Space Qualification of Laser Diodes

Stéphanie Minec-Dubé
(stephanie.minec-dube@sodern.fr)

www.sodern.com

ESA-NASA Working Group in Optoelectronics
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SUMMARY

- **EADS-SODERN Activities**
- **Laser Diodes Applications: ATV-VIDEOMETER and PHARAO**
- **Laser diodes validation approach**
- **Evaluation Flowchart**
- **Control and E/O characterizations performed**
- **Failures observed:**
  - ✓ Indium soldering defect
  - ✓ Package Induced Failure
- **Conclusion**

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EADS SODERN

- **Created in 1962**
- **Shareholders :**
  - EADS Space Transportation 90%
  - AREVA (French Atomic Energy Agency) 10%
- **380 employees (out of which 270 hold engineering and technical degrees)**
- **Turnover (FY 2005) €50 Millions**
- **Certified ISO 9001 (2000 version) in 2002**
- **Business Distribution :**
  - Space & Optics: 70%
  - Neutron : 30%

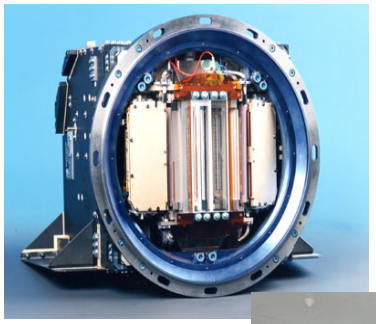
EADS-SODERN Space Activities

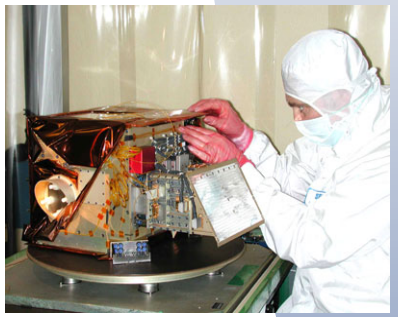
Attitude Control
- Star Trackers
- Earth Sensors
- Optical Rendez-vous Sensors

Earth Observation
- Cameras & Global Monitoring Equipment
- Detection Units
- Infrared Imagers

Scientific Instrumentation
- Micro-Gravity experiments
- Deep Space exploration
- Mars exploration

Defence Optronics





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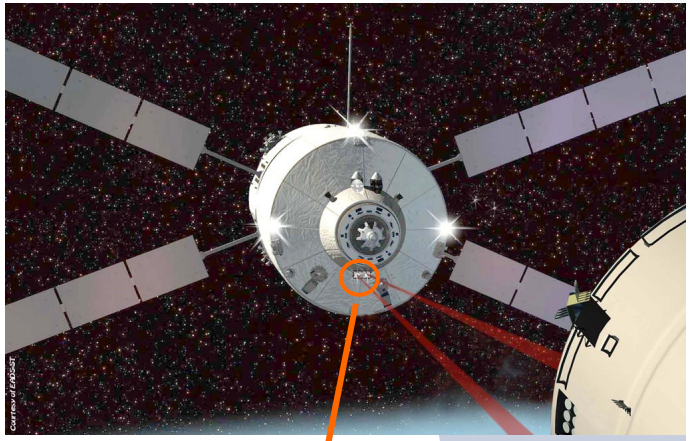
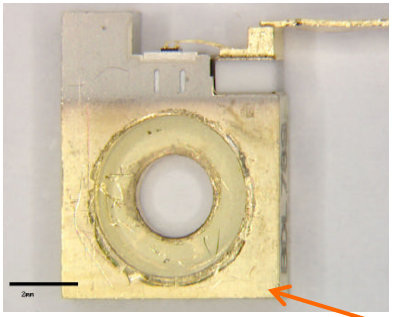
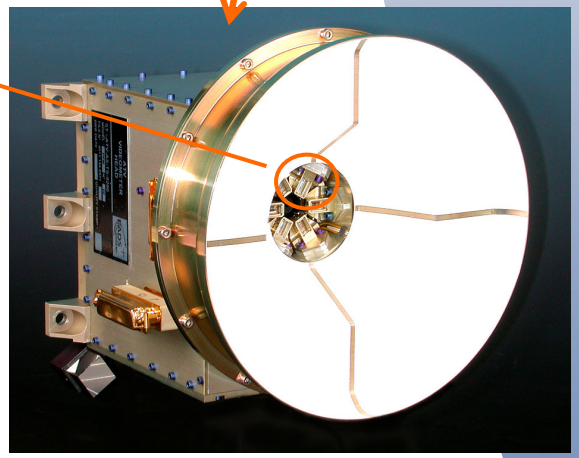
Laser Diodes Application : Videometer for ATV (European Automatic Transfer Vehicle)

