Sensors 4 RPC

A proposal for funding to INFN

CMS Frascati and Napoli

Additional material:

1) CMSfbgupscopeCostsRev08.xls
2) SensingT_CMS_Proposal_rev4.ppt

Available at twiki page https://twiki.cern.ch/twiki/bin/view/CMS/RpcSensors

T/RH monitoring in RPC

•Temperature (T) and relative humidity (RH) are parameters that affect the response of RPC detectors.

• Several studies on dark currents monitoring carried out during CMS commissioning in 2008 and 2009 have shown that the thermal stabilisation of RPC's in the 21-24 ◦ C range is essential for the operation and that the working point depends strongly on temperature variations.

•The dependance on RH is less crucial, however the stabilization is much more critical due to the dimensions of SGX5 and the cavern humidity variation range.

• Presently T and RH monitoring is performed with six conventional electrical sensors in each of the existing RE stations (6T and 4 RH), while each Barrel chamber has one T and RH sensor.

•Typical requested precisions are +-0.1°C for temperature monitoring and +-2% for RH monitoring.

Optical sensors

•The development of optical sensors based on the Fiber Bragg Grating (FBG) technique for T measurement has provided an optimal solution with respect to the electrical sensors such as radiation hardness, insensitivity to magnetic field, precision, lack of electrical noise, ease of installation, minimal cabling, precision (+-0.1^{o}C). Both the Italian Frascati and Naples groups have long lasting experience in the development and deployment of FBG sensors for a variety of measurements.

• Optical sensors are proposed for use in RE4,3,2 disks, where the use of conventional electrical sensors is not possible due to cabling space limitations. The costs of the solution proposed are comparable to those of conventional electrical sensors.

•Each RE4,3,2 chamber will be equipped with one FBG sensor for T measurement. Sensors will be purchased bare and enclosed in a thermicalconducting housing. Samples of sensors will be tested in Frascati for radiation hardness, and all will be installed at CERN on RE4 chambers. The design of sensor housings will allow ease of disassembly from chambers prior to chamber disinstallation from disks for maintainance and repair. Clear optical fibers will be routed to the existing CERN interrogation system for readout and integrated in the CMS sensors slow-control framework.

•RH monitoring will be performed via conventional electronic sensors, homogeneous to those employed in the existing RE disks (4 sensors/disk).

•Finally, an R&D programme has started in early 2010 for the development of optical sensors for fluoridric acid detection in the RPC gas mixture. Options will be considered in case of positive results to install a few sensors in the USC gas distribution racks, upstream and downstream of the RPC detectors in the closed loop recirculation gas system.

T/H sensors

- **Sensors for T and H monitoring in RE4 new endcap stations and for existing stations RE2 and RE3 (in collaboration with LNF, Napoli and CERN)**
  - Expertise on FBG sensors in HEP detectors (FINUDA, BTEV, CMS) and industrial applications
  - S.Bianco (Frascati), M.Caponero (Frascati and ENEA), S.Colafranceschi (Frascati PhD), G.Breglio (Napoli), S.Buontempo (Napoli), L.Passamonti (Frascati tech), D.Pierluigi (Frascati tech), M. Giordano (Napoli), A. Cusano (Benevento), A. Cutolo (Benevento), A. Saccomanno (Napoli PhD), A. Irace (Napoli)
  - Explore possibility of using optical sensors for gas contaminants (PRIN funded) F.Felli (Frascati and Roma1), M.Parvis(Frascati and Polito), G.Saviano(Frascati and Roma1)

  - RESOURCES
    - Clean room in Frascati for sensors assembly and QA/QC
    - Lab space in Frascati
    - Use of lab facilities in Uni/INFN Napoli, Benevento, CNR-Napoli, ENEA-Frascati, Ing. Roma1, Polito

Costs breakdown

		kEUR	UNITS	QTY	kEUR	INFN	CERN
Miss. Int							
	Contatti collaboratori e ditte				12	12	0
Miss.Estero							
	Installazione sensori su camere	4	mu	0.5	2		

INFN CERN

Altri costi di attrezzature coperti da materiale disponibile a Frascati:

strumento interrogazione ……………… 18,0
attuatore piezoelettrico………………… 5,0
celle peltier……………………………. 4,0
giuntatrice……………………………… 12,0

Costi in kEUR - Vedi file CMSfbgupscopeCostsRev08.xls per altre voci (consumi, missioni, etc)

Timeline

Prevediamo quattro fasi:
1) a Frascati il test dei sensori nudi, il packaging, e il controllo prima della spedizione.
2) l'installazione dei sensori sulle camere e' divisa in due casi
   2.a) montaggio sulle camere RE4 mano a mano che sono pronte
   2.b) montaggio sulle camere RE2,3 durante gli shutdown
   Stima del tempo di installazione della fibra sulla camera, test e certificazione:
   due persone sono in grado di fare fra due e tre camere al giorno.
3) routing delle fibre ottiche in USX, e da USX a USC

Profilo di spesa:
Il piano di spesa delle voci costruzioni apparati e' tutto nel primo anno di finanziamento, le missioni della fase 2a) sono nel primo anno, quelle delle fasi 2b e 3 dipendono dalla schedule degli shutdown.

Instrumentation available at Frascati

	COST kEUR
FBG interrogation system for acceptance tests	18
Piezoelectric actuator	5
Peltier Cells	4
Splicing machine	12

T sensors: timeline
WBS 8.0

weeks

TASK	SUBTASK	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	Ppower
Sensors Certification and packaging at Frascati																			
	acceptnc test	x	x	x	x	x													1
	packaging		x	x	x	x	x	x	x										2
	splice		x	x	x	x	x	x	x										1
	QA test			x	x	x	x	x	x	x									2
Shipment to Cern					x	x	x	x	x	x	x								
QA after shipment						x	x	x	x	x	x	x							1
Installation of sensors on RE4 chmbrs																			
	Installation						x	x	x	x									2
	QA test							x	x	x	x								2
Installation of sensors on RE2,3 chmbrs																			
	Installation						x	x	x	x	x	x	x	x	x	x			2
	QA test							x	x	x	x	x	x	x	x	x	x		2
Cabling																			
	Cabling USX-US(	x	x	x	x														2
	Cabling on Disks							x	x	x	x	x	x	x	x	x	x	x	2
	Splicing muffola											x	x	x	x	x			Ext. Firm

Temperature and Humidity sensors tasks and responsibilities

- Sensors certification and packaging (Frascati resp.) at Frascati clean room and lab, with possibility of using labs at Enea, Uniroma1, Uninapoli, Unibenevento for parallelization. S.Bianco (Frascati), M.Caponero (Frascati and Enea), G.Breglio (Napoli), L.Passamonti (Tech. Frascati), A.Russo (Tech. Frascati), Tech. Enea.
- Installation at CERN (Napoli resp.). S.Buontempo (Napoli), S.Colafranceschi (Frascati phd), M.Caponero (Frascati and Enea), G.Cusano (Napoli), Tech. Frascati, Tech. Napoli

