LONG PERIOD GRATING SENSOR TECHNOLOGY FOR ENVIRONMENTAL MONITORING

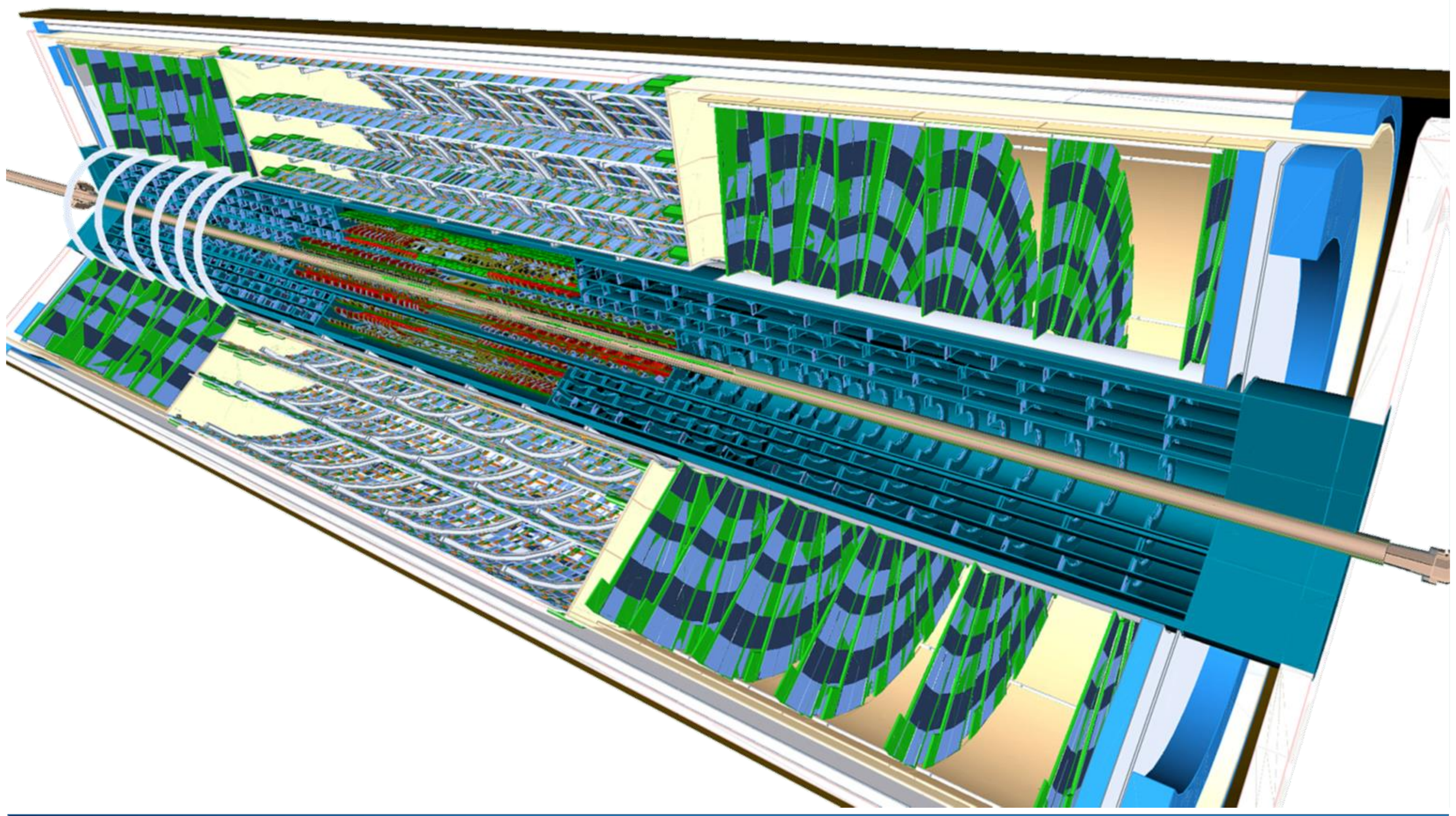
Lorenzo Scherino[a,b], Paolo Petagna[a], Jérôme Noël[a], Tiago Neves[a], Enrico Junior Schioppa[c], Andrea Cusano[b], Marco Consales[b], Giuseppe Quero[b], Patrizio Vaiano[b], Gaia Berruti[b], Anna Borriello[d], Mauro Zarrelli[d], Aldobenedetto Zotti[d], Simona Zuppolini[d]