- Optical "Rendez-Vous" sensor for the docking of the ATV to the ISS
- The laser diodes beams illuminate the Rendez-Vous Target (RVT) mounted on the ISS and composed of laser retro-reflectors. Reflected light towards the VDM is detected and analyzed
- 6 laser diodes per model
- Characteristics
  - ✓ Laser diode on **submount**
  - ✓ Fabry-Perot laser diode
  - ✓ AsGa/AlGaAs
  - ✓ **810nm**
  - ✓ **multimode**
  - ✓ 2W optical power
  - ✓ Modulated emission(10% DC maximum)
  - ✓ Au-Sn soldering
- Progress of the project
  - ✓ Laser diodes **successfully qualified**
  - ✓ Videometer Qualification model delivered
  - ✓ First Flight Models delivered



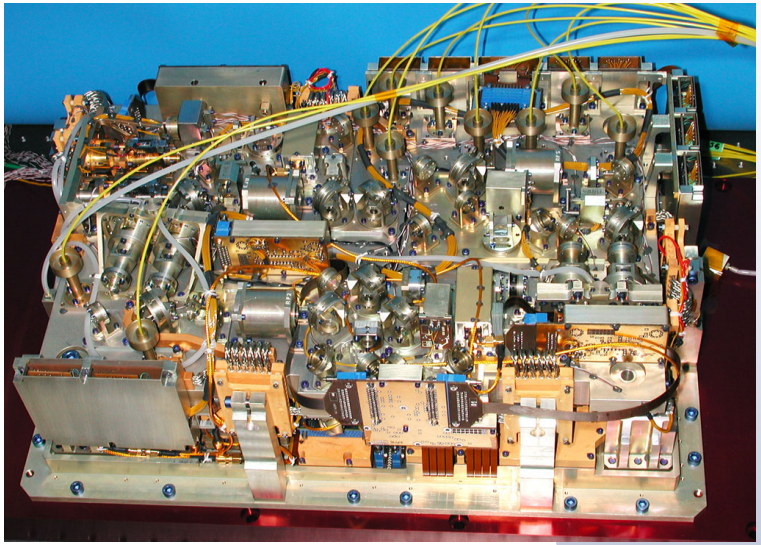


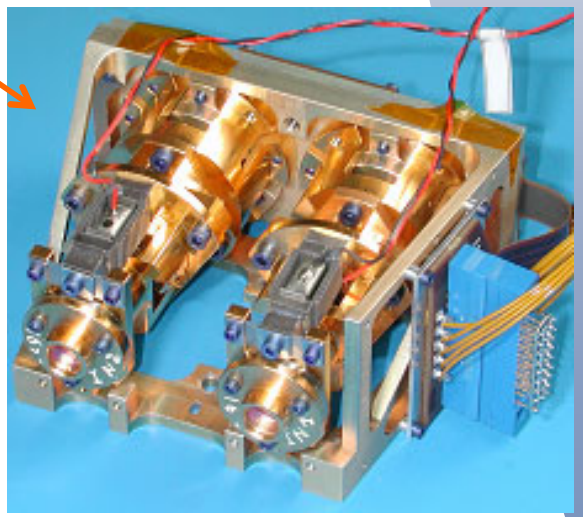


Laser Diodes Application: PHARAO atomic clock

- Scientific program under CNES contract
- Development of the laser diodes in charge of EADS-SODERN with the support of the CNES specialists (O. Gilard and G. Quadri)

- A cesium clock to fly aboard the ISS
- The Laser Source provides laser beams to perform
  - ✓ Optical capture
  - ✓ Selection of Cesium atoms
  - ✓ detection
- Laser diodes are used in Extended Cavity Laser Diode
- 8 laser diodes per model
- Characteristics
  - ✓ Fabry-Perot laser diode
  - ✓ AsGa/AlGaAs
  - ✓ **852nm**
  - ✓ **singlemode**
  - ✓ 150mW optical power
  - ✓ Continuous emission
  - ✓ EM packaging : submount
  - ✓ FM packaging : hermetic package
- Progress of the project
  - ✓ Engineering model delivered in March 2006
  - ✓ Up-screening and qualification of the Flight models laser diodes in progress





