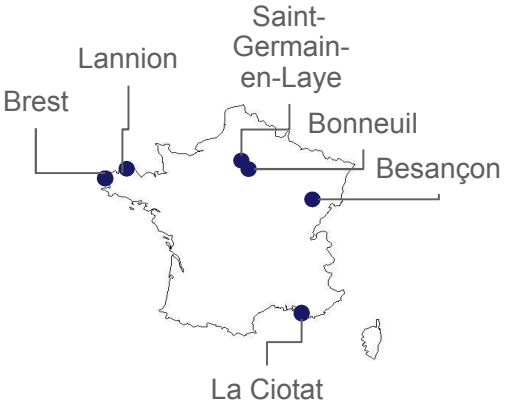
Hardened Fiber Bragg Grating for temperature and strain measurements in nuclear environment "HOBAN" PROJECT

A. Morana[1], S. Girard[1], E. Marin[1], A. Boukenter[1], Y. Ouerdane[1]
G. Mélin[2], T. Robin[2], L. Lablonde[2], B. Cadier[2]
J. Périsse[3], J.S. Genot[3], J.R. Macé[3]
J. Kuhnhenn[4], U. Weinand[4]
J. Grelin[5], L. Hutter[5]

Université de Saint-Etienne[1], Ixblue[2], Areva[3], Fraunhofer INT[4], Smart-Fibres[5]

2eme journées thématiques du club "fibres optiques et réseaux"
"Les capteurs et l'instrumentation à fibres optiques"
Cergy-Pontoise, May 25Th 2016

iXBlue group activities

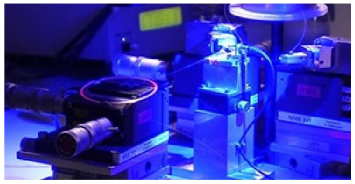


5 Divisions

- Navigation Systems

- Acoustic Systems

- Motion Systems



- Photonics (Lannion et Besançon)

- Survey and services

iXBlue - Division Photonique - Lannion

- iXFiber founded in 2006
- From 8 to 35 employees in 2016
- Sole French company to fabricate and sell specialty optical fibers
- Know-how, Innovation, Intellectual Property
- iXFiber is now a **recognized brand** for

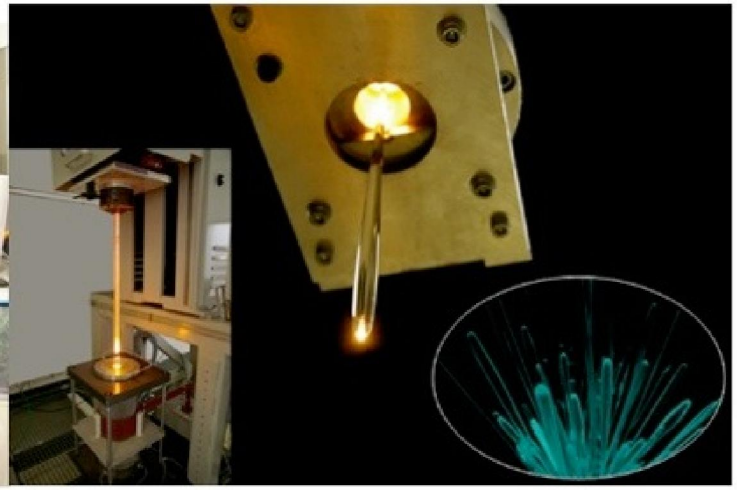
  - Specialty optical fibers
  - Fibered optical components

