Structural and Environmental monitoring with FOS

J. G. Carrión, M. Frövel

National Institute for Aerospace Technology (INTA)

E. Currás, D. Moya,I. Vila, A.L. Virto,

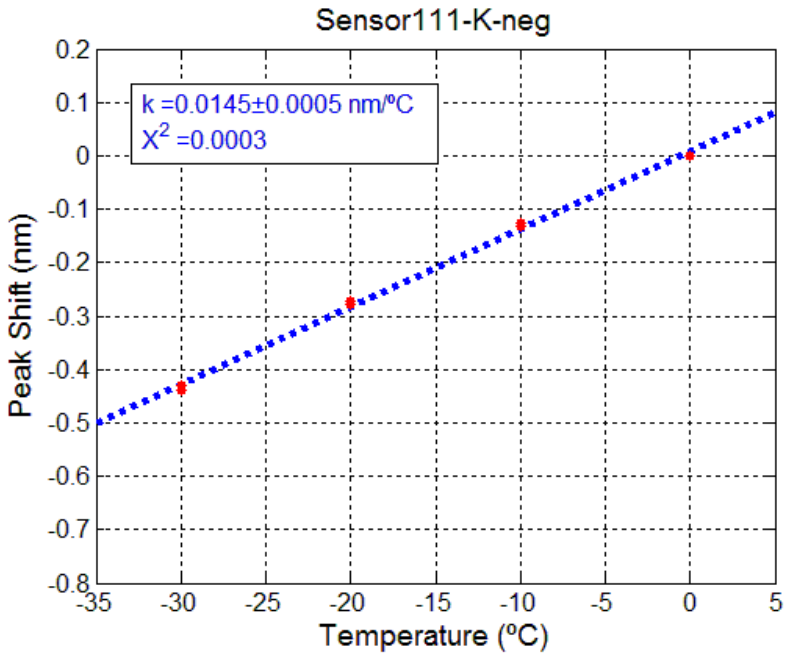
Instituto de Física de Cantabria (IFCA-Santander)

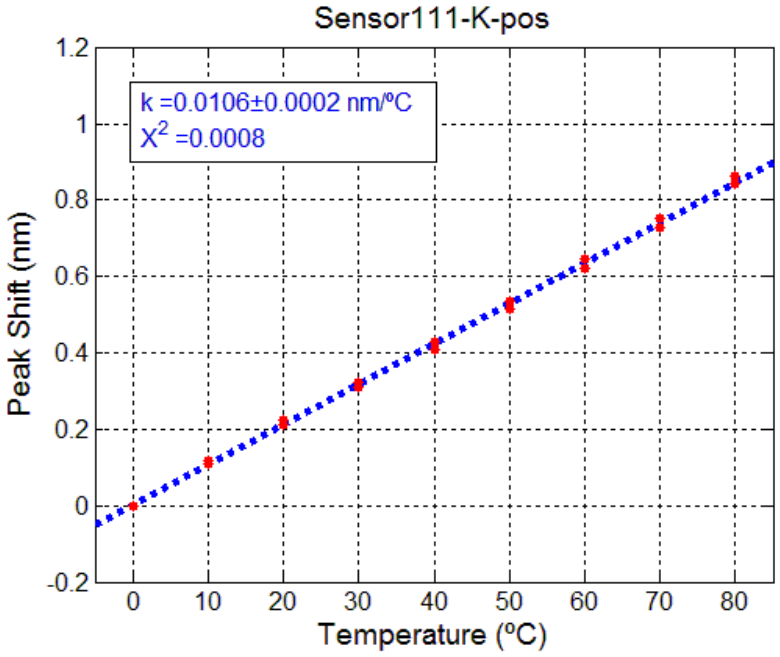
Outline

- FOS research activities
  - FBG sensors Thermal calibration and Humidity measurement
  - Qualification of irradiated FOS
- Advanced Deliverable for AIDA:
  - ILD FTD Mechanical mock-up
  - Technological demonstrator
  - Discussion
- Summary

