FBG monitoring for FTD

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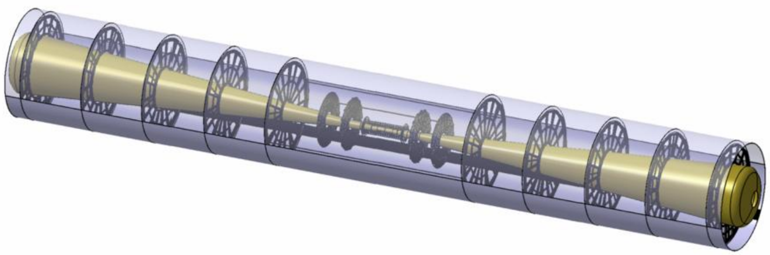
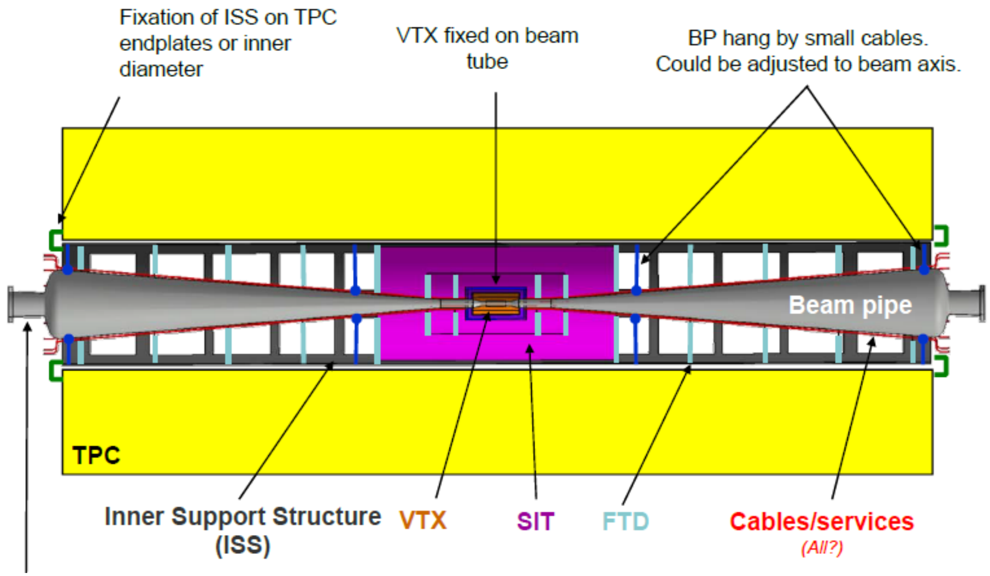
Outline

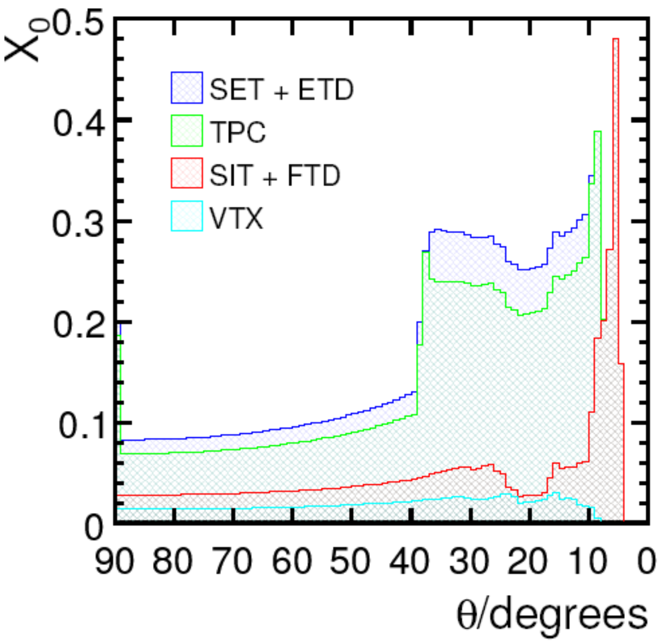
- Motivation
- FBG Introduction
- Initial R&D activities
- State of the art of embedded FOS monitoring
- R&D activities For ILD Forward Tracking in collaboration with AIDA Project
- Outlook

FTD



The material in the tracker increases, it is needed to have solutions to mitigate it in order to have good physics performnace





· Structural monitoring of silicon tracker systems:

Using IR-transparent microstrips for tracker alignment

Improving their transparency

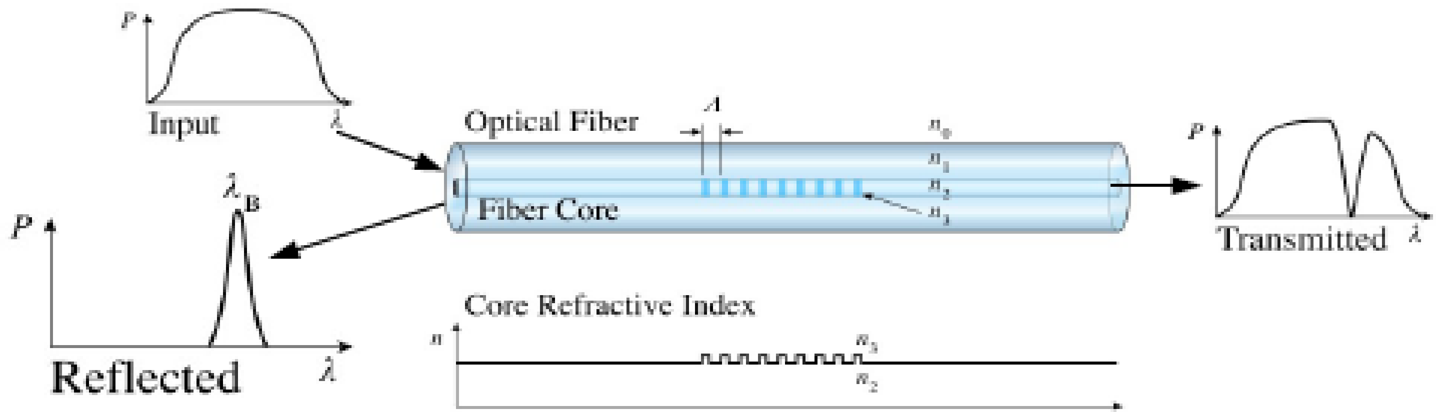
-Struct.&environmental monitoring of tracker & vertex systems:

Using integrated fiber optic sensors (FOS) as monitors

Embedding FOS in the tracking sensor itself

Introduction to Fiber Grating Optical Sensors (I)

