO and ICREA (Spain)

SIII-I1 **Plasmonic Fibre Probes as Nanoantennas for Local Sensing and Light Control**

Optical fibres are historically at the base of near-field optics for nanoscale sensing and microscopy. Fibres with sub-wavelength aperture provide resolution below 100 nm, however are inefficient. Plasmonic nano-antenna probes are a highly promising alternative fibre. We investigate resonant optical nano-antennas both at the end of metal-coated glass fibers and on surfaces. Antenna resonances, excitation conditions, and field localization are directly probed in the near field by single fluorescent molecules, quantum dots or intrinsic luminescence of the metal. In this presentation the optical analogue of monopole, dipole, multipole and multi element antennas will be presented, focusing on nanoscale field concentration, directionality, spectral resonances and sensing applications.

14:30-15:00 H. Wen, **Prof. Michel J. F Digonnet,** S. Fan
Stanford University (United States of America)

SIII-I2 **Sensing Using Slow Light in Fiber Bragg Gratings**

On the edge of the bandgap in a fiber Bragg grating (FBG) narrow peaks of high transmission exist at frequencies where light interferes constructively in the forward direction. In the vicinity of these transmission peaks, light bounces back and forth numerous times across the periodic structure and consequently experiences a large group delay. Since the sensitivity of a sensor to most external perturbations is proportional to the reciprocal of group velocity, in these slow-light regions the sensitivity of an FBG is expected to be significantly enhanced over traditional FBG sensors operated around the Bragg wavelength.

In this presentation, we will describe means of producing and operating FBGs that support slow light with a group index that can be in principle as high as several thousand. We will present simulations elucidating how to select the FBG parameters, in particular index modulation, length, and degree of apodization, to generate such low group velocities, and quantify the very large improvement in strain and temperature sensitivities resulting from these new slow-light configurations. As a proof of concept, we will report an FBG with a group index of 69, or a group velocity of ~4,350 km/s, comparable to that of acoustic waves in glass. This is by far the lowest group velocity reported to date in an optical fiber. The measured characteristics of this slow-light FBG as a strain sensor will also be reported.

Poster Session III

15:00-15:30 **Poster Presentation by the Session Chair Prof. Wolfgang Ecke**

15:30-16:30 **Posters III View** (Includes the view of the post-deadline papers)

16:30-17:00 **Coffee Break/ Posters III View**

17:05-17:45 **Posters III (Group Discussion)**

17:50-18:30 **Posters III Plenary**

19:30 **Gala Dinner at *Bolsa* Palace** (departure from Workshop Venue)

Poster Session III (18 Regular Papers + postdeadline papers)

SIII-72 **Temperature- and strain-independent curvature sensor based on multimode interference**

S. Silva, O. Frazão, L. A. Ferreira, F. M. Araújo, INESC Porto (Portugal); F. X. Malcata, ISMAI (Portugal); J. L. Santos, INESC (Portugal)

This work describes a fibre optic sensing structure that is sensitive to curvature, and features a low temperature- and strain cross-sensitivity. It is based on multimode interference, and relies on a single mode – step index multimode – single mode fibre configuration. It was observed that the transmitted optical power in such layout becomes highly sensitive to the wavelength of operation and to the length of the multimode fibre. The optical spectrum entertains two dominant loss bands, at wavelengths that have similar responses both to temperature and strain, and different responses to curvature. Based on this result, an interrogation approach is proposed that permits substantial sensitivity to curvature (8.7±0.1 nm.m) and residual sensitivities to temperature and strain (0.3±0.1 pm/ºC and -0.06±0.01 pm/με, respectively).

SIII-73 **Enhancing absorption and sensitivity within structured optical fibres**

J. Canning, W. Padden, D. Boskovic, M. Naqshbandi, L. Costanzo, G. Huyang, H. Bruyn, T. H. Sum, M. J. Crossley, University of Sydney (Australia)

We propose enhancing the absorption of a species inside the channels of a structured optical fibre by depositing a high index layer within the air holes. This layer draws out the optical field within the mode increasing the overlap interaction. Simulations support the general idea and an experimental demonstration is reported using a novel approach to film formation with TiO2 nanoparticles. For the sake of demonstration, we use porphyrin with carboxylic groups that attach to the TiO2. The deposition of particles well coated with porphyrin is compared to those not fully coated prior to deposition in the holes. The latter case is found to give the best results since scattering loss is reduced when the porphyrins are not initially attached to the TiO2 particle. This is expected if film formation through intermolecular forces has occurred.

SIII-74 **Dynamic interrogation of long period gratings with modulated fibre Bragg gratings**

J. P. Carvalho, L. Coelho, INESC Porto (Portugal); L. Correia, Military Institute of Engineering (Brazil); O. Frazão, P. A. S. Jorge, J. M. Baptista, I. Dias, J. L. Santos, INESC (Portugal); J. Weyl, Federal University of Pará (Brazil); M. J. Pontes, Federal University of Espírito Santo (Brazil); M. A. Martinez, CEFET-RJ (Brazil); A. P. Barbero, R. M. Ribeiro,

Fluminense Federal University (Brazil); A. J. G. Abelém, Federal University of Pará (Brazil); M. T. R. Giraldi, Military Institute of Engineering (Brazil)

It is reported a LPG dynamic interrogation technique based on the modulation of fibre Bragg gratings located in the readout unit that permits to attenuate the effect of the 1/f noise of the electronics in the resolution of the LPG-based sensing head. The concept is tested to detect variations of the external refractive index and a resolution of 2.0×10−4 NIR was achieved without system optimization. Additionally, the effect in the sensor resolution when introducing Erbium and Raman optical amplification is experimentally investigated.

SIII-75 Feedback controlled single wavelength interrogation technique for miniature all-silica EFPI fibre optic pressure sensors

K. Bremer, E. Lewis, G. Leen, B. Moss, University of Limerick (Ireland); S. Lochmann, I. Mueller, Hochschule Wismar (Germany)

This paper proposes a novel technique to stabilise the output wavelength of a tuneable laser source to operate always in the linear range of a miniature all-silica Extrinsic Fabry-Perot Interferometric (EFPI) fibre optic pressure sensor. The technique is based on a fibre optic hybrid sensor, which consists of a miniature all-silica EFPI fibre optic pressure sensor with an incorporated in-Fibre Bragg Grating (FBG). The FBG temperature reference sensor is used as a feedback element to stabilise the output wavelength of a tuneable laser source. Therefore the novel interrogation technique allows high speed pressure measurements in high temperature environments.

SIII-76 Digital control of a white light system for interrogation of optical fiber interferometric sensors

E. Velosa, C. Gouveia, University of Madeira (Portugal); P. A. S. Jorge, INESC (Portugal); J. M. Baptista, University of Madeira (Portugal)

A digital control system to interrogate optical fiber interferometric sensors is presented. The system was implemented using a DAQ board and LabView Software, it is based on white light interferometry, and can use four different synthetic heterodyne and pseudo-heterodyne signal detection schemes. The system was tested and compared with standard hardware instrumentation using a fiber optic Mach-Zehnder interferometer to readout strain sensitive Fabry-Pérot sensors in a differential configuration. It is shown that the virtual instrumentation has a good performance being a viable alternative for use in compact portable sensing systems.

SIII-77 Fibre optic remote sensing based on long period gratings with In Situ optical source

D. Viegas, J. P. Carvalho, University of Porto (Portugal); L. Coelho, INESC Porto (Portugal); J. L. Santos, University of Porto (Portugal); L. A. Ferreira, F. M. Araújo, O. Frazão, INESC Porto (Portugal)

In this work the concept of long period based optical fibre sensors with the broadband light illumination generated just after the sensing structure is presented. This new approach allows the interrogation in transmission of the sensing head while integrated in a reflective configuration, which means the LPG sensor is seen in transmission by the optical source but in reflection by the measurement system. Also, it is shown that with this illumination layout the optical power balance is more favorable when compared with the standard configurations, allowing better sensor performances particularly when the sensing head is located far away from the photodetection and processing unit. This is demonstrated for the case of the LPG structure applied to measure strain and using ratiometric interrogation based on the readout of the optical power reflected by two fibre Bragg gratings spectrally located in each side of the LPG resonance.

SIII-78 All-fibre interferometric configurations based on suspended-core fibres for pressure measurement

S. H. Aref, INESC Porto (Portugal); M. I. Zibaii, M. Kheiri, H. Porbeyram, H. Latifi, Shahid Beheshti University (Iran); O. Frazão, F. M. Araújo, L. A. Ferreira, J. L. Santos, INESC (Portugal); J. Kobelke, K. Schuster, IPHT-Jena (Germany)

In this work, two all–fibre interferometric configurations based on suspended core fibres (SCF) are investigated. A Fabry-Pérot cavity made of SCF spliced in-between segments of single-mode and hollow-core fiber is proposed . An alternative sensing head configuration formed by the insertion of a length of SCF as a birefringence element in a Sagnac interferometer is also demonstrated. The sensitivity to pressure and temperature was determined for both configurations.

SIII-79 Bragg gratings in the germanium-doped concentric rings of an Yb3+-doped core solid photonic bandgap fibre

K. Cook, W. Padden, J. Canning, University of Sydney (Australia); S. Février, University of Limoges (France); B. Li, University of Sydney (Australia)

We demonstrate the inscription of Bragg gratings in each of the three, concentric, germanium-doped rings of an ytterbium-doped-core photonic-bandgap fibre. These rings can support several modes and the effective indices of these modes are derived experimentally from the grating peaks. They are found to be in excellent agreement with numerical simulation.

