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RÉPUBLIQUE FRANÇAISE
AMBASSADE DE FRANCE EN AUSTRALIE

# Nicolas Baudin travel grant - Internship in France proposal form

** = mandatory fields*

## SECTION 1 : Hosting institution in France

### Hosting institution in France*

| | |
|---|---|
| Name* | University Paris Sud – Univeristy Paris Saclay |

### Hosting laboratory / research team in France

| | |
|---|---|
| Name* | Institut de Chimie Moléculaire et des Matériaux d'Orsay |
| Address* | ICMMO, Bat 410, 91405, Orsay |
| Web site* | http://www.icmmo.u-psud.fr |

### Supervisor of the intern in France

| | |
|---|---|
| Name(s)* | Lancry matthieu |
| Function* | HDR, permanent A/Prof |
| E-mail* | Matthieu.lancry@u-psud.fr |
| Contact ph* | +3319156218 |

## SECTION 2 : Internship offer

**Topic of the internship (title)***

Reliable Fiber Bragg Gratings sensors for extreme environments

**Dates of the internship***
(nb: this program supports 3 to 6 month internships with a starting date earlier than December 31, 2018)

**Start:** (from) 15/09/2018 **End:** (to) 14/02/2018

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**Scientific and academic objectives of the internship***
(detailed description of the internship content, work expected from the intern and expected outcomes)

Fiber Bragg grating (FBG - a spatial modulation of refractive index changes in optical fibres) based sensor technology operating in extreme temperatures is a major technological breakthrough making instrumentation for extreme environments possible. It's development and validation of innovation in a practical application will meet the new needs of the industry, particularly by designing fiber micro-sensors that will be incorporated in specific materials and processes in the areas of engine air carriers (aeronautics, SAFRAN), space (launchers, Eurocryospace) or advanced manufacturing (e.g. 3D laser additive manufacturing of metal and ceramics parts). Having innovative, reliable and robust instrumentation, based on FBGs in optical fibers for measurements of high temperature and strain (thermal measurements and / or mechanical deformations) will be an undeniable asset for industrial programs in the short and medium term. These programs are at the forefront of technological development (e.g. engines of the future, laser assisted 3D synthesis, high power lasers, nuclear plants, steel processing). They require characterization tools that can operate in harsh environments for qualification processes and products. In collaboration with CEA Saclay (focusing on nuclear applications but also fiber sensors generally for extreme environments) and Safran (aeronautic) this overall project will develop Fiber Optic sensors based on FBGs that can operate in extreme environments, especially at high temperatures (700-1500 °C). Following recent developments, these sensors are being developed to measure the temperature and strain in extreme environments. This new fiber Bragg grating technology adds extreme temperature resistance to the intrinsic advantages of FBG-based metrology such as spectral multiplexing capabilities (multiple measurement points on a single optical fiber) and electromagnetic immunity. Ultra-high temperature performance is needed across sectors such as Aerospace (aircraft engines), Advanced Manufacturing (3D laser additive manufacturing metal parts), optics (high power laser), steel and aluminium smeltering industry, nuclear (instrumentation of future reactors) and space (launchers). Two innovating FBGs to solve this high temperature problem now exist: in particular the FBG regeneration process (discovered by our Australian partner) is the only current approach that can enable photonic technologies to operate in such harsh environments at elevated temperatures (standard FBGs do not survive above 600 °C). In the simplest interpretation the regeneration process is the rebirth of a grating that is first annealed out. A second approach would be to take advantage of the selectivity in spatial and time domains that near IR femtosecond lasers offer. In this project, the technology of glass taken for granted in the macro scale will be applied on a sub-micron scale with a degree of unheralded finesse using laser patterning and writing of temperature stable submicronic structures - glass smithing with nanoscale resolution becomes feasible.
Scientific and Technological objectives
(1) Studying and maximizing FBG temperature performance through material control (ICMMO and UTS)
(2) FBG lifetime mastering to get drift-less photonic sensors (ICMMO, UTS, CEA)
(3) Demonstrating and applying the outcomes to practical sensing systems (CEA and SAFRAN).

The project therefore brings together a number of key objectives, which can be summarized as follows: (1) Studying and maximizing FBG temperature performance through material control: The usual dopants like Germanium, Fluorine or Boron in the silica fiber core determine the high temperature processing. Therefore, most commercial optical fibers are not designed for operation above 1000 °C. However, if one examines the melting point of compatible oxides, there is at least one common oxide that raises silica melting point - $Al_2O_3$, which melts above 2000 °C. Alumina doping in the core of a fibre helps to harden the core making it resistant to fibre fuse effects. This task (ICMMO and UTS) will explore mainly the impact of $Al_2O_3$ in $SiO_2$ sol-gel glasses on increasing the processing temperature to equal or surpass that of the pure silica cladding. Recent work has already identified 3 glass vitrification regions for $SiO_2$-$Al_2O_3$ glasses: 0-15% $Al_2O_3$, $50Al_2O_3$-$50SiO_2$ and 60-$70Al_2O_3$. Following this idea, multiphoton FBG writing will also be undertaken by the internship using femtosecond laser facilities at CEA and ICMMO. Our Australian partner J. Canning from UTS has also demonstrated that femtosecond written FBGs can be regenerated and they already have their own high temperature performance. A part of the project aims to undertake a detailed comparison and study between UV regenerated (UTS) and the alternative way based on femtosecond IR writing (CEA) of Bragg gratings. (2) FBG Lifetime mastering to get drift-less photonic sensors (ICMMO, UTS): For such 800-1500 ºC temperatures, actual implementation of the technologies is crucial to properly understand this environment and its demands as much as understanding the component glass performance. To emphasise this point, a long-term assessment of an early regenerated grating has been recently done during 9000h at 800°C. This reveals that much has to progress before the technology is considered for this regime. Accelerated aging experiments will be done during this internship to ensure (lifetime prediction in a reliable manner) long-term operation above 1000 ºC - the aluminosilicate (including $Al_2O_3$ fiber) approach may offer the best solution. A connection between changes in optical properties, structural relaxation and viscous flow will be studied by ICMMO-UTS and used to optimize and predict the thermal and optical resistance of glass technologies in the all-critical industrial 800-1500 °C window. Additionally, we will have to consider the combination of aging and viscous flow, which is an area that demands both fundamental and applied research. (3) CEA will perform genuine long-term tests that evaluate and validate structures in actual working environments. This study may lead to drift-less optical fiber sensors, removing detuning of the sensors that is a major issue for their adoption and deployment by major industrial players and especially in collaboration with SAFRAN.
Expected outcomes: Deployment of FBG high temperature sensors arrays to real life applications requires fulfilling stringent end-user demands. Moreover, efficient solutions must be developed in order to propose femtosecond or UV laser regenerated FBGs as a reliable and mature industrial solution with regard to well-established techniques such as thermocouples. Among the key issues for the deployment of calibrated arrays of high Temperature FBGs, are: i) the availability of collective, ideally internationally recognized, and standardized temperature calibration methods, ii) an efficient process for the regeneration of FBG sensing lines with an arbitrary topology (currently limited by the use of conventional furnaces), iii) better understanding of the regeneration process itself in order to draw silica optical fibres optimizing the regeneration ratio and the thermal stability of the Bragg wavelengths (together with their tolerance to radiation in case of nuclear projects), iv) improvements in stability and v) high temperature coatings able to protect and package the regenerated FBGs.

**Name of industrial partner ***
(participation of an industrial partner is highly recommended)

CEA-LIST in Saclay and SAFRAN

**Main contact at the French industrial partner***

Guillaume Laffont, guillaume.laffont@cea.fr

**Main contact at the French industrial partner's branch in Australia** (if applicable)

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**Role of the industrial partner in the internship project**

The project takes advantage of the CEA LIST world-class facilities dedicated to FBG sensor technologies. At CEA LIST, G. Laffont has built up comprehensive FBG laser writing platforms, and full optical characterization equipment as well as custom built annealing facilities were fabricated for regeneration and post annealing with unprecedented accuracy. One activity of the CEA LIST will focus on highly technological characterizations such as holding in extreme temperature, regeneration and temperature calibration of multiplexed sensors (arrays made of tens of ultra-stable FBG over a single optical fiber) and testing of their response time in temperature. CEA LIST will also study the deployments on such temperature resistant gratings for several demanding applications under study. Qualification campaigns will be performed within high-ends facilities (tokamak, additive layer manufacturing) but also in airplanes engines with SAFRAN.

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**Australian partner university**

| | |
|---|---|
| Is the internship project proposed in the framework of an existing collaboration with an Australian partner university?* | ☒ **YES**<br>☐ **NO** |
| If yes: name of institution | UTS: University of Technology Sydney |
| Name of lab/research team in collaboration | interdisciplinary Photonics Laboratories |
| Main contact | Prof John Canning |
| Function | Cliquez ici pour taper du texte. |
| E-mail | john.canning@uts.edu.au |
| Contact ph | Cliquez ici pour taper du texte. |

## SECTION 3 : Expected profile of applicant

**Level of study ***
(priority will be given to Bachelor's degree Honours students and Master's students)

Master student if possible, if not PhD student

**Discipline***

Solid physics and optical engineering, optical materials and photonics

**Required qualities, knowledge and skills***

High level of experimental and analytical competency, creative, ability to communicate clearly, demonstrate initiative, focus and independent whilst capable of listening, willingness to be cross-disciplinary with particular emphasis on materials, physics and devices. "Adventurous" with an interest in France and Europe and traveling.

**Other specific eligibility criteria ***
(such as citizenship requirements, language requirements…)

Speaking English