Thermal fibers calibration

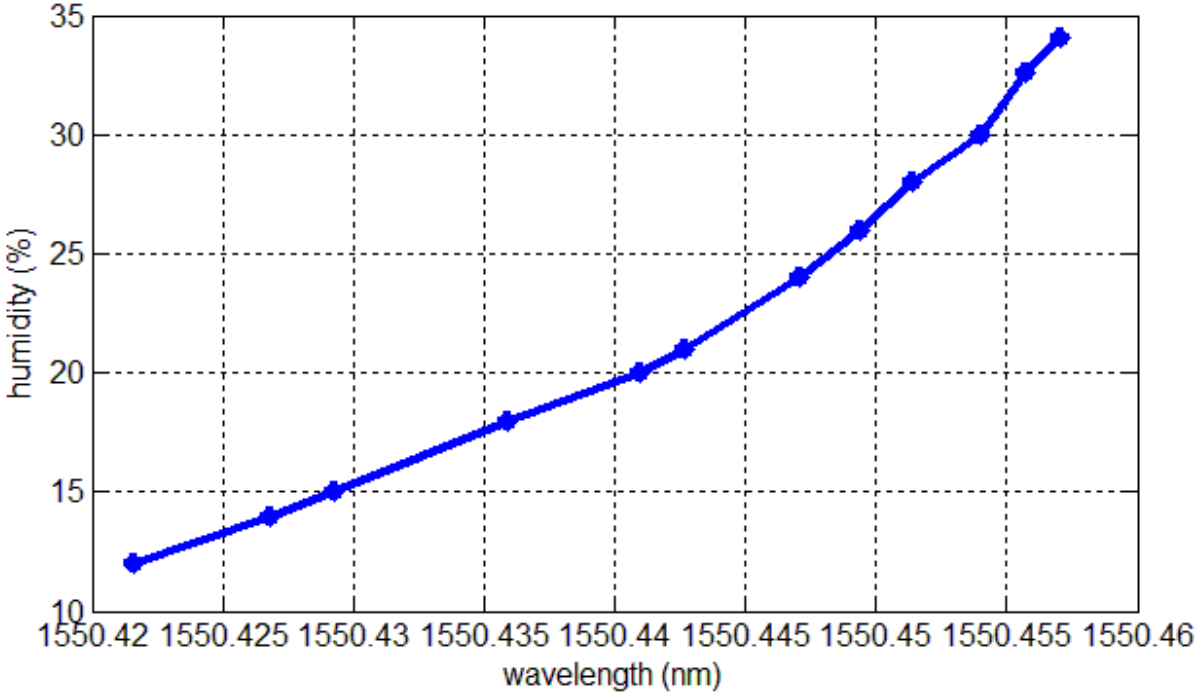
- Temperature calibration at IFCA of FBG sensors with different Coatings
- Acrylate coating has a phase change at 0 ºC , affecting FBG temperature sensitivity





Humidity in Valencia PXD Mock-up

- Some measurements where done at Thermal set-up at IFIC
- Polyimide coated FBG where used to measure temperature and humidity inside BELLE II mock-up volume
- thermo-hygrometer measurement vs FBG signal change



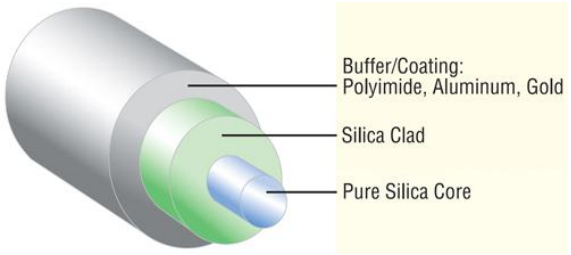
FBG qualification vs Irradiation

Aim:

Find most radiation tolerant FBG sensor.

