Successful Fiber Sensing Technologies and Hot Topics for the Near Future

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Successful Fiber Sensing Technologies and Hot Topics for the Near Future

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Abstract: Inside the Photonics field Optical Fiber Sensors (OFS) are currently being used and will still be used in the future in a wide number of applications because its properties present technical advantages over traditional techniques or, sometimes, is practically the only feasible solution. In this paper, the more successful techniques will be reviewed. Then a prospective for the near future of the market and hot topics in which invest research resources will be suggested.

Keywords: Optical Fibre Sensors, Fibre Optic, Optical Transducers, Optoelectronic Units, OFS Market trends.

1. INTRODUCTION

The **New Photonics Field** must be understood as the set of techniques and scientific knowledge which are applied to the generation, propagation, control, amplification, detection, storage and processing of signals of the optical spectrum, along with their technologies and derived uses. The Photonics field can be divided into several areas and that, in many cases, Electronics and Photonics overlap. There are cases where electrons control photons as there are others in which photons control electrons. Therefore, 'complementary harmony' can exist between Electronics and Photonics.

Within the Photonics field there is an area in which the above-mentioned complementary harmony between both fields is very clear and contributes to enhance the behavior that could now be achieved together: the Photonic Sensing Technology area, in which Optical Fiber Sensing Technology is included [1].

FIGURE 1 - Conceptual illustration of an Optical Sensor: Light from the object with its state information encoded in it, after travel through the optical channel, arrives the optoelectronic unit and then the decoded information, in the electrical domain, is able to be used.

As can be deducted from the figure 1, a Photonic/Optical Sensor can be considered as a photonic system of which the measured object magnitude (measurand) or input signal (O_i), introduces modifications or modulations in some of the characteristics of the light in an optical system. After being detected, processed and conditioned, the system will deliver an output signal (O_e), usually in the electric domain, which will be a valid reproduction of the object variable. The transmitted or reflected light can be modulated by the measurand or modulating signal in its amplitude, phase, frequency or polarization characteristics. In accordance with this concept, if any of the processes or parts use fibre-optic technology, a subdivision of OS known as Fiber/Fibre Optic Sensors (FOS), or Optical Fiber/Fibre Sensors (OFS), is created [2]. In this paper, a prospective for the near future of the market and hot topics in which invest research resources will be suggested.

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2. MARKET SITUATION

According to very recent data from Optoelectronic Industry and Development Association (OIDA) in general terms the market of Photonics was of $139B, $187B and in 1997 and 2000 respectively. In 2004 the photonics market was 61% related with computer products, 30% related with consumer and the 9 % related with communications. Removing the Bubble (1999-2002) from the photonics Market History, the overall photonics market show a Sustainable average annual growth rate (AAGR) was about the 12%. According to OIDA the Photonics market will be of about $ 0.5 T for 2010 and about $1T for 2015 what is, really, a very important expected market for the near future. Inside this impressive general Market growth there are areas in which the annual growth is very important being photonics sensing area include among the mentioned. The expected growth per annum of fibre sensing area is higher that 100%.

As can be see in figure 2 and according to the mentioned OIDA study the areas dotted of major growths and hence areas in which to invest R&D resources are Security, Aerospace, Shipboard, Wells, and power and Pipe lines, to mention the more significants.

It must be mentioned that in figure 2, the data from environmental and biomedical sectors are not include. If we analyse the later, a big market of more or less the half of the total for OFS at 2008 it is expected.