- Gratings can be used as “single wave reflectors” *aka* Bragg reflectors



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

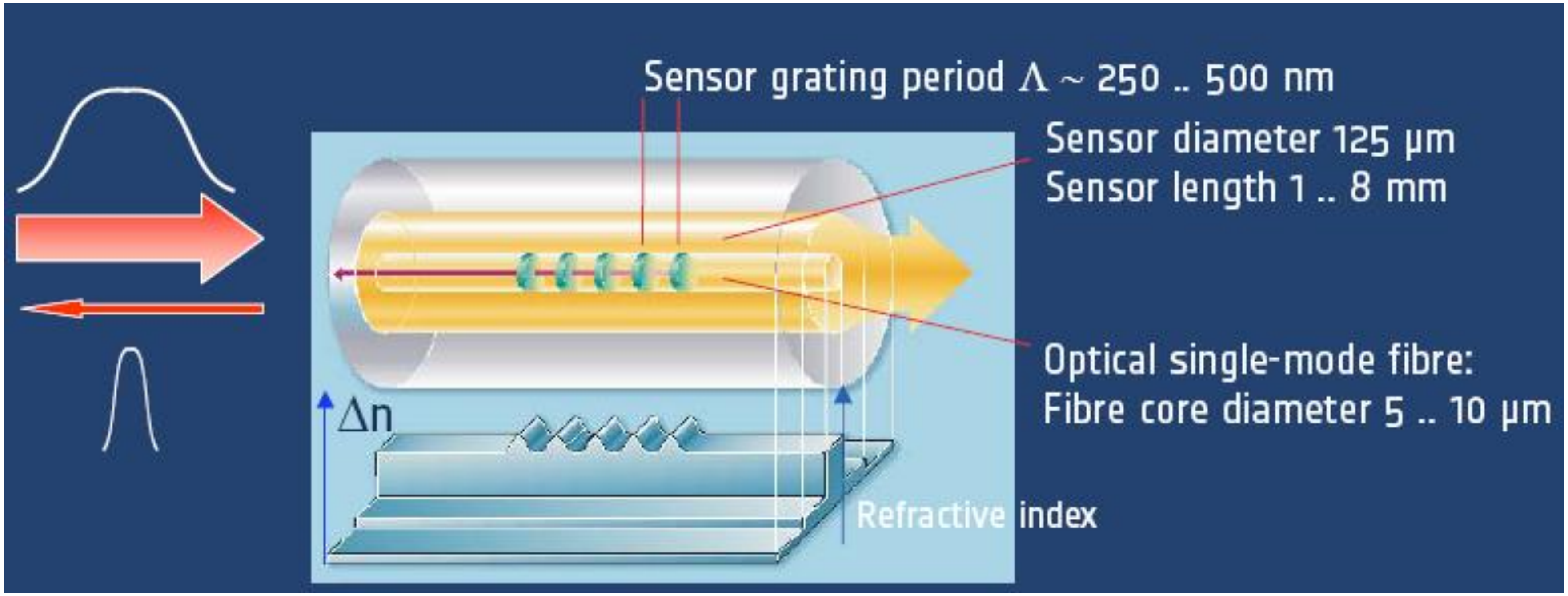
- λ_B is sensitive to strain and T: $\left[\frac{\Delta\lambda_B}{\lambda_B}\right] = C_S\epsilon + C_T\Delta T$ { ~10 pm/K, ~1 pm/με }

- Bragg reflectors can then be used as sensing elements in optical fibers

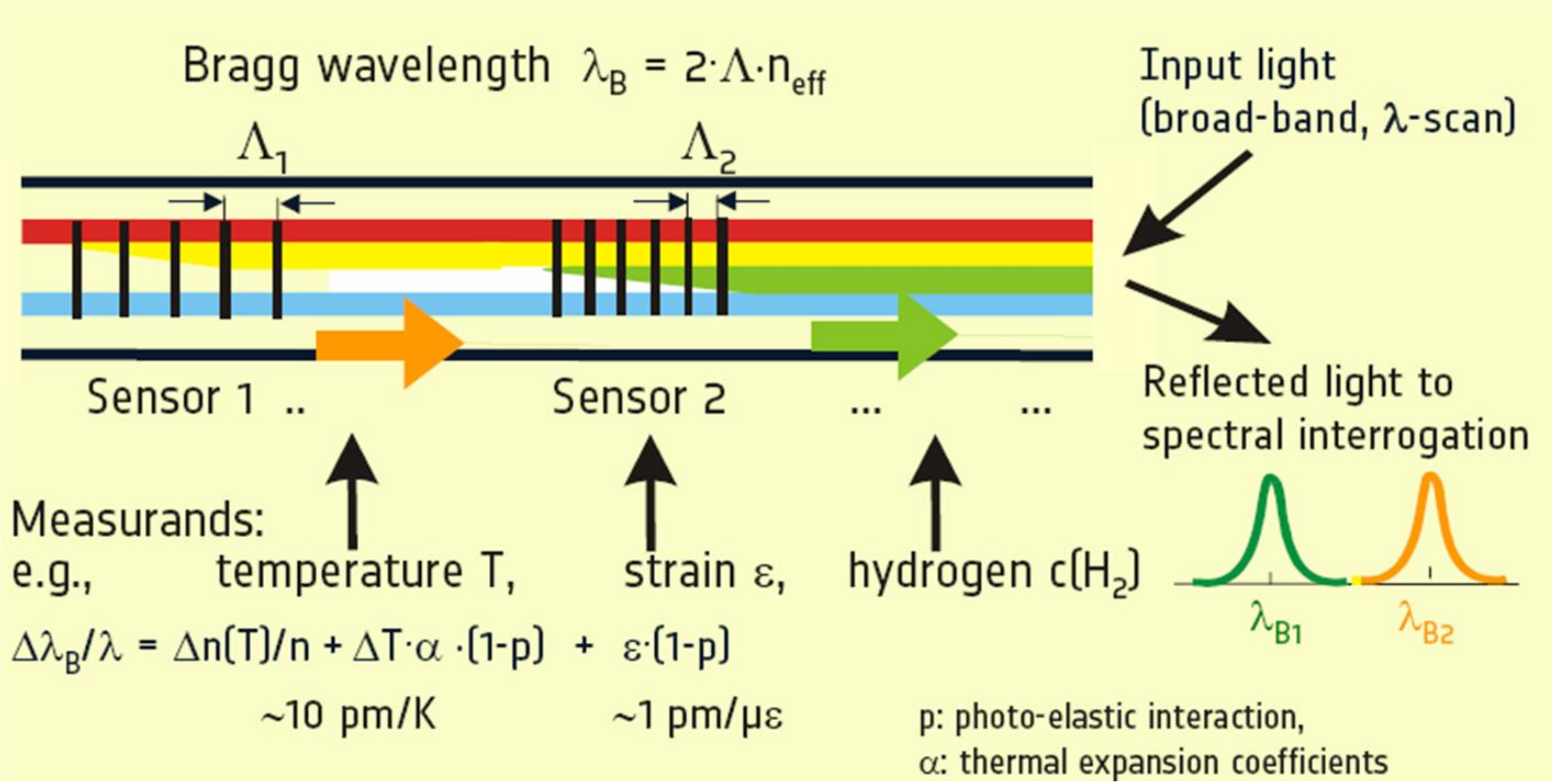
- Other quantities (humidity, %CO2, magnetic field,…) can be measured using coatings sensitive to these measurands.