Quantify the change in sensors strain sensitivity

Find main fiber parameters affecting FBG sensor sensitivity

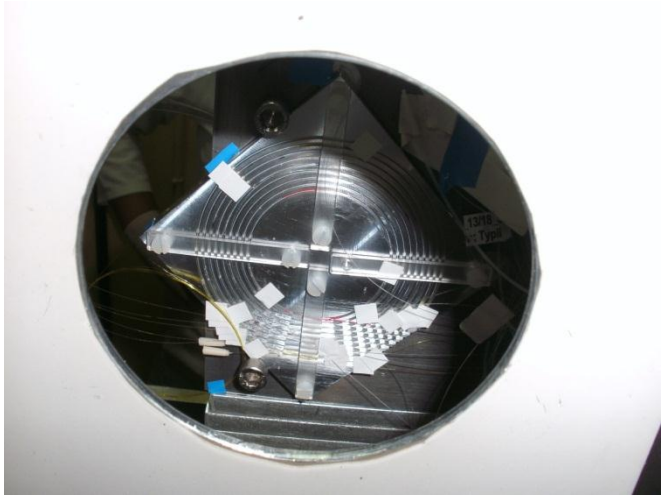


Select Fibers with different Coating (polyimide, Ormocer and Acrylate) fiber type (Ge doping concentration, another dopings…) and manufacturing process (draw tower, H2 loading, annealing, etc).

Introduction to main R&D lines

Irradiation of Fiber Grating Sensors

Two FBG active irradiation campaigns done at "*Centro Nacional de Aceleradores*" (CNA) with protons up to an absorbed dose of 1.5 GRad and 10 MRad.



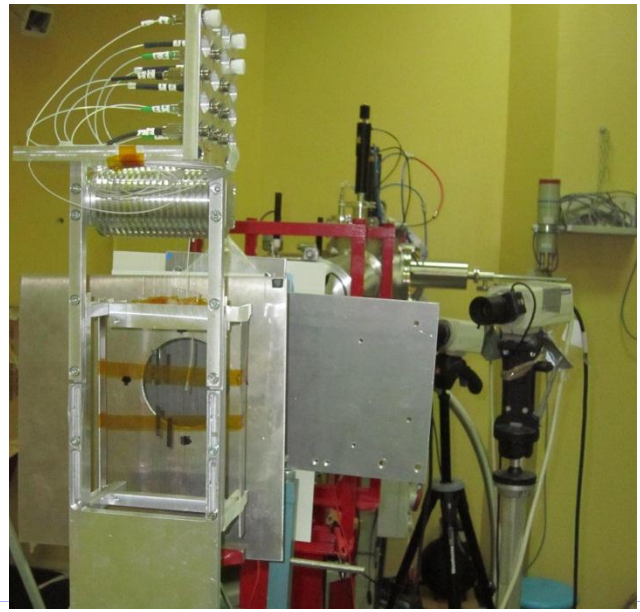
Outcome of irradiations:

- **Reflected** lambda affected by type of **coating**

  Acrylate coated fibers displayed no peak shift

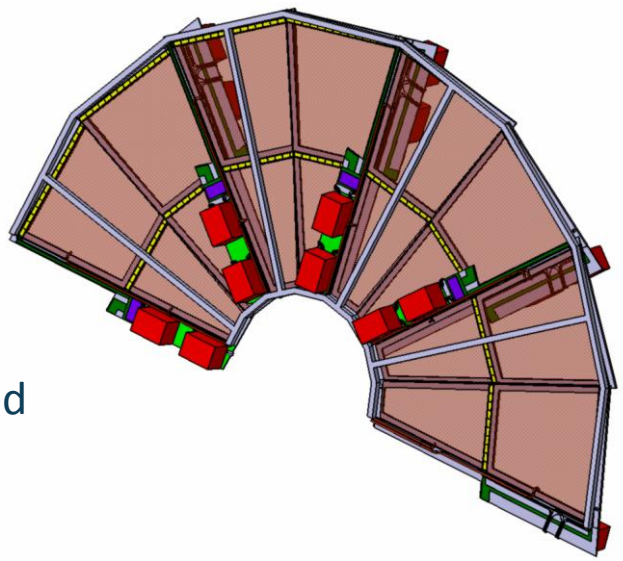
- **Attenuation** is affected by the type of **core**

