Qualification strategy for high reliability submarine .98µm pump laser module

jean luc goudard, Avanex France, Nozay 91

AVANEX®

UNLEASH THE POWER OF THE OPTICAL LAYER

Summary

- **Introduction**
- Qualification approach
- Laser chip qualification
- Sub component qualification
- Module qualification
- Conclusions

Introduction

- Submarine networks requires very high reliability :
  - Difficulties and cost to repair
  - Traffic rerouting
- Reliability requirements :
  - For the whole link level (Trans-pacific link for example) :
    - < 2 failures in 25 years
  - At the pump component level (including repeater redundancy)
    - < 100 FITs (95% UCL) – 25 years
- A strategy to achieve such high reliability has been developed at Avanex.

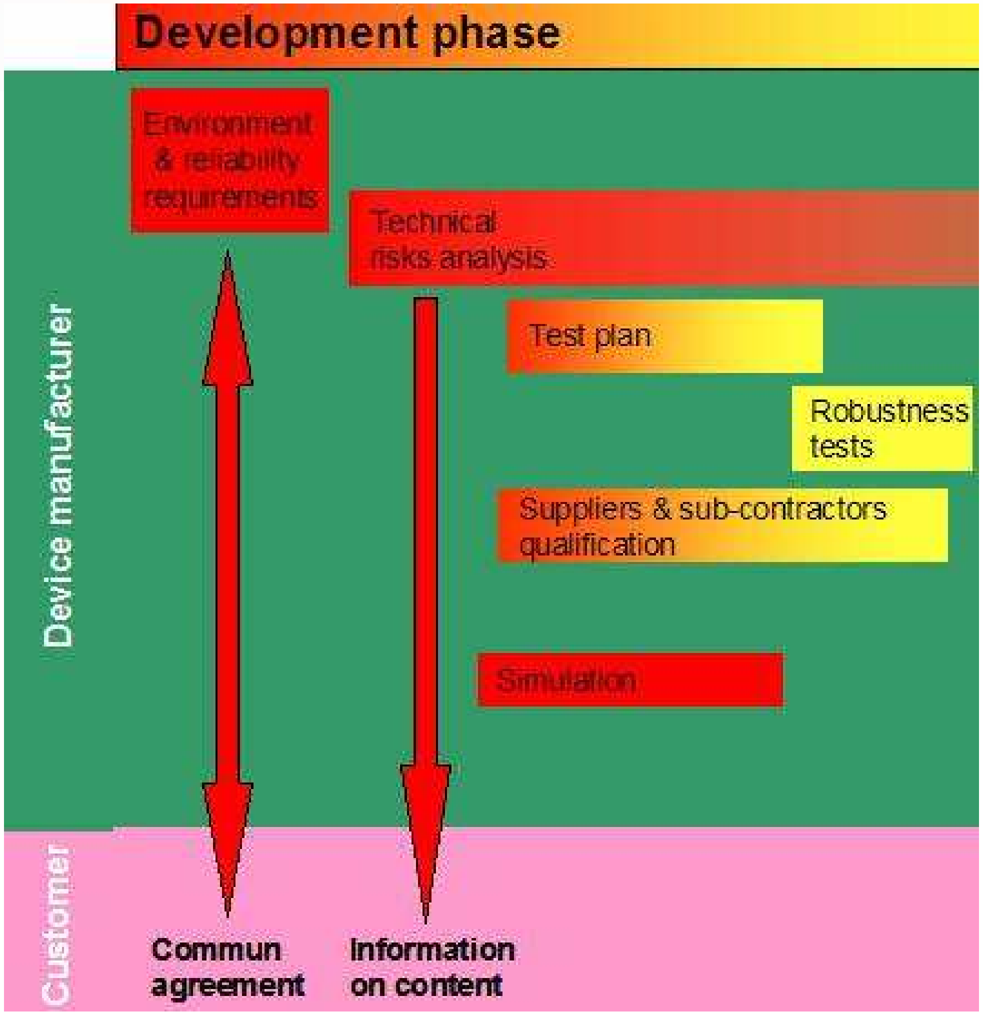
Summary

- Introduction
- **Qualification approach**
- Laser chip qualification
- Sub component qualification
- Module qualification
- Conclusions

Qualification approach

- Mainly develops for terrestrial application
  - time to market reduction
  - cost reduction
  - first steps in the development phase are usable for high reliable applications
    - risk analysis and risk assessment

Qualification approach



Qualification approach

- This qualification approach takes into account the reliability target at the early stages of the development process.
  - Good knowledge of customer’s environmental requirements.
  - Risk analysis and associated test plan
  - Robustness tests
- Other steps of this process, implemented in the manufacturing phase will be not described here.

