Optoelectronic Component Testing Overview

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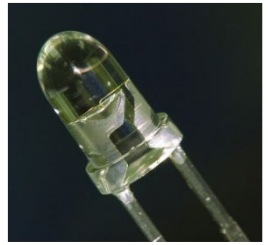
Introduction to Optoelectronics Parts