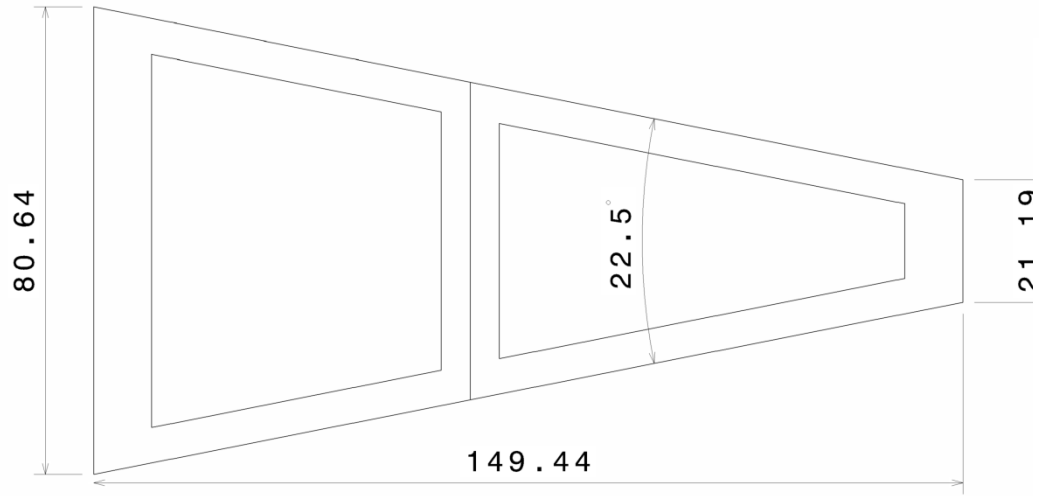
- Annealing observed after irradiation (two weeks). Studying it now in more detail

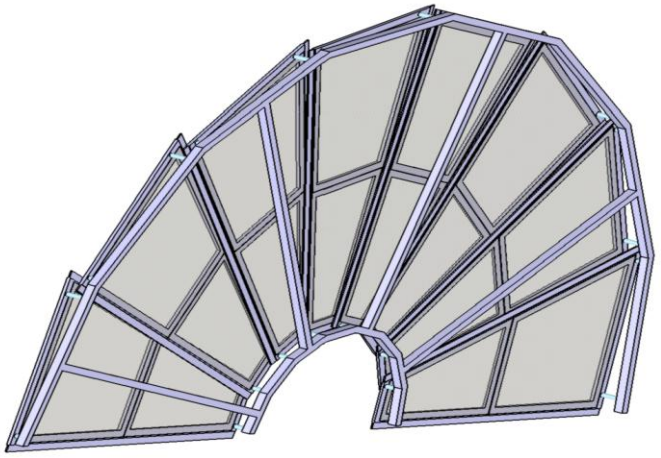


R&D activities For ILD Forward Tracking Within AIDA

- The aim is to manufacture some ILD FTD support petals, both for real sensor support and mechanical mock-ups
- Petals matching the geometry of the 3th FTD geometry has been chosen, being the biggest one
- Sensors and electronic will be mounted in this mock-up. In order to be able to mount CNM manufactured sensors (four inches Wafers) , the structure will be scaled 0.65 :1
- Petals mechanical and thermal behavior will be tested
- A final petal configuration will be selected.