[a] Experimental Department, Detector Technology Group, CERN – European Organization for Nuclear Research, CH-1211 Geneva, Switzerland
[b] University of Sannio, Department of Engineering, Optoelectronics Group, I-82100 Benevento, Italy
[c] Università del Salento, Dipartimento di Matematica e Fisica "E. De Giorgi", 73100 Lecce, Italy
[d] Institute for Polymers, Composites and Biomaterials (IPCB) - National Research Council, I-80055 Portici, Italy

1. Motivation

For the Inner Tracker (ITk) detector of the ATLAS experiment at CERN the environmental monitoring is essential for optimal operative conditions. A constant relative humidity monitoring is required in fifty different points inside the ITk detector, where the dew point is lower than -60°C.

In this context, Fiber Optic Sensor (FOS) technology based on Long Period Grating (LPG) and Fiber Bragg Grating (FBG) have been combined to provide a unique sensing device.

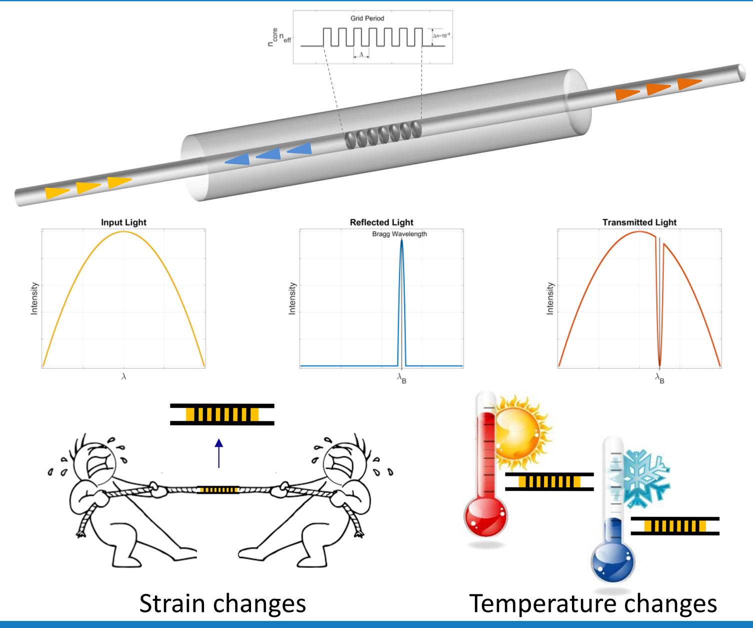


2. FBG working principle

FBGs are devices where a permanent photo-induced periodic modulation of the refractive index of the fibre core is realized. When the light guided within the core hits on this periodic microstructure one specific wavelength gets reflected and all other wavelengths can pass unperturbed.

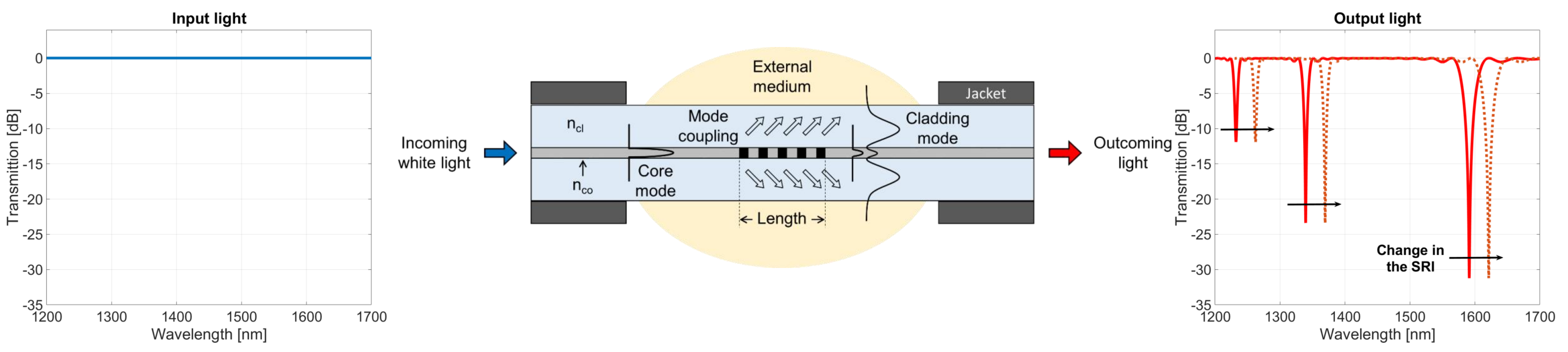
$$\lambda_B = 2 * n_{eff} * \Lambda$$

Λ = grating period ~ hundreds of nm
n_{eff} = effective refractive index (RI) of the fiber core
λ_B is the reflected Bragg's wavelength



3. LPG principle of operation

Long Period Fiber Gratings (LPGs) are in fiber photonic devices realized by creating a periodic refractive index modulation of the core of a single-mode optical fiber along a small portion of its length.

