PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Francesco Fienga

XXIX Cycle

Training and Research Activities Report – Second Year

Tutor: prof. Giovanni Breglio

coTutor: eng. Salvatore Buontempo

1. Information

I received the MSc. cum laude in Experimental Particle Physic the 17th July 2013 with the thesis: *"Differential single-top measurements at CMS"*.
From April 2013 to March 2014 I worked at CERN being involved in the upgrade of the CMS detector. During this period I had the chance to come in touch with the fiber optic sensor technology and its applications in harsh environments like the CERN experimental facilities.
From April 2014 I started my PhD in Information Technology and Electrical Engineering at the University of Naples Federico II. For the first year I didn't receive a scholarship but for the second and third years I will receive a scholarship within the *POR Campania FSE 2007-2013/2014 - 2020 Asse IV - V Obiettivo operativo i2)1)m)*.
From June 2014 to February 2015 I received a scholarship as part of the research project *VEM, Virtual Energy Management, CUP: E61H13000000008* on the topic *"Studio finalizzato alla definizione e progetto di sistemi optoelettronici"*, *Rif. Borsa DIETI 14/2014, Prot. 2014/0050962*.
My tutors are prof. Giovanni Breglio (UNINA) and eng. Salvatore Buontempo (CERN/INFN).

2. Study and Training activities

	Credits Second Year								
		1	2	3	4	5	6		
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	**Total**	**Check**
Modules		0	3	0	0	5	3	11	**10 - 20**
Seminars		1.2	6.3	0	0	0	0	7.5	**5 - 10**
Research		8	8	5	8	8	8	45	**30 - 45**

Modules

- LabVIEW Core1 [3CFU]
- Charged particles accelerators [5CFU]
- Practical approach to Monte-Carlo software [3CFU]

Seminars

- Seminars followed at the XII Seminar on Software for Nuclear, Subnuclear and Applied Physics (24-29 May 2015). Certificate with the list of the seminars attached. [31,5 hours]

3. Research activity

My research activity is focused on the development of innovative fiber optic sensors to be used in harsh environment such as the particle physics detectors and accelerators. For this purpose I'm collaborating with the CERN-CMS fiber optic sensors group, with the INFN-Napoli section, with the Physics Department of the University of Naples Federico II and with the Optoelectronic Division of the University of Sannio.

I'm working on the development of a novel dosimetric sensors based on a fiber grating (FBG or LPG) integrated with a dosimetric fluid, whose refractive index changes as a function of the radiation dose absorbed.
As it is well known, the reflected wavelength (λ_B) of FBG has correlation with its effective refractive index (n_{eff}) and grating pitch (Λ). In general conditions, the n_{eff} of FBG is not influenced by the external refractive index. However, if fiber cladding diameter is reduced along the grating region to certain extent, the n_{eff} is significantly affected by external refractive index. The FBG refractive index sensors are based on the interactions between the fundamental mode and the external medium. From this result it follows that, in principle, it is possible to realize a dosimeter by using a FBG as SRI sensor immersed in a dosimetric fluid. We are also considering to use a LPG sensor instead of an etched FBG as SRI sensor.
As dosimetric fluid we are considering to use the Fricke solution. The standard Fricke dosimeter is an aqueous solution air saturated (oxygen concentration about 0.25 mol m^{-3}) that contains:

- 1 mol m^{-3} (10^{-3} M) ferrous sulphate $FeSO_4$ or ferrous ammonium sulphate $Fe(NH_4)_2(SO_4)^{2-}$,
- 400 mol m^{-3} (0.4 M) sulphuric acid H_2SO_4 with pH 0.46,
- 1 mol m^{-3} (10^{-3} M) sodium chloride NaCl added to nullify the effects of traces of organic impurities that increasing the yield of Fe^{3+} will lead to an underestimate of the absorbed dose.

The Fricke dosimeter is based on the oxidation of ferrous ions (Fe^{2+}) to ferric ions (Fe^{3+}) through a series of chemical reactions that take place in the aqueous acidic solution following the absorption of ionizing radiation. Oxygen is consumed during the course of irradiation, but the yield of ferric ion is not affected significantly by the changing of oxygen concentration until oxygen is virtually exhausted. The chemical reactions taking place when the Fricke dosimeter is irradiated consume oxygen, but the yield of ferric ion is not affected significantly by the changing oxygen concentration until oxygen is virtually exhausted. Exhaustion of the oxygen originally present in the solution marks the upper limit to the dose that can be measured. The highest dose that an air-saturated solution can register accurately is about 400 Gy with low LET radiation, *e.g.* X, γ, or e^-. The so called break point in the plot is at about 550 Gy where almost all the oxygen is consumed. The lower limit that the Fricke dosimeter can register is somewhere between 30 and 40 Gy when conventional spectrophotometry is used and the optical pathlength of the solution in the cuvette is 1 cm. The response of the Fricke dosimeter is linear over this dose range.
Reading the Fricke solution with a fiber grating will allow to monitor the dose on-line. At the present a detailed study on the optical properties of the Fricke solution are being performed in order to design the proper fiber grating to measure the refractive index changes of the solution under

irradiation. In the next months several experimental campaigns will be carried out with the first prototype..
This work is also included in the activities of the project OPTOFER ("*Tecnologie optoelettroniche innovative per il monitoraggio e la diagnostica dell'infrastruttura ferroviaria"*, Ricerca e Competitività 2007-2013 PON 03PE_00155, D.M. 593/2000, n. 810 del 07/03/2014), in which I'm working with the colleagues of the INFN-Napoli, UNINA Physics Dept. and UNISANNIO Optoelectronic Division to develop new prototype of dosimeter based on the fiber optic sensor technology.