iXBlue - Division Photonique - Lannion : virtual tour

Main factory building

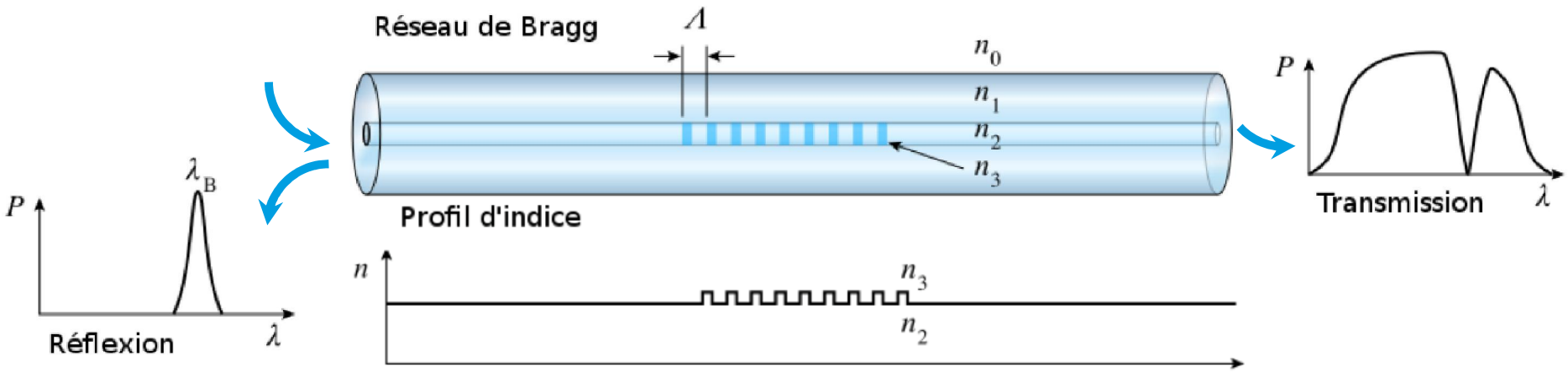
MCVD lathes

Characterization laboratory



Draw towers

FBGs : Fibre Bragg Gratings

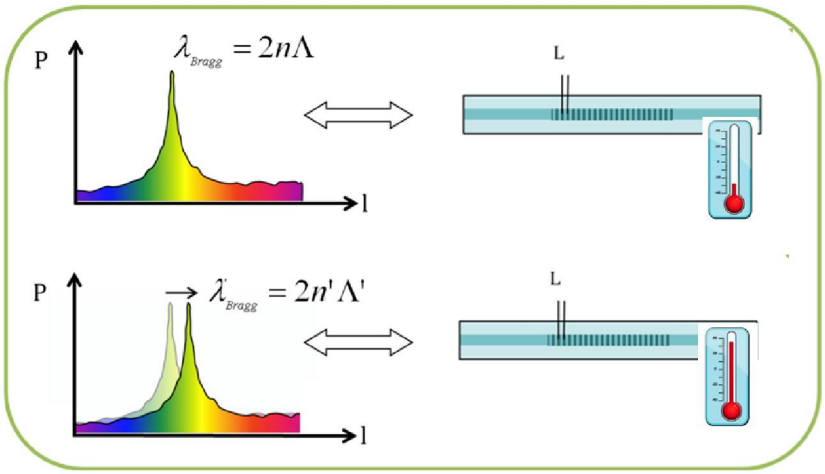


- (almost…) Permanently induced periodical modulation of fiber core index
- FBGs ⇔ wavelength selective components : mirrors, filters,…
- Bragg wavelength widely adjustable : $\lambda_B = 2n_{eff}\Lambda$

FBGs : Bragg wavelength variation

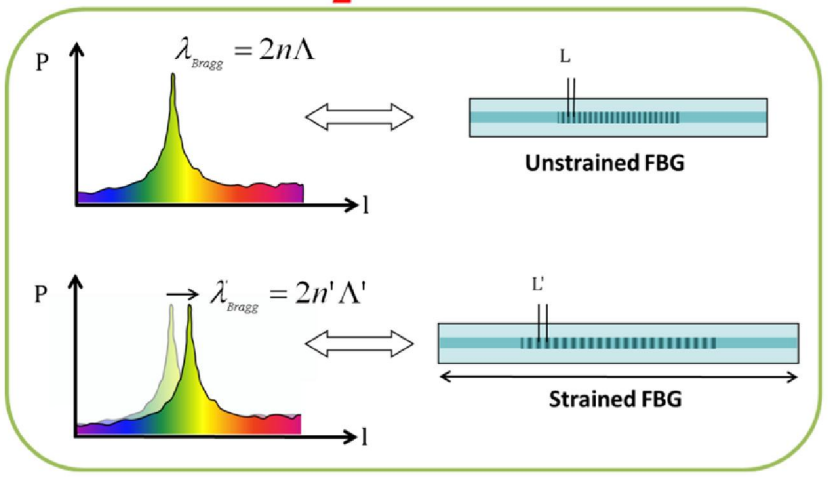
$$\frac{\Delta\lambda_B}{\lambda_B} = \boldsymbol{a}\Delta T + \boldsymbol{b}\varepsilon + \boldsymbol{c}\Delta P$$