Fiber Bragg Grating Optic Sensor

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



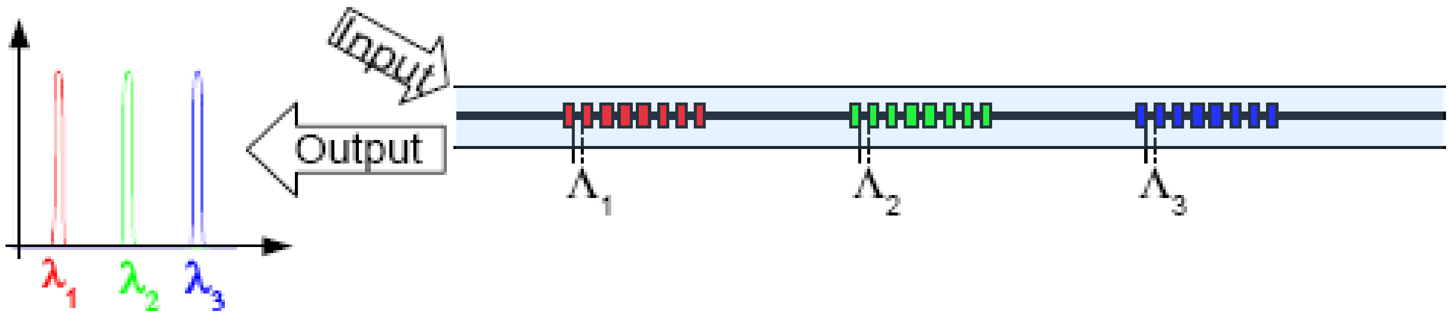
Fiber Bragg Grating Sensor



– Sensitivity to other agents (HR%) achieved by different fiber coatings or refractrometer technics.

Introduction to Fiber Grating Optical Sensors (II)

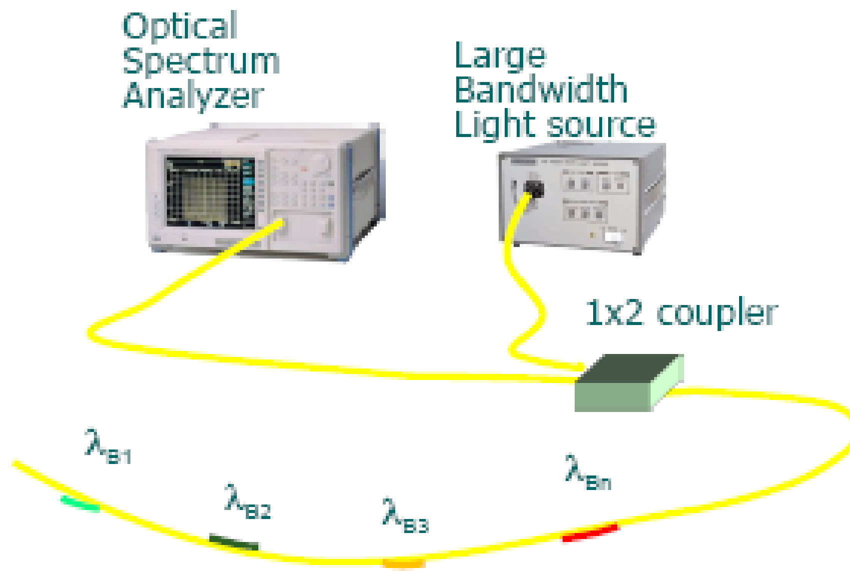
- Gratings for different wavelengths can be recorded in the same fiber: measurand mapping capability



- Optical fibers can be embedded in materials

We have then *smart structures* capable of self-monitoring

- Light source and analyzer can be up to km away from the sensor itself

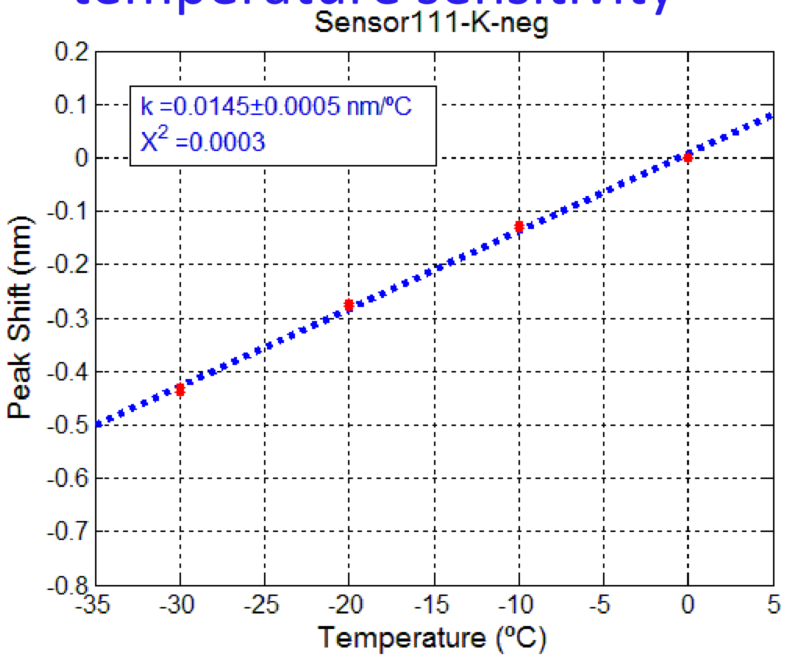


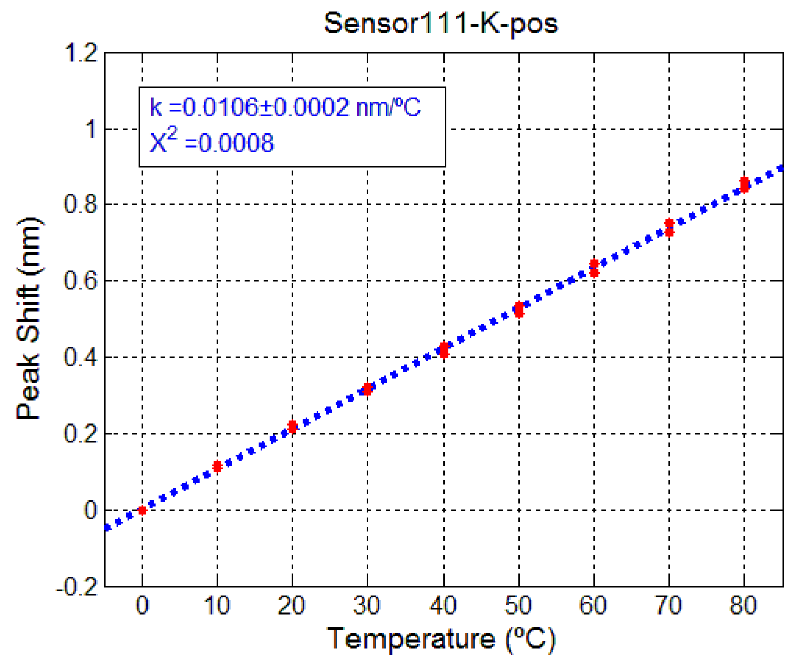
Advantages of FBG sensors

- General attributes of Fiber Optic Sensors:
  - Immunity against:
    - High electromagnetic fields, high voltages.
    - High and low temperatures.
    - Nuclear radiation environments (not in all the cases)
  - Light-weight, miniaturized, flexible, low thermal conductivity.
  - Low-loss, long-range signal transmission(“Remote sensing”)
- Specific FBG attributes:
  - Multiplexing capability (sensor network)
  - Embedding in composite materials.
  - Wavelength encoded (neutral to intensity drifts)
  - Mass producible at reasonable costs.
  - Very high and low temperatures (4 K to 1200 K).