SIII-80 Magnetic field strength measurement using tailored dispersion characteristics of phase-shifted fibre Bragg gratings

P. Orr, University of Strathclyde (United Kingdom); M. Stevenson, J. Canning, University of Sydney (Australia); P. Niewczas, University of Strathclyde (United Kingdom)

Magneto-optical activity giving rise to circular birefringence and Faraday rotation is not usually an appropriate basis for point measurement of magnetic field strength, acting as it must over extended lengths. In this paper we report on investigations into the dispersion characteristics of structured fibre Bragg gratings for the purposes of implementing novel polarimetric point sensors. Phase-shifts inscribed along the grating profile introduce windows in transmission that correspond to highly resonant wavelengths undergoing large group delay. We demonstrate through fabrication of structured gratings that their dispersion characteristics can be tailored, producing regions of spectrally co-located reflection and large group delay. Importantly, it is shown how a number of such regions can contribute to a single enhanced group delay in reflection. Through simulation we discuss the potential for implementing polarimetric magnetic field sensors which operate in reflection.

SIII-81 Surface-plasmon-resonance sensor based on H-shaped optical fibre

D. Viegas, University of Porto (Portugal); M. Hautakorpi, Aalto University (Finland); A. Guerreiro, J. L. Santos, University of Porto (Portugal); H. Ludvigsen, Aalto University (Finland)

We propose and theoretically study a novel surface-plasmon-resonance sensor based on an H-shaped, elliptical-core optical fibre. The two grooves of the H-fibre are coated with a thin, uniform metal layer that in turn is covered with a high-index dielectric layer to allow broad spectral tunability. The sensor maintains linear polarization and facilitates effortless splicing. Electromagnetic mode analysis indicates a sensitivity of 1800 nm/RIU (refractive-index unit) for aqueous analytes.

SIII-82 Fiber optic intensity sensor referenced with virtual instrumentation for measuring displacement

A. J. G. Fernandes, C. Gouveia, University of Madeira (Portugal); P. A. S. Jorge, INESC Porto (Portugal); J. M. Baptista, University of Madeira (Portugal)

In this work it is presented a system to control a self-referencing fiber optic intensity displacement sensor using virtual instrumentation. To ensure higher flexibility and dynamic optimization, the use of an optical fiber delay line or an electrical delay line is avoided by implementing a delay line in the virtual domain, preserving the self-referencing and sensitivity characteristics of the proposed optical intensity sensing structure.

SIII-83 A Raman intensity sensor induced by the Rayleigh scattering in a ring configuration

C. Correia, J. M. Baptista, M. B. Marques, O. Frazão, INESC Porto (Portugal)

In this work, a laser sensor that uses the multipath interference produced inside a ring cavity to measure the power loss induced by a moving taper intensity sensor is described. The laser is created due to the virtual distributed mirror formed by the Rayleigh scattering produced in a dispersion compensating fibre when pumped by a Raman laser. Two laser peaks were formed, one of them is obtained by the Raman gain (1555 nm) inside the ring and the second is created by the combination of the Raman gain and the Rayleigh scattering (1565 nm). A taper sensor is used as displacement sensor and with the increases of losses the second laser peak amplitude is reduced. In the process the first peak is maintained constant and can be used as reference level.

SIII-84 Acoustic source location of partial discharges in transformers

S. E. U. Lima, O. Frazão, INESC Porto (Portugal); R. G. Farias, Federal University of Pará (Brazil); F. M. Araújo, L. A. Ferreira, V. Miranda, J. L. Santos, INESC Porto (Portugal)

Acoustic emission monitoring is often used in the diagnosis of electrical and mechanical incipient faults in high voltage apparatus. Partial discharges are a major source of insulation failure in power transformers and the differentiation from other sources of acoustic emissions is of the utmost importance. Also, it is important to give an indication of the PD source location in order to obtain a useful diagnosis. This paper reports the developments in partial discharges source location through the associated acoustic emissions using three different algorithms.

SIII-85 An all-fiber beam shaping using multimode fiber

M. Mayeh, F. Farahi, University of North Carolina at Charlotte (United States of America)

A new beam shaping technique has been developed by inverse etching the end face of a multimode fiber to form a concave cone tip. Concave tip fiber can convert a Gaussian beam profile to a flat top beam with a uniform intensity distribution. A flat top beam with intensity variation of approximately 5% and flat top diameter to spot diameter ratio of 67% has been achieved. With this technique one can also change the beam shape from a Gaussian to a donut by moving the observation plane. A flat top multimode fiber beam delivery has been tested for stimulation of prostate nerves.

SIII-86 Interrogation of microresonators using multimode fibers

P. Caldas, P. A. S. Jorge, F. M. Araújo, L. A. Ferreira, G. Rego, J. L. Santos, INESC Porto (Portugal); S. Berneschi, Research Center "Enrico Fermi" (Italy); F. Cosi, S. Soria, S. Pelli, G. Nunzi Conti, CNR-IFAC (Italy)

In this work we describe the characterization of high Q optical microresonators using an all fiber based system. Silica microspheres fabricated on a fiber tip by electric arc discharge are characterized using a simple interrogation system based on an adiabatic fiber taper coupler and on the collection of scattered radiation by a multimode fiber.

SIII-87 Fiber-optic simultaneous measurement of strain and temperature using a PM-PCF-based Sagnac interferometer incorporating a pumped EDF

O-J. Kwon, H-J. Kim, S. Chu, M-S. Yoon, S. Park, Y. Shim, Y-G. Han, Hanyang University (Korea)

A simple and flexible sensing configuration for discrimination of temperature and strain is investigated by implementing a PM-PCF-based Sagnac fiber loop mirror incorporating an EDF. The integration of an optical source and the sensing probe can obviously simplify the overall system configuration without requiring any additional broadband light source. Since the ASE of the EDF was reduced by the increase of temperature, the transmission peak power of he proposed sensor decreased as the temperature increased. The temperature sensitivity of the transmission peak power was estimated to be –0.04 dB/°C. When the strain was applied to the proposed sensing

head, the transmission peak power was not changed by the applied strain because the ASE power of the EDF was independent of the strain. However, the peak wavelength shifted into the longer wavelength because the variation of the peak wavelength was directly proportional to the applied strain. The strain sensitivity was measured to be 1.3 pm/με.

SIII-88 Residual thermal stress-induced integrated optical waveguides on Bi12GeO20 substrate

S. S. Sato, J. C. Santos, University of São Paulo (Brazil); M. A. R. Franco, Institute for Advanced Study (Brazil)

The residual thermal stress studies of an optical waveguide based on bismuth germinate - BGO, the Pockels electro-optic effect and the modal optical analyses were investigated for the optical modulation purpose. The analyses were performed by a full vector finite element based program. The optical propagation characteristics of the stress-induced waveguides and the main electro-optic parameters were evaluated considering different geometrical design.

SIII-89 Analysis and realization of a fiber-optic turbidity sensor based on measurements of scattered light

P. Dabral, M. R. Shenoy, B. P. Pal, B. D. Gupta, Indian Institute of Technology Delhi (India)

We propose a method for sensing the turbidity of a solution by inserting a fiber-optic probe in conjunction with a mirror. The probe consists of seven fibers, which illuminate as well as collect the light scattered from the sample after reflection from the mirror, in order to estimate the turbidity of the sample solution. We have estimated turbidity in terms of total interaction coefficient, a parameter that contains strong signature of the turbidity of a liquid. A light-scattering model based on Monte Carlo simulations is employed to simulate the power collected by the probe, which match reasonably well with the experimental results. The method is simple, and should be useful for detecting suspended impurities in a liquid even in small quantities.

Friday, September 10th, 08:30 - 12:50

Session IV: Distributed, Multiplexing, System Applications, and Field Trials

Chair:

Prof Luc Thévenaz, ***EPFL, Switzerland***

Invited Talks

08:30-9:00 **Prof. Luc Thévenaz,** S. Foaleng-Mafang, K-Y. Song, S. Chin, J-C. Beugnot, N. Primerov, M. Tur
EPFL (Switzerland)

SIV-I1 **Recent Progress Towards Centimetric Spatial Resolution in Distributed Fibre Sensing**

Optical fibre sensors based on stimulated Brillouin scattering have now clearly demonstrated their excellent capability for long-range distributed strain and temperature measurements. The fibre is used as sensing element and a value for temperature and/or strain can be obtained from any point along the fibre. While classical configurations have practically a spatial resolution limited by the phonon lifetime to 1 meter, novel approaches have been demonstrated these past years that can overcome this limit. This can be achieved either by the prior activation of the acoustic wave by a long lasting pre-pumping signal, leading to the optimized configuration using Brillouin echoes, or by probing a classically generated steady acoustic wave using a ultra-short pulse propagating in the orthogonal polarization of a highly birefringent fibre. These novel configurations can offer spatial resolutions in the centimetre range, while preserving the full accuracy on the determination of temperature and strain.