$$a = \alpha + \xi$$



Response to temperature
~10 pm/°C @ 1.55µm

$$b = 1 - \frac{n^2}{2}[\rho_{12} - \nu(\rho_{11} + \rho_{12})]$$



Response to strain
~1.2 pm/ppm @ 1.55µm

For sensing applications, discriminate temperature & strain is mandatory

Introduction

HOBAN : European project funded by EIT via KIC InnoEnergy

*"DEVELOPMENT OF **H**ARDENED **O**PTICAL FIBER **B**R**A**GG GRATING SE**N**SORS"*

Overall Status

Ongoing project – Duration: 3 years (2014-2017)

Project Coordination and Management

Jocelyn PERISSE, Project Manager
E-mail: jocelyn.perisse@areva.com
Phone: +33 (0)472 747 309

Project Consortium

The participating institutions are a mix of industries and research organisations:

- AREVA, France (leading project partner)
- Fraunhofer Institute, Germany
- iXBlue, France
- Smart Fibres Ltd, UK
- Université Jean Monnet, Saint-Étienne, France

http://www.kic-innoenergy.com/innovationproject/our-innovation-projects/hoban/

Project added value

- HOBAN is aiming at developing FBGs based temperature (up to 350°C) and strain (up to 3000 µstrain) monitoring systems that can withstand harsh nuclear environment (up to 1 MGy over 40 years)
- Using of state of the art hardening techniques against high radiation field and elevated temperature
- Combining compact sensing element, long distance signal transmission and remote monitoring
- Multiplexing measurement points, combined with down-sizing of cabling and ingress solutions
- Adopting mature technologies issued from telecommunications and oil & gas market
- Qualifying the sensor technology according to nuclear industry standards

HOBAN at a glance

IP

AREVA

- Nuclear market customer
- Product technical specifications
- Nuclear sector business

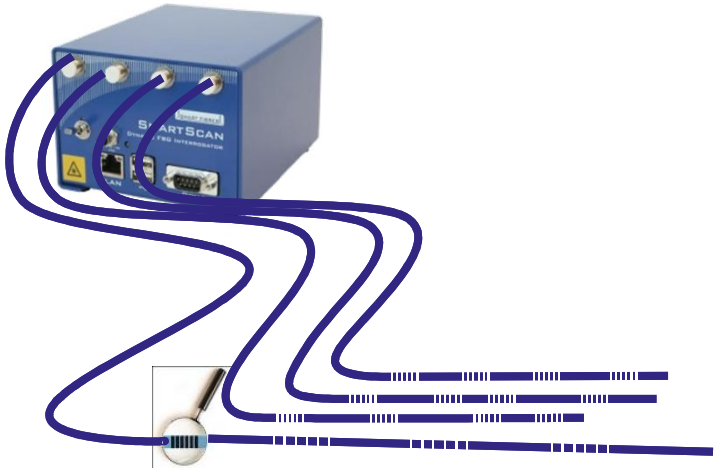
SMART FIBRES
SENSE THE FUTURE

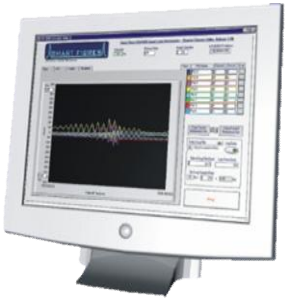
- FBG sensors & monitoring system
- Industry business operator

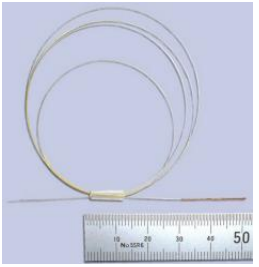
IP

IXBLUE
DEEP INSIGHT. SHARPER SENSES.

