SWARM LASER:

QUALIFICATION AND INTEGRATION OF THE OPTICAL FIBRE COMPONENTS.

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INTRODUCTION

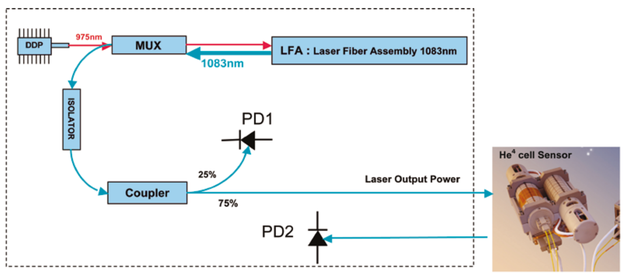
In the frame of the SWARM mission, an Absolute Scalar Magnetometer (ASM) was developed by CEA-LETI in partnership with CNES (Centre National d'études spatiales) for the dynamic measurement of the earth's magnetic field. This magnetometer is based on the principle of pumping a He4 cell by a Laser emitting at 1083nm.

IXSPACE was in charge of:

- The integration of the Ytterbium optical fibre laser used in the SWARM magnetometer [3].
- The optical fibre components selection and procurement for the Laser system.
- The qualification of these components, the manufacturing of two qualification models.
- The manufacturing of the seven Laser Flight Models.

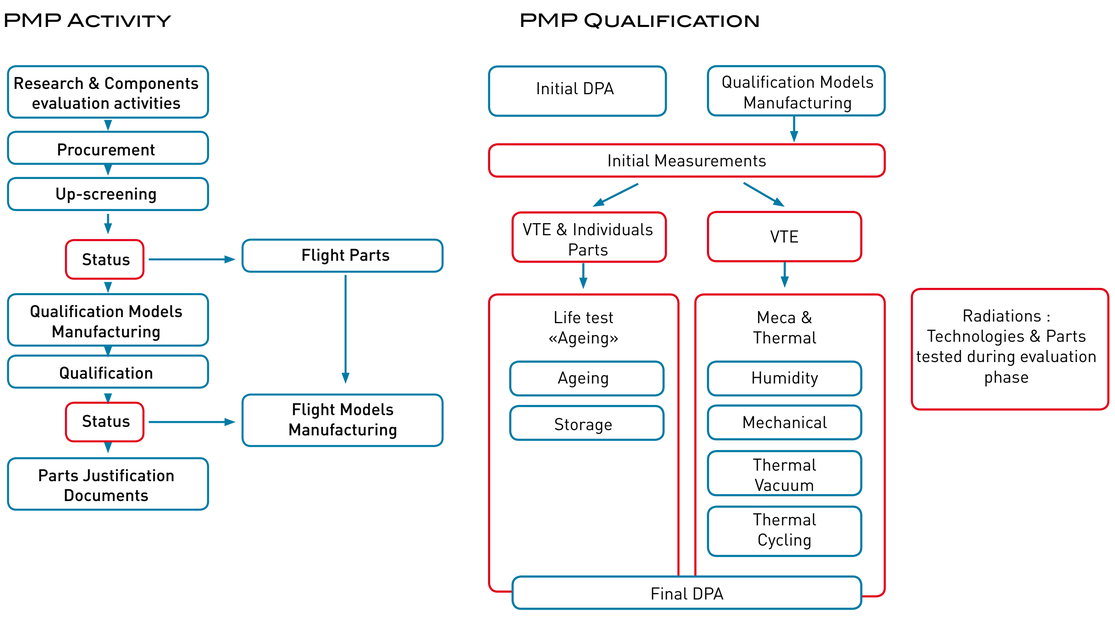
Strongly based on our lessons learned during the Fiber Optical Gyroscope qualification campaign [1] & [2], a specific PMP (Parts, Material and Process) qualification program was carried out.

LASER DESCRIPTION



The Ytterbium optical fibre Laser used for the pumping of the Helium cell of the magnetometer is an athermal Bragg grating photo-written in an active Ytterbium fibre (LFA) [3] manufactured by KOHERAS, a Danish company, and procured by the CEA (Commissariat à l'énergie atomique). A pump Laser diode at 980nm (DDP) is used in the pumping of the LFA through an optical Polarizing Maintaining Multiplexer (MUX). The system comprises also an optical fibre photo-detector for the power feedback (PD1), an isolator for the back reflection, an optical fibre coupler and a second optical fibre photo-detector (PD2) for the sensor return signal from the helium cell.