09:00-09:30 **Dr. Katerina Krebber,** P. Lenke, S. Liehr, N. Noether, M. Wendt, A. Wosniok
BAM (Germany)

SIV-I2 **Distributed Fibre Optic Sensors Embedded in Technical Textiles for Structural Health Monitoring**

Technical textiles with embedded distributed fiber optic sensors have been developed for the purposes of structural health monitoring in geotechnical and civil engineering. The distributed fiber optic sensors are based on Brillouin scattering in silica optical fibers and OTDR in polymer optical fibers. Such "smart" technical textiles can be used for reinforcement of geotechnical and masonry structures and the embedded fiber optic sensors can provide information about the condition of the structures and detect the presence of any damages and destructions in real time. Thus, structural health monitoring of critical geotechnical and civil infrastructures can be realized. The paper highlights the results achieved in this innovative field in the framework of several German and European projects.

Poster Session IV

09:30-10:00 **Poster Presentation by the Session Chair Prof. Luc Thévenaz**

10:00-10:45 **Posters IV View**

10:45-11:15 **Coffee Break/ Posters IV View**

11:20-12:00 **Posters IV (Group Discussion)**

12:05-12:45 **Posters IV Plenary**

Poster Session IV (50 Regular Papers)

SIV-90 Measurement with 2 m resolution using a Raman-assisted BOTDA sensor featuring 75 km dynamic range

S. M. López, F. Rodriguez-Barrios, Institute of Applied Physics (Spain); A. Carrasco-Sanz, University of Granada (Spain); P. Corredera, Institute of Applied Physics (Spain); J. D. Ania-Castañon, Institute of Optics (Spain), L. Thévenaz, EPFL (Switzerland); M. Gonzalez-Herraez, University of Alcala (Spain)

We have used distributed Raman amplification to extend the measurement distance of a Brillouin Optical Time-Domain Analysis (BOTDA) sensor. We successfully demonstrate a dynamic range of 75 km with 2 meter spatial resolution.

SIV-91 Impact of self phase modulation on the performance of Brillouin distributed fibre sensors

S. Foaleng-Mafang, EPFL (Switzerland); F. Rodríguez, S. M. López, Institute of Applied Physics (Spain); M. Gonzalez-Herraez, University of Alcalá (Spain); L. Thévenaz, EPFL (Switzerland)

The spectral broadening of the pump pulse through self phase modulation in a time domain distributed Brillouin sensor is demonstrated to have a non-negligible detrimental effect, leading to a doubling of the effective gain linewidth after some 20 km in standard conditions. The theoretical modeling is fully confirmed by experimental results.

SIV-92 A novel fiber optic technique for quasi-distributed and dynamic measurement of length change and refractive index

S. Liehr, K. Krebber, BAM (Germany)

We present a novel technique for dynamic and simultaneous measurement of displacement and refractive indices at multiple reflection points in optical fibers. This quasi-distributed sensor is based on the incoherent optical frequency domain reflectometry (I-OFDR) technique and allows for µm-resolution length change measurement and precise refractive index measurement. We show that the dynamic measurement ability and the simple sensor design allows for new applications in the field of structural health monitoring and chemical process control.

SIV-93 Distributed gas sensor based on a photonic bandgap fiber cell with laser-drilled, lateral micro channels

H. Lehmann, H. Bartelt, R. Willsch, IPHT-Jena (Germany); R. Amezcua-Correa, J. C. Knight, University of Bath (United Kingdom)

The fabrication, characterization, and use of a laser-drilled hollow core photonic band gap fiber (HC-PBGF) as a gas sensor in the near infrared region, from 1.5 µm to 1.7 µm wavelengths, are discussed. HC- PBGFs with laser-drilled, lateral micro channels have the ability to realize fast-responding, distributed gas sensor cells with large optical path lengths. By using white light spectroscopy as a sensor interrogation method, together with chemometric methods, not only the detection of individual gases but also the quantification of composed gas mixtures is possible.

SIV-94 Distributed optical fibre sensing of temperature using time-correlated two-photon excited fluorescence

C. J. Dalzell, T. P. J. Han, I. S. Ruddock, University of Strathclyde (United Kingdom)

Distributed temperature sensing based on time-correlated two-photon excited fluorescence (TPF) in doped optical fibre is described. Counter-propagating laser pulses generate a TPF flash at the position of their overlap which is scanned along the fibre by a variable relative time delay. The flash is transmitted to one end where it is detected and analysed to yield the temperature from its thermal dependence. With the fluorescence power being completely independent of excitation pulse duration and temporal profile, the sensor does not require ultrashort excitation pulses for operation. There is potential for high spatial resolution as the length of the sensed region depends only on pulse duration. Preliminary results are presented for praseodymium doped single-mode fibre.

SIV-95 A new MRI-compatible optical fiber tactile sensor for use in minimally invasive robotic surgery systems

R. Ahmadi, J. Dargahi, M. Packirisamy, Concordia University (Canada); R. Cecere, McGill University (Canada)

In conventional open surgery, using finger palpation, surgeons can distinguish between different types of tissues. However, in the current commercially available minimally invasive robotic surgery (MIRS) systems, direct tactile feedback is negligible. In the present paper, based on a novel concept, a new bend-type optical fiber tactile sensor is proposed, designed, simulated, fabricated, and tested. In both dynamic and static loading conditions, the proposed tactile sensor measures forces interacting between tissues and surgical tools whether they are distributed contact forces or concentrated contact forces, or even if these forces are in combination. As a result, the sensor can identify the size and the position of blood vessels or of abnormal tissues, one of which could be a tumorous lump within normal tissues. In addition, the static force measurement provided by the sensor allows surgeons to maintain contact stability in any static interactions between surgical tools and tissues while at the same time avoiding tissue damage because of excessive contact force. In the meantime, because the sensor is based uniquely on optical fibers, it is insensitive to electromagnetic fields. As a result, it is compatible with Magnetic Resonance Imaging (MRI) devices, which are currently in widespread use in surgical operating rooms.

SIV-96 Measurement of the longitudinal and circumferential muscular activity associated with peristalsis using a single fibre grating array

J. W. Arkwright, N. G. Blenman, I. D. Underhill, S. A. Maunder, CSIRO Materials Science and Engineering (Australia); N. J. Spencer, M. Costa, S. J. Brooks, Flinders University (Australia); M. M. Szczesniak, P. G. Dinning, University of New South Wales (Australia)

Diagnostic catheters based on fibre Bragg gratings (FBG's) are proving to be highly effective for measurement of the muscular activity associated with peristalsis in the human gut. The primary muscular contractions that generate peristalsis are circumferential in nature; however, it has long been known that there is also a component of longitudinal contractility present, acting in harmony with the circumferential component to improve the overall efficiency of material movement. To date, there have been relatively few reports on the measurement or inference of longitudinal contractions in humans and all have been limited to detection at a single location only. This is due to the lack of a viable recording technique suitable for real-time in-vivo measurement of this type of activity over extended lengths of the gut. We report the detection of longitudinal motion in lengths of excised mammalian colon using an FBG technique that should be viable for similar detection in humans. The longitudinal sensors have been combined with our previously reported FBG pressure sensing elements to form a composite catheter that allows the relative phase between the two components to be detected. The catheter output has been validated using digital video mapping in an ex-vivo animal preparation using lengths of rabbit ileum.

SIV-97 A fiber optics textile composite sensor for geotechnical applications

O. Artières, TenCate Geosynthetics (France); G. Dortland, TenCate Geosynthetics (The Netherlands)

The fiber optics in structural health monitoring systems for civil engineering applications have been widely used. By integrating fiber optic sensing into a geotextile fabric, the TenCate GeoDetect® system is the first designed specifically for geotechnical applications. This monitoring solution embodies fiber optics on a geotextile fabric, e.g. a textile used into the soil, and combines the benefits of geotextile materials, such as high interface friction in contact with the soil, with the latest fiber optics sensing technologies. It aims to monitor geotechnical structure and to generate early warnings if it detects and localizes the early signs of malfunctioning, such as leaks or instability. This is a customizable solution: Fiber Bragg gratings, Brillouin and Raman scattering can be built into this system. These technologies measure both strain and temperature changes in soil structures. It can provide a leak and deformation location within accuracies resp. 1 l/min/m and 0.02%. The TenCate GeoDetect® solution provides objective, highly precise, and timely in-situ performance information, allowing the design professional and owner to understand system performance in addition to providing alerts for negative "geo-events" (subsidence) and other potentially deleterious events.

SIV-98 Impact of the pulse modulation format on distributed BOTDA sensors based on Simplex coding

M. A. Soto, G. Bolognini, F. Pasquale, Sant'Anna School of Advanced Studies (Italy)

We experimentally analyse the impact of pulse modulation format on BOTDA sensors exploiting Simplex coding. A careful optimisation of modulation format is required to avoid spurious oscillations causing severe penalties in the measurement accuracy.

SIV-99 Strain measurement of a fiber loop rosette using high spatial resolution Rayleigh scatter distributed sensing

D. K. Gifford, A. K. Sang, S. T. Kreger, M. E. Froggatt, Luna Technologies (United States of America)

Strain is measured with high spatial resolution on fiber loops bonded to a metal test sample to form a fiber rosette. Strain measurements are made using an Optical Backscatter Reflectometer to detect changes in the phase of the Rayleigh Scatter of the fiber with 160 µm spatial resolution along the length of the fiber. Using this experimental set-up, applied strain levels as well as the axis along which the loads are applied are measured. Thermal gradients are also detected. The high spatial resolution and strain sensitivity of this technique enable highly functional fiber rosettes formed of small diameter loops of standard low-bend-loss optical fiber.