- Radhard optical fiber & FBG manufacturer
- High performance products for Defense and Space







Rad. & Temp. hardened FBG Sensors

IP

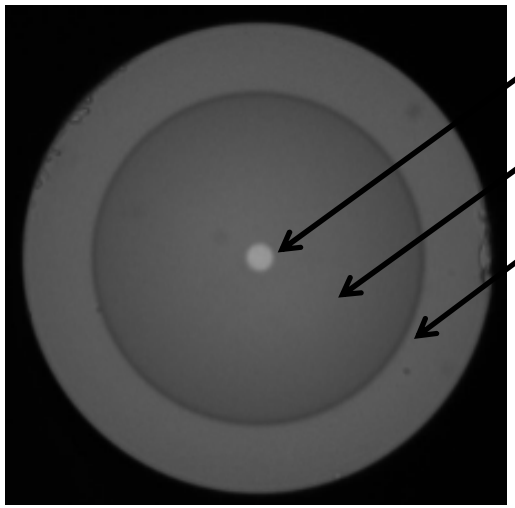
Université Jean Monnet SAINT-ETIENNE

Fraunhofer INT

- Rad. & Temp. hardened OF technical skills & expertise
- FBG manufacturing and characterization facilities
- Radiation & Temperature test facilities

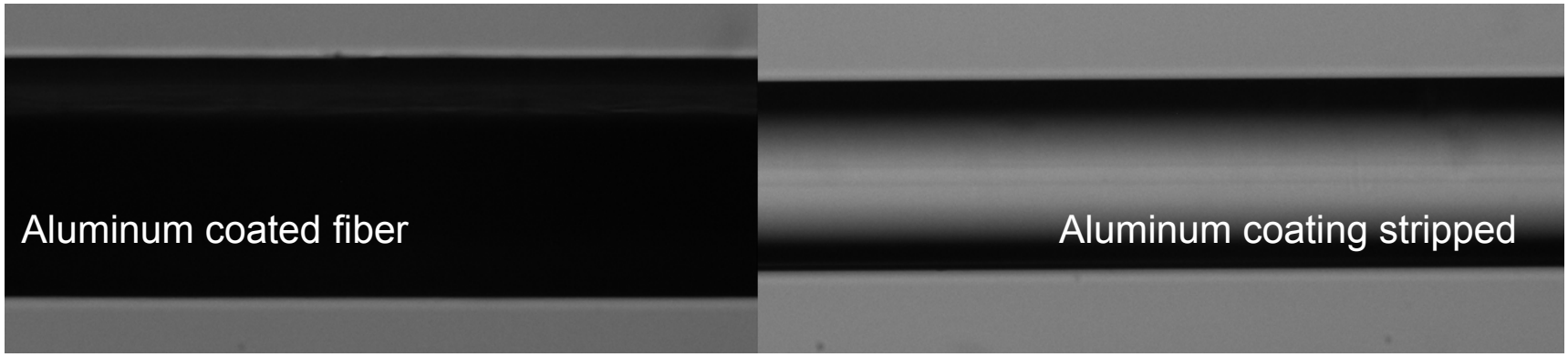
Development of a radiation hardened temperature resistant fiber

- Radiation resistance (up to a few MGy) : pure silica core single-mode fibre
- Temperature resistance (up to 400°C) : aluminum coating



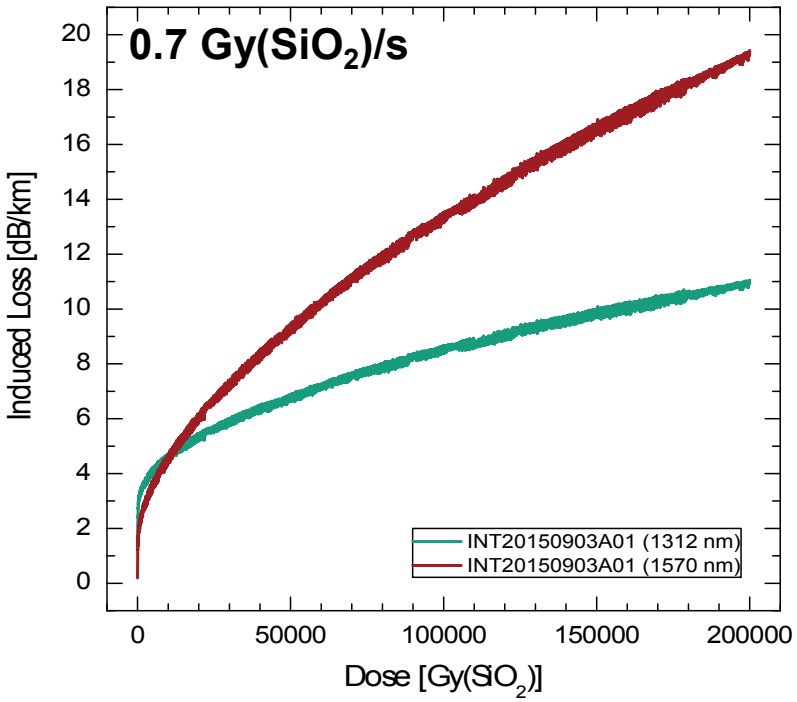
Pure silica core
Fluorine doped cladding
Pure silica external cladding