R&D activities: Thermal Calibration

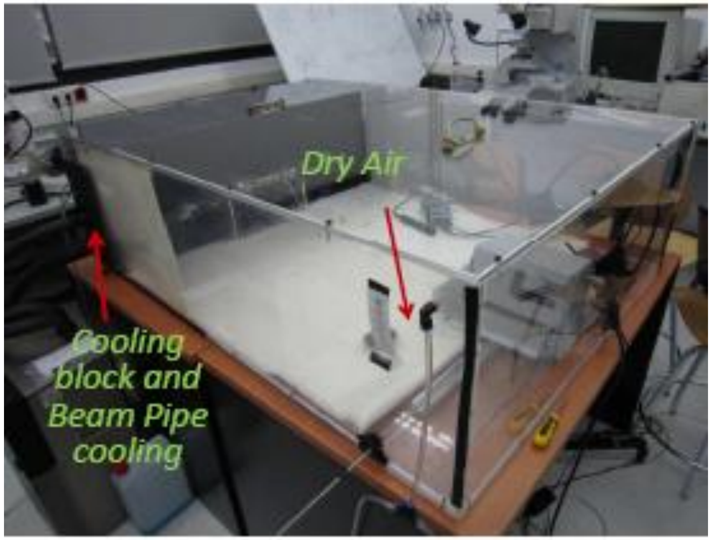
- Temperature calibration at IFCA of FBG sensors with different Coatings (gluing FOS with kapton to Linkam thermal plates with 0.1º precision)
- Acrylate coating has a phase change at 0 ºC , affecting FBG temperature sensitivity



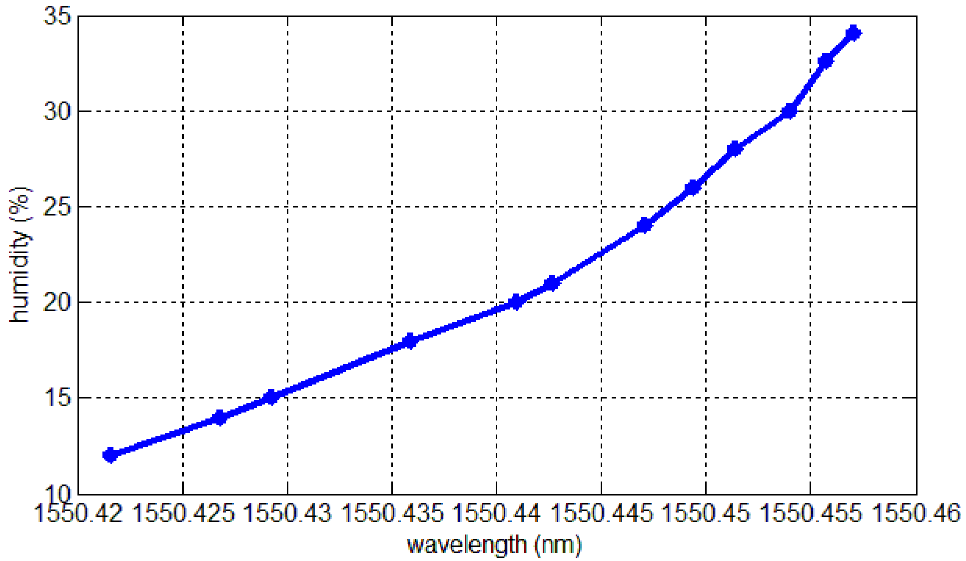


R&D activitis: Humidity measurement

- 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



Free FBG outside cage



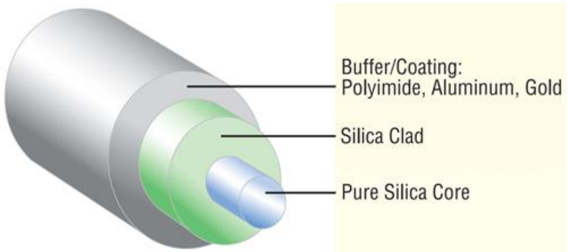
R&D :FBG qualification vs Irradiation

Aim:

Find most radiation tolerant *FBG sensor*.

Quantify the change in sensors strain sensitivity

Find main fiber parameters affecting FBG sensor sensitivity

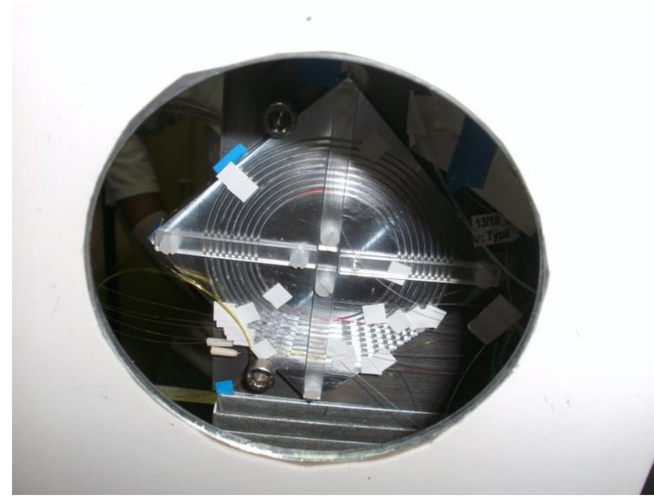


Select Fibers with different Coating (polyimide, Ormocer and Acrylate) fiber type (Ge doping concentration, another dopings…) and manufacturing process (draw tower, H2 loading, annealing, etc).

R&D :FBG qualification vs Irradiation

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:

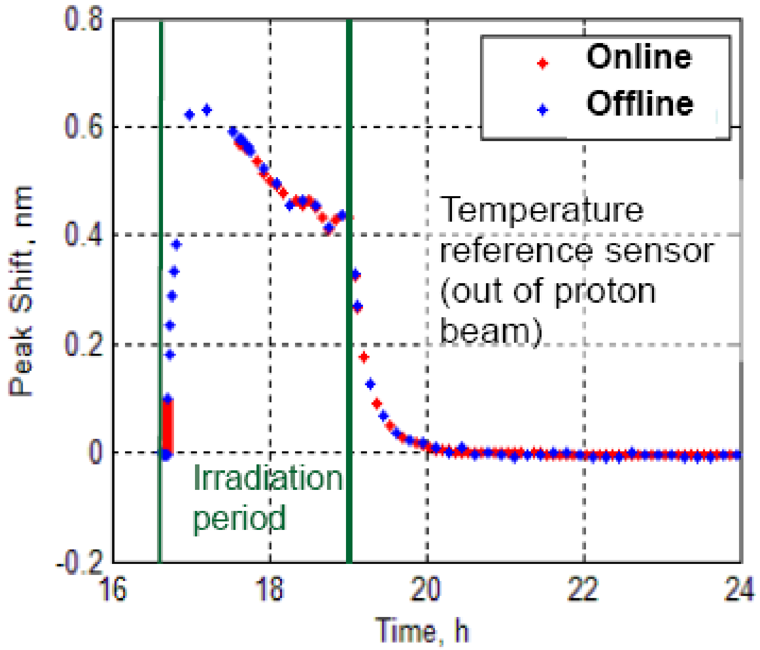
- **Reflected** lambda affected by type of **coating**