SIV-100 Low-cost Brillouin optical time domain analysis (BOTDA) distributed sensor setup

A. Zornoza, A. Loayssa, Public University of Navarra (Spain)

We present a solution for Brillouin optical time domain analysis (BOTDA) long-range distributed sensing that contributes to improve considerably one of the most important problems these sensors have nowadays: the cost of the setup. We achieve this by simplifying the process to obtain a stable frequency shift between pump and Stokes waves. The technique we propose consist in obtaining the Stokes wave from the pump by frequency shifting in two steps: the first one with a so-called passive Brillouin frequency shifter (BFS), and the second one by low-speed modulation. Moreover, we demonstrate preliminary measurements of this system in typical long-range conditions, with 25km of fiber at 1m resolution, highlighting the sensor capacity.

SIV-101 Fibre laser sensor based on a phase-shifted chirped grating for acoustic sensing of partial discharges in power transformers

S. E. U. Lima, O. Frazão, INESC Porto (Portugal); R. G. Farias, Federal University of Pará (Brazil); F. M. Araújo, L. A. Ferreira, V. Miranda, J. L. Santos, INESC Porto (Portugal)

Partial discharges are a major source of insulation failure in electric power transformers. Their detection can be achieved through the associated acoustic emissions, and this work reports on the investigation of a fibre laser sensor based on a phase-shifted chirped fibre grating for acoustic emission detection in the power transformer environment. The performance of the sensing head is characterized and compared for different surrounding media: air, water and oil.

SIV-102 Experimental study for the detection of the "laminar/turbulent" aerodynamic transition on a wing aircraft, using fiber optic sensors

S. Molin, D. Dolfi, Thales Research & Technology (France); M. Doisy, Thales Underwater Systems (Frances); A. Seraudie, D. Arnal, E. Coustols, ONERA (France); J. Mandle, Thales Avionics (France)

We demonstrate the feasibility of detection of the nature (laminar/turbulent/transitional) of the aerodynamic boundary layer of a profile of a wing aircraft model, using a Distributed FeedBack (DFB) Fiber Laser as optical fiber sensor. Signals to be measured are pressure variations: ΔP~1Pa at few 100Hz in the laminar region and ΔP~10Pa at few kHz in the turbulent region. Intermittent regime occurring in-between these two regions (transition) is characterized by turbulent bursts in laminar flow. Relevant pressure variations have been obtained in a low-speed research-type wind tunnel of ONERA Centre of Toulouse. In order to validate the measurements, a "classical" hot film sensor, the application and use of which have been formerly developed and validated by ONERA, has been placed at the neighborhood of the fiber sensor. The hot film allows measurement of the boundary layer wall shear stress whose characteristics are a well known signature of the boundary layer nature (laminar, intermittent or turbulent). In the three regimes, signals from the fiber sensor and the hot film sensor are strongly correlated, which allows us to conclude that a DFB fiber laser sensor is a good candidate for detecting the boundary layer nature, and thus for future integration in an aircraft wing. The work presented here has been realized within the framework of "Clean Sky", a Joint Technology Initiative of the European Union.

SIV-103 Fiber optical sensor solutions for increase of efficiency and availability of electric power generators

M. Willsch, T. Bosselmann, M. Villnow, Siemens AG (Germany)

Multiple fiber optical sensors have been developed for strain, vibration, temperature, magnetic field and air flow measurement in electric power generators. This paper describes the recent state of development and reports about todays field experience.

SIV-104 Ultrasonic modal detection in carbon fibre plates using fibre optic sensors

G. Thursby, B. Culshaw, University of Strathclyde (United Kingdom)

Ultrasonic Lamb waves can be detected by various optical sensors, including polarimetric and FBG fibre sensors embedded within the sample plate. The difference between the responses of two types of optical fibre sensors, both positioned at different depths within a carbon fibre composite plate, to the first symmetric (S0) and antisymmetric (A0) Lamb waves are described. These responses illustrate the difference in characteristics between the two modes and may be used to identify phenomena such as mode conversion that might be caused by either structural features or damage within the material.

SIV-105 Suspended-core Fabry-Pérot temperature sensor interrogation through a dual wavelength Raman fiber laser

A. M. R. Pinto, Public University of Navarra (Spain); O. Frazão, J. L. Santos, INESC Porto (Portugal); M. López-Amo, Public University of Navarra (Spain); J. Kobelke, K. Schuster, IPHT-Jena (Germany)

The interrogation of a suspended-core Fabry-Perot interferometric cavity through the illumination of a dual wavelength Raman fiber laser is reported. The proposed scheme is based on the use of a dual wavelength source for the generation of two quadrature phase-shifted signals that allows the recovery of the temperature change. The dual wavelength Raman fiber laser is based on fiber Bragg gratings combined with a virtual mirror. The use of this source allows a passive and accurate interrogation of the temperature variation, while taking advantage of the Rayleigh scattering growth as a virtual mirror in the laser.

SIV-106 Polymer photonic sensing skin

X. Chen, C. Zhang, D. J. Webb, Aston University (United Kingdom), B. V. Hoe, G. V. Steenberge, Ghent University (Belgium); K. Kalli, Cyprus University of Technology (Cyprus); F. Berghmans, H. Thienpont, Vrije Universiteit Brussel (Belgium); W. Urbanczyk, Wroclaw University of Technology (Poland); K. Sugden, Astasense Ltd. (United Kingdom); G-D. Peng, University of New South Wales (Australia)

A highly flexible sensing skin with embedded polymer optical fibre Bragg gratings is characterised The response to pressure and strain compare favourably to a similar skin instrumented with silica fibre Bragg grating sensors.

SIV-107 Smart medical textiles with embedded optical fibre sensors for continuous monitoring of respiratory movements during MRI

J. Witt, BAM (Germany); F. Narbonneau, Multitel (Belgium); M. Schukar, K. Krebber, BAM (Germany); J. Jonckheere, M. Jeanne, Inserm CIC-IT (France); D. Kinet, Multitel (Belgium); B. Paquet, Centexbel (Belgium); A. Depré, Elasta (Belgium); L. T. D'Angelo, University of Technology Munich (Germany); R. Logier, Inserm CIC-IT (France)

We report on three respiration sensors based on pure optical technologies developed during the FP6 EU project OFSETH. The developed smart medical textiles can sense elongation up to 3%, while maintaining the stretching properties of the textile substrates for a good comfort of the patient. The sensors, based on silica and polymer fibre, are developed for monitoring of patients during MRI examination. The OFSETH harness allows a continuous measurement of respiration movements while all vitals organs are free for medical staff actions. The sensors were tested in MRI environment and on healthy adults.

SIV-108 Smart CFRP systems for the controlled retrofitting of reinforced concrete members

M-B. Schaller, GGB mbH (Germany); S. Käseberg, HTWK Leipzig (Germany); M. Kuhne, University Weimar (Germany)

During the last ten years an increasing amount of Carbon Fiber Reinforced Polymer (CFRP) applications to rehabilitate damaged concrete elements was observed. Thereby some important disadvantages of the brittle materials must be considered, for example the low ductility of the bond between CFRP and concrete and brittle failure of FRP. With embedded sensor systems it is possible to measure crack propagation and strains. In this paper a sensor based CFRP system will be presented, that can be used for strengthening and measuring. The used optical fibers with Fiber Bragg Gratings (FBG) have a large number of advantages in opposite to electrical measuring methods. Examples are small dimensions, low weight as well as high static and dynamic resolution of measured values. The main problem during the investigations was the fixing of the glass fiber and the small FBG at the designated position. In this paper the possibility of setting the glass fiber with embroidery at the reinforcing fiber material will be presented. On the basis of four point bending tests on beams (dimensions of 700 x 150 x 150 mm) and tests on wrapped columns the potential of the Smart CFRP system is introduced.

SIV-109 Extension of the maximum measuring range in distributed Brillouin fiber sensors by tunning the Stokes/anti-Stokes power ratio

A. Minardo, Second University of Naples (Italy); R. Bernini, CNR-IREA (Italy); L. Zeni, Second University of Naples (Italy)

In this work, we extend the use of the gain-loss technique in order to enhance the long-range capabilities of Brillouin based distributed sensors. In particular, we take advantage of the use of an unbalanced pair of Stokes and anti-Stokes lines, in order to better compensate for SBS spectra distortion resulting from pump depletion. Numerical results confirmed the validity of the approach.

SIV-110 Distributed crystal fibre sensing for extreme environments

C. J. Dalzell, T. P. J. Han, I. S. Ruddock, University of Strathclyde (United Kingdom)

Distributed sensing of temperature can be achieved by using time-correlated two-photon excited fluorescence (TPF). To assess the extension of this technique to crystal fibres for high temperature applications, various aspects are considered including the two-photon absorption cross-section (δ),

dopant density and the geometry of single crystal fibres. By comparing the fluorescence yield for two-photon excitation with that for single-photon excitation of the same transition, δ for ruby was measured over the 0.8-1.2 μm range with maximum room temperature values of 5.9 × 10-3 GM for epolarisation and 4.6 × 10-3 GM for o-polarisation at 840 nm. It is shown that values of this magnitude are adequate for a practical TPF based crystal fibre sensor to be realised.