Costs breakdown for sensors

Costr. App.		costo/unitario (keuro)	Numero/disk	costo/disk (INFN) **keuro**		costo CERN
	Sistema Interrogazione @ USC	30	1			30
	Switch ottico	15	1			15
	Sistema interrograzione @Frascati	0	1	0		0
	Sensori FBG	0.12	75	9		
	Cavo FO 75conduttori	0.4	1	0.4		
	Muffola distribuzione	0.4	1	0.4		
	Scatola di housing/piastrina	0.03	75	2.25		
	Rack	0.4	1	0.4		
	TOTALE/disk			12.45		
				INFN		**CERN**
	TOTAL ALL DISKS		**disks 6**	**€ 74,700.00**	**97,110.00 CHF**	**45,000.00 EUR**

Instrumentation already available at LNF lab and CERN

strumento interrogazione .... 18,0 k€
attuatore piezoelettrico.................... 5,0 k€
celle peltier................................. 4,0 k€
Giuntatrice.................................. 12,0 k€

Total cost completely driven by sensor cost. We will profit from already existing instrumentation in lab

Costs for standard sensors: preliminary exercise

n sensori 75*6 = 450

n moduli ADC = 450sensori/128ch = 4

n.4 ADC CAEN A3801A............. 3.5*4 = 14.0

n.1 CAEN EASY3000........................... 2.8

n.1 CAEN easybranch A1676A.............. 1.5

TOT... 17.3

n.450 sensori classe 1/10DIN 450*25EUR/sens=.... 11.3

n.450 cavi * 40m/cavo = 22km

22km*1EUR/km...22.0

TOTALE DEI TOTALI...50.6

corrispondente a 113EUR/ch

APPENDIX

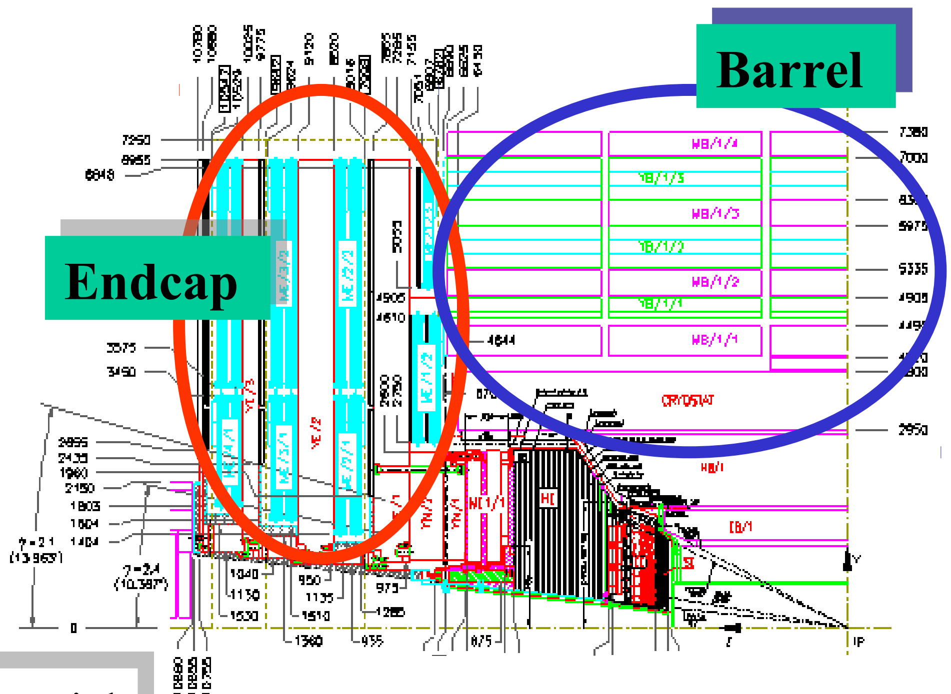
Layout di installazione delle fibre

Vedi la proposta dettagliata nel file:
SensingT_CMS_Proposal_rev4.ppt
disponibile nella twiki page
https://twiki.cern.ch/twiki/bin/view/CMS/RpcSensors

Sensors in Upscope endcaps

Baseline

- Six stations in the Barrel
- Four station in the Endcap up to $\eta = 2.1$



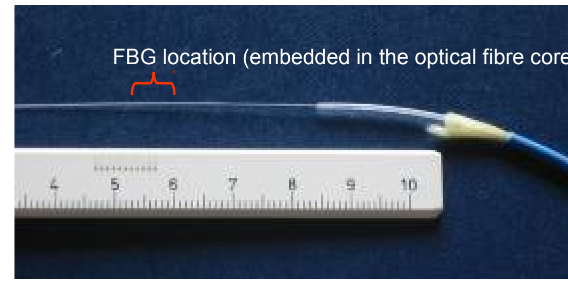
However, due to technical and financial reasons, only three layers up to $\eta = 1.6$ are present in the endcap region.

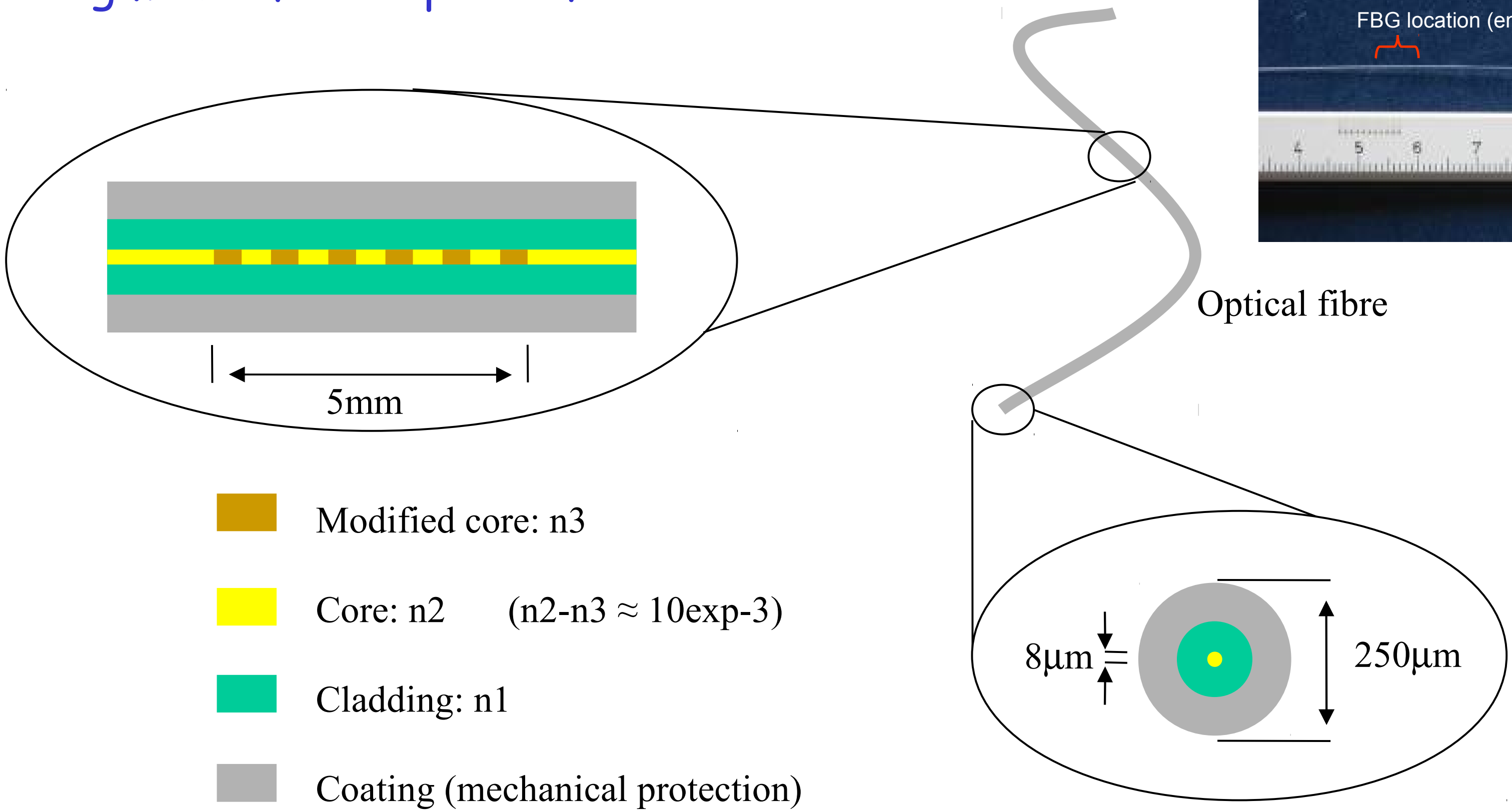
	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2

