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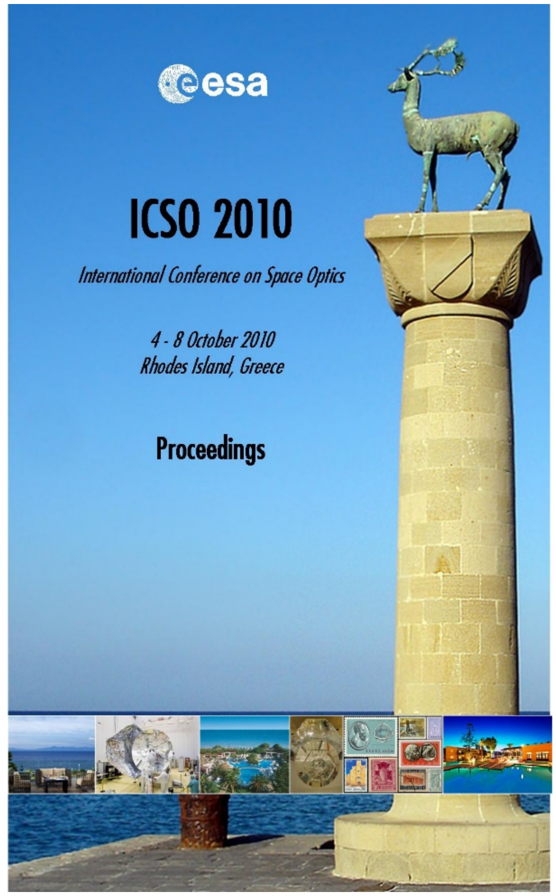

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SWARM LASER: QUALIFICATION AND INTEGRATION OF THE OPTICAL FIBRE COMPONENTS.

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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 He^4 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, the optical fibre components selection and procurement for the Laser system, as well as the qualification of these components. IXSPACE has manufactured the engineering model, the two qualification models as well as the seven Laser Flight Models.

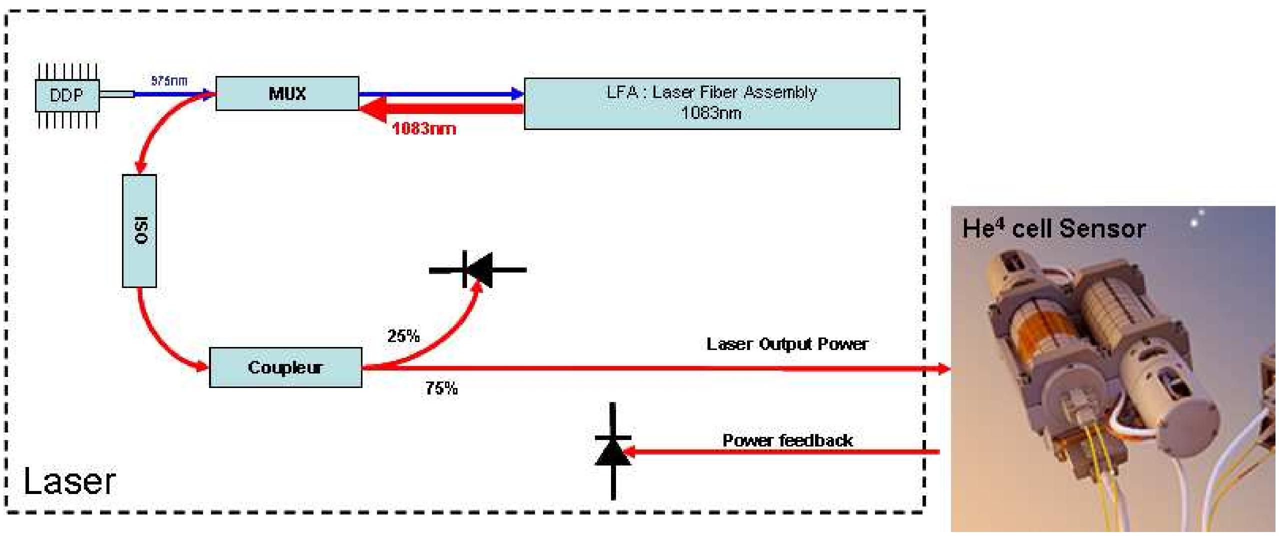

Fig. 1. Laser SWARM configuration

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

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

I. PMP APPROACH

IXSPACE collaborated with the CNES and the CEA to define precisely the qualification program for the optical fibre components (see figure 2). A Parts Materials and Process activity plan was written. This PMP plan covers all the activities of procurements, qualification and rules to apply in case of non conformity during the program.

The qualification in radiation was achieved during the evaluation phase. The parts were individually tested. The table 1 summarizes the test conditions that cover the mission requirements.

Total Ionising Dose (TID) Test Conditions			Displacements Damage (DD) Conditions		
TID level (kRad(Si))	Dose rate (rad/h)	Bias conditions	DD level (p/cm²)	Energy (MeV)	Bias conditions

4	50	"OFF"	$3.6x10^{10}$	60	"OFF"

Tab. 1. Total Ionising Dose Test and Displacement Damage Test Conditions

The philosophy of this qualification is to test sub-systems instead of individual components. The advantages of this approach are:

(1) To test very finely the influence of the environment directly on the sub-systems (VTE: Véhicule de Test). The evolutions can be more easily detected on a Laser sub-system than on the component itself.

(2) To test the optical components in real conditions of use.

(3) To combine on a single sub-system the different constraints of the mission following a file of environmental tests that simulates a part of the profile of life of a flight system.

(4) To be able to accept evolutions on a component by proving that it has no effect on the Laser sub-system level.

(5) To qualify the materials and the processes at the same time as the components.

Some individual components will also be tested in order to complete the ageing qualification (see the section III. COMPONENTS AGEING QUALIFICATION).

The figure 2 left describes the PMP activity, with successively: research and evaluation of several references of components. After the selection, procurement is done and all the parts are "up-screened". Several parts are selected for the qualification and the other ones for the flight models.

If the qualification is successful, the flight models are manufactured. For the complete traceability, a justification file is created for each component.

The figure 2 right describes the major qualification paths.

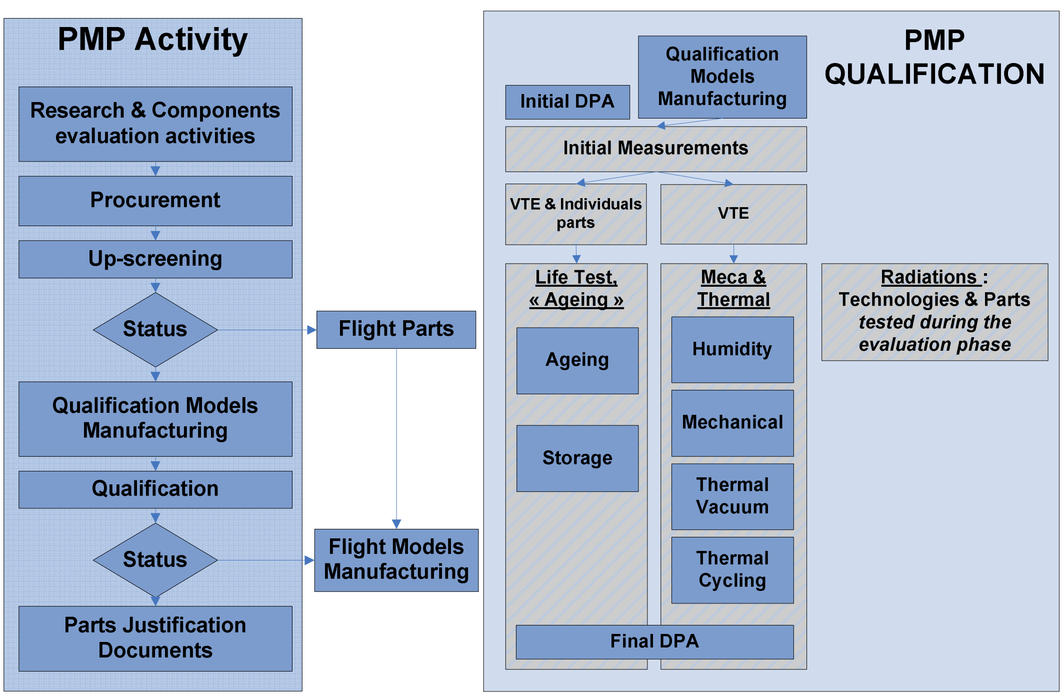

Fig. 2. General Flowchart : PMP Activities & Qualification

II. SCREENING

The optical fiber components have been procured screened by the manufacturer. During this procurement phase, some information about the screening conditions could be collected. For each component, the screening applied by the manufacturer depends of the type of component. Due to the procurement level (commercial datasheet or procurement specifications), a "up-screening" has to be done. Table 2 summarizes both the screening tests performed by the manufacturers, and then, the additional up-screening done by IXSPACE.

	Manufacturer Screening	**Up-screening**
Pump Laser Diode	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	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
Passives components (Isolators, Multiplexer and Coupler)	Information not available (procurement on commercial datasheet)	External visual inspection; Thermal Cycling : 10 cycles [-40°C;+85°C]

Tab. 2. Screening and Up-screening applied to the optical components

For the photodiodes and the passives components, the information lack is due to the commercial level procurement of these parts. Concerning active components, the purpose of X-rays examination is to none destructively detect defects within the sealed case and internal anomalies such as foreign materials, particles, improper interconnecting wires, and voids in the attach material.

The PIND test is specially applied to the pump laser diode to detect the free particles. Without pre-encapsulation inspection, a PIND Test is mandatory due to the criticism of defect occurred by a free particles inside the module. The purpose of the burn in and the temperature cycling is respectively to test the robustness of the die and the assembly of the components.

III. COMPONENTS AGEING QUALIFICATION

The Ageing qualification program is based on the knowledge and the data collected during the procurement and evaluation phases. The duration of the life test has to cover the total mission time. The Arrhenius law is used (see [2])

$$AF = e^{\frac{E_a}{k}\left(\frac{1}{T_{j_{Use}}}-\frac{1}{T_{j_{Test}}}\right)} \qquad (1)$$

With:

AF: Acceleration factor
Ea: failure mechanism activation energy
k: Boltzman's Constant (8.6171E-5 eV)
T_{jUse}: use environment junction temperature (°K)
T_{jTest}: test environment junction temperature (°K)

The knowledge of the Energy of activation (Ea) for each part permits to define the total time and the number of components necessary to cover the 4.25 years of the mission. The table 3 summarizes the number of parts with the following conditions of qualification: test temperature=70°C; Ageing time=3000h and all parts biased in the nominal mission conditions.

	Accelerator factor	**Number of parts tested during 3000 h @ 70°C for a MTTF > 4.25 years**	**MTTF (years) covered by 3000 h @ 70°C**
Pump Laser Diode	**8.5**	**4**	**5**
optical fibre photo-detector for the sensor return signal	**4.8**	**6**	**4.26**
optical fibre photo-detector for the power feedback	**87**	**1**	**12.9**

Tab. 3. number of parts for the qualification

It was decided to use a representative Laser for this ageing qualification path (VTE), and several components to complete the necessary total number (see Tab.3).

A. Individual Pump Laser Diodes Results

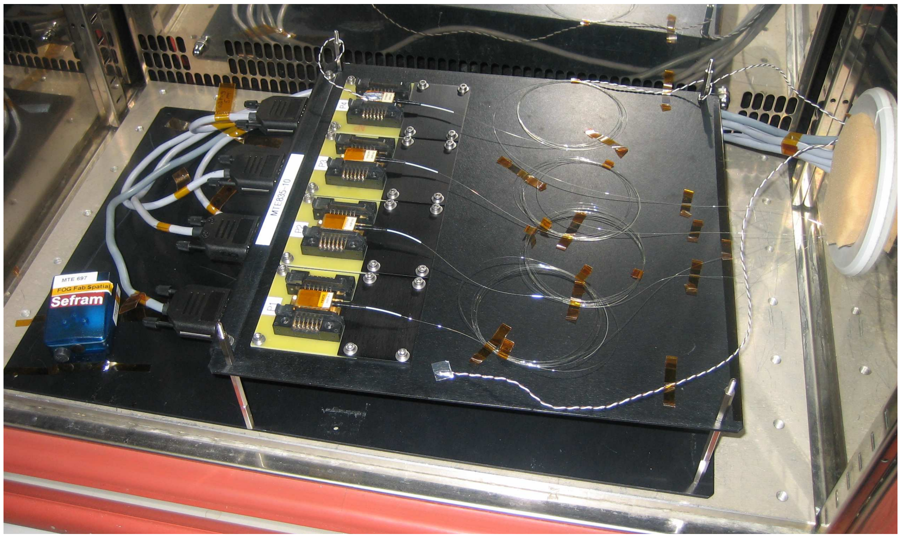

Fig. 3. Pump Laser Set-Up

	Qualification Results **after 3000h of life test (70°C / Iop=100mA) & 500h of storage (85°C, “DDP off”)**	**Qualification Criteria**
Max Threshold current I_{th} (mA)	12mA	< 50mA
Drift Ith (%)	No drift measured	< 15%
Max Operational Current I_{op} (mA)	110mA	< 200mA
Max Drift efficiency (%)	8 %	< 10%
Emission Wavelength (nm)	974,85 nm < $\lambda_{operational}$ < 975,25 nm	974,5 nm < $\lambda_{operational}$ < 975,5 nm

Tab. 4. Pump Laser Diode Results

Four laser pump modules were individually tested in life test (@70°C during 3000h / 100mA) and storage (@85°C during 500h). The measurement of the principal parameters (see table 4) showed a nominal operation after this qualification.

IV. SUB-SYSTEMS QUALIFICATION

Two qualification models were manufactured (sub-systems VTE) and the different environmental constraints were combined through two files of tests. The first VTE was submitted to the thermal and mechanical tests, and the second one to the ageing and storage tests. All the tests are described in the table 5.

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

Tab. 5. Qualification applied at the sub-system VTE level.

The table 6 summarizes the results. P_{BOL} and P_{EOL} are respectively the output power of the Laser at the Begin Of Life and at the End Of Life.

The two VTEs show a nominal operation after the qualification.

	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. 6. VTE: qualification results.

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.

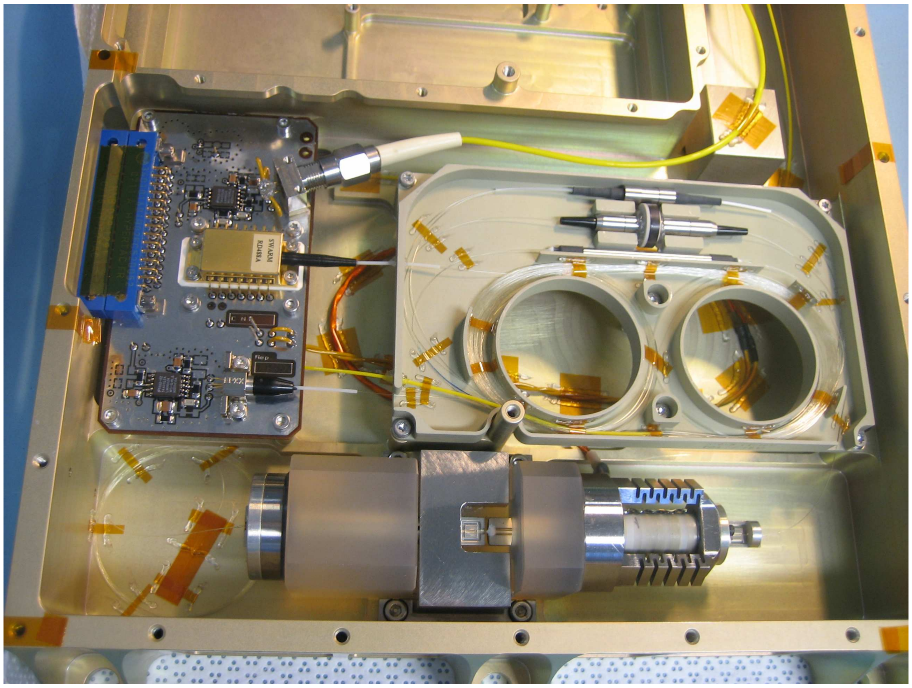

Fig. 4. SWARM Laser, IXSPACE flight model

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