SIV-111 Self-referenced wavelength-sensitive monitoring technique for quasi-distributed fiber Bragg grating sensors

C. Caucheteur, D. Kinet, N. B. Soltana, P. Mégret, M. Wuilpart, University of Mons (Belgium)

In this work, we demonstrate the operating principle of a quasi-distributed monitoring system based on the concatenation of identical low reflective fiber Bragg gratings (FBGs) interrogated by means of an optical time domain reflectometer (OTDR). A filter inserted between the OTDR and the FBGs allows the height of the FBG reflection peaks in the OTDR trace to depend on their resonance wavelength, and therefore to the measurand. The proposed configuration is kept very basic and cost-effective, as a standard OTDR and some passive components are used. It is suited to interrogate a few tens of sensors in a measurement time that does not exceed a few seconds, whatever the number of sensors.

SIV-112 Fiber optic sensors for CMS-CERN

A. Cusano, University of Sannio (Italy); G. Breglio, OptoSmart s.r.l. (Italy); A. Irace, University of Naples (Italy); M. Consales, University of Sannio (Italy); A. Buosciolo, M. Giordano, CNR-IMCB (Italy); A. Cutolo, University of Sannio (Italy); S. Buontempo, National Institute for Nuclear Physics (Italy); P. Petagna, European Organization for Nuclear Research (Switzerland)

In this paper we present the activity that our research group is making on Fiber Optic Sensors (FOS) applications to monitor high-energy physics (HEP) experiments. Starting from the consideration that Fiber Optic radiation hardness has been widely proven, we have applied the technology of Fiber Optic Sensors to this very relevant field of interest. Here, we give the experimental evidences of the possibility to use such a class of sensors also in these very complex environmental side conditions. In particular, regarding the Compact Muon Solenoid (CMS) experiment at the CERN, we have monitored temperatures and strains in different locations by using Bragg Grating sensors, and we are now starting the development of a new class of Relative Humidity sensor based on Fiber Optic technology. Preliminary results are very encouraging, letting us consider the use of FOS technique as a robust and effective solution for monitoring requirements in HEP detectors for other physical and environmental parameters.

SIV-113 Automated suppression of polarization-fluctuation in resonator fiber optic gyro by a resonator with twin 90° polarization-axis rotated splices- theoretical analysis

X. Wang, Z. He, K. Hotate, The University of Tokyo (Japan)

We present the theoretical analysis on the effectiveness of the polarization-fluctuation suppression feedback control in resonator fiber optic gyro (R-FOG) with twin 90° polarization-axis rotated splices. Previously reported experimental results have shown that this feedback scheme is effective in improving the long-term bias stability of R-FOG by keeping the length difference of the fiber segments between two 90° polarization-axis rotated splicing points (ΔI) to a half of the beat-length of the polarization maintaining fiber (B/2). In this paper, the effectiveness of the feedback loop is verified theoretically using Jones transfer matrix. Simulation results indicate that: (1) the error signal of the feedback loop (the y axis polarized component in the output of the resonator) changes linearly with ΔI; (2) the error signal diminishes as ΔI is adjusted to the ideal condition of B/2, which are in good accordance with our experimental results.

SIV-114 Fiberoptic sensor network for monitoring new building cladding systems

R. Unzu, J. A. Nazabal, Public University of Navarra (Spain); G. Vargas, Alonso, Hernández & associates architects (Spain); R. Hernández, University of the Basque

Country (Spain); C. Fernández-Valdivielso, N. Urriza, M. Galarza, M. López-Amo, Public University of Navarra (Spain)

This paper shows the utilization of a fiberoptic sensor system for monitoring the enclosure of a communication tower. Such enclosure is composed by double glass panels filled with an alveolar type structure. The system monitors remotely 31 FBG based sensors. The results related to the measurements recorded into the glass alveolar panel has been used for assessing the structural reliability of the panel, under thermal and mechanical working conditions.

SIV-115 Unsupervised grouping of industrial textile dyes using K-means algorithm and optical fibre spectroscopy

A. M. Cubillas, O. M. Conde, P. Anuarbe, A. Quintela, J. M. López-Higuera, University of Cantabria (Spain)

A method for the unsupervised clustering of optically thick textile dyes based on their spectral properties is demonstrated in this paper. The system utilizes optical fibre sensor techniques in the Ultraviolet-Visible-Near Infrared (UV-Vis-NIR) to evaluate the absorption spectrum and thus the colour of textile dyes. A multivariate method is first applied to calculate the optimum dilution factor needed to reduce the high absorbance of the dye samples. Then, the grouping algorithm used combines Principal Component Analysis (PCA), for data compression, and K-means for unsupervised clustering of the different dyes. The feasibility of the proposed method for textile applications is also discussed in the paper.

SIV-116 A process for embedding fiber Bragg gratings in flexible skin foils

A. F. Silva, University of Minho (Portugal); F. Gonçalves, TMG Automotive (Portugal); L. A. Ferreira, F. M. Araújo, INESC Porto (Portugal); P. M. Mendes, J. H. Correia, University of Minho (Portugal)

Optical fiber sensors are increasingly used for monitoring purposes, but flexible smart structures based in this type of technology have many industrial applications. This paper explores a new approach for integrating optical fiber sensors in flexible substrates that can be mounted in host structures to monitor. This approach combines two well establish components, Fiber Bragg grating (FBG) sensors and flexible skin-foils. A three-layer foil construction based on the spread-coating process was defined, in which the fiber was embedded in the middle layer. Such disposition ensured protection to the optical fiber element without reducing the sensitivity to external stimulus. The functional prototypes were subject to thermal and mechanical tests, in which its performance was evaluated. The smart structure behaves linearly to temperature cycles by 0.01 nm/ºC and is able to withstand high strain cycles without affecting the measurement characteristics. The obtained results validated this approach. In addition, the flexibility of the explored method allows custom fiber layouts, finishing patterns and colors, enabling this way a range of possible application fields.

SIV-117 Low-cost, self-referenced all-fibre polarimetric current sensor for the monitoring of current in the railway catenary

M. L. Filograno, University of Alcalá (Spain); P. Corredera, Institute of Applied Physics (Spain); L. M. Lerma, O. Esteban, M. Gonzalez-Herraez, University of Alcalá (Spain)

In this paper a low-cost all-fiber current sensor is described that fulfills the requirements of robustness, sensitivity, accuracy and cost required for the monitoring of catenary current in changeover sections of the high-speed railway network. Its optical configuration is simplified through the use of few devices with extremely simplified alignment. This allows high sensitivity for low current values and a resolution below the ampere level. The sensing head is packed in a compact box withstanding temperature and position variations without affecting the sensitivity of the set-up. The electronics incorporates self-referencing that makes it robust to small misalignments and power variations in the optical source. Field tests will be reported in the conference.

SIV-118 Real time monitoring of railway traffic using fiber Bragg gratings

M. L. Filograno, A. Rodriguez-Barrios, University of Alcalá (Spain); P. Corredera, S. M. López, Institute of Applied Physics (Spain); M. Rodriguez-Plaza, A. Andres-Alguacil, ADIF (Spain); M. Gonzalez-Herraez, University of Alcalá (Spain)

In this work we present field tests concerning the application of Fiber Bragg Grating (FBG) sensors for the monitoring of railway traffic. The test campaigns are performed on the Spanish high speed line Madrid–Barcelona, with different types of trains (S-102 TALGO–BOMBARDIER, S-103 SIEMENS-VELARO and S-120 CAF). We located the FBG sensors in the rail track at 70 km from Madrid in the country side, where the trains primarily are tested during commercial operation with maximum speeds between 250-300 km/h. The FBG sensor interrogation system used allows the simultaneous monitoring of four FBG sensors at 8000 samples/s. The different position of the FBG sensors in relation with the rail can be used with different purposes such as train identification, axle counting, speed and acceleration detection, wheel imperfections monitoring and dynamic load calculation.

SIV-119 How reliable do fibre Bragg grating patches perform as strain sensors?

V. G. Schlütter, N. Kusche, W. R. Habel, BAM (Germany)

In Germany, the first guideline for the use of fibre Bragg grating strain sensors, "Optical Strain Sensor based on Fibre Bragg Grating", has been developed by the GESA guideline group of VDI "The Association of German Engineers" and published by Beuth Verlag. This guideline provides the basic specifications of these sensor types and the sensor characteristics which have to be known for a reliable sensor performance. In conformity to this guideline, experimental investigations on the strain transfer characteristics of fibre Bragg grating patches have been carried out. A comparison between patches and resistance strain gauges during tensile tests and combined temperature and tensile loading was carried out. The evaluated strain gauge factor and the temperature sensitivity of the strain gauge factor have been compared to the manufacturer's data. The overall performance of the patches has been evaluated. The experimental investigations showed that there are partial disagreements between the manufacturer's specifications and the observed characteristics.

SIV-120 FIBer Bragg gratings for optical sensing (FIBOS) for an aerospace application

R. L. Heredero, M. Frovel, H. Laguna, A. Anderson, D. Garranzo, G. Ramos, T. Belenguer-Dávila, National Institute of Aerospace Technology (Spain)

FIBOS, as one of the payloads of a picosatellite called OPTOS, will be used to measure temperature during the mission with Fiber Bragg Gratings. Description and calibration of FIBOS are presented.