I'm involved in the CMS iPipe project. This is a very challenging project in which, in collaboration with the CERN-CMS fiber optic sensor group, we have installed four arrays of FBG sensors on the central beam pipe of the LHC accelerator, in the CMS experimental cavern. The central beam pipe is a very fragile beryllium pipe long 3m and with a diameter of 10cm. It's placed in the centre of the CMS experiment and it's the place where the billions of proton-proton collision will happen during the LHC operation.
The aim of our project is to continuously monitor the temperature and the eventual deformations of the pipe, 24/7 for the next years of operation of the LHC. In fact, each array contains 7 strain sensors (glued on the beam pipe) and 9 temperature sensors.
I took part in the installation of the arrays, the calibration of the sensors and the analysis of the data developing some code in C++.

Beside the iPipe project, in the framework of the CMS experiment, as part of the CERN-CMS fiber optic sensor group, I'm taking part to others monitoring activities (strain and temperature) of other parts of the detector carried out by means of FBG sensors system. Indeed, we have 572 FBGs monitoring the temperature of the 572 Resistive Plate Chambers that are part of the Muon system of the CMS detector; I took care of the calibration parameters calculation of those sensors. I have also taken part in the installation and monitoring of 36 FBGs (28 strain and 8 temperature) that are going to be used as a structural health monitoring system on the YE4 disk of the CMS detector; the data analysis for this system is under development.

In the framework of the CERN-CMS fiber optic sensor group I have carried out a detailed study of the state of art of the ionizing radiations effects on FBG in order to define new tests aimed to quantify experimentally the effect of the effective ionizing radiation dose absorbed by the sensors during a typical LHC run, with the real dose rate which is linked to the instant luminosity of the LHC. These tests will be performed during the third year of my PhD.

Finally, during the second year of my PhD, I took part to the experimental phases of the project Campus SiHM "*Controllo e "Health Monitoring and Management" di Sistemi Complessi e Strutture Miste Metallo – Composito operanti in Ambienti Ostili sottoposte a Sollecitazioni Gravose"*. We installed a FBG strain monitoring system on sensitive part of an helicopter lending gear, on the upwind of the bogie of an airplane and on the metallic structure of an astrophysics antenna to monitor the response to typical external solicitations when the structure is intact and when it has been damaged.

4. Products

I'm author of the publication which has sprung from the participation to the conference FOTONICA2015:

Fiber optic sensors structural monitoring of the beam pipe in the CMS experiment at the CERN [http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=7322062]

5. Conferences and Seminars

During the second year I attended the Summer School entitled *"XII Seminar on Software for Nuclear, Subnuclear and Applied Physics"* held in Alghero (24-29 May 2015), organized by the INFN. [https://agenda.infn.it/conferenceDisplay.py?confId=8781]

I presented the work related to the iPipe project at the following conferences:

- **17th Italian National Conference on Photonics, FOTONICA 2015,**
  Torino 6-8 May 2015
  talk: Fiber Optic Sensors Structural Monitoring of the Beam Pipe in the CMS Experiment at the CERN [http://www.fotonica2015.it/documenti/Fotonica_2015_programma.pdf]

- **GE Annual Meeting 2015**
  Siena, 24-26 June 2015
  poster: Application of FBG sensors to strain and temperature monitoring of the CMS underground detector at CERN laboratories [http://ge2015.diism.unisi.it/poster_schedule.pdf]

- **CMS Upgrade and Physics Workshop 2015**
  Ischia, 8-11 September 2015
  talk: Application of FBG sensors to strain and temperature monitoring of the CMS underground detector at CERN laboratories [https://indico.cern.ch/event/371835/call-for-abstracts/29/]

- **6th EOS Topical Meeting on Optical Microsystems, OμS'15**
  Capri, 17-19 September 2015
  poster: Fiber optic sensors temperature and strain monitoring of the central beam pipe in the CMS experiment at CERN [http://www.myeos.org/system/files/final_program.pdf]

- **101° Congresso Nazionale della Società Italiana di Fisica, SIF 2015**
  Roma, 21-25 September 2015
  talk: Fiber optic sensors structural health monitoring of the CMS underground detector at the CERN laboratories. [http://congresso.sif.it/talk/184]

Another abstract as been submitted and accepted to the 8th European Workshop on Structural Health Monitoring (EWSHM2016), that will take place in the city of Bilbao, 5-8 July 2016. The talk title is "Fibre optic sensors structural health monitoring of the central beam pipe in the CMS experiment at the CERN laboratories".

6. Activity abroad

During the sencond year I've been at CERN mainly to take part in the commissioning of the iPipe project. These are the days I spent at CERN during this second PhD year:

- 01/12/2015 – 12/12/2015
- 15/02/2016 – 29/02/2016

7. Tutorship

I'm currently tutoring the McS Thesis work of a student in Electronic Engineering. This work is framed in the CERN-CMS fiber optic sensor group activities