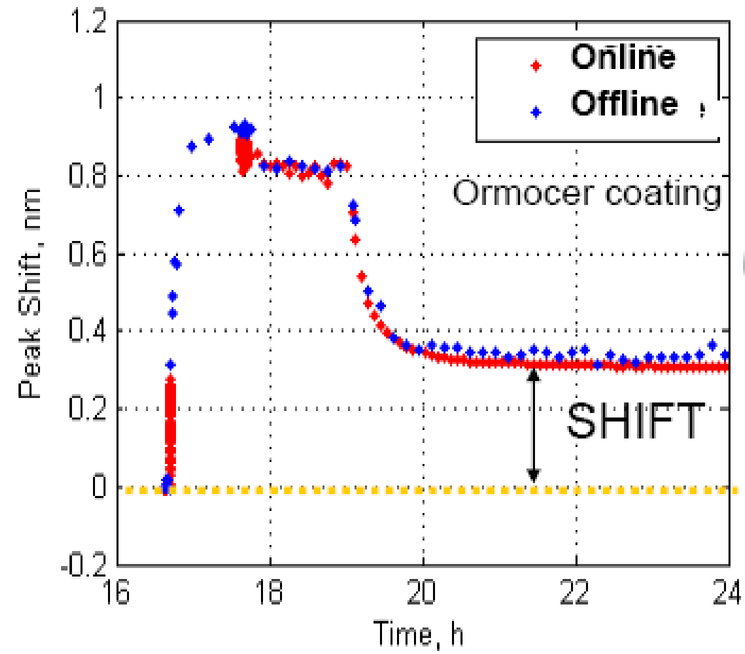
  Acrylate coated fibers displayed no peak shift

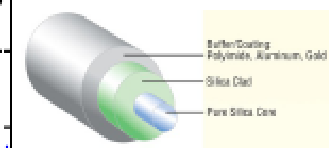
- **Attenuation** is affected by the type of **core**

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

Irradiation Campaign: Effect on the fiber

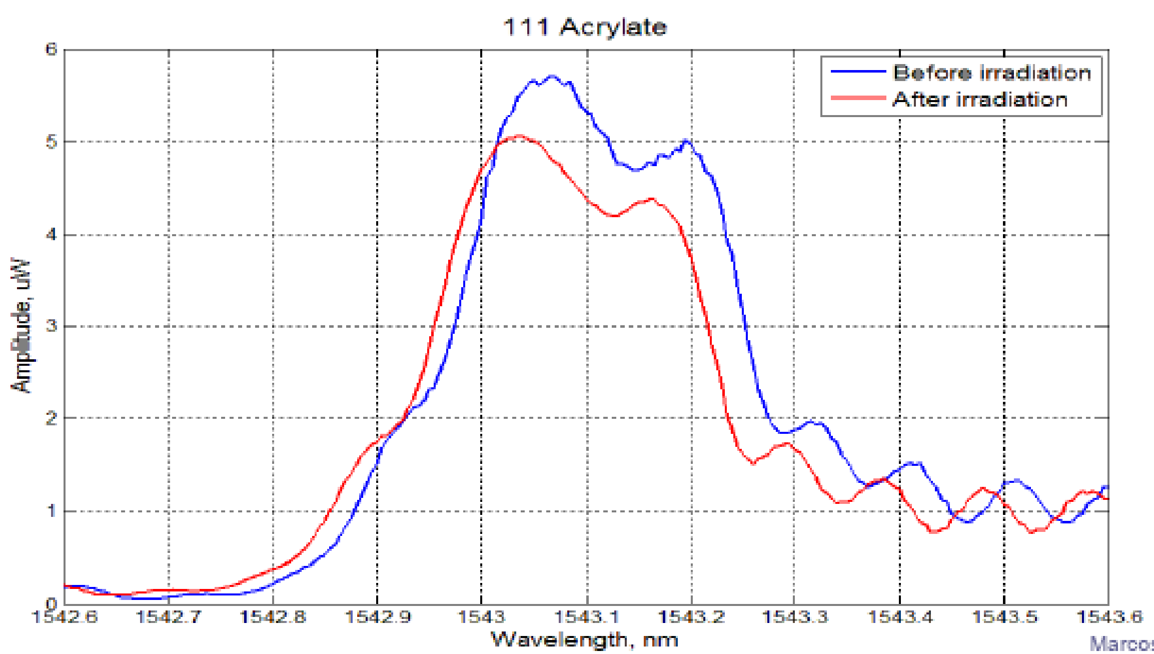






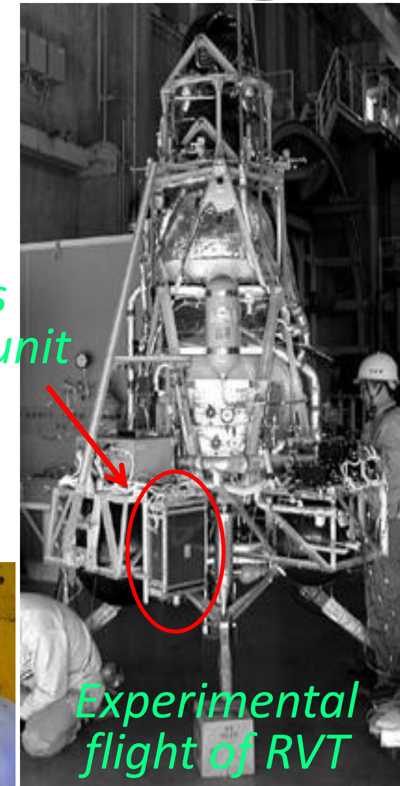
Most resistant sensor to irradiation: acrylate

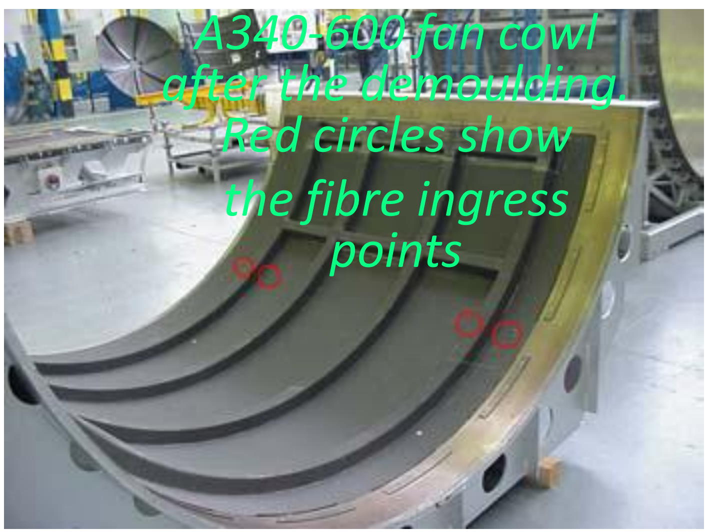
Peak shift: *O(pm)*

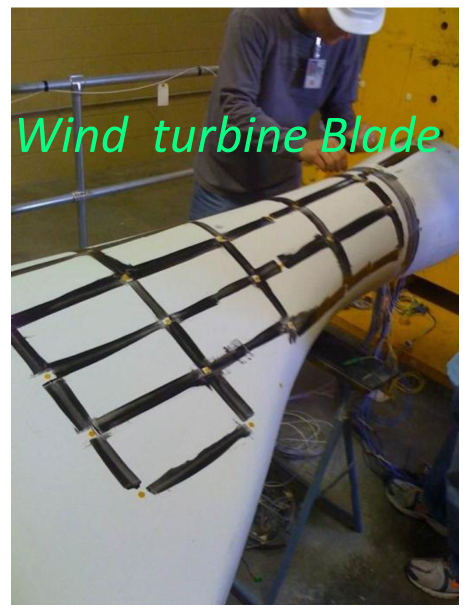


Embedded FOS: State of the art

- Embedded FBG for structural health monitoring is an established technique in several areas, developed during last 10 years, some applications:
  - Wind turbines blades monitoring
  - Aeronautics and Aerospace CFRP structures health monitoring