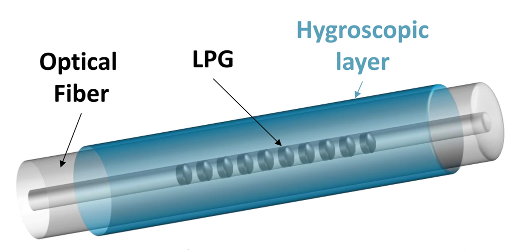


LPGs act coupling the fundamental guided core mode to discrete forward propagating cladding modes, and to each of them at a distinct wavelength where the so-called **phase matching condition** is satisfied:

$$\lambda_{res\_i} = (n_{eff\_co} - n^i_{eff\_cl}) \times \Lambda$$

Λ = grating period ~ hundreds of µm
$n_{eff,core}$ = effective refractive index (RI) of the fiber core
$n^i_{eff,clad}$ = effective RI of the i[th] cladding mode
$\lambda_{res,i}$ = resonance wavelength of the i[th] cladding mode

To realize a Relative Humidity sensor, the LPG is coated with hundreds of nm of Titanium dioxide (TiO_2):

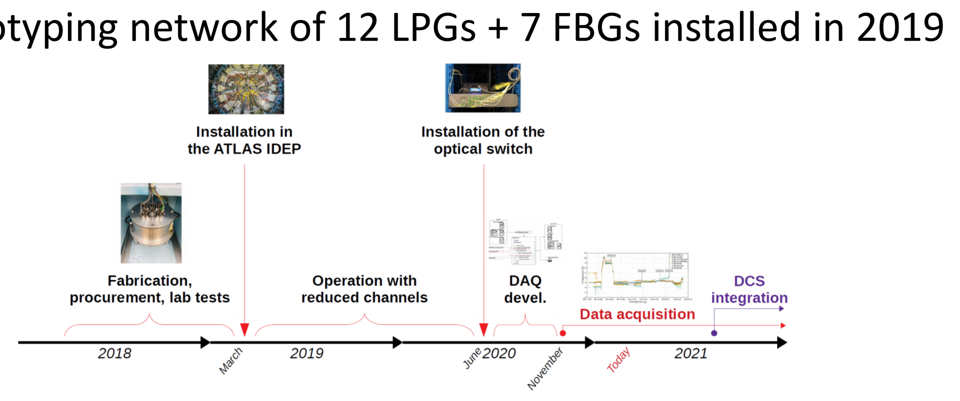


Integration of nano-scale TiO_2 overlays

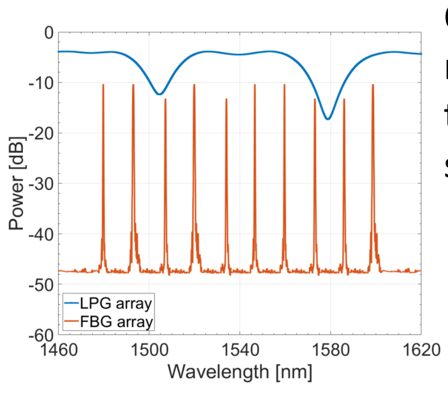
Moisture absorbtion/desorption by the coating → Modification of coating RI → Spectral variation of attenuation bands