Qualification approach

◆ Risk analysis

- Review by the project team : including Product Design, Reliability and Engineering.
- Based on
  - Preliminary bill of materials
  - Preliminary flow chart
- Each step of the process is evaluated based on previous experience and knowledge.
- This is an iterative process,
  - each time the process is modified, risk analysis is performed again
- A ranking process is used in order to highlight major risks

Qualification approach

- For all identified major risks, a dedicated program is defined in order to assess the risk :
  - Specific tests on partial products or on test vehicles
    - For example, if sealing process is critical, tests can be made on an empty packages
  - Validation of external suppliers.
    - From our experience, a failure in qualification is often associated with raw materials issue.
  - Modeling
- At the end of the development, all majors risks have to be removed.

Summary

- Introduction
- Qualification approach
- **Laser chip qualification**
- Sub component qualification
- Module qualification
- Conclusions

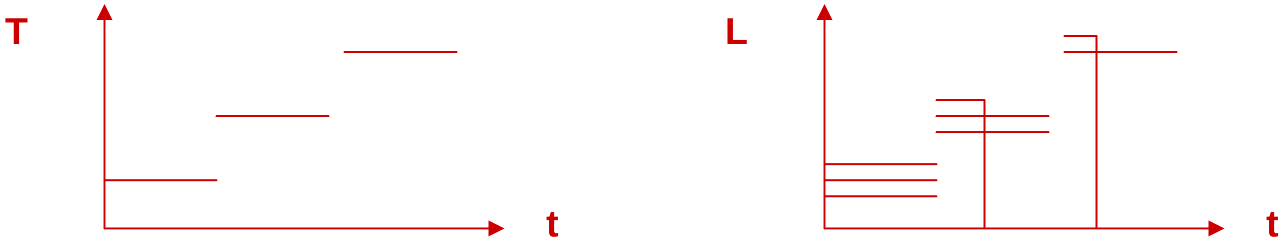
Laser chip qualification

- Main factors for a reliable .98µm laser chip are
  - Chip design,
  - Epitaxy process,
  - Mirror treatment
  - Assembly of the chip on its submount

- For all these steps, the risk analysis process is used.

Laser chip qualification

- In order to have a first evaluation on the reliability of the chip on submount, a step stress test is performed :
  - Chips from different wafers are submitted to temperature step at constant current and constant duration.



  - During this test optical power (L) and voltage (V) are monitored
    - this allows to get time to failure for each failed device
  - For each step, time to failure is analyzed using a Weibull model (β =1 is expected – random mechanism)
  - Failed parts are analyzed to verify a unique failure mechanism
    - Visual inspection (COMD, …)
    - Optical power (L) versus time signature
    - Failure analysis (EBIC, cathodoluminescence,…)

