Space Qualification of Laser Diodes

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

www.sodern.com

ESA-NASA Working Group in Optoelectronics
21-22 June 2006
• 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
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
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
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
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
  - 810 nm
  - 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
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
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)
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
**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

+ 2 witness devices

- **Environmental Tests**
  - Moisture Tests
    - 3 devices
  - Thermal Tests
    - 3 devices
  - Mechanical Tests
    - Sine and random vibrations
    - Mechanical shocks
    - 3 devices

- **Endurance Tests**
  - Life-Tests
    - Stressed on $t^°$ and current
    - 1500h minimum
    - 4 devices
  - Life-Tests under vacuum
    - Stressed on $t^°$ and current
    - 1500h minimum
    - 3 devices

- **Manufacturer Assessment**

**Control (visual and E/O)**
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
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 $t^\circ$

![Graph showing optical power and voltage versus current with temperature as a parameter.](image)
E/O Characterizations performed (III)

- Characterizations of the emission spectrum
  - Versus current, temperature, modulations
  - Important drift of the wavelength versus these parameters
  - $\sim 0.3\text{nm/°C}$ 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
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
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 avoided for space applications
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
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.
SUMMARY

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

- 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