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Context at the beginning of the projects

- For PHARAO and Videometer, as for other programs , EADS-SODERN has designed and made space equipments using COTS active/passive key components

- Use of commercial component may be a cost effective solution
- But, following aspects must be treated appropriately
  - ✓ Selection of the technology and the manufacturer
  - ✓ Evaluation of the space environment integrity
  - ✓ Screening and LAT to be performed on Flight Models
  - ✓ Implementation of Laser diodes (temperature, packaging, …) in the equipment

- Laser diodes market
  - ✓ Small quantities (modest budget compared to telecom market)
  - ✓ No qualified components (space or Telcordia)

Description of the proposed approach

- Re-using expertise and know-how in component development plan

  ⇒ Validation in different steps:

1. Selection of appropriate manufacturers according to data-sheets (parameters, flexibility)
2. Procurement of commercial devices from the different selected manufacturers

   (2 for ATV-Videometer)
3. Pre-Evaluation (Environments and E/O tests) ⇒ select a manufacturer
4. Evaluation of the selected manufacturer
   - ⇒ validation of the manufacturer and the possible use of this device for space application
   - ⇒ Taking into consideration for the system the results of E/O performances in operating conditions
   - ⇒ Define the screening and LAT to be performed
5. Procurement of Flight Models Laser diodes (same production lot)
6. Up-screening
7. Lot Acceptance Tests (similar to Evaluations Tests)

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Evaluation Flowchart

Construction Analysis
-Visual inspection
-Materials Analysis
-Pull-test on the bondings
-Die-shear of the laser chip
-Micro-section of the die

1 device

Manufacturer Assessment

+ 2 witness devices

Environmental Tests

Control (visual and E/O)

Moisture Tests
3 devices

Thermal Tests
3 devices

Mechanical Tests
Sine and random vibrations and mechanical shocks
3 devices

Control (visual and E/O)

Endurance Tests

Control (visual and E/O)

Life-Tests
Stressed on t° and current
1500h minimum
4 devices

Life-Tests under vacuum
Stressed on t° and current
1500h minimum
3 devices

Control (visual and E/O)

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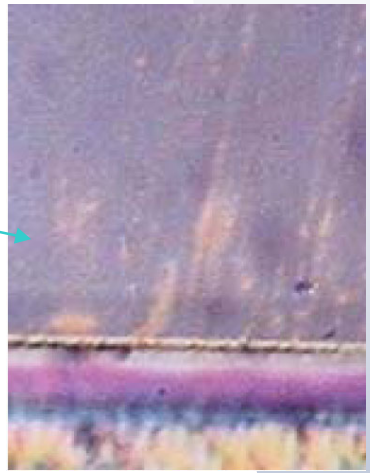
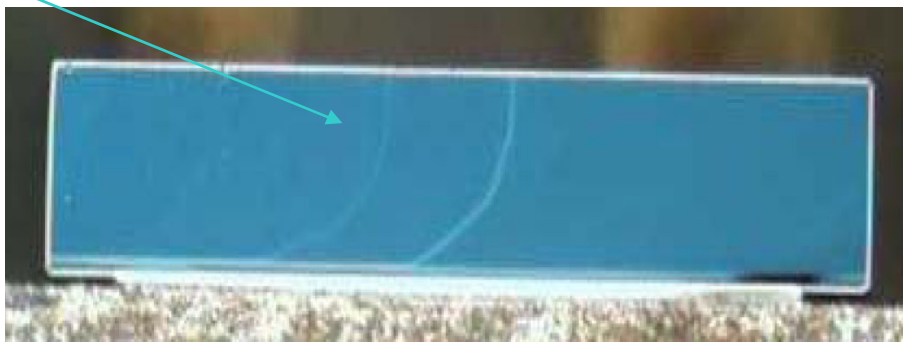
Control during tests

- Visual inspection of the die in particular the critical area which surround the emission area
  - ✓ Discoloration
  - ✓ Contamination
  - ✓ Mirror coating defect
  - ✓ Striation