SIV-121 Raman distributed temperature sensing in underground GeoExchange system

M. Giuseffi, P. Ferdinand, CEA - Atomic Energy and Alternative Energies Commission (France); A. Vrain, M. Philippe, H. Lesueur, BRGM (France)

Underground heat exchangers are instrumented by eight multimode optical fiber cables connected to a distributed temperature sensing (DTS) Raman system which provides real time temperature monitoring, versus operational conditions of the installation. A user-friendly Labview® software has been developed, allowing the configuration of the full installation, the signal processing of raw DTS data and storage, as well as the visualization of any temperature profile, on request. Preliminary temperature profiles are very promising. This platform will allow R&D about geothermal exchanges, will provide a full scale bench to characterize new equipments, and will encourage professionals to develop this renewable energy sector.

SIV-122 An approach to monitor railway pantograph-catenary interaction with fiber optic sensors

M. Bocciolone, G. Bucca, A. Collina, L. Comolli, Milan Polytechnic (Italy)

With the increase of the speed in the railway operation, a particular care has to be addressed to the interaction between pantograph and catenary: the variation of contact force and, consequently, the contact loss probability increases. The contact between pantograph and catenary is an electromechanical contact and when a contact loss occurs electrical arcing

phenomena arise. One of the most important effects of arcing phenomenon is the increase of wear for both contact wire and contact strip. The monitoring of contact force between pantograph and catenary in the high frequency range (up to values greater than 100 Hz) should be useful to put in evidence problems on the pantograph-catenary interface. In this work the use of fiber optic strain gauges, with FBG technology, to measure the pantograph-catenary contact force is discussed. This solution is insensitive to the electrical disturbances caused by the sparks and can be safely used in-line. Starting from a static and dynamic validation of the sensors, using as a reference traditional electrical strain gauges, a method to estimate the contact force was developed and tested.

SIV-123 Long-range hybrid double-bus network with point and distributed Brillouin sensors using Raman amplification

M. Fernandez-Vallejo, D. Olier, A. Zornoza, R. A. Perez-Herrera, S. Díaz, C. Elosúa, C. Bariain, A. Loayssa, M. López-Amo, Public University of Navarra (Spain)

We propose a hybrid network that combine point and distributed Brillouin sensors in an architecture that also deploys remote distributed Raman amplification to extend the sensing range. A 46-km proof-of-concept network is experimentally demonstrated integrating point vibration sensors based on fiber-optic tapers, with distributed temperature sensing along the network bus. The sensor network with a double-bus topology offers a higher optical signal to noise ratio and dynamic range than a single-bus for intensity point multiplexed sensors. In this network, we include low-cost intensity sensors that are able to measure vibrations in the 0.01 to 50 Hz frequency range, which are important in the monitoring of large infrastructures such as pipelines.

SIV-124 Permanently bent single mode optical fiber as novel evanescent wave sensor

A. Iadicicco, University of Naples "Parthenope" (Italy); D. Paladino, University of Sannio (Italy); S. Campopiano, University of Naples "Parthenope" (Italy); W. Bock, University of Quebec in Outaouais (Canada); A. Cutolo, A. Cusano, University of Sannio (Italy)

A novel optical fiber sensing scheme based on evanescent wave interaction is proposed. It involves locally and permanently bent single mode optical fibers. Permanent bends induce significant power coupling between core and cladding modes. Order and number of excited cladding modes depend on bend features and determine the field profile at the output of the bent region. This in turn constitutes a simple mechanism to tailor the field distribution in single mode optical fibers useful for spatial light modulation. Moreover, since guided cladding modes are strongly influenced by the surrounding refractive index, the power transmitted at the output of the bent region as well as its dependence on the optical wavelength are strongly sensitive to the SRI opening new scenarios in sensing applications.

SIV-125 Design of a surface attachable hybrid fiber sensor packaged in a polyimide film for engineering applications

M. Ramakrishnan, G. Rajan, Y. Semenova, G. Farrell, Dublin Institute of Technology (Ireland)

The design of a polyimide film packaged hybrid fiber sensor for simultaneous strain and temperature measurement is presented. This hybrid sensor operates in the intensity domain by converting the polarization and wavelength information from a polarization maintaining photonic crystal fiber (PM-PCF) sensor and fiber Bragg grating sensor (FBG) respectively into intensity variations. The strain sensitivity of a polarimetric sensor for various lengths of the PM-PCF is studied. The effective strain sensitivity of the FBG sensing system is adjusted to match that of the polarimetric sensor by varying the slope of the edge filter. The packaging aspects of the hybrid fiber sensor are also presented in this paper.

SIV-126 Location of vibrational disturbance using a serial array of identical low-finesse fiber Fabry-Pérot interferometers

R. M. Manuel, University of Johannesburg (Republic of South Africa); M. G. Shlyagin, S. V. Miridonov, Center for Scientific Research and Higher Education of Ensenada (México); J. Meyer, University of Johannesburg (Republic of South Africa)

An optical fiber sensor system for location of a vibrational disturbance along the fiber is presented. The sensor system is based on a serial array of identical F-P interferometers, formed directly in the single mode SMF-28e fiber by pairs of fiber Bragg gratings with reflectivity of 0.04 % each. Interferometers were interrogated by a DFB diode laser which was intensity modulated at 10 kHz. A method for localization of a disturbed interferometer and experimental results for a serial array of 14 sensors are presented. Simple sensor configuration and the use of low-frequency components make it potentially inexpensive and suitable for applications where a continuous monitoring of long structures has to be performed for appearance of vibrations.

SIV-127 Stable multiwavelength fiber laser for referencing intensity sensor networks using multiple amplified ring resonators

M. Fernandez-Vallejo, R. A. Perez-Herrera, C. Elosúa, C. Bariain, M. López-Amo, Public University of Navarra (Spain)

An experimental comparison of the stability performance of two different optical multiwavelength lasers is shown based on erbium highly doped fiber amplification. The two laser structures compared were: a star configuration using a 2x4 coupler to extract the signal from the ring to 4 FBGs and a structure with 4 active ring resonators that use both the same pump laser. Both lasers use Fiber Bragg gratings (FBG) to select the operation wavelengths within the resonant ring cavity. The stability of this new laser is compared with the achieved by a single ring configuration. The improvement of both stabilities depending on the time and temperature for the new structure was experimentally demonstrated. The utilization of the new configuration for multiplexing optical fiber sensors has also been carried out. The sensors provide amplitude modulation in response to the curvature introduced by a temperature-sensitive element. Each sensor is identified by a different wavelength generated by each FBG. The signal generated by the grating firstly is used as reference signal ant secondly is launched towards the sensors and the transmitted signal is measured. The sensors show a stable and linear response when measurements are carried out using simultaneously all the outputs of the structure for transmitting the multiple wavelengths to the sensors and utilizing the serial referencing output of the laser.

SIV-128 Broadband photonic crystal fiber coupler with polarization selection of coupling ratio

L. R. Jaroszewicz, K. A. Stasiewicz, P. Marć, M. Szymański, Military University of Technology (Poland)

In the paper a new broadband photonic crystal fiber coupler is presented. The proper application of the biconical taper technology has been used for manufacturing the coupler without air holes collapse in LMA10 fiber (NKT Photonics Crystal). This coupler, operates in the weakly coupling condition, protects coupling operation in range from 900 nm to 1700 nm. The coupling ratio between output arms is depending on wavelength and can be tuning by selection the proper input state of polarization. It gives opportunity to use the broadband crystal fiber coupler in many applications in which it is necessary to tune a coupling between output arms during the measurement.

SIV-129 Distributed humidity sensing based on Rayleigh scattering in polymer optical fibers

P. Lenke, M. Wendt, S. Liehr, K. Krebber, BAM (Germany)

In this document a new distributed sensor based on Rayleigh scattering in polymer optical fibers (POF) is proposed and first measurement results of the proposed sensor are shown. Dierent from Silica glas optical fibers POF absorb high quantities of water resulting in a change of their molecular structure and thereby reducing the present small scattering centers in areas of high humidity. The interdependence between scattering intensity and relative humidity is being investigated in case of steady cycles as well as stepwise changes of humidity and in the presence of moisture. A quantitative measure of humidity and scattering is presented.

SIV-130 Performance evaluation of an IGBT module by thermal analysis using fiber Bragg grating

J. P. Bazzo, T. Lukasievicz, M. Vogt, M. L. S. Martins, H. J. Kalinowski, J. C. C. Silva, Federal University of Technology – Paraná (Brazil)

This paper proposes a new method to estimate the energy losses in insulated gate bipolar transistors (IGBT) modules. The technique is based on measuring the temperature of the semiconductor junction through optical sensors based on fiber Bragg gratings. The IGBT module is monitored through software, enabling a real-time evaluation of performance, which facilitates the analysis of the device in different operating conditions. The results are compared with conventional techniques to validate the method.

SIV-131 Numerical modeling of a birefringent photonic crystal fiber for discrete and distributed pressure sensing

R. C. R. Miraglia, C. J. S. Matos, Mackenzie Presbyterian University(Brazil)

Discrete and distributed pressure sensing are theoretically studied with a birefringent microstructured fiber. Results compare favorably with those for a conventional fiber. Distributed pressure sensing with low temperature crosssensitivity are feasible with optical frequency-domain reflectometry.

SIV-132 Hybrid OTDR-fiber laser system for remote sensors multiplexing

M. Bravo, M. Fernandez-Vallejo, M. López-Amo, Public University of Navarra (Spain)

This paper describes the development of a hybrid multiplexing network for optical fiber sensors using a multiwavelength lasing long-range structure and the simultaneous utilization of an OTDR on the same network to interrogate displacement sensors based on microbenders. With this design, simultaneous interrogation of displacement and temperature was carried out 50 km away from the system header.