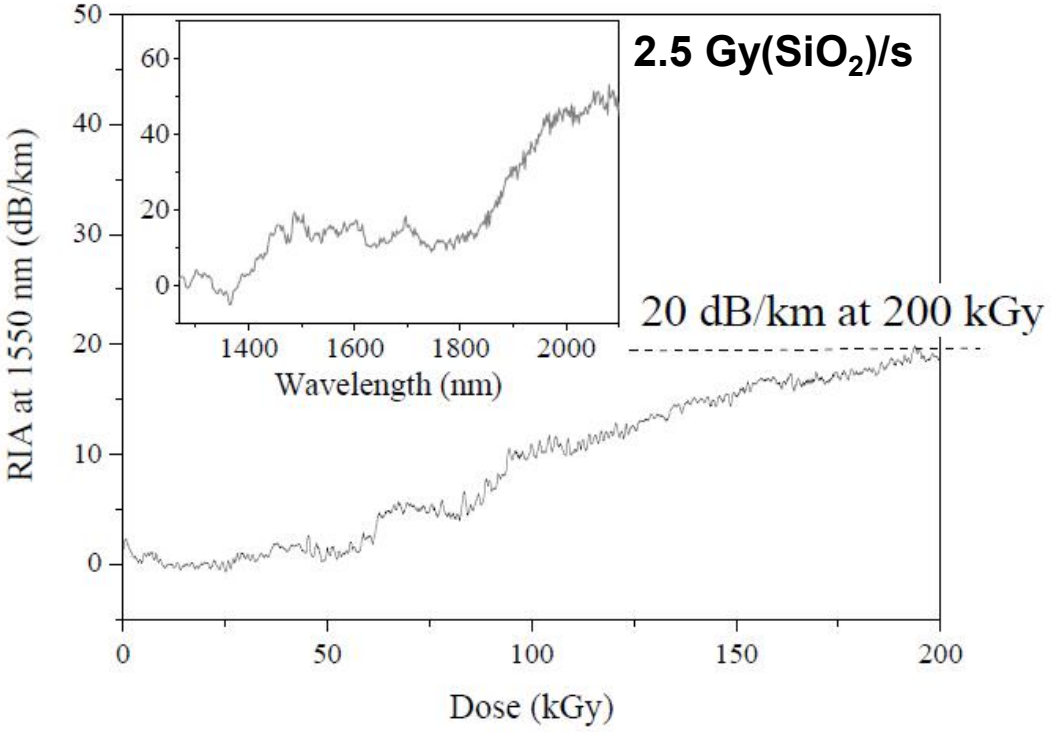
15 dB/km @ 1.55µm
0.1 dB for 1 turn at r=7.5mm @ 1.55µm
3.8 GPa of mean tensile strength



Radiation hardened resistant fiber : impact of total dose at RT

- Irradiation : 1.25 MeV γ-rays **(left)** or 10 keV X-rays at 2.5 Gy(SiO_2)/s **(right)**





- Moderate Radiation Induced Attenuation up to several 100 000Gy

J. Kuhnhenn and al. « γ radiation tests of RH-FBG sensors for radiation environments », submitted to RADECS 2016

A. Morana and al. « RH-FBG sensors for harsh environments », submitted to NSREC 2016

WO2015091502

- “Method for manufacturing a treated optical fiber for radiation-resistant temperature sensor”
- Patent hold by AREVA/Université de Saint-Etienne

Selection of a radiation resistant fiber
(pure silica or fluorine doped core)