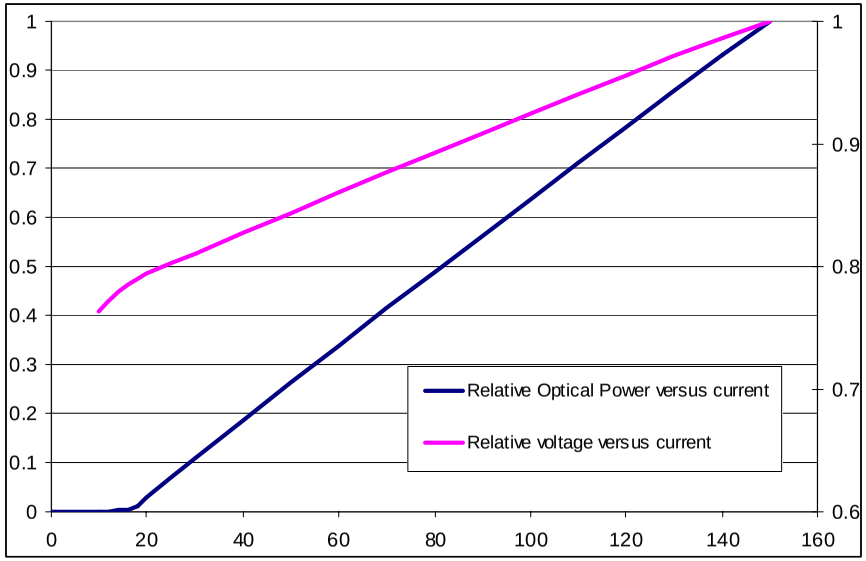
- E/O characterizations to check any drift

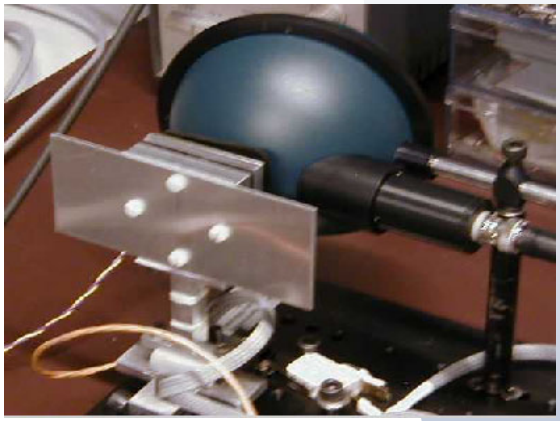
E/O Characterizations performed (I)

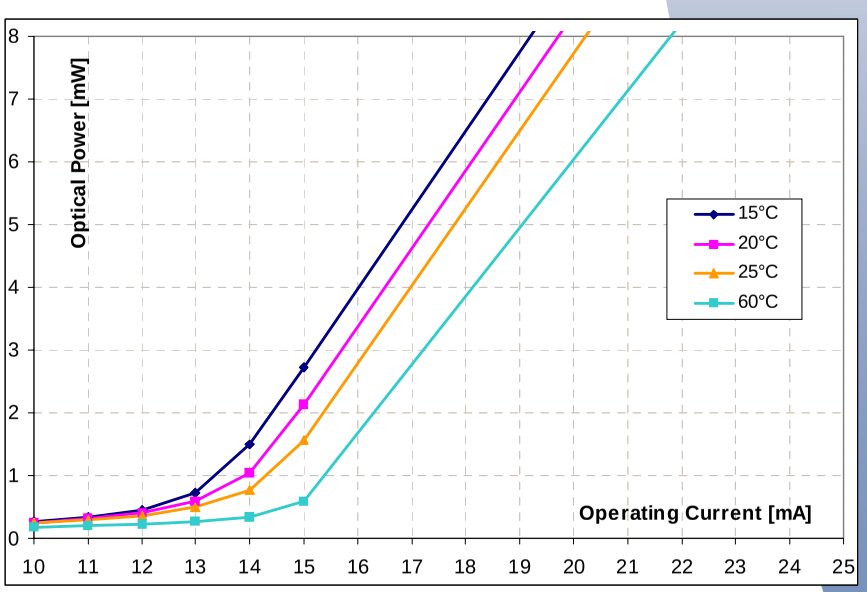
- Development of specific test benches for E/O characterizations
  - ✓ Optical power
  - ✓ Voltage
  - ✓ Emission Spectrum
  - ✓ Farfield intensity pattern
- Development of specific test benches for environmental tests
- Adaptation of the E/O facilities according to the project needs
  - ✓ Temperature (wavelength shift)
  - ✓ Continuous or modulated current
  - ✓ Stability of the farfield