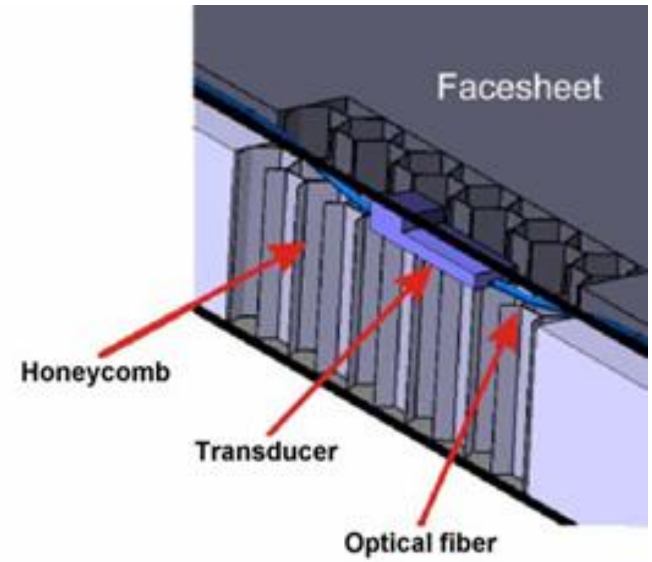


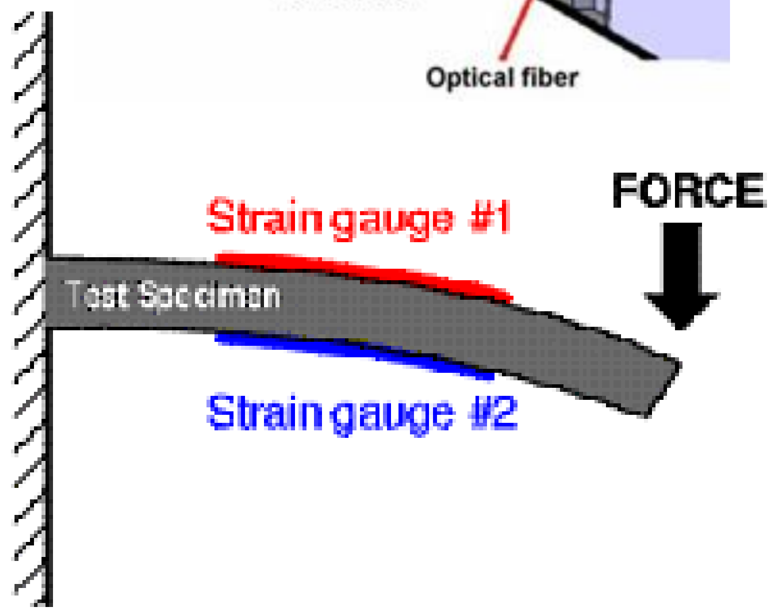




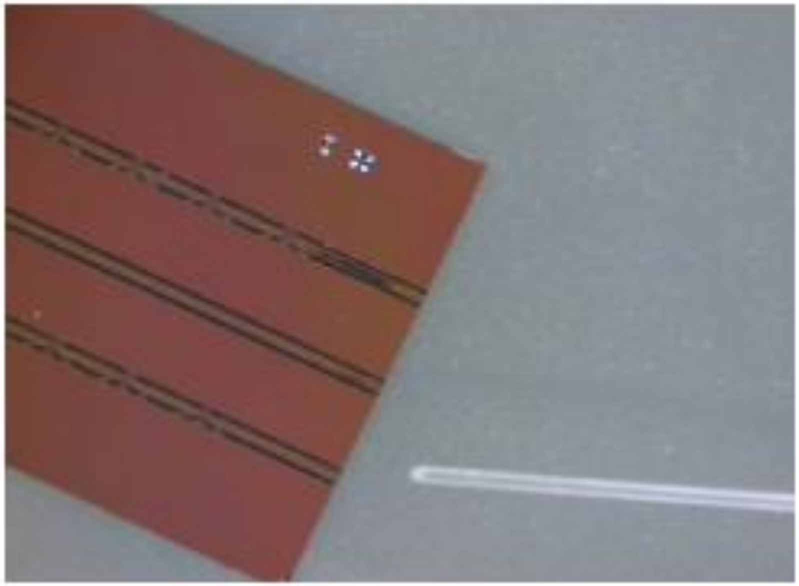
Embedded FOS: State of the art

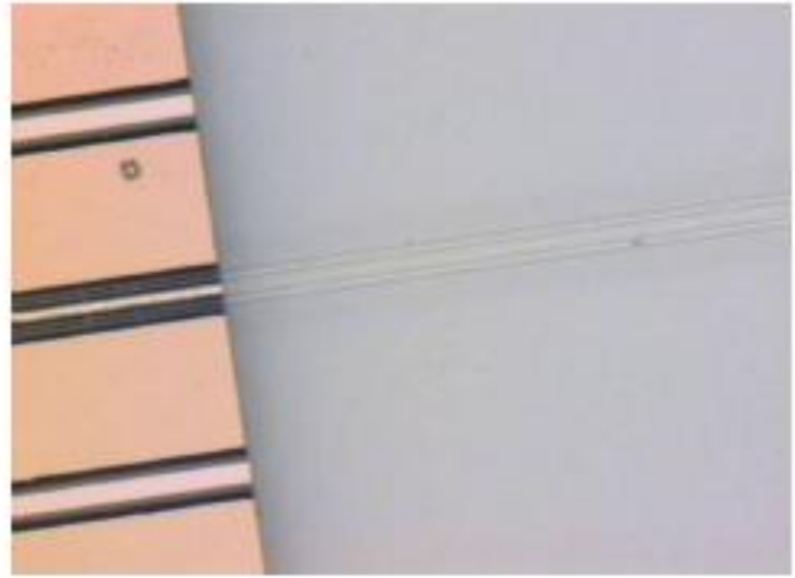
- The basic principle: embeded FOS in CFRP structure at defined position. Use measured deformation to:
  - Determine the deformed shape of the structure
  - Calculate displacements between structure locking points
  - Calculate temperature distribution and gradients in the CFRP structure.