Fiber optic sensors. FBG, POS. Generalities

Fibre Bragg Grating (FBG) sensor:
Diffraction grating written inside the core of an optical fibre

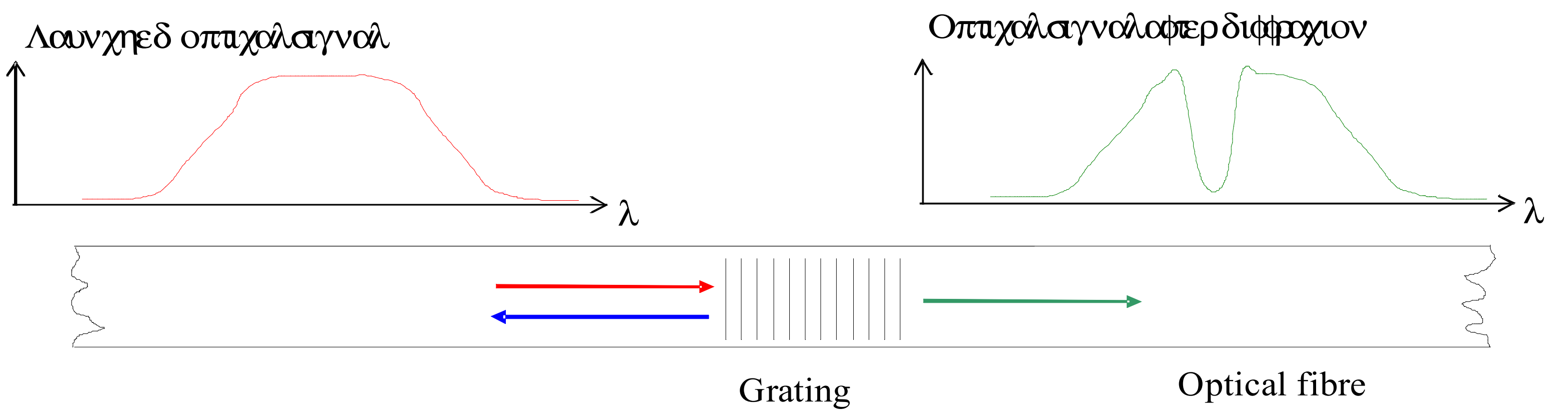
Grating is made by modifying the refraction index of a segment of the optical fibre

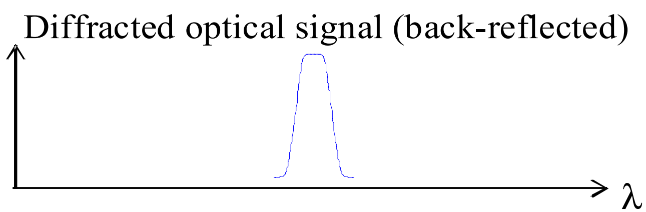




Light propagating along the fiber can be diffracted by the grating

Grating is designed to produce a narrow-band back-reflected signal





Launched signal: Δλ≈60nm

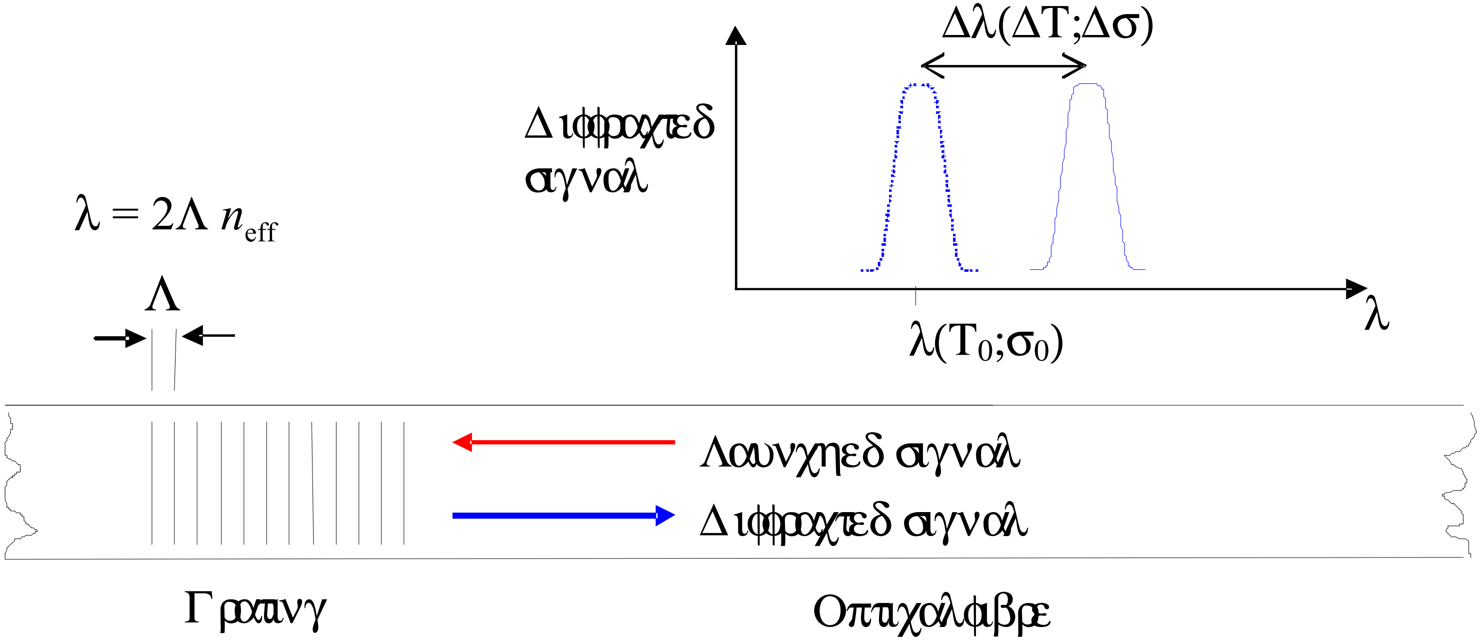
Diffracted signal: Δλ ≈0.3nm @-3dB

Wavelength of diffracted signal is a function of grating features (grating pitch Λ, effective refraction index n_{eff})