E/O Characterizations performed (II)

- Characterizations of the Optical power and Voltage
  - ✓ Versus current, temperature, modulations
  - ✓ Important drift of the threshold current versus t°

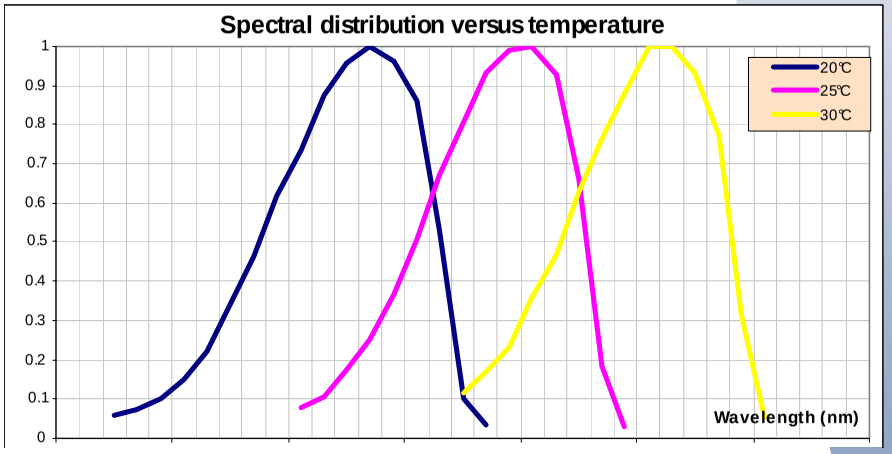






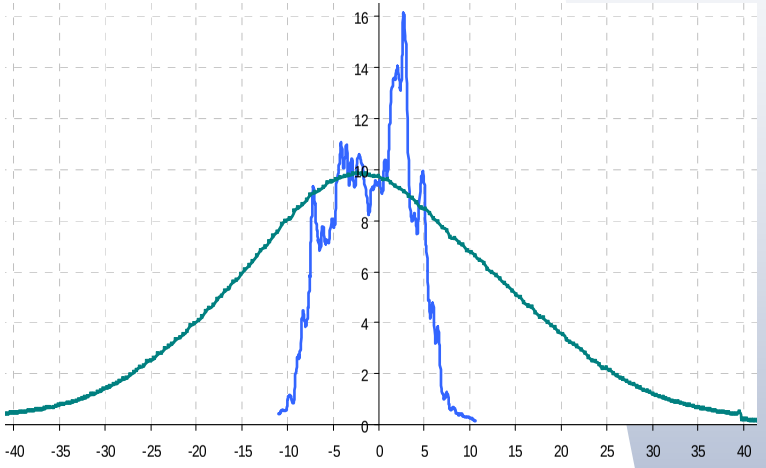
E/O Characterizations performed (III)

- Characterizations of the emission spectrum
  - ✓ Versus current, temperature, modulations
  - ✓ Important drift of the wavelength versus these parameters
  - ✓ **~0.3nm/°C** measured, in accordance with the AsGa material

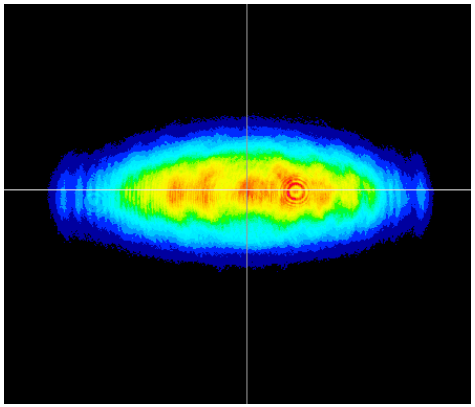


E/O Characterizations performed (IV)

- Characterizations of the farfield pattern
  - ✓ For multimode laser diodes
    - Absolute intensity in the 2 axes: parallel and perpendicular to the junction
    - versus current and temperature
    - And characterizations of the temporal stability