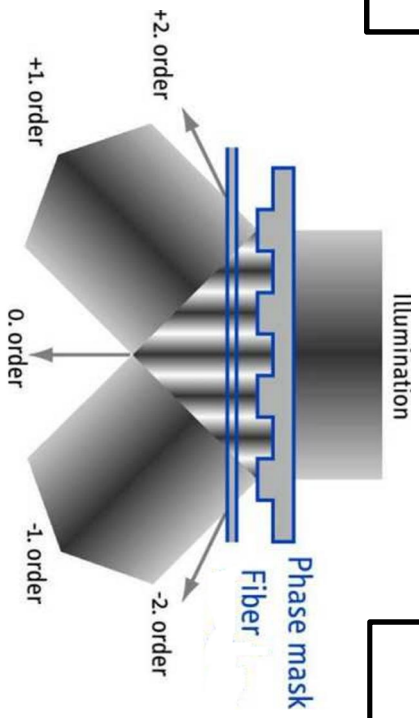
↓

FBG inscription by a femto-seconde laser
(pulse temporal width <150fs)

↓

FBG thermal cycling
(typically at T=750°C for t >15min)

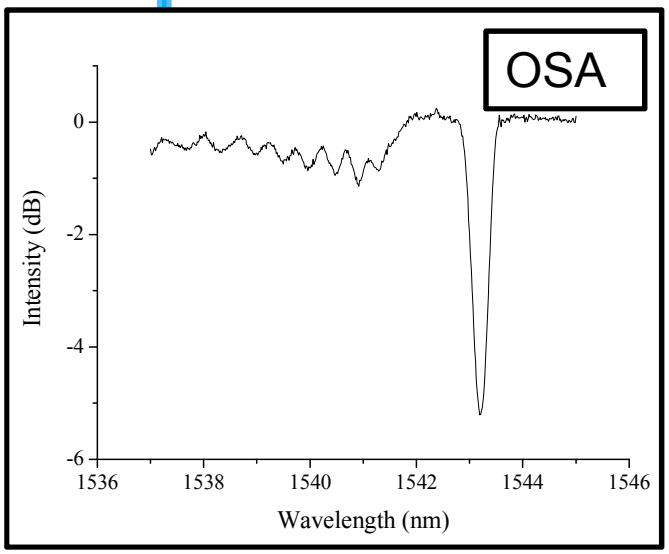
Hardened FBG inscription set-up



Light source

Uncoated fiber
Phase mask
Cylindrical lens

femto-second laser

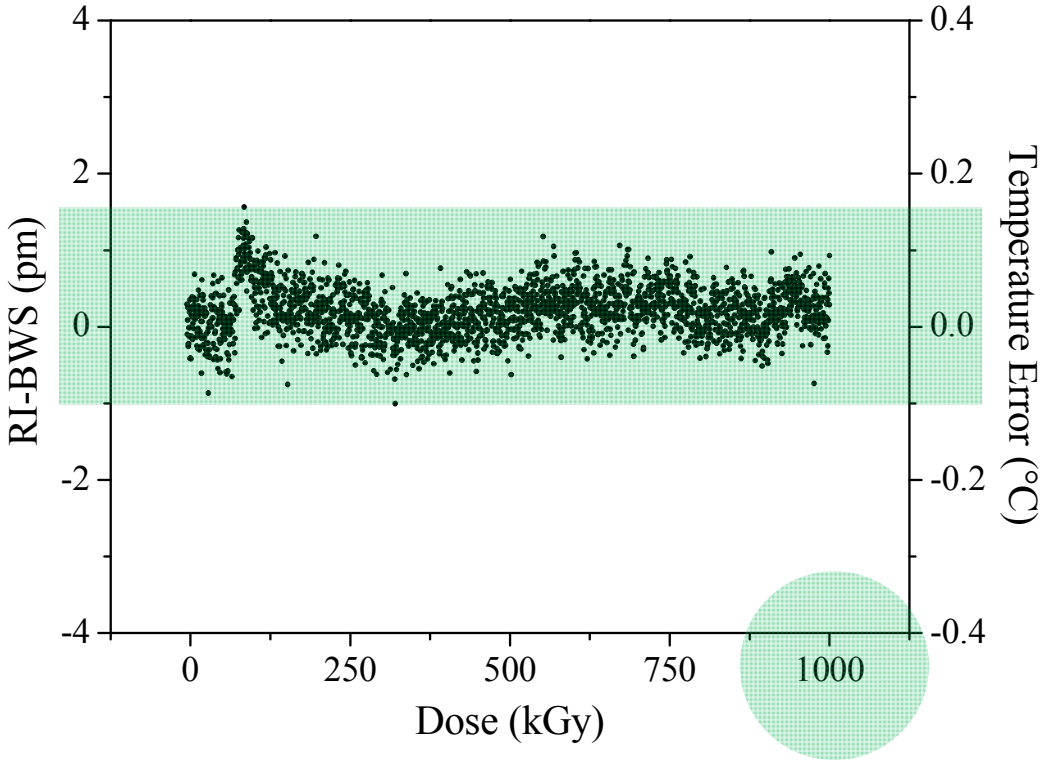


FWHM=0.37 nm

Side lobe suppress ratio = 0.35

FBGs characterization : impact of total dose

- Optimized conditions for FBGs writing (pulse width, scanning frequency,…)