Mechanical and thermal excitation of the grating modify the wavelength of the diffracted signal

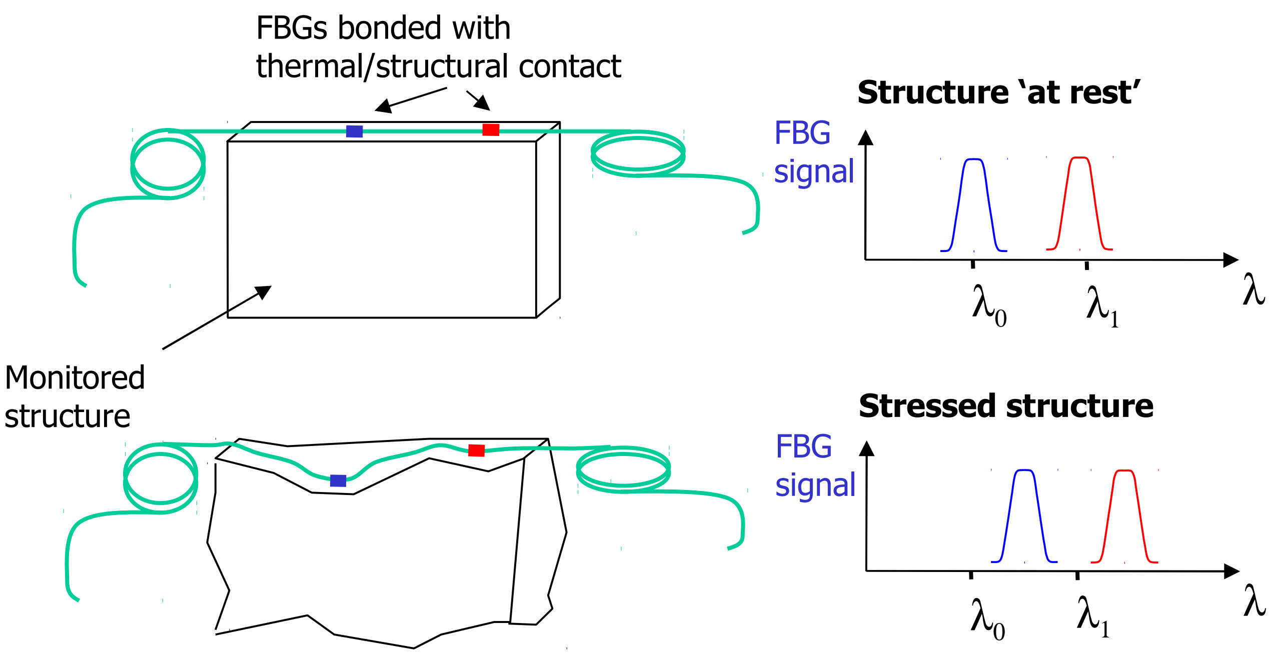
$\Delta\sigma = 1\ \mu\varepsilon \Rightarrow \Delta\lambda = 1$ pm *(typical values)*

$\Delta T = 0.1\ K \Rightarrow \Delta\lambda = 1$ pm



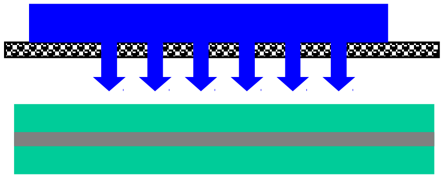
Fibre Bragg Grating (FBG) sensor: optical strain gauge.

- Directly integrated in an optical fiber core
- Many sensors along the same optical fiber (WDM read-out)
- Long term stability in static and dynamic regime
- Electromagnetic field insensitivity
- Hostile environment endurance and mass lightness.

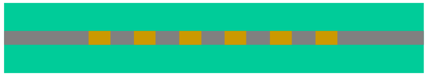


FBG sensor have fair 'intrinsic' Radiation Hardness capability

FBG production:
a grating is 'written' modifying the refractive index of the 'core' by a space-modulated UV beam.
(UV modifies *wrong* Ge-Si, Ge-O and Ge-Ge bonds)

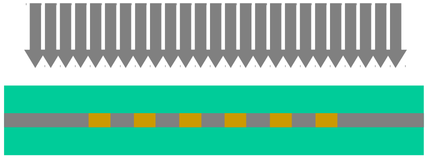


Optical fiber exposed to space-modulated UV

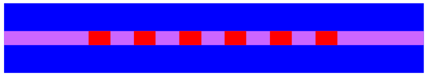


FBG grating 'written' in the core of the optical fiber

Exposition to uniform ionising radiation affects the refraction index of the optical fiber mainly producing a 'bias' effect



FBG exposed to uniform ionising radiation



FBG exposed to uniform ionising radiation

Effect of ionizing radiation on optical fibers already reported:

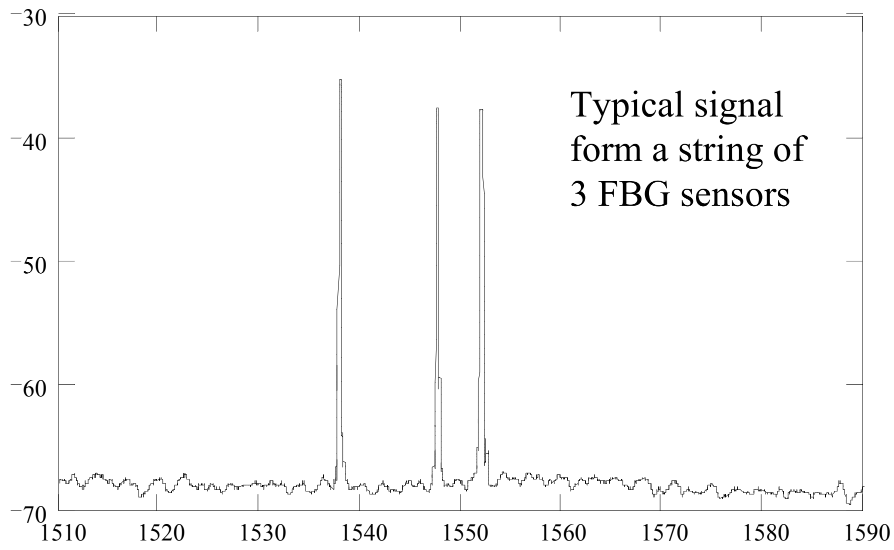
Transmission attenuation (slightly wavelength-dependent)

FBG sensing is based on narrow-band wavelength-encoded measurement, with excellent signal-to-noise ratio:

FBG sensing has high tolerance to Transmission attenuation of optical fiber cables