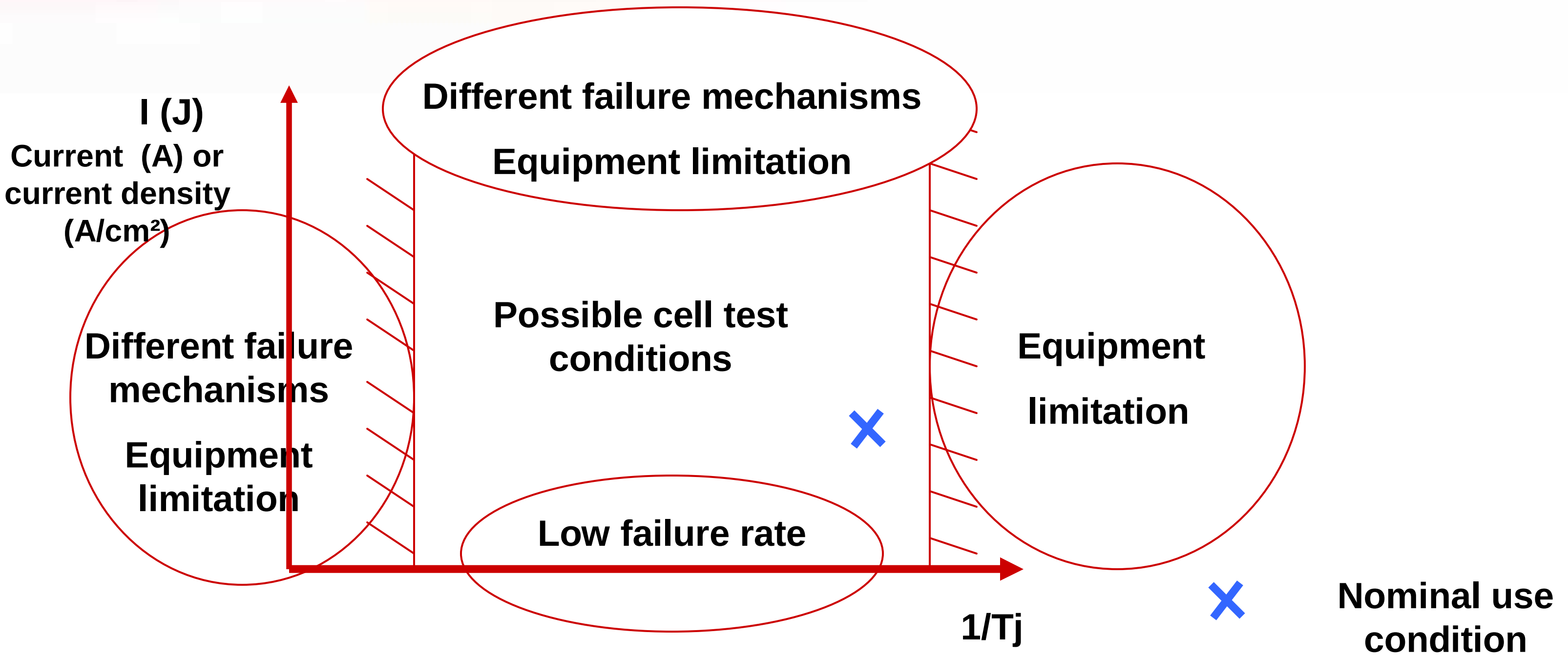
Laser chip qualification

- The reliability estimation is made through a multi cell ageing program (high temperature high current).
- It is known from previous reliability studies that for GaAs pump lasers :
  - λ (Failure rate) = A $(J/J_0)^n$ exp (Ea /kTj_0 – Ea/kTj) where
    - A is a constant
    - J, J_0 the current density (J_0 at reference temperature)
    - n is the current density accelerating factor (in the range of 2 to 5)
    - Ea: Activation energy (in the range of .5 to .7 eV)
    - Tj, Tj_0 : the junction temperature, (T_{J0} at reference temperature)
  - Knowing λ in one condition (J_0, Tj_0), one can compute its value for other conditions using n and Ea.

INTELLIGENT PHOTONIC SOLUTIONS™

AVANEX®

Laser chip qualification



- Choice of the cell test conditions

Laser chip qualification

- The choice of test conditions is a trade off between
  - Number of cells : >5 and < 10
  - Choice of stresses : to have a wide range of accelerating factors using estimates from previous experience (n', Ea')
  - Number of parts in each cell which predict same number of defects in all cells.
- Estimate λ (n', Ea', J, Tj) * N (J, Tj) = cst
  - Where N (J, Tj) is the number of parts in the cell J,Tj
- A typical program consists of about one thousand of parts

Laser chip qualification

- At the end of the program, times to failure are analyzed
  - Verification of random failure mechanism using Weibull model
  - Computation to get maximum likelihood estimates of n and Ea

Other tests like die shear tests and wire bonding destructive pull test are also performed on representative samples.

Summary

- Introduction
- Qualification approach
- Laser chip qualification
- **Sub component qualification**
- Module qualification
- Conclusions

Sub components qualification

- Main subcomponents are
  - Pigtail which includes a fiber grating for wavelength stabilization.
    - Fiber grating is mainly qualified using :
      - non destructive pull tests.
    - Pigtail is mainly qualified using
      - Environnemental tests like
        - thermal cycling
        - damp heat storage
        - high temperature storage

Sub components qualification

- Package and lid with getter to trap water and organic compounds.
  - Internal atmosphere and hermeticity are qualified using
    - Liquid-liquid shock test
    - Damp heat and high temperature storage
    - Hermeticity test (He inside the package)
    - RGA

Summary

- Introduction
- Qualification approach
- Laser chip qualification
- Sub component qualification
- **Module qualification**
- Conclusions

Module qualification

- **Key factors for a reliable package are :**
  - **coupling stability**
    - **Sub-micronic mechanical stability is necessary**

    ➔ YAG welding
  - **Atmosphere with > 5% of oxygen , low water content, low organic pollution**

    ➔ Organic free process , O^2 inside the package, getter for both water and organic trapping
    - **In order to prevent package induced failure (PIF) : high optical power “craks” organic compounds and carbon can deposit on laser mirror ➔ COMD**

Module qualification

- Qualification tests are based on Telcordia GR 468:
  - Shock and Vibrations
    - ➔ To test interfaces
  - Thermal cycling, temperature storage, damp heat
    - ➔ To verify coupling stability
- Other tests are added
  - Long term ageing with in situ monitoring
    - ➔ To get a predictable model of the coupling drift that can be used in unitary selection
  - Customer's specific shock and vibration tests related to shipping and deployments

Summary

- Introduction
- Qualification approach
- Laser chip qualification
- Sub component qualification
- Module qualification
- **Conclusions**

main steps

Development

- Environmental requirements
- Robust design
- Risk analysis
- Risk assessment
- Limits
- Failure mechanisms
- Sub component qualification

Qualification

- Test program
- Degradation model
- Relevant selection file

Manufacturing

- Process monitoring (SPC)
- Pedigree review
- Unitary selection using model
- Rejection of outliers

Conclusions

- Methodology
  - Risk analysis as earlier as possible in the development process
  - Relevant qualification program
  - Unitary selection and rejection of outliers
- This methodology allows us to fulfill our customer's requirements.
- This methodology could be applicable to other high reliability applications