- 10 keV X-rays at 50 Gy(SiO_2)/s
- FBG temperature thermo-regulated at 30°C

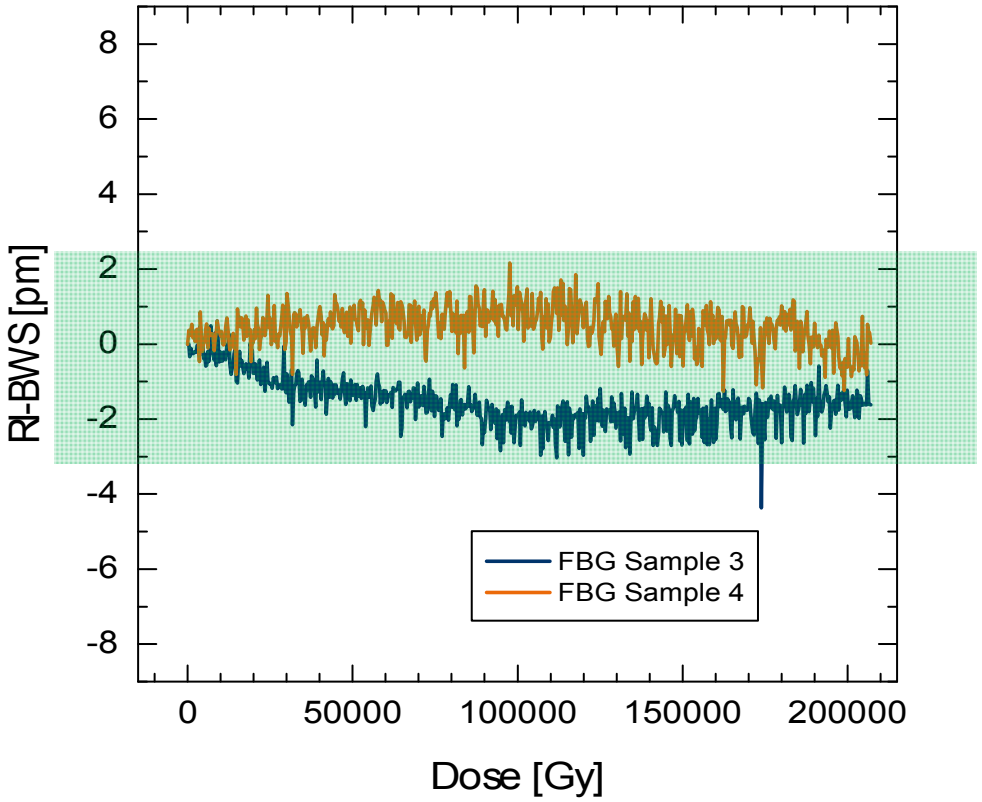


- Almost no Bragg wavelength shift while increasing dose up to 1MGy

A. Morana and al. « RH-FBG sensors for harsh environments », submitted to NSREC 2016

FBGs characterization : impact of total dose

- Optimized conditions for FBGs writing (pulse width, scanning frequency,…)
- ~1.25 MeV γ-rays from ^{60}Co source at 1 Gy(SiO_2)/s
- FBG temperature thermo-regulated at 100°C