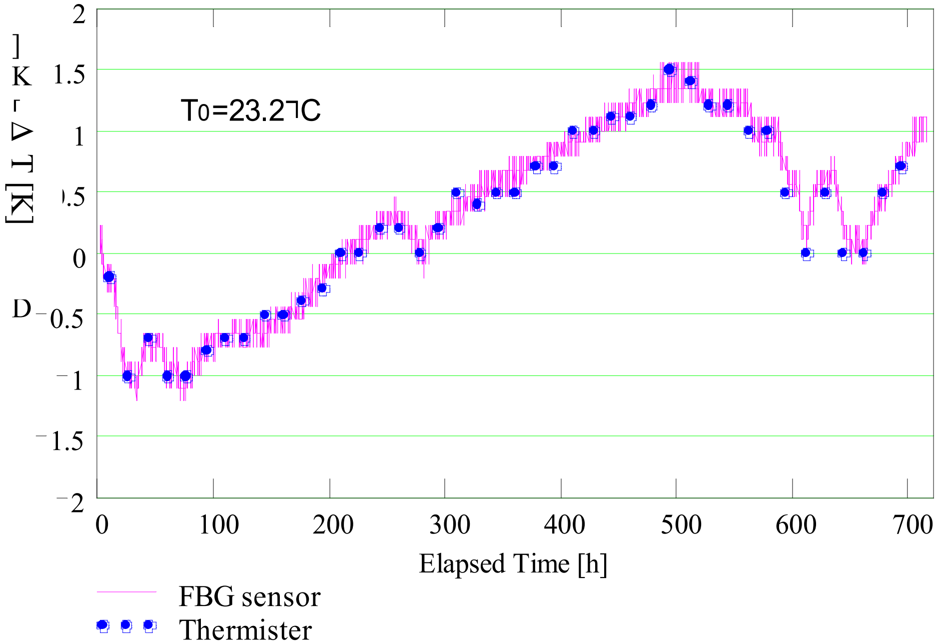
<u>Typical FBG features</u>

Reflectivity >90%
Reflective bandwidth @-3dB <0.3 nm
Side lobe suppression >15dB



Temperature sensing by FBG sensors

Typical resolution: 0.1K (at room temperature)
- Temperature dependence of glass refraction index
- Thermal expansion coefficient of glass

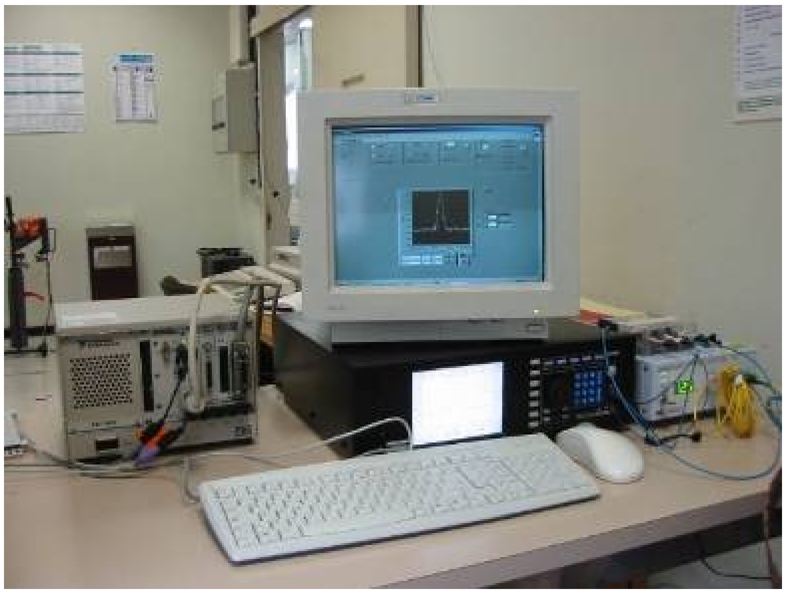


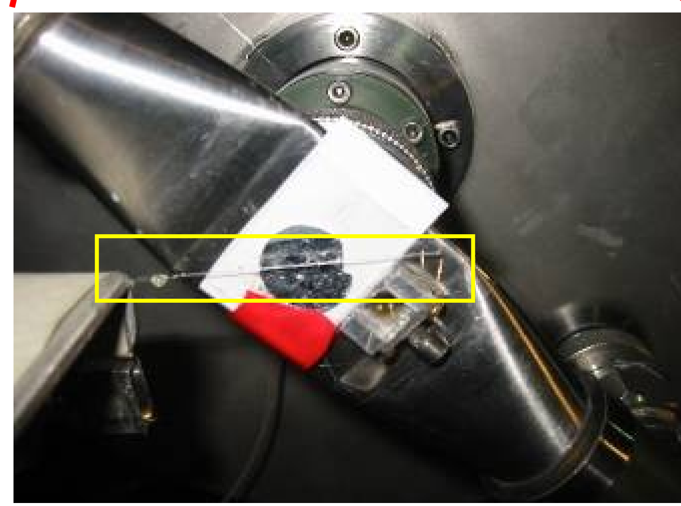
M. Caponero et alt.;
"long term thermal deformation and creep monitoring of CFRP components" – ENEA Internal Report

Results of Rad Hardness tests
Frascati, Enea

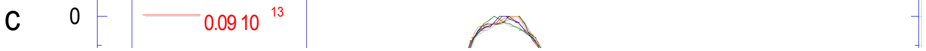
Neutron beam 14MeV - FNG facility at ENEA Research Centre 'Frascati'

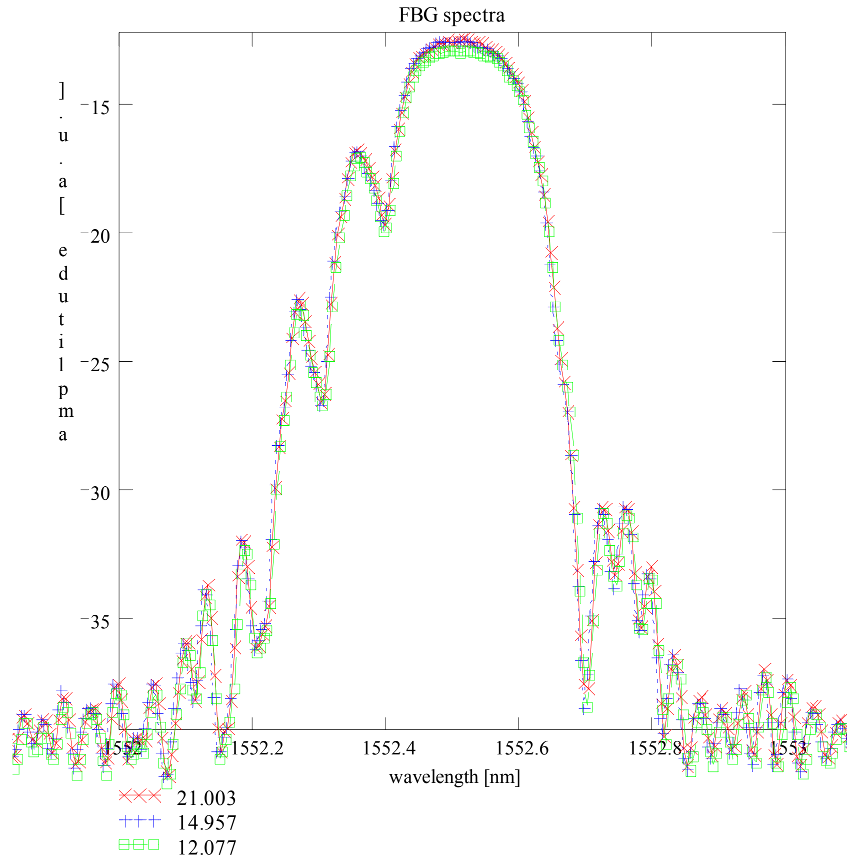
Total flux:
21.03 • 10^{13} n/cm2 @14MeV
(≈35.97 • 10^{13} n/cm2 @ 1MeV)
Monitoring of FBG spectra during exposition