4. Test installation in ATLAS ID

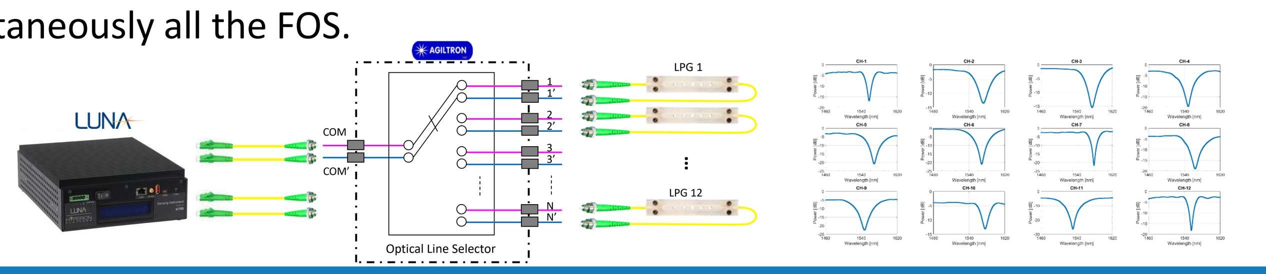
A prototyping network of 12 LPGs + 7 FBGs installed in 2019



5. Optical Switch



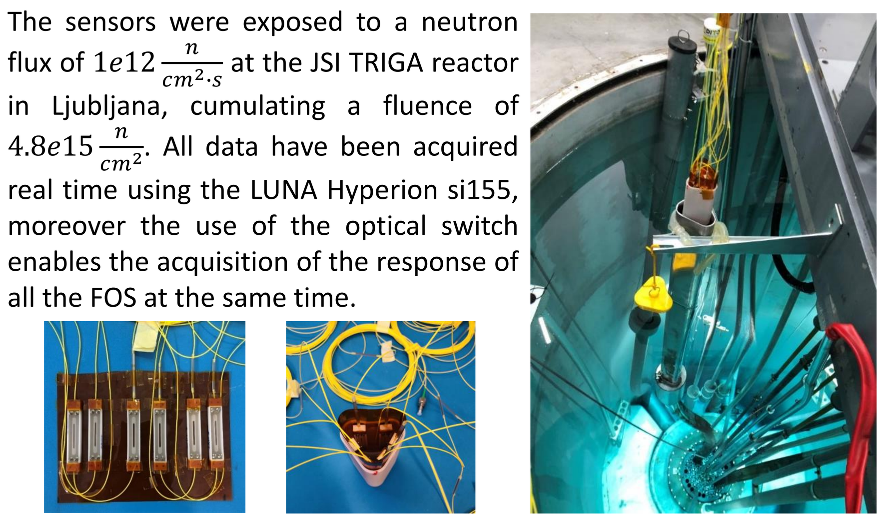
One of the main problems regarding LPG-based technology is the level of multiplexing, mainly due to limitations in term of available bandwidth compared to the FBGs. For this reason, a custom optical switch was used, in order to read simultaneously all the FOS.