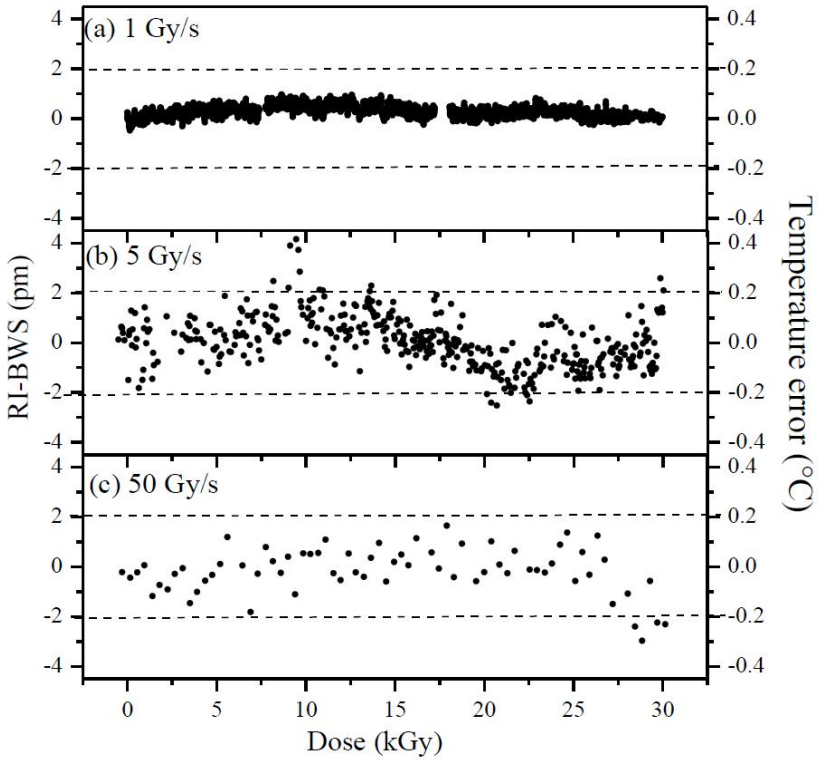


- Almost no Bragg wavelength shift while increasing dose up to 200 000 Gy

J. Kuhnhenn and al. « γ radiation tests of RH-FBG sensors for radiation environments », submitted to RADECS 2016

FBGs characterization : impact of dose rate

- Optimized conditions for FBGs writing (pulse width, scanning frequency,…)
- 10 keV X-rays at 1, 5 and 50 Gy(SiO_2)/s
- FBG temperature thermo-regulated at 30°C



- Almost no Bragg wavelength shift for dose rate from 1 to 50 Gy/s

A. Morana and al. « RH-FBG sensors for harsh environments », submitted to NSREC 2016

HOBAN : status after one year

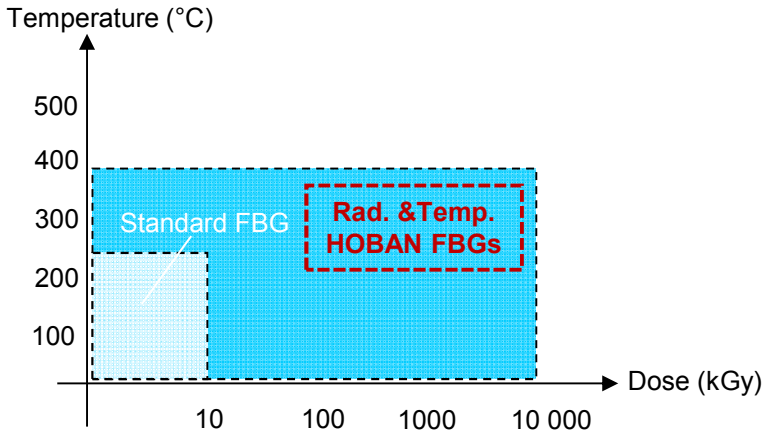
- A radiation hardened monomode optical fiber has been developed in order to withstand high temperature (up to 350°C) and high irradiation field (up to 1MGy over 40 years)

- Numerous parameters related to FBGs writing conditions have been investigated in order to obtain reproducible and optimized properties

- Obtained FBGs exhibit a remarkable stability (maximal temperature uncertainty of +/- 0.2°C) under harsh irradiation environments (up to 1 MGy)

HOBAN : two busy years to come…

- Continue FBGs irradiation tests, in particular at maximal temperature/dose



- Optimize sensor head design, in particular toward temperature versus strain discrimination
- Define and develop suited interrogator and cabling solutions
- Produce a sensors batch, install and test them on the field

Thanks for your attention

www.kic-innoenergy.com

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