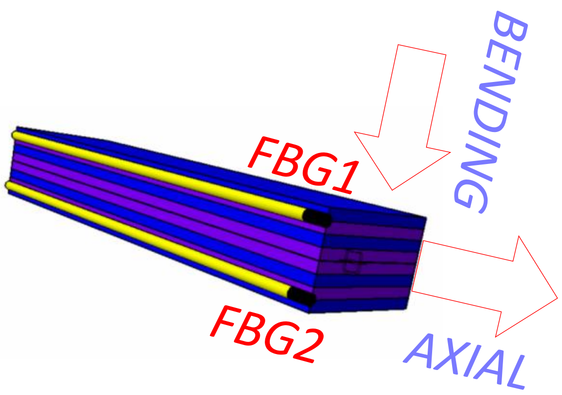
Design of micromechanical fixations for **bonding of fibers to silicon sensors**
Wafer with machined groove done at CNM-Barcelona





Embedded FOS: Example

- **Calculation of flex and axial effect on a beam** submitted to both loads at the same time.
- **Embedding** two sensors symmetrically with respect to the neutral line (half thickness) both effects can be calculated
  - Flex strain in both sensors will be of opposite signal (traction / compression)
  - Axial strain is the same for both sensors:



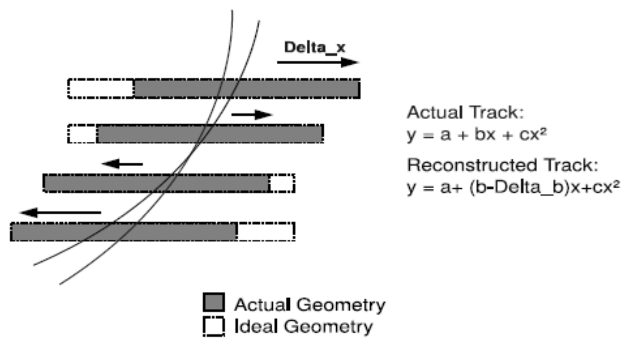
$$\varepsilon_1 = \varepsilon_{bend} + \varepsilon_{axial}$$
$$\varepsilon_2 = -\varepsilon_{bend} + \varepsilon_{axial}$$

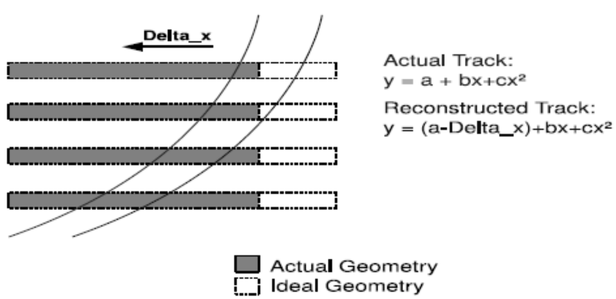
$$2^*\varepsilon_{axial} = (\varepsilon_1 + \varepsilon_2)$$
$$2^*\varepsilon_{bend} = (\varepsilon_1 - \varepsilon_2)$$

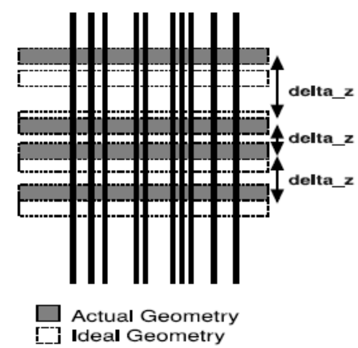
This values allow us to calculate the deflection and axial deformation .

_Monitoring requirements: Weak Modes

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







R&D activities For ILD Forward Tracking Within AIDA

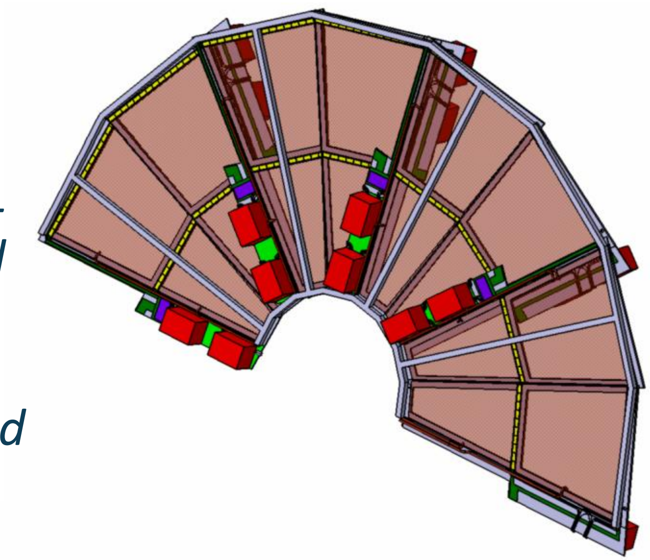
The aim is to manufacture some ILD FTD *support* petals, both for real sensor support and mechanical mock-ups

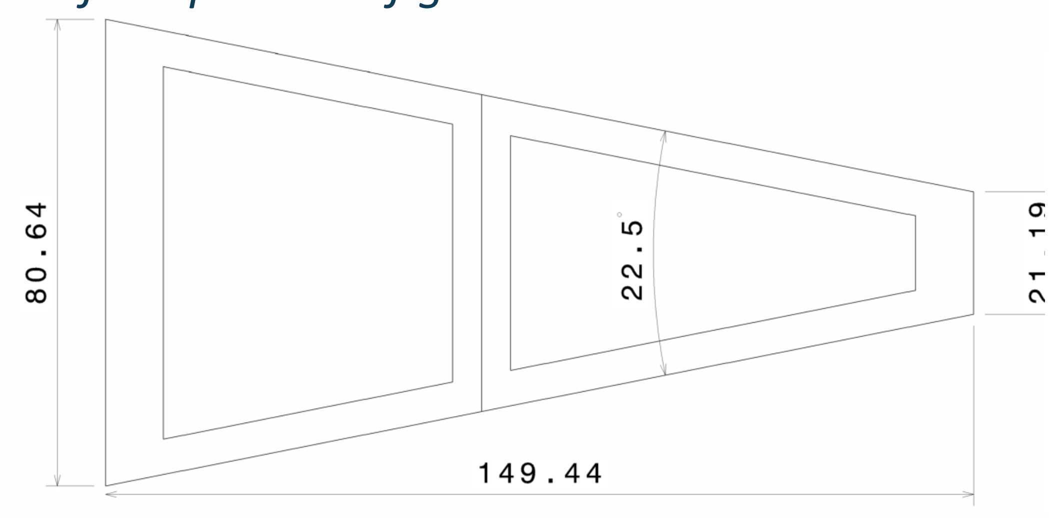
Petals matching the geometry of the 3th FTD geometry has been chosen, being the biggest one

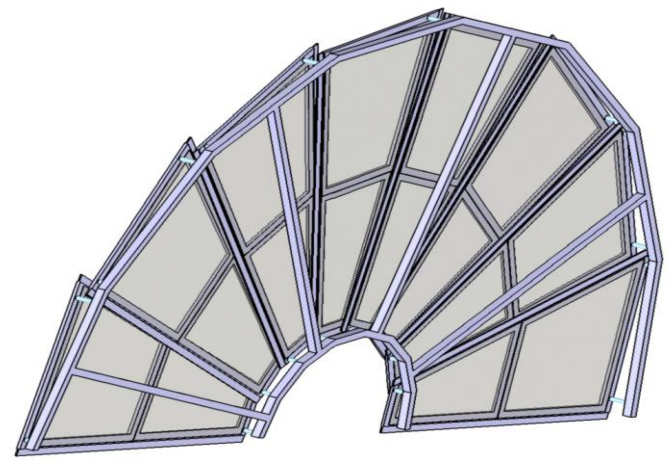
Sensors and electronic will be mounted in this mock-up. In order to be able to mount CNM manufactured sensors (four inches Wafers) , the structure will be scaled 0.65 :1

Petals mechanical and thermal behavior will be tested

A final petal configuration will be selected.