R&D activities For ILD Forward Tracking Within AIDA

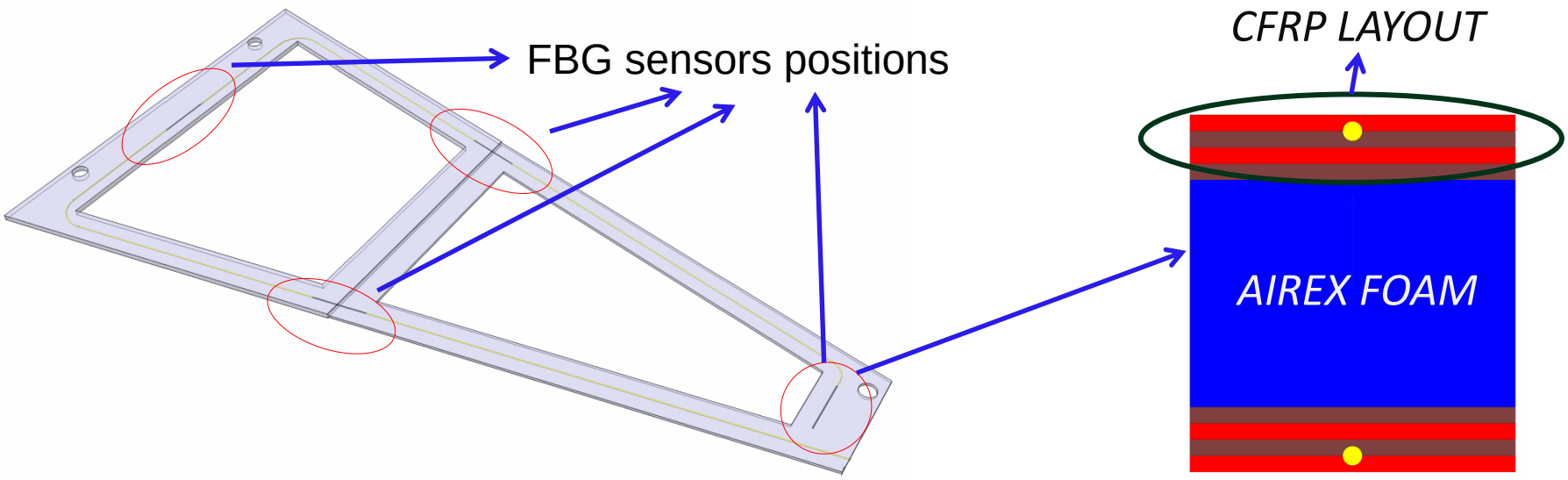
After carrying out thermal and mechanical test In the mock-up

New petal prototype or Technological Demonstrator will be manufactured at INTA (scaled) with FBG sensors embedded in a predefined position of the petal.

The purpose: Be able to monitor petal deformed shape in real time when this is subject to thermal and mechanical loads.

- **INTA** has the needed **equipment** for CFRP manufacture (Autoclave, cutting system, prime material Fridge)
- Composite material department has experience on FBG sensors embedding

FEA simulations are in progress to define the relation between **strain measured by the FBG sensors** and **deformed shape** of the technological demonstrator and displacement of the locker points.



R&D activities For ILD Forward Tracking: AIDA

This technological demonstrator is planned to be tested within the framework of AIDA collaboration

One of the AIDA deliverables is the manufacturing of a thermo-mechanical SETUP at DESY (expected to be finished this year)

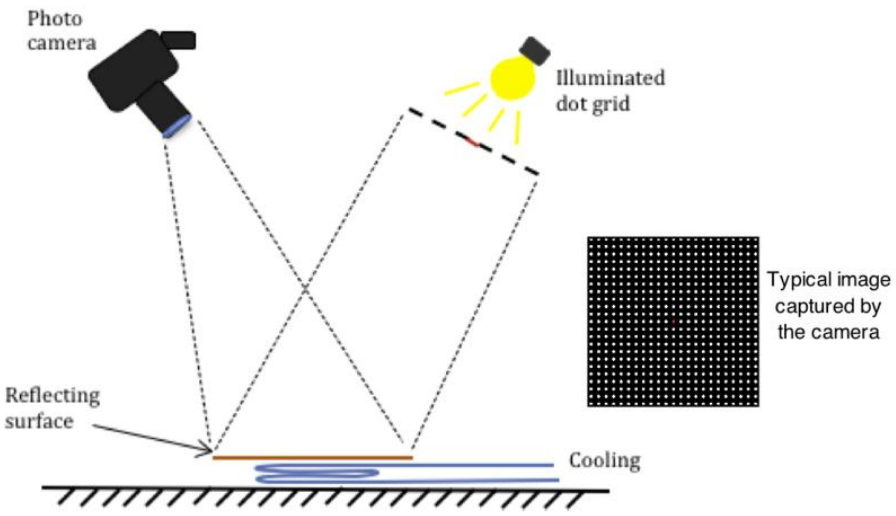
This thermo-mechanical setup will allow us to apply loads to our FTD prototype:

Thermal loads (cooling of the structure up to working temperature)

Displacement between demonstrator locking parts

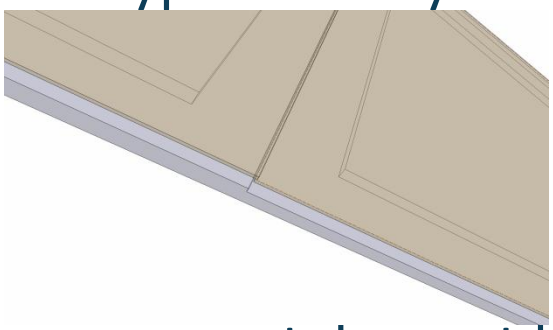
The setup will have a deformation measurement optical system with a resolution of 10 μm for mock-ups to be tested.