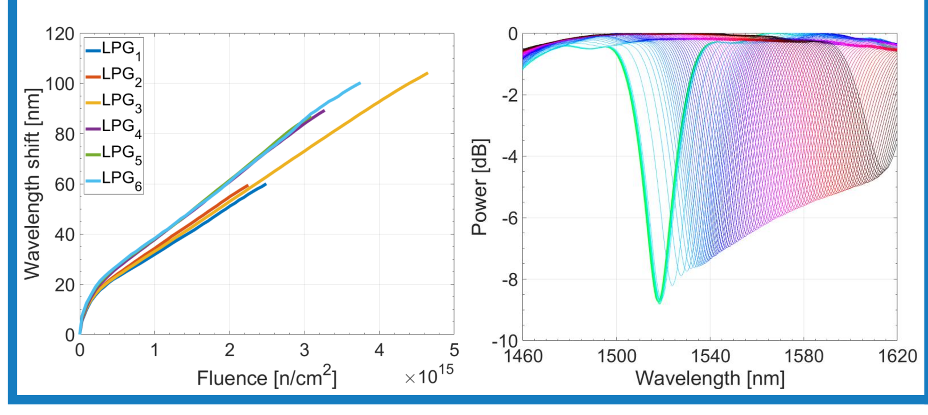


6. Response to radiation

Neutron Irradiation

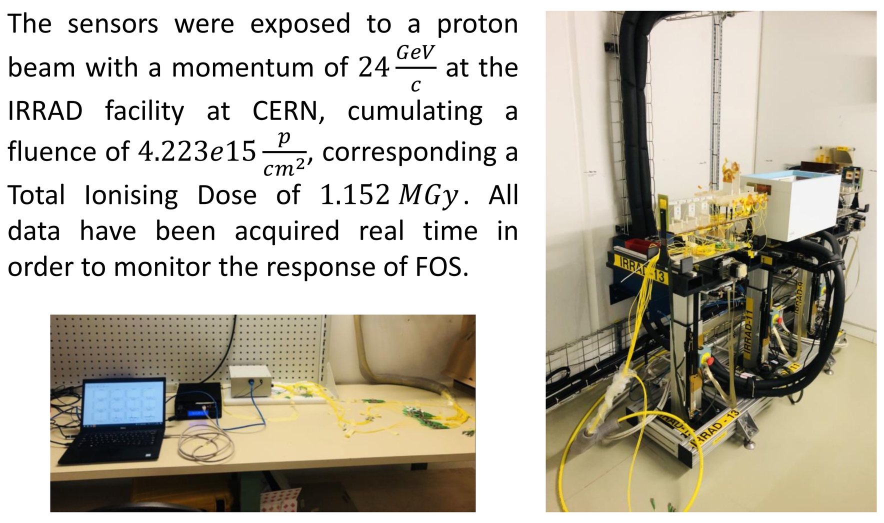
The sensors were exposed to a neutron flux of $1e12 \frac{n}{cm^2 \cdot s}$ at the JSI TRIGA reactor in Ljubljana, cumulating a fluence of $4.8e15 \frac{n}{cm^2}$. All data have been acquired real time using the LUNA Hyperion si155, moreover the use of the optical switch enables the acquisition of the response of all the FOS at the same time.