SIV-133 An application of FBG accelerometers for monitoring pantographs of underground trains

M. Bocciolone, G. Bucca, A. Cigada, A. Collina, L. Comolli, Milan Polytechnic (Italy)

The use of FBG based sensors for the monitoring of the pantograph-catenary interaction is very attractive due to the insensitivity of fiber optic sensors to the electromagnetic disturbances and due to their ability to be electrically insulated. In fact, the monitoring of pantograph-catenary interaction with traditional sensors needs a complicated set-up to electrically insulate sensors, to power the signal conditioning devices and to transmit the signal to the data acquisition system, and to avoid interferences between the measurement signals and electromagnetic disturbances typically generated by continuous sparking and eventual arcing phenomena caused by contact loss between the pantograph collector and the contact wire of overhead line. In this work the application of a commercial FBG accelerometer on a pantograph of an underground train, instrumented for experimental in-line tests, is analyzed. In particular, a comparison between a traditional capacitive accelerometer and a FBG accelerometer is presented to highlight the proper working of the fiber optic sensor during in-line tests and to take the use of this kind of fiber optic sensor into consideration for monitoring aim in the pantograph-catenary interaction, simplifying the measurement set-up. The first results show that this approach is promising.

SIV-134 Single-mode distributed temperature sensing using OFDR

W. Hill, J. Kübler, M. Fromme, LIOS Technology GmbH (Germany)

Distributed temperature sensing (DTS) using Raman-OFDR is not limited by non-linear effects or low duty cycles in long single-mode fibres. It shows full spatial and temperature resolution at a range of 30km. The availability of hydrogen resistant fibres favours single-mode DTS in applications with chemical load such as oil and gas production.

SIV-135 Multipoint Dynamically Reconfigure Adaptive Distributed Fiber Optic Acoustic Emission Sensor (FAESense™) System for Condition Based Maintenance

E. Mendoza, J. Prohaska, C. Kempen, Y. Esterkin, S. Sun, S. Krishnaswami, Redondo Optics Inc., Northwestern University (United States of America)

This paper describes preliminary results obtained under a Navy SBIR contract by Redondo Optics Inc. (ROI), in collaboration with Northwestern University towards the development and demonstration of a next generation, stand-alone and fully integrated, dynamically reconfigurable, adaptive fiber optic acoustic emission sensor (FAESense™) system for the in-situ unattended detection and localization of shock events, impact damage, cracks, voids, and delaminations in new and aging critical infrastructures found in ships, submarines, aircraft, and in next generation weapon systems. ROI's FAESense™ system is based on the integration of proven state-of-the-art technologies: 1) distributed array of in-line fiber Bragg gratings (FBGs) sensors sensitive to strain, vibration, and acoustic emissions, 2) adaptive spectral demodulation of FBG sensor dynamic signals using two-wave mixing interferometry on photorefractive semiconductors, and 3) integration of all the sensor system passive and active optoelectronic components within a 0.5-cm x 1-cm photonic integrated circuit microchip. The adaptive TWM demodulation methodology allows the measurement of dynamic high frequnency acoustic emission events, while compensating for passive quasi-static strain and temperature drifts. It features a compact, low power, environmentally robust 1-inch x 1-inch x 4-inch small form factor (SFF) package with no moving parts. The FAESense™ interrogation system is microprocessor-controlled using high data rate signal processing electronics for the FBG sensors calibration, temperature compensation and the detection and analysis of acoustic emission signals. Its miniaturized package, low power operation, state-of-the-art data communications, and low cost makes it a very attractive solution for a large number of applications in naval and maritime industries, aerospace, civil structures, the oil and chemical industry, and for homeland security applications.

SIV-136 Bridge monitoring by Brillouin based distributed stain measurements

A. Minardo, Second University of Naples (Italy); R. Bernini, CNR-IREA - Institute for the Electromagnetic Survey of the Atmosphere (Italy); L. Amato, Tecno In S.p.A. (Italy); L. Zeni, Second University of Naples (Italy)

We report the results of a load test performed on a road-bridge. In particular, the tests were performed by a portable prototype based on stimulated Brillouin scattering in optical fibers. The optical fiber sensor was able to provide the strain profile along the beam, with a spatial resolution of three meters and a strain accuracy of ± 20 εμ. Comparison with finiteelements- method simulations, as well as with data collected by vibrating wire strain gauges, permitted to confirm the validity of the SBS-based approach in monitoring the deformation of large structures.

SIV-137 Use of fiber optic sensors for measurement railway vibrations

A. Barreda, T. Molina, E. Valero, S. Recuero, AIDO (Spain)

This paper presents the results of an investigation about the involvement of the tram vibration in nearby buildings. The overall objective is studying vibration generated in urban environments by tram, transmission to the ground and receiving them by the constructions of the environment. Vibrations can generate noise and vibrations in buildings. That is why it is necessary to generate a performance protocol to characterize the level of vibration affecting rail, road infrastructure and sidewalks and nearby buildings, to assess the influence of the train (speed , type, profile wheel ,..), rail (area of rolling) and route of step and finally define interim corrective measures. In this study will be undertaken measures levels (energy) and vibration frequencies of excitement in route through optical techniques: optical fiber networks with distributed Bragg sensors. Measuring these vibrations in different configurations constructive allow us to evaluate the suitability of different sections for different types of uses or environments. This study aims to help improve the safety of the built environment of a railway operation, in turn increasing the comfort for passengers and reducing the environmental impact to the environment.

SIV-138 Comparison of optical and electrical measurements of the patograph-catenary contact force

M. Bocciolone, G. Bucca, A. Collina, L. Comolli, Milan Polytechnic (Italy)

In railway engineering the monitoring of contact force between pantograph and catenary gives information about the interaction between the two systems and it is useful to check the status of the overhead line. Indeed the failure of the catenary is one of the main causes of out of order problems. This study was conducted in a test campaign on an underground train instrumented with sensors able to monitor the line status. One of the more important measured quantities is the

pantograph contact force, and two measurement systems were implemented: one optical and another electrical. The optical one was based on FBG sensors applied on the pantograph collector strip; the electrical one was based on two load cells positioned at the sides of the collector strip. The in-line measurements show that the optical solution is very promising, providing very reliable results that can be successfully used in the monitoring application, allowing the determination of the critical point in the line. The thermal compensation of any FBG sensors is a known problem and here is no exception: a thermal compensator was used to get also mean value measurements and the results are discussed.

SIV-139 Automatic classification of steel plates based on laser induced breakdown spectroscopy and support vector machines

F. Anabitarte, J. Mirapeix, O. M. Conde, A. M. Cubillas, L. Rodriguez-Cobo, C. Galindez, A. Cobo, University of Cantabria (Spain)

Welding processes are one of the most widely spread industrial activities, and their quality control is an important area of research. The presence of residual traces from the protective antioxidant coating, is a problematic issue since it causes a significant reduction in the welding seam strength. In this work, a solution based on a Laser Induced Breakdown Spectroscopy (LIBS) setup and a Support Vector Machines (SVMs) classifier to detect and discriminate antioxidant coating residues in the welding area without destroying the sample before the welding procedure is proposed. This system could be an interesting and fast tool to detect aluminium impurities.

Friday, September 10th, 12:50 - 13:00

EWOFS2010 CLOSING

13:00-14:30 Lunch

How to get to the Workshop Venue

Latitude: 41°1'45.01"N
Longitude: 8°38'32.50"W

The organization plans to provide bus transportation from the airport to the Workshop hotels at specific hours of September 7. For further details please see the EWOFS2010 web page. Also, for the attendees that decide to stay at Hotel Fenix in Porto centre, bus transportation to and from the Conference Venue will be available.

By Car

From the North:

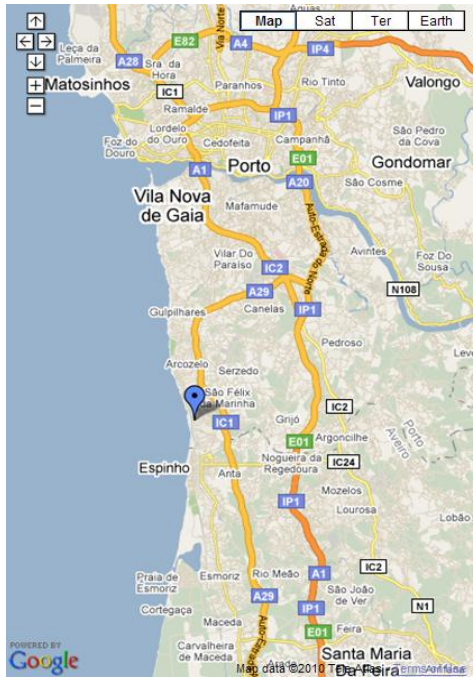
Coming from Porto Airport, take the exit A3-Porto Braga, at about 1km, go straight ahead VRI-Porto. At the end of this road take the exit A4-Vila Real, than turn off at the exit A3-Porto. Then follow the instructions below.

Coming along A28, take the exit A4-Vila Real, than turn off at the exit A3-Porto. Then follow the instructions below.