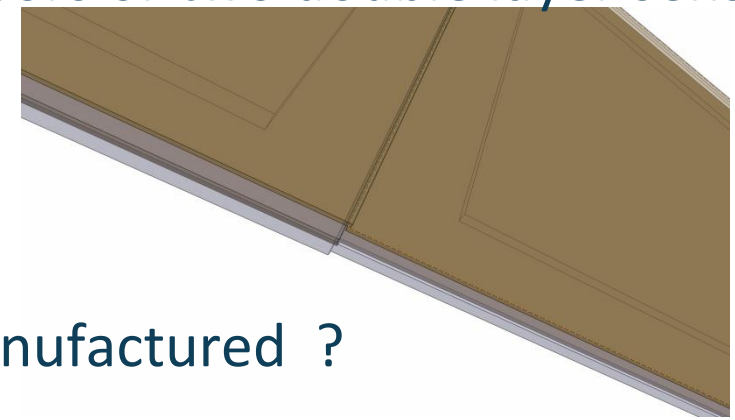
The idea is to apply different loads to the FTD petal like prototype and compare the deformation measured by Thermo-mechanical set-up optical system and by the FBG sensors.



Open questions for FTD petals mock-ups manufacture

- Sensor Type?One layers 4 sensors or two double layer sensors?





- How many petals must be manufactured ?

- Petal materials (rigidity / material budget)
  - Monolithic CF layout
  - Sandwich layout

-

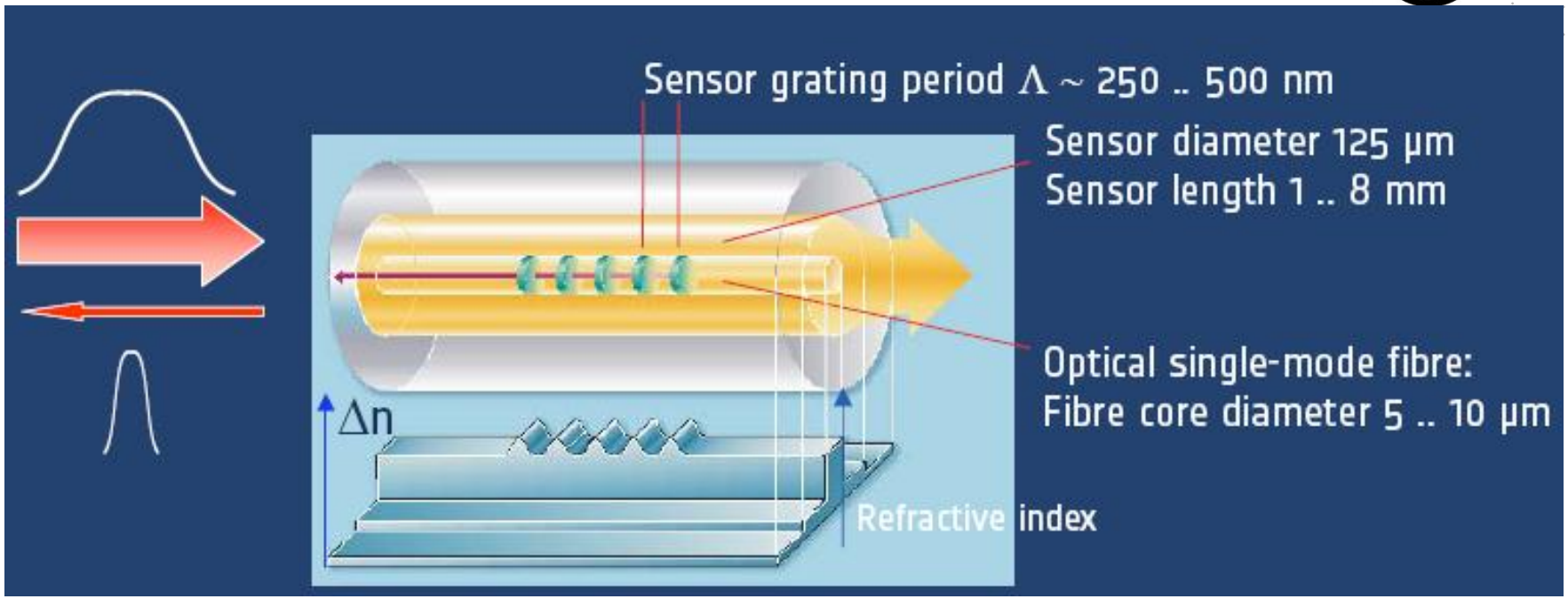
- Cooling needs. Enough with air cooling?

