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

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“Les capteurs et l’instrumentation à fibres optiques”
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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

\[
\frac{\Delta \lambda_B}{\lambda_B} = a \Delta T + b \varepsilon + c \Delta P
\]

\[ a = \alpha + \xi \]

Response to temperature
\~10 \text{ pm/°C @ 1.55\textmu m}

Response to strain
\~1.2 \text{ pm/ppm @ 1.55\textmu m}

For sensing applications, discriminate temperature & strain is mandatory.
HOBAN: European project funded by EIT via KIC InnoEnergy
“DEVELOPMENT OF HARDENED OPTICAL FIBER BRAGG GRATING SENSORS”

Overall Status

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

Project Coordination and Management

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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

HOBAN at a glance

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 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

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

• Rad. & Temp. hardened FBG Sensors

• FBG sensors & monitoring system
  • Industry business operator

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

• 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 100 000 Gy

*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*
FBG hardening process

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-second 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

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
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 1 MGy 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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