M. Caponero et al.
Proc. 10th conference Astroparticle, Particle and Space Physics, Detectors and Medical Physics Applications
M. Barone, A. Gaddi (ed.)
World Scientific Publishing (2007) 533 - 539



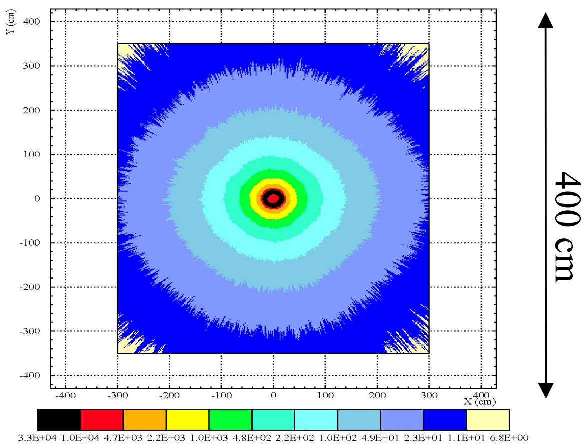


Slight spectrum modification up to $12 \bullet 10^{13}$ /cm2 neutrons@14MeV

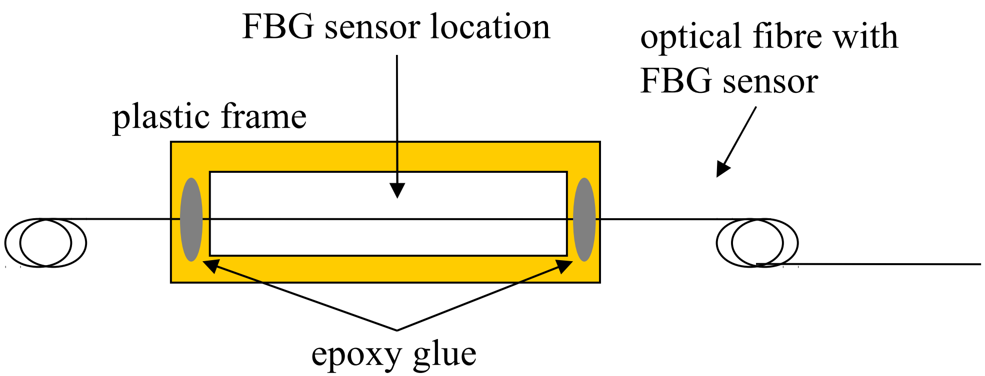
No further modification up to $21 \bullet 10^{13}$ /cm2 neutrons@14MeV

M. Caponero et al.
Proc. 10th conference Astroparticle, Particle and Space Physics, Detectors and Medical Physics Applications
M. Barone, A. Gaddi (ed.)
World Scientific Publishing (2007) 533 - 539

γ-rays ^{60}Co – CALLIOPE facility at the ENEA Research Centre 'Casaccia'



CALLIOPE dose rate profile



M. Caponero et al.
Proc. 10th conference Astroparticle, Particle and Space Physics, Detectors and Medical Physics Applications
M. Barone, A. Gaddi (ed.)
World Scientific Publishing (2007) 533 - 539

Set up for irradiation: FBG slightly stretched and glued on a plastic frame

R&D in progress for optical sensors as gas contaminants detectors in RPCs

Frascati, Enea, Roma 1, Polito

RPC MUON DETECTORS
GAS recirculation closed loop

The large detector volume
and the expensive gas mixture make a closed loop
recirculation system mandatory

Gas total volume: 18 m^3
Active surface: 4000 m^2
Installed gaps: >800
Flux: 8 m^3/h

Gas mix composition

95.2% of C2H2F4

4.5% of iC4H10

0.3% SF6

40% RU

gas mixture (due to the presence of HF) tends to release some elements from zeolite framework, K and Ca increase in gas when currents increase.

Fluorine is constantly produced and the zeolite traps it efficiently.

Purifiers fail to filter HF and need to be regenerated.

HF production increases with radiation

Proposing use of Plastic Optical Fiber: gas pollutants monitoring

POF: Plastic Optical Fiber
Large diameter plastic optical fiber

POF sensors for gas pollutants based on the technique of the 'evanescent wave attenuation measurement'
(light transmitted at the core/cladding interface)