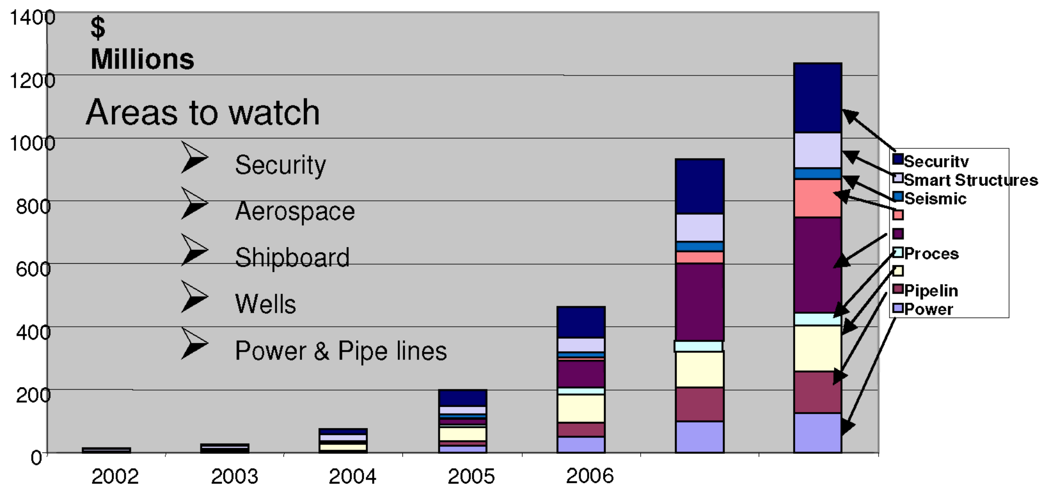

FIGURE 2.- Expected evolution of the optical fibre sensor market. Source: d. krohn light wave venture, OIDA.

3. HOT TOPICS: THREE SUGGESTIONS

Within the above paragraphs above a very brief summary of the more successful and well established fiber sensing techniques has been presented. Now three hot topics will be pointed out.

3.1.-New techniques for Distributed Sensing

As mentioned before distributed sensing is, probably, the "star" technique in fiber optic sensing. However, up to now a few commercial companies are exploiting this technology because the current technology does not properly match the requirements of real applications yet.

Up to now, driven by optical telecommunications requirements, tremendous development of fibers and components has been done. However, for distributed sensing systems these fibres do not match the requirements to optimize the interaction between the fibre system and the measurand and, therefore, new fibres and coatings are needed. Works are in progress using Photonic Crystal Fibres as transducers with very promising results [3-5]. Additionally and "harmoniously" with the development of new fibers, new interrogation and processing techniques are required to obtain better spatial resolution, better precision and stability in conjunction with lower prices than those offered by the current technology. New projects like FIDES [6] and PSS [7] are in course in Europe to contribute to reach the mentioned objectives.

3.2.- New Photonic Crystal Fibre Effects and Devices.

Microstructured fibres known as photonic crystal fibres or holey fibres have attracted a great deal of attention for sensing technology in the last few years as was shown in the recent EWOFS and OFS conferences [8-511]. Because of their appearance in sensing, this technology was not included in the last subsection. Microstructured fibre technology with its lattice of air holes running along the length of the fibre has matured, and provides a large variety of novel optical properties and improvements compared to standard optical fibres. Due to the wavelength-scale periodically-arranged material, these structures provide a completely new means of fabricating tailored optical properties either using modified total internal reflection or the photonic bandgap effect [12]. In addition and as consequence of the numerous micro or even nano-scale structures and holes along the fiber, it is possible to obtain superior mode control, polarisation properties, and the potential of close interaction between optical fields and the material under test [13].

Three main features of microestructured fibres make these fibres attractive for sensing applications. The first feature is the possibility of obtaining long interaction lengths between light propagating in the fibre and very small volumes of gases or liquids positioned in the air holes. The second one is the freedom in the design of the fibre optical properties including the number of guiding cores. The third is the great potential that can be obtained by making post-engineering of the fiber.