Coming along A3, take the exit on the left, in the direction of Lisbon. Go along the Porto ring road (IC23) and after crossing the River Douro, already in A1/IP1, turn off at the 3rd exit in the direction of A29. On the A29, after passing various exits, take the exit 3 (S. Félix Marinha / Praias). At the first roundabout, turn off at second road on the right. At the second roundabout, turn off again at the second road on the right. At the end of this road as you reach the traffic lights, turn left and you will find the hotel on your right

From the South:

Follow the A1 and take the Espinho exit, after the tollgate follow the directions for Espinho. Once on the IC24/A41 go out in the direction of Porto/Gaia and take the first exit (S. Félix Marinha / Praias). Turn left at the first roundabout and turn off at the third road on the right. At the second roundabout, turn off at the second road on the right. At the end of this road as your reach the traffic lights, turn left and you will find the hotel on your right.



Plan of the main roads arriving at the workshop venue

By Taxi

From Porto airport:

- Fare: ~ 45 €
- Duration: ~ 40 min.

Using the transfer provided by Hotel Solverde

- Price: 30 € / room / journey
- Duration: ~ 40 min.

Using the Underground and Train

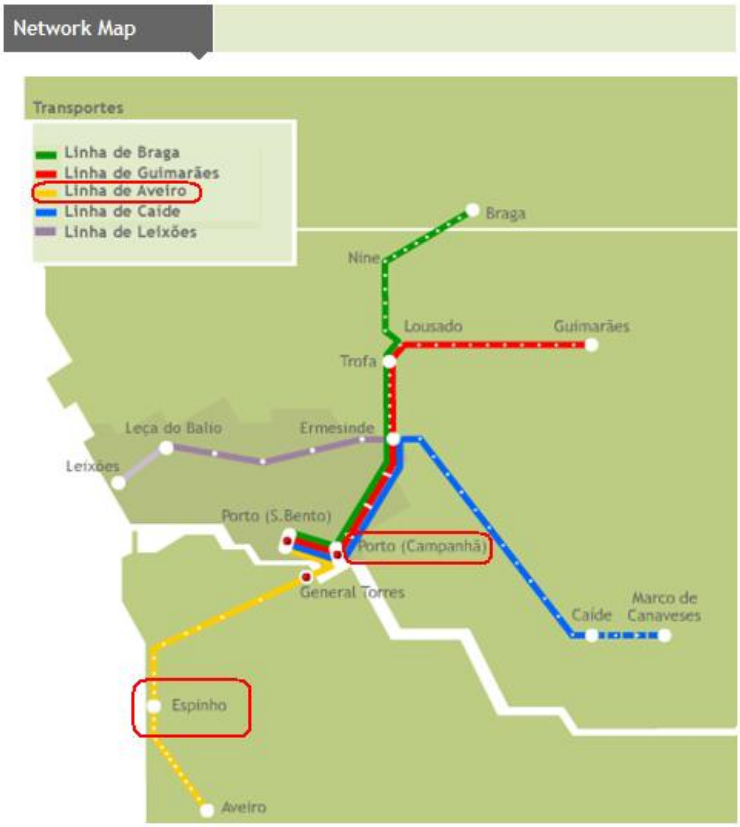
- Underground from Airport to Campanhã Station

• Fare: 1.45 €
• Duration: ~ 33 min.
• Timetable: there are underground trains leaving every 30 minutes from 06:00 to 01:00 (Please confirm timetable and fare details at www.metrodoporto.pt)

Plan of the Undergroung system in Porto

- Train from Campanha Station to Espinho Station
• Fare: 1.40 €
• Duration: ~ 25 min.
• Timetable: there are 4 trains per hour from 6:00 to 20:45 (Please confirm timetable and fare details at www.cp.pt)

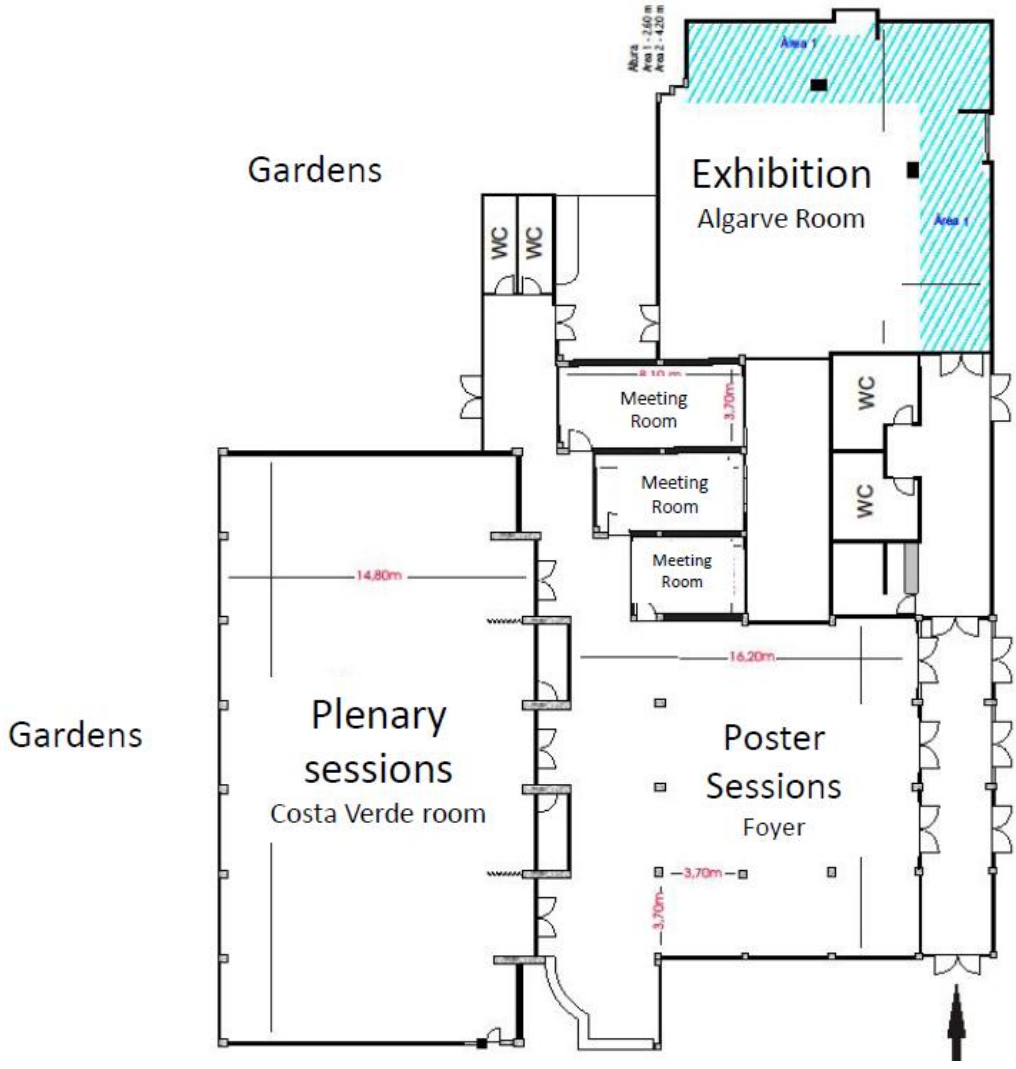
From Espinho Station to the Hotel Solverde, please contact Hotel Solverde – telephone: 00351 22 733 80 30.



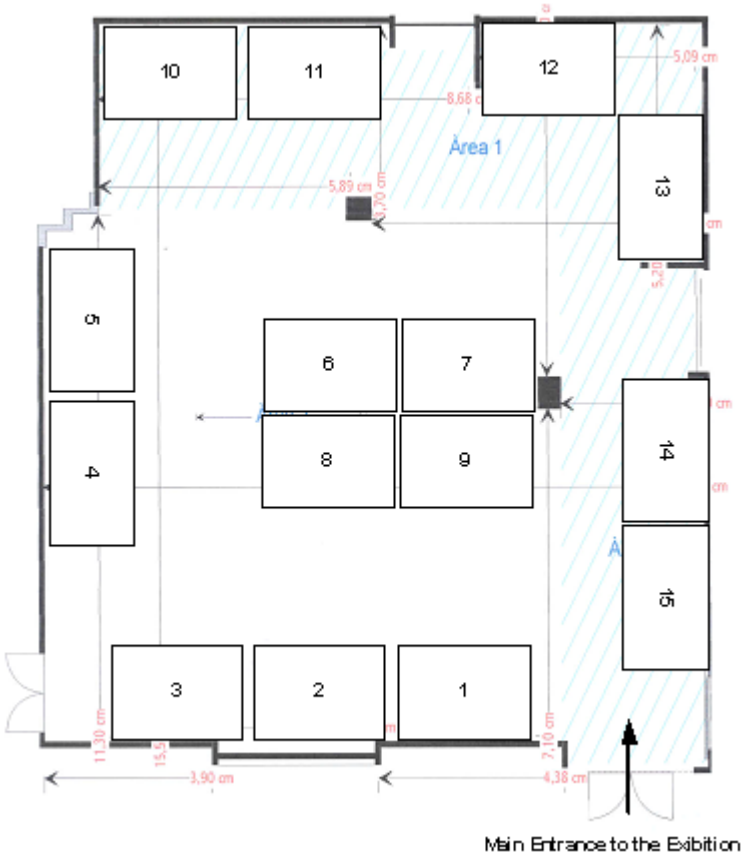
Plan of the Train system in Porto

Scheme of train stations along the Aveiro line (Linha de Aveiro)

Workshop Floor Plan



Exhibition Floor Plan



Companies present at the Exhibition


vytran

NKT Photonics
the power of light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TECHNOLOGIES
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