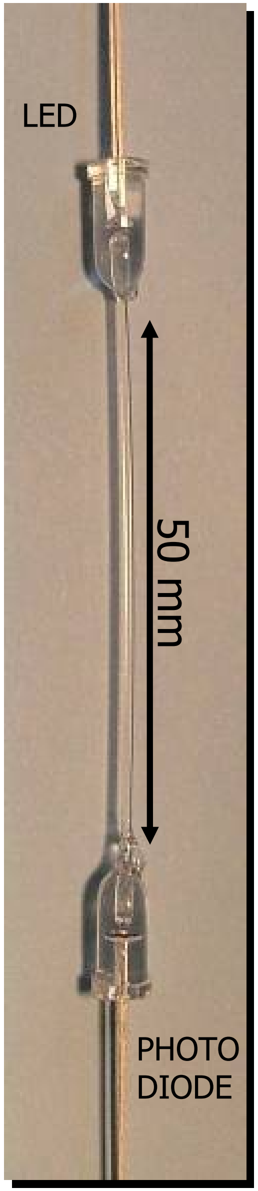
Sensor fabrication

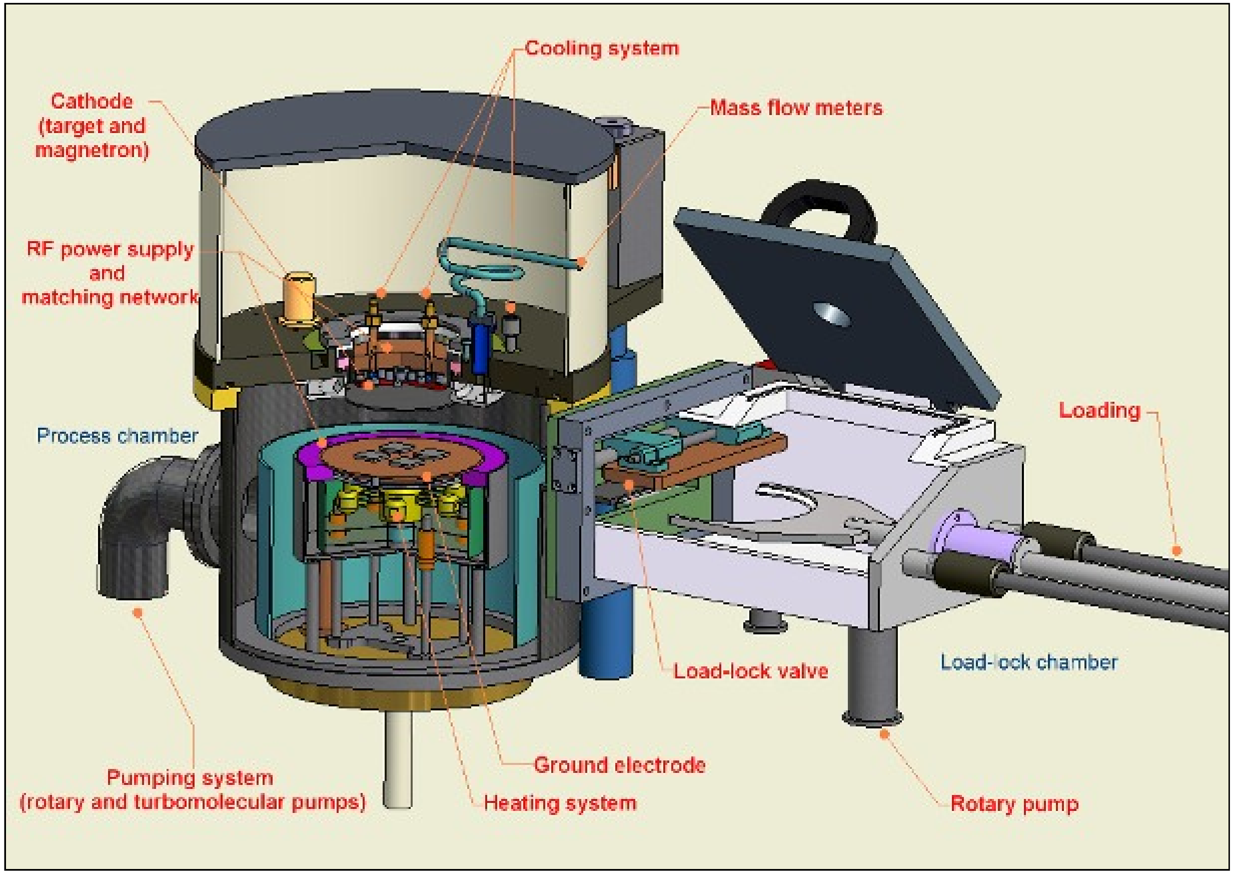
1) The plastic cladding of the fiber is removed
2) The fiber is coated with a chemical substance 'sensitive' to the pollutant to be monitored

Sensing principle

1) Optical property of the coating is affected by the quantity of pollutant that has been 'intercepted'
2) The variation of the light intensity transmitted by the coated fiber is related to the quantity of 'intercepted' pollutant.

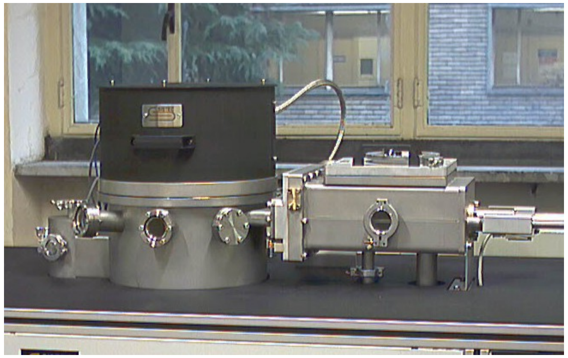
NOTE: Usually irreversible cumulative measurement (!!)





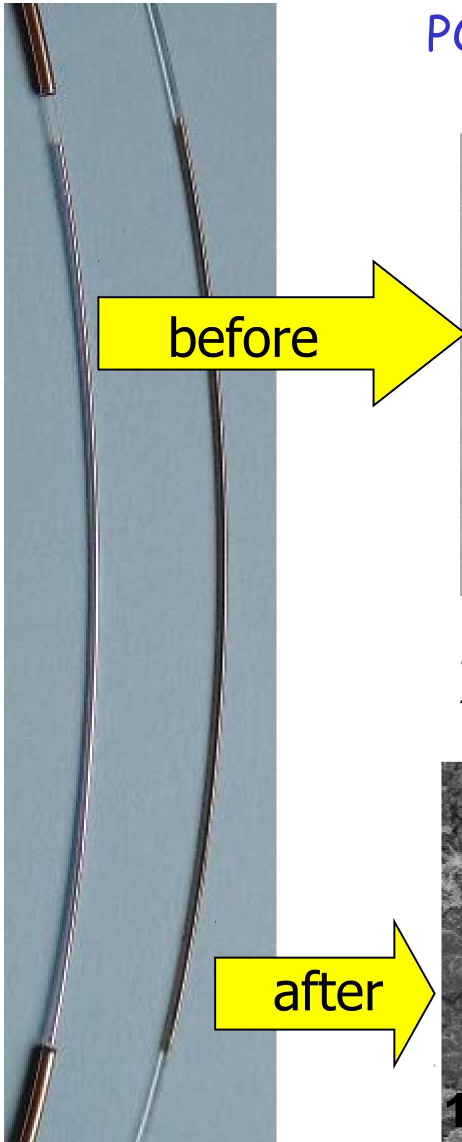
PECVD
Plasma Enhanced Chemical Vapour Deposition

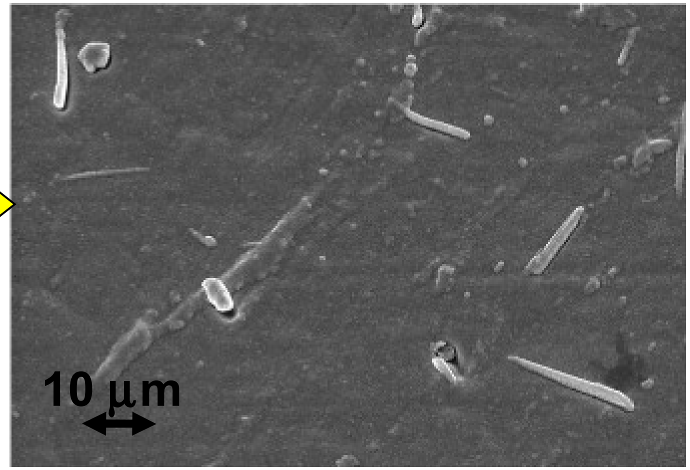
Turin Polytecnic
Department of
Electronic Engineering