R&D activities For ILD Forward Tracking Within AIDA

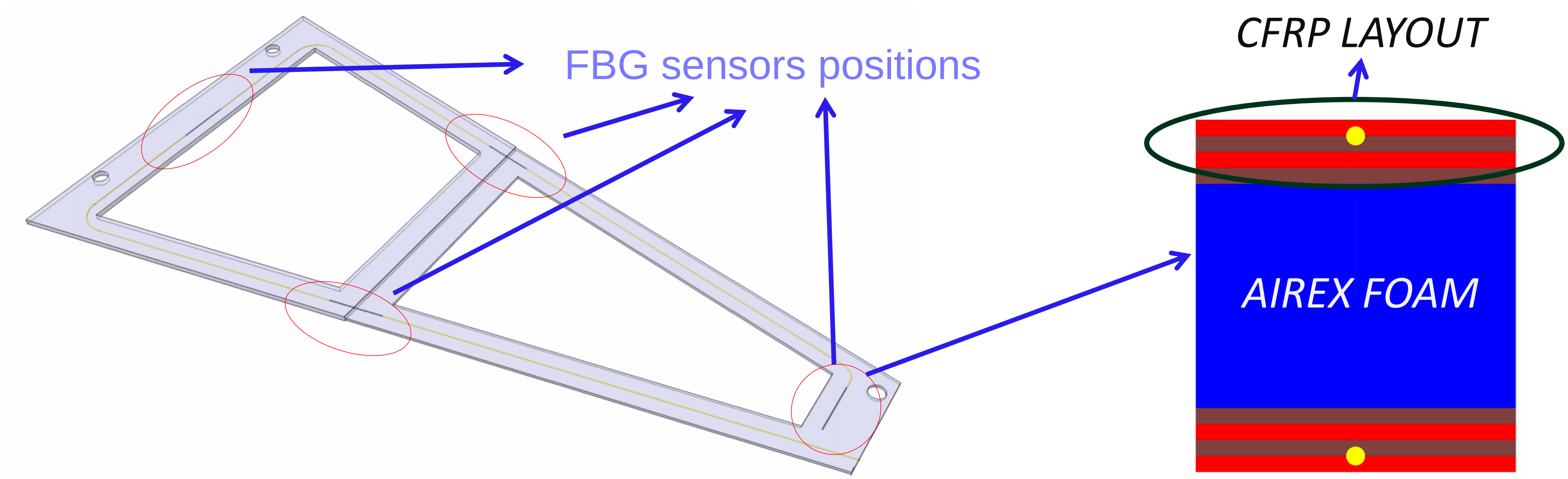
After carrying out *thermal and mechanical test In the mock-up*

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 (WP 9.3)

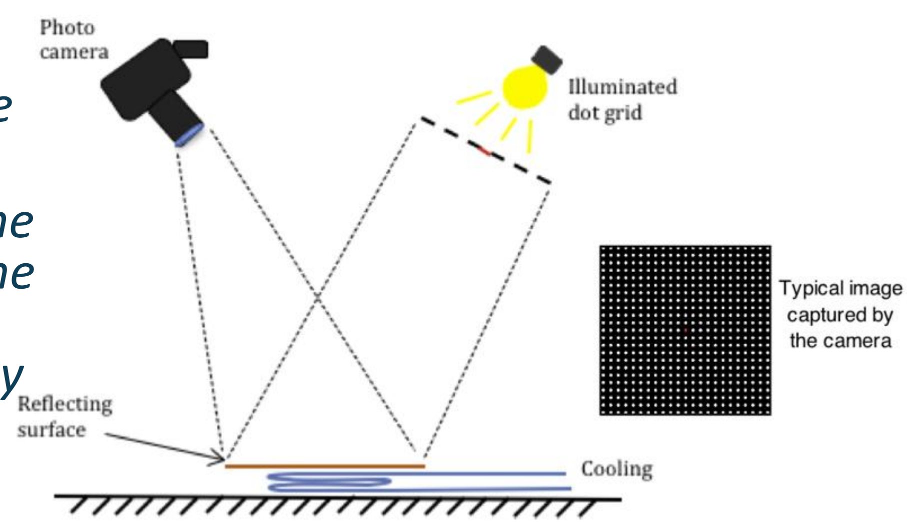
One of the AIDA deliverables is the manufacturing of a thermo-mechanical SETUP at DESY *(expected to be finished this year)*

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.

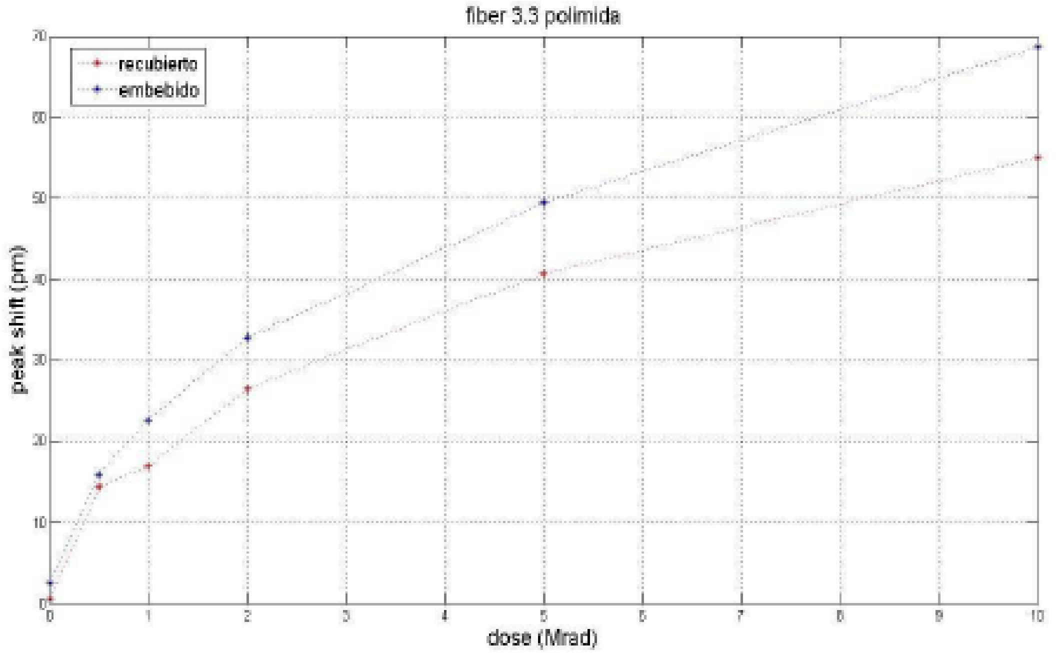
The idea is to apply different loads to the FTD petal like prototype and compare the deformation measured by Thermo-mechanical set-up optical system and by the FBG sensors.



THANK YOU !

BACKUP

PRELIMINARY RESULTS OF IRRADIATION



D.Moya, Tracking-Vertex session, Granada Sept. 29th 2010

Rad-Hard Qualification of FOS

- We need to proof radiation hardness of the sensor in the fiber and of the fiber embedded in hosting material (CF laminate)

- Irradiation campaign at Spanish National Centre for Accelerators (CNA-CSIC)
- New Cyclotron facility (18MeV protons), here 15.5 MeV protons
- 9 fibers, 3 different coatings, 2 different sensors irradiated