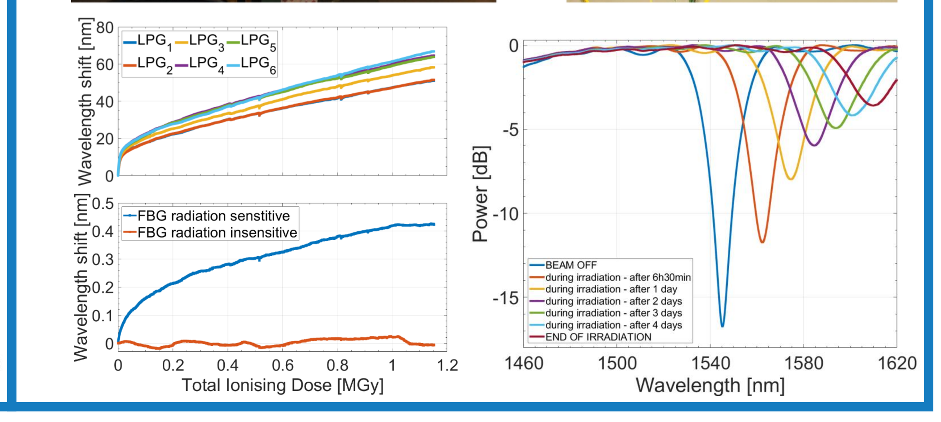




Proton Irradiation

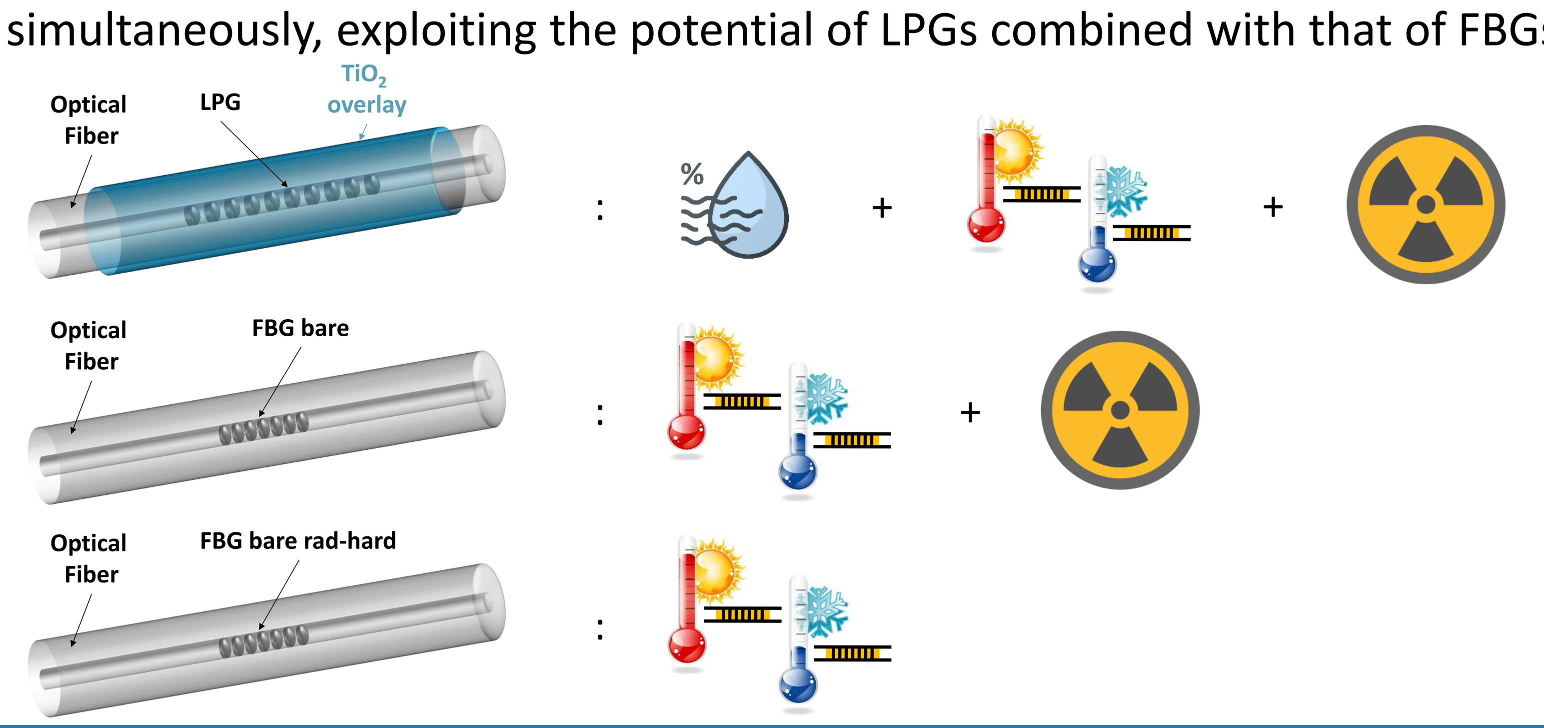
The sensors were exposed to a proton beam with a momentum of $24 \frac{GeV}{c}$ at the IRRAD facility at CERN, cumulating a fluence of $4.223e15 \frac{p}{cm^2}$, corresponding a Total Ionising Dose of $1.152\ MGy$. All data have been acquired real time in order to monitor the response of FOS.





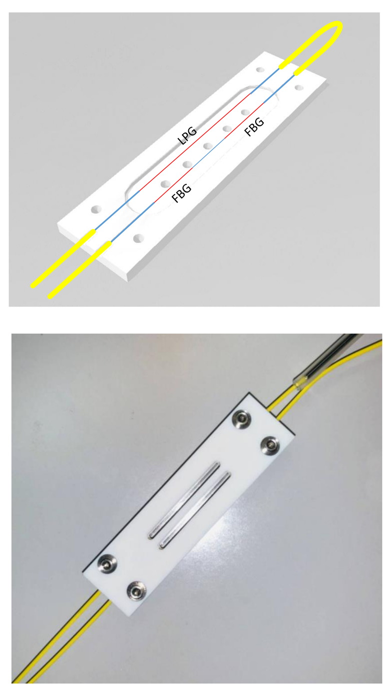
7. Measure of T, RH and TID

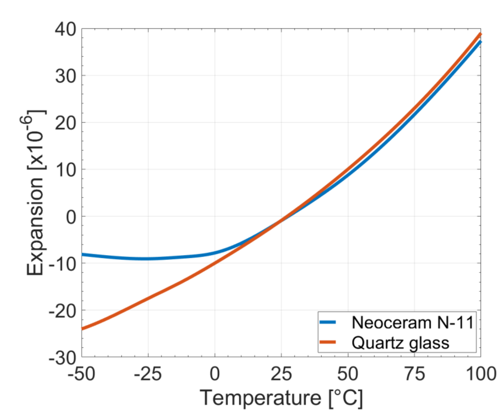
Based on the results from the irradiation campaigns, the goal is to read T, RH and TID values simultaneously, exploiting the potential of LPGs combined with that of FBGs.



8. Packaging

An ad hoc package was developed that contain the three sensors, so that the different parameters within the experiment could be monitored with a single device. The package was realized of a material such that it would not affect the response of the sensors.





Realized in NEOCERAM N-11
CTE almost constant for T<0

3 signals from each point of ITk: $T\ [°C]$, $RH\ [\%]$, $TID\ [Gy]$