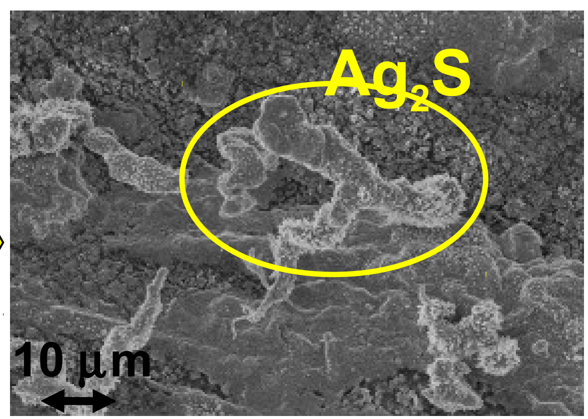
POF sensor for H_2S

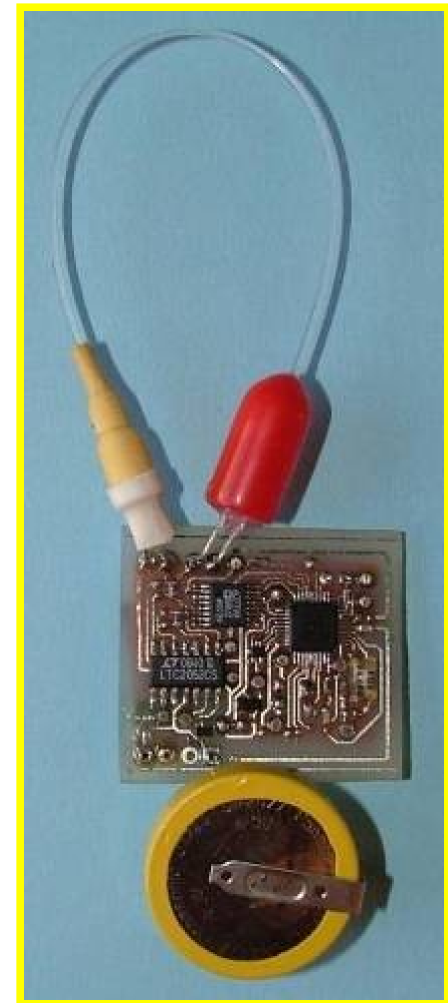
Coating: Ag





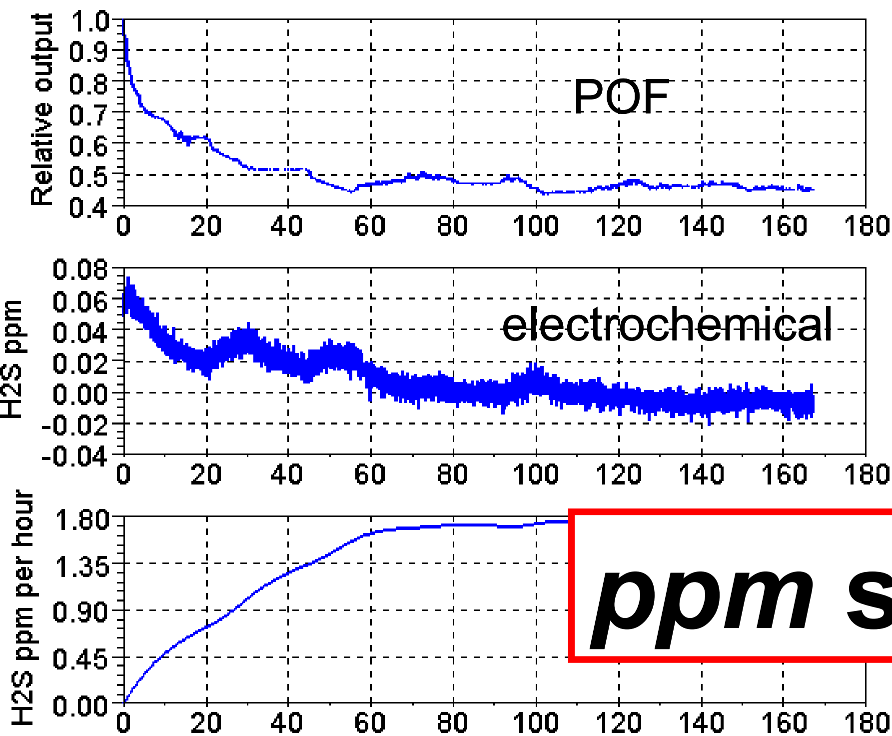
$$2\,Ag + S^{--} \Rightarrow Ag_2S + 2\,e^{--}$$

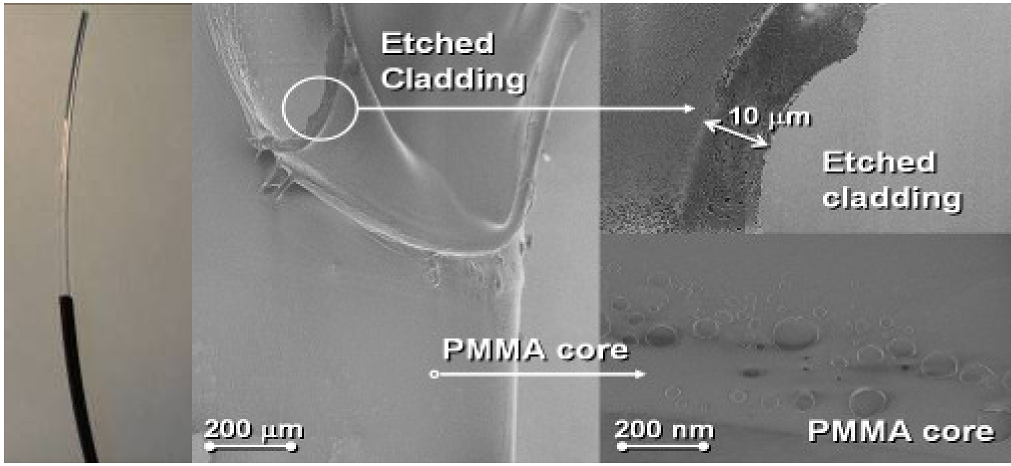




POF sensor for H_2S sensing
R&D in progress for F^- detection

POF Sensor sensitivity (first plot) compared to electrochemical sensor sensisivity (plot in the middle)





Preparation of POF sensor. Cladding chemical Ablation (etilacetate, 40s)

***ppm* sensitivity**

Experience of the CMS Frascati group

- FINUDA at DAFNE (1998)
  - Operated Monitoring geometrical stability of uvtx detector
- BTeV at Fermilab (2002)
  - R&D of Monitoring geometrical stability of uvtx
  - R&D of Monitoring repositioning displacement of uvtx
- CMS (2005)
  - Proposal for Monitoring geometrical stability of uvtx and repositioning
- CMS (NOW)
  - R&D for gas pollutants for RPC
- CMS (NOW)
  - Proposal T, H, gas pollutants in RPC upscope
- CMS (upgrade)
  - Proposal for T, H, gas pollutants in hi-eta MPGD muon detectors

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2. S. Bianco, M.A.Caponero, F.L. Fabbri, A.Paolozzi **Omega-Like Fiber Bragg Grating Sensors as Position Monitoring Device: A Possible Pixel Position Detector in CMS?** Frascati Preprint LNF - 06 / 13(NT) 23-05-2006.
3. L.Benussi et al., **Results on Position Monitoring and Displacement> (Omega-Like Device) by Means of Fiber Bragg Grating Sensors for the BTeV Detector**. Frascati Preprint LNF-03/15(IR) 10-09-2003.
4. L.Benussi et al., **The Omega-Like: A Novel Device Using Fbg Sensors To Position Vertex Detectors With Micrometric Precision**, Nucl. Phys. Proc. Suppl. **172** (2007) 263.
5. E.Basile et al., **A novel approach for an integrated straw tube - microstrip detectors**, IEEE Trans. Nucl. Sci. **53** (2006) 1375
6. E.Basile et al., **Micrometric position monitoring using fiber Bragg grating sensors in silicon detectors** arXiv:physics/0512255

Publications LNF

1. T/RH effect in RPC
   - L.Benussi et al, **Sensitivity and environmental response of the CMS RPC gas gain monitoring system,** LNF-08-27(P), JINST 4:P08006,2009. e-Print: arXiv:0812.1710
   - L.Benussi et al., **A NEW APPROACH IN MODELING THE RESPONSE OF RPC DETECTOR,** presented by S.Colafranceschi at RPC10, Darmastadt, to appear on NIM (2011)
1. Optical sensors in CMS and HEP
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