PARTS, MATERIAL & PROCESS QUALIFICATION APPROACH



UP-SCREENING

Some information about the screening conditions applied by the manufacturer could be collected. Due to "the procurement level" (commercial datasheet or procurement specifications), an "up-screening" has to be done. Table 01 summarizes both the screening and up-screening applied.

	Screening (Manufacturer level)	Up-screening (IXSPACE level)
Pump Laser Diode (Commercial Level & Procurement Specification)	168h @100°C & 650mA burn-in at Laser diode; 100% fine leak test before pigtail; 20 thermal cycles [-40°C;+70°C]	External visual inspection / X-Rays; PIND Test; Thermal Cycling : 10 cycles [-40°C;+85°C]; Burn In : 168h @ 70°C
Photodiodes (Commercial Level & datasheet Procurement)	Information not available (procurement on commercial datasheet)	External visual inspection / X-Rays; Thermal Cycling : 10 cycles [-40°C;+85°C]; Burn In : 168h @ 70°C
Isolators, Multiplexer and Coupler (Commercial Level & datasheet Procurement)	Information not available (procurement on commercial datasheet)	External visual inspection; Thermal Cycling : 10 cycles [-40°C;+85°C]

Tab. 01. Screening and Up-screening applied to the optical components

DESTRUCTIVE PHYSICAL ANALYSIS OF COMPONENTS

External Visual Inspection
MIL-STD-883E, TM2009

Pigtails Fiber Pull
GR-1209-CORE

X-Rays Inspection
MIL-STD-883E_TM2012

PIND Test (Particles detection)
MIL-STD-883E, TM2020

Seal Test
Fine leak : MIL-STD-883E, TM1014, Condition A
Gross leak : MIL-STD-883E, TM1014, Condition C

RGA (Residual Gas Analysis)
MIL-STD-883E, TM1018

Internal Visual & SEM Inspection
MIL-STD-883E, TM2017

Bond Pull Test (wire bondings)
MIL-STD-883E, TM2011

Die Shear Test
MIL-STD-883E, TM2019.5

Tab. 06. Typical Construction Analysis for an active component (Laser module, Photodiodes...)

Pump Laser Diode analysis — X-Rays Inpection — Inside view

Photo-Detector Analysis (PD2) — Inside view of a photo-detector (PD2)

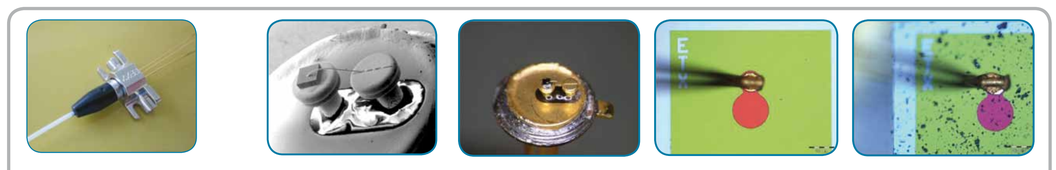


Photo-Detector Analysis (PD1) — X-Rays Inpection — Inside view

External Visual Inspection
MIL-STD-883E, TM2009

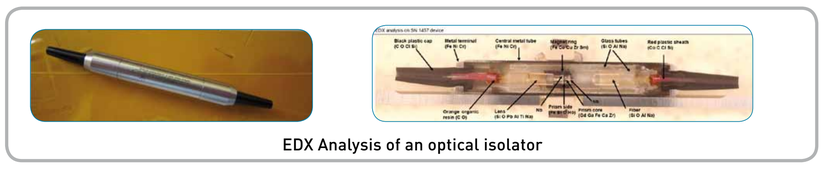
Pigtails Fiber Pull
GR-1209-CORE, 90° Side Pull Test

X-Rays Inspection
MIL-STD-883E_TM2012

µ-sections / Optical & SEM Inspection

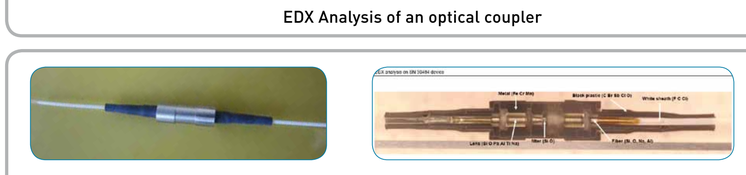
EDX Analysis

Tab. 07. Typical Construction Analysis for a passive component (Isolator, Coupler, Mux...)