Microstructured fibres can be used, among others, for: i) *Evanescent-wave sensing* in which the strength of the evanescent field and the long interaction length makes index-guiding fibres interesting for evanescent wave sensing devices; ii) *Gas sensing,* for which either index guided or the photonic band fibres can be used. See figure 3. The gas inside the holes interact with the field confined inside the hole/s; iii) *Enhanced fluorescense biosensing* in which the light guided by the core is used to excite the chromophore and the fluorescence emitted from the biomolecules is collected in the fibre;

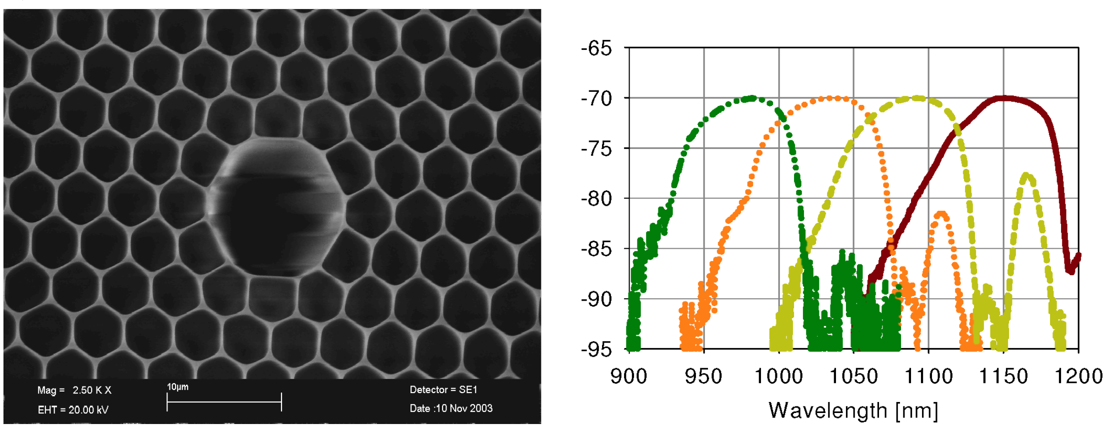

FIGURE 3 - Band gap guided holey fibers respectively(left) and Pass band tuning by increasing structural Dimension. Courtesy of the ORC, UK.

iv) *Bend sensing* in which a deformation of the fibre introduces a phase shift between the beams propagating in the different cores, which can be deducted from the resulting interference pattern; v) *Grating based sensors* using both long and short period grating structures in index-guiding micro-structured fibres. These fibres offer a significant interaction between the guided light and the gas, liquid or solid placed inside the holes irradiated by the evanescent field from the core, enabling changes in the behaviours of the gratings to be detected. vi) *Atom guides* in which the atoms are guided through the central fibre-hole driven by a magnetic field produced by a current through wires placed in adjacent air holes; vii) *Non-linear properties* using the strong confinement of the optical field within the core of index-guiding hollow fibers. This allows for strong nonlinear effects.

At this moment, very important research effort is being devoted to this technology because of their design flexibility offers a great number of potential applications both for future optical communications systems and for sensing sectors, among others [14-17]. Research efforts to enable the development of fibres specifically designed to match given applications and with lower propagation losses are required.

3.3.- New Optofluidic devices

Very small particles (or molecules of even atoms) can today be trapped and manipulate by means of focalized intense laser beams. Then it is possible to trap very tiny particles and molecules and then using other light beams with the proper characteristics detection and measuring of particle behaviours cam be done with out any physical contact (not perturbations) of the particle.

So the combination of the microfluidics and photonics will enable hybrid devices for sensing what we can refer to as Optofluidic devices or sensors.

4. CONCLUSIONS

After framed the fiber sensing technology as an area inside the photonic field some key fiber sensors concepts are stated. Then the most successful and mature techniques, based on the architecture of the transducer, are briefly presented. Finally, hot fiber sensing topics in which intense R&D works will be invested in the near future are pointed out: i) New effects, fibers and signal processing techniques to improve the dynamic range and resolution of fiber distributed sensors; ii) new effects, new structures and devices based on Photonic Crystal fibers and iii) hybrid devices and sensors based on optofluidic devices.

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