Summary

- Starting the mechanical design of the CFRP supports for the advanced deliverable. First mechanical mockups and eventually fully equipped modules (need to discuss all the details)
- Decision on the sensors geometry can be taken soon, should start the discussion on the type of sensors: double metal, thin, resistive, striplets, etc
- Profit from the large synergy with the thermo-mechanical infrastructure of the AIDA WP9.3 task.

BACKUPs

Fiber Bragg Grating Optic Sensors



$$\lambda_B = 2\, n_{eff}\, \Lambda$$

Keep in mind: Physically, FGB sensors have a section of an optical fiber with a length of few millimeters.

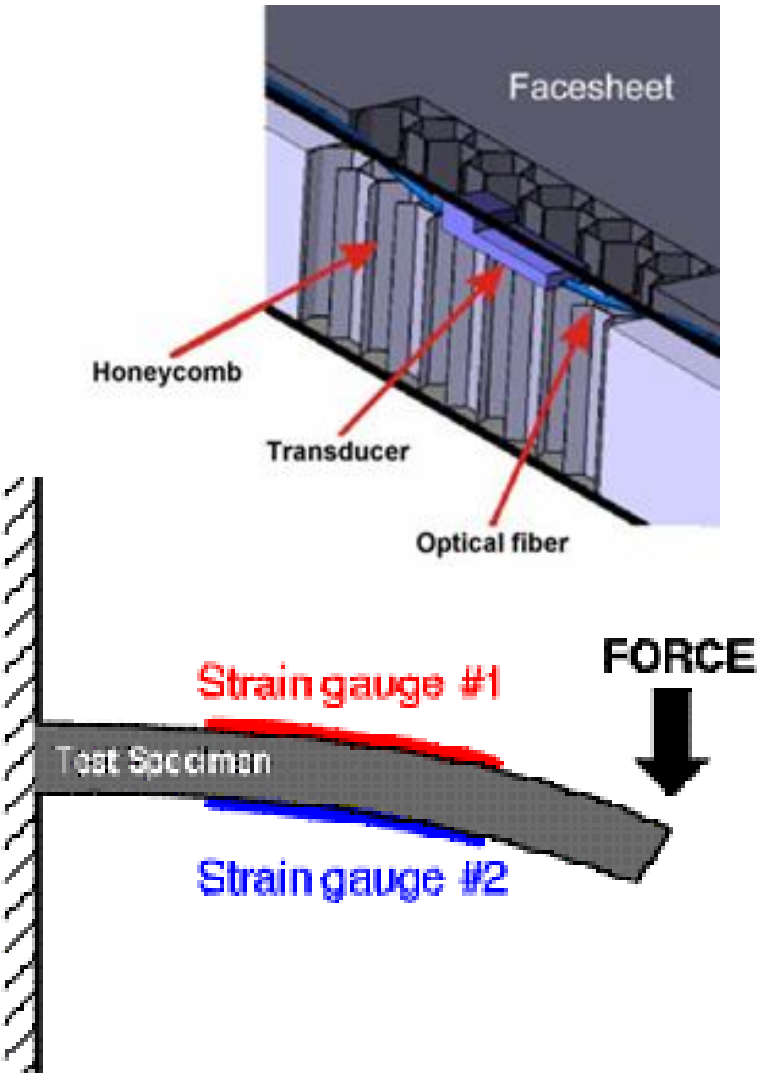
Embedded FOS: State of the art

The basic principle: **embed** FOS in CFRP structure at **defined position**. The **structure deformation** is **transmitted** to the sensors and these values give us the possibility to:

Determine the **deformed shape** of the structure

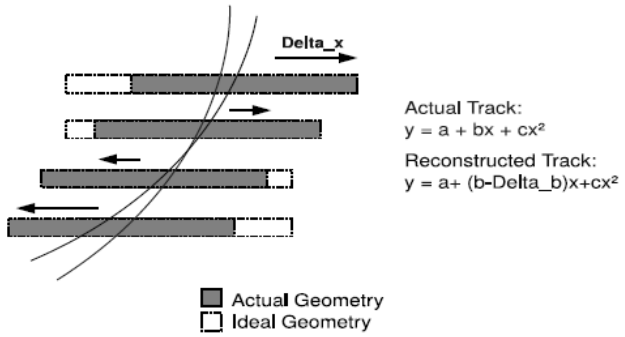
Calculate **displacements** between structure **locking points**

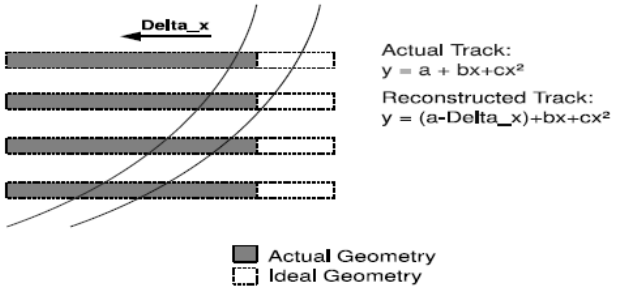
Calculate **temperature distribution** and gradients in the CFRP structure.

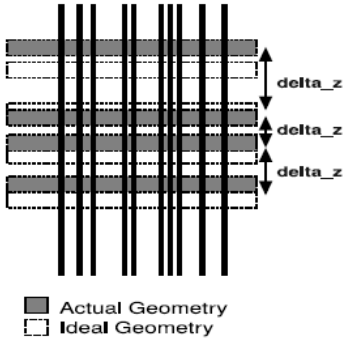


Monitoring requirements: Weak Modes

– First lesson from LHC detectors: position and deformation monitors must cover the weak modes of software (track-based) alignment algorithms.







Influence of the Fiber Coating on the Proton Radiation Sensitivity of Fiber Bragg Gratings

E. Currás, A. L. Virto, D. Moya, I. Vila, J. G. Carrión, M. Frövel, J. García-López, M. C. Jiménez, Y. Morilla and F. R. Palomo

***Abstract*— We report on the effect of the fiber coating on the radiation sensitivity of Fiber Bragg Gratings (FBG). For the first time this type of study has been carried out using a 13.5 MeV proton beam up to a fluence of 3.3 × 10^{15} protons/cm^2 (total absorbed dose of 15 MGy). We observed a clear dependence of the radiation sensitivity on the coating, in particular, we have investigated the irradiation induced changes on the strain sensitivity; FBG strain coefficient remains stable for all the fiber within a 5%. This result demonstrates the suitability of FBGs as displacement transducers in the very hostile environment of the new generation of high-intensity particle physics proton colliders**

***Index Terms*—Fiber Bragg Gratings, proton radiation effects**

The effect of the fiber coating on the gamma radiation sensitivity of FBGs has been already reported up to a moderate dose (40kGy) with a clear conclusion: the radiation-induced FBG wavelength shift strongly depends on the coating material [6]. In this same study, the modification of the FBG temperature sensitivity is explained as a consequence of the elasto-optic effect and the modified mechanical stress of the irradiated coatings.

In our study, the main goal was to determine the effect of the irradiation on the FBG strain sensitivity; the linearity (*k* factor) of each FBG sensor against the strain was determined before and after the irradiation. Polyimide and Ormocer are coatings that are bonded together to the glass fiber as the fiber