FOS irradiation Results and Omega Shape manufacture

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Outline

- Introduction to Irradiation
- Activation of the Samples
- Parameters of influence
- Preliminary conclusions
- Stability of the FBG's after irradiation
- Omega shape manufacture
- Schedule and Outlook

Irradiation campaign: facility

- Irradiation campaign at Centro Nacional de Aceleradores (CSIC) in Seville.
- New Cyclotron facility (max. energy of 18 MeV protons, here 15.5 MeV protons)

FBG sensors irradiation: Introduction

- Sensors (written in nine optical fibers) supported by an aluminum holder.
  - Irradiation intensity uniform over all the sensors
  - An FBG sensor was glued to the FOS Al support outside the irradiation area used as reference in order to measure the temperature change.
  - Final fluency of 3.3 10E15 protrons/cm2 (expected SLHC values)
- F.O embedded in Composite samples
  - 20 samples where irradiated up to 4 different doses
    - 5 at 2.5 x 10^{14} protons / cm^2
    - 5 at 9 x 10^{14} protons / cm^2
    - 5 at 15 x 10^{14} protons / cm^2
    - 5 at 33 x 10^{14} protons / cm^2
  - They are now been metalographically prepared at INTA for the Nanoindentation at Universidad Carlos III

Activation of the Irradiation Sample

- Both samples were activated after irradiation
  - The F.O. embedded composite samples where dismounted and sent to INTA for the preparation of Nanoindentation
  - The FBG's samples are still activated (the support or the Ormocer coating) . Finally it is going to be necessary dismounting the Fibers from the support with the samples still hot.
    - Problem: We would like to make a visual inspection of each sensor position in the irradiation area. With the support irradiated the fibers must be dismounted as fast as possible.
    - Then the fibers will be measured. If they are activated, we will have to wait until they de-activation. If not, we will start with the calibration of the sensors

Parameters of Influence: Core material

- The Core of the Fiber optic can be of different types
  - Pure Silica: More resistant to radiation in terms of attenuation of the signal. The problem is that they are not photosensitive, and the fabrication of FBG-s in this kind of material is more difficult and expensive
  - Ge doped: The core is doped with Ge and sometimes with Ce. It Is the more usual fiber in the market. This type of core is photosensitive. In this kind of fibers the FBG sensors can be fabricated by ultraviolet laser. The fabrication in this kind of fiber is less expensive.
- The Ge dopping concentration is an important parameter.

Parameters of influence: Fabrication type

- There are many fabrication types. Three of them were used for the FBG-s irradiated:
  - Type I FBG’s Fabrication method. Only for Ge doped silica. The FBG is written by an Ultraviolet light. 2 Types:
    - Normal: Once the F.O. is manufactured, the coating is removed and with an UV light the grating period is recorded during 2 minutes. Then the F.O. is recoated
    - Drawtower: During the manufacture of the Fiber, before apply the coating of the F.O. , the grating period is recorded during some seconds, and then the fiber is coated.
  - Type II FBG’s Fabrication method. This method can be used for any F.O.. A phentosecond Laser is used to record the bragg grating period. The core is practically melted by the high energy of the laser

Parameters of influence: Coating

- The coating can change the initial value of the wavelength of the FBG. This is because of the internal stress introduced on the core as result of the coating. Three different coatings were chosen:
  - Acrylato: smaller mechanical strength
  - Ormocer: middle strength
  - Polyimide: highest strength
- The coating also affect the reaction of the FBG-s with the strain and Temperature (K factor is dependence of the coating young module)

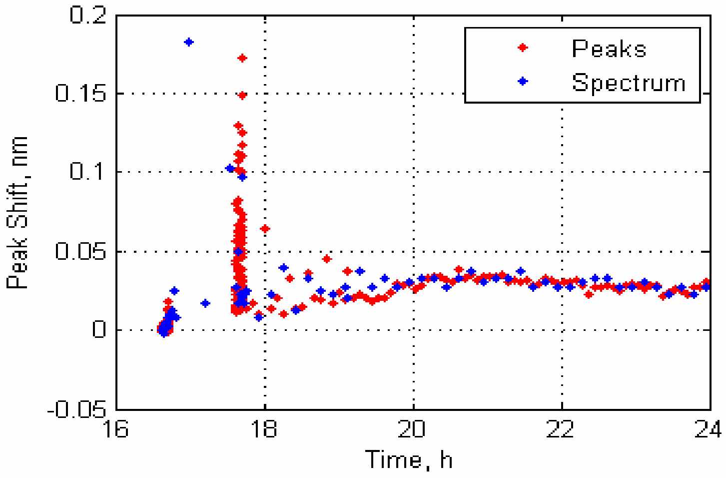
Preliminary conclusions: Fiber optics position

- There were problems with the positioning of the FBG's before irradiation. Some ormocer sensors seems not to been irradiated at all. To be confirmed
  - Difference between the peak-shift of the same type of sensors.

02 Ormocer Fiber	Sensor Nº	021	022	023	024
	Peak shift	-0,30617	-0,37754	-0,33223	-0,04462
01 Ormocer Fiber	Sensor Nº	011	012	013	014
	Peak shift	-0,02211	-0,0068	-0,0116	-0,00183

  - So much different behavios during irradiation

011



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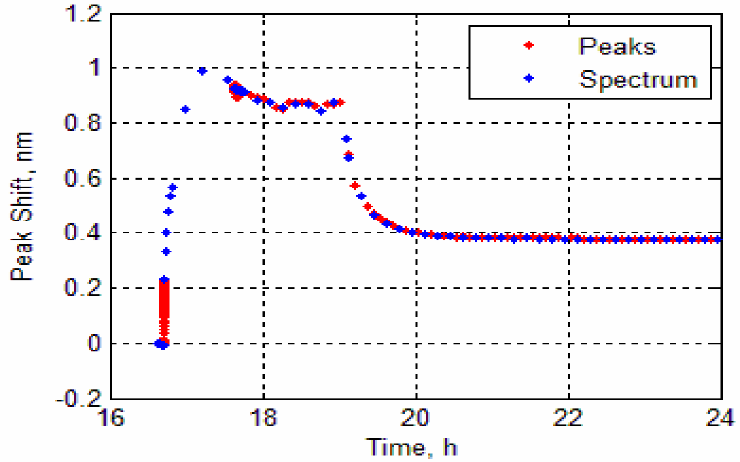

Preliminary conclusions: Fiber optics position

- We have this same problem with another sensors.
- The acrylate sensors has a very small change of peakshift or atenuation
- We have the same problem with the polyimide sensor 211
- All the sensors will be visually inspected by a microscope so we can check if the sensors has been irradiated.

Sensor	Coating	Attenuation	Peak- shift
O11	ormocer	0,56	25
O12	ormocer	0,37	10
O13	ormocer	0,39	12
O14	ormocer	0,59	3
O21	ormocer	6,23	308
O22	ormocer	8,8	379
O23	ormocer	5	334
O24	ormocer	1,14	46
O3	ormocer	0,01	206
O4	ormocer	0,03	307
O5	ormocer	0,21	359
111	acrylato	0,42	-3
112	acrylato	0,15	-14
TEMP	polimida	0,07	-3
211	polimida	0,44	10
212	polimida	6,05	140
213	polimida	6,26	173
214	polimida	7,16	175
221	polimida	7,56	158
222	polimida	6,92	175
223	polimida	6,92	173

Preliminary conclusions : Δλ

- It seems that the peak shift is only dependant of the coating of the fiber. The FBG's wavelength change because of the change of the mechanical properties of the coating. For the ormocer for example there are 2 fibers of Type 1 drawtower and 3 of Type II. The peak shift is of the same order for all of them.

SENSOR	111	112	TEMP	021	022	023	024
λ before	1543,09147	1556,70164	1579,97002	1530,36627	1540,23824	1550,35274	1560,23057
λ After	1543,08417	1556,68547	1579,96555	1530,67244	1540,61578	1550,68497	1560,27519
Δλ (nm)	0,0073	0,01617	0,00447	-0,30617	-0,37754	-0,33223	-0,04462

SENSOR	03	011	012	013	014	05	04
λ before	1530,23316	1530,34985	1540,25489	1550,3163	1560,22263	1549,92204	1540,06483
λ After	1530,43829	1530,37196	1540,26169	1550,3279	1560,22446	1550,27877	1540,36961
Δλ (nm)	-0,20513	-0,02211	-0,0068	-0,0116	-0,00183	-0,35673	-0,30478

SENSOR	211	212	213	214	221	222	223
λ before	1530,78032	1534,79001	1538,78534	1542,65345	1546,67373	1550,56059	1554,44931
λ After	1530,78833	1534,9268	1538,9554	1542,82597	1546,83117	1550,73343	1554,6216
Δλ (nm)	-0,00801	-0,13679	-0,17006	-0,17252	-0,15744	-0,17284	-0,17229

Preliminary conclusions: Attenuation

- The signal of the fiber optic sensor is attenuated as the fiber is irradiated. The attenuation of the signal after irradiation can be seen in the next table:

Sensor	Coating	Type	Manufacture	Ge-doped	Attenuation(dB)
O11	ormocer	I	Drawtower	Yes (?)	0,56
O12	ormocer	I	Drawtower	Yes (?)	0,37
O13	ormocer	I	Drawtower	yes (?)	0,39
O14	ormocer	I	Drawtower	yes (?)	0,59
O21	ormocer	I	Drawtower	yes (?)	6,23
O22	ormocer	I	Drawtower	yes (?)	8,8
O23	ormocer	I	Drawtower	yes (?)	5
O24	ormocer	I	Drawtower	yes (?)	1,14
O3	ormocer	II	¿Normal?	No?	0,01
O4	ormocer	II	¿Normal?	No?	0,03
O5	ormocer	II	¿Normal?	No?	0,21
111	acrylato	I	Normal	yes (?)	0,42
112	acrylato	I	Normal	yes (?)	0,15
TEMP	polimida	I	Drawtower	yes (?)	0,07
211	polimida	I	Drawtower	yes (?)	0,44
212	polimida	I	Drawtower	yes (?)	6,05
213	polimida	I	Drawtower	yes (?)	6,26
214	polimida	I	Drawtower	yes (?)	7,16
221	polimida	I	Drawtower	yes (?)	7,56
222	polimida	I	Drawtower	yes (?)	6,92
223	polimida	I	Drawtower	yes (?)	6,92

Preliminary conclusions: Attenuation

- The three FBG's of Type II and the Acrylate Fiber manufactured in a normal way has an small attenuation.
- Fibers fabricated by drawtower have an attenuation of orders of magnitude larger than the other types of fibers (dB).
  - Exceptions:
    - The 4 Ormocer sensors which seen not to be irradiated
    - The Temperature sensor (no irradiated)
    - The 211 polyimide sensor (left outside the irradiation area in order to compare the results with irradiated sensors.)
- Conclusion: The attenuation of the fiber seens not to be dependant of the material of coating. Two main factors could affect the attenuation:
  - Fabrication method (Normal, Type II < Drawtower)
  - The type of fiber core used (pure silica> Ge^+ doped)

Preliminary conclusions: Stability

- A study of stability was made.
- The data for this stability study are taken during the hours after irradiation.
- The stability of all the sensors was between 1 and 2 pm (0.1 or 0.2 ºC perhaps?) after the irradiation.

Sensor	Coating	Stability
O11	ormocer	2,1
O12	ormocer	2,2
O13	ormocer	2
O14	ormocer	1,5
O21	ormocer	1,1
O22	ormocer	0,9
O23	ormocer	0,9
O24	ormocer	1,9
O3	ormocer	1,7
O4	ormocer	1,1
O5	ormocer	1,4
111	acrylato	1,5
112	acrylato	1,3
TEMP	polimida	0,8
211	polimida	1
212	polimida	0,7
213	polimida	1
214	polimida	0,6
221	polimida	1
222	polimida	1,2
223	polimida	1

Preliminary conclusions: K factor

- The Fiber Optic Sensors must be dismounted before from the suport. Then after checking that none of the fiber has been activated, they are going to be recalibrated.
- The mechamical recalibration will be made at INTA with the same set up used before irradiation

- The thermal callibration will be made in the INTA and in the IFCA
- Then we will see which parameter has more influence in the change of the K factor with irradiation.
- It is expected the coating be the most important parameter.

Omega Shape : Manufacture

- Two omega Shapes are been manufactured at INTA with fiber optic embeded. Two different layout of composites are being used, one with 4 layers and the other with 6 layers. This will allow us to see how the fabrication parameters (temperature, pressure, output of fiber….) can be optimized for the omega and s-shape fabrication.
- As soon as this 2 first omega Shapes are manufactured and after they are checked in the INTA, they will be sent to Imanuel
- Then the prototypes of Omega Shape and S-shape will be manufactured
- Finally the are going to be characterized.

Schedule & outlook

- Free FBG-s irradiation conclusions
  - We have some preliminary conclusions :
    - The coating is the most important parameter for the Peak-shift
    - The Fabrication method and the Type of fiber used are the most important parameter for the attenuation
  - But:
    - More details about the fiber used for the fabrication of the sensors is needed
    - A better support structure must be design
    - More irradiations tests must be make (Next irradiation is being planed)
- Omega and S-shape Manufacture
  - 2 first omegas with FO embedded are being fabricated at INTA to optimize the process.
  - They will be sent to Imanuel as soon as possible