  - ✓ For singlemode laser diodes
    - Cartography of the diodes



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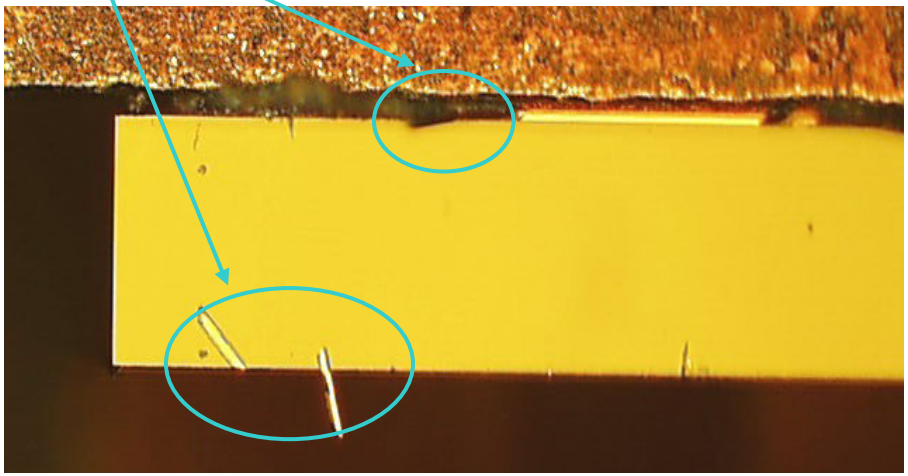
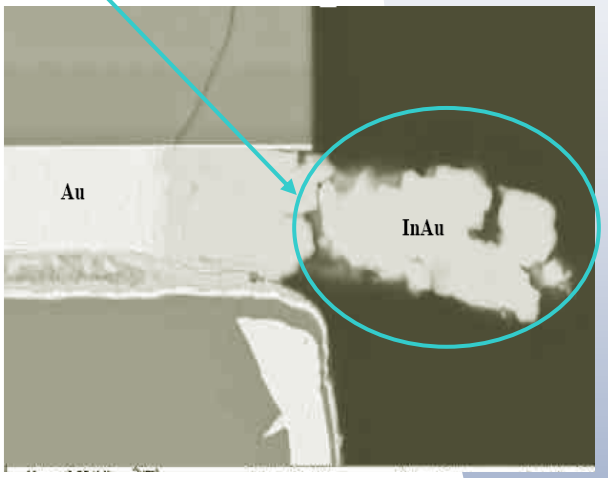
Failure observed : soldering defect

- **Indium Soldering defect**
  - ✓ Overflow of the soldering because of creation of **Au-In intermetallic**
  - ✓ Chipouts which could detach





⇒ **Indium soldering to be avoid for space applications**

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Failure observed: PIF (1)

- Package Induced Failure (=PIF)

In presence of **organic compounds** closed to the laser and in **lack of oxygen** and when the diodes are in **operating mode**

⇒ **carbon deposition** in the emission area

⇒ Up to thermal runaway

⇒ Up to a rapid and very important loss of the optical power

Failure observed: PIF (2)

- PIF was assessed by EADS-SODERN on the two types of laser diodes
  - ✓ 852nm 150mW
  - ✓ 810nm 2W

- See even at ambient temperature

- Lifetime without failure dependant of the tests conditions: could be in less than 100h

- Dependant of different factors
  - ✓ **Optical power density**: current, temperature and modulation
  - ✓ **Packaging**: presence of organic compounds
  - ✓ Oxygen partial pressure

Failure observed: PIF – Conclusion (3)

- To prevent PIF, EADS-SODERN suggests to evaluate laser diodes in the **conditions as close as possible to the flight model conditions**
  - ✓ **optical power density** (current, temperature, modulation)
  - ✓ pressure
  - ✓ **packaging**
  - ✓ during more than 1000 hours

- In case of non compatibility of the diodes in the conditions of the program under vacuum, the solution is to use or develop a specific **hermetic** package

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- Overview of PHARAO and Videometer projects
  - ✓ VIDEOMETER : First Flight Models delivered
  - ✓ PHARAO Source Laser: Engineering Model delivered
- Capability of laser diodes proved for space applications
  - ✓ Indium soldering to be avoid
  - ✓ Concern of the vacuum sensitivity to be taken into consideration
- Large scale of possible missions
  - ✓ Lateral sensor for formation flights