EDX Analysis of an optical isolator

EDX Analysis of an optical coupler



EDX Analysis of an optical mux

SUBSYSTEMS QUALIFICATION

Conditions

VTE#1: 1 Damp Heat: 2 Mechanical Random Vibration: 3 Mechanical Sinus Vibration: 4 Test under Vacuum: 5 Atmospheric Temperature Cycling: VTE#2: 1 Ageing: 3000h, 70°C, biased Iop=100mA 2 Storage: 500h, 85°C, unbiased	 744h / 70%RH / 50°C & 168h / 90%RH / 25°C 3 axis, ~20g RMS, 20Hz to 2kHz, 3 axis, [5-20Hz; 11mm], [20-60Hz; 20g] , [60-100Hz; 6g] , [100-125Hz; 3g] 10 cycles, [-20°C;+50°C], ~1°C/min 90 cycles, [-20°C;+50°C], ~10°C/min

Tab. 02. Qualification applied at the sub-system VTE level.

Results

	VTE #1	VTE #2	Qualification Criteria
End of life output power P_{EOL}	$0,89xP_{BOL}$	$0,92xP_{BOL}$	$P_{EOL} > 0,85xP_{BOL}$* *Begin Of Life
Power Stability on 1 hour (dB) *After 1 hour of warm-up*	< 0,4dB	< 0,3dB	< 0,5dB

Tab. 03. VTE: qualification results.

INDIVIDUAL PARTS QUALIFICATION

Radiation Evaluation

Total Ionising Dose (TID)			Qualification Criteria		
TID level (kRad(Si))	Dose rate (rad/h)	Bias conditions	DD level (p/cm^2)	Energy (MeV)	Bias conditions
4	50	«OFF»	$3.6x10^{10}$	60	«OFF»

Tab. 04. VTE: qualification results.

Ageing Qualification Conditions

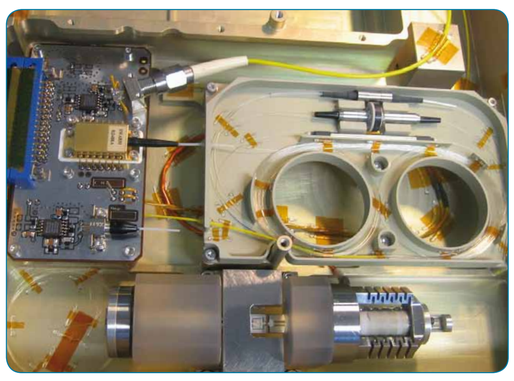
Pump Laser Diodes (DDP x 5) Feedback Photo-detector (PD1 x 1) Sensor Photo-detector (PD2 x 6) Mux + Isolator + Coupler (subsystem x 3)	1 Ageing: 3000h, 70°C, biased Iop=100mA 2 Storage: 500h, 85°C, unbiased

Tab. 05. Qualification applied at the individuals Components.

All the individual parts passed the Ageing Qualification.

CONCLUSION

Both the sub-systems tested (the VTE and the individual components added for the life test), succeeded the qualification requirements making this space qualification campaign a success. These good results have confirmed the capacity of the optical fiber technologies to meet the mission requirements and withstand the very harsh space environment. This qualification campaign allows IXSPACE to deliver in 2010 seven flight models according to the space requirements.



REFERENCE

[1] T. Buret, D. Ramecourt, and F. Napolitano, "From space qualified fiber optic gyroscope to generic fiber solutions available for space application", Proceedings International Conference on Space Optics (ICSO), October 14-17 2008, Toulouse, France

[2] S. Rougelot, S. Mariojouls, T. Buret, D. Ramecourt, and X, Calmet, "Procurement and qualification of optical components for space Fibre Optic Gyroscope application", Proceedings International Symposium on Reliability of Optoelectronics for Space (ISROS), May 11-15 2009, Cagliari, Italy

[3] J.M.Leger et al, "Athermal Fiber Laser for the SWARM Absolute Scalar Magnetometer", International Conference on Space Optics 2010 (ICSO), October 4-8 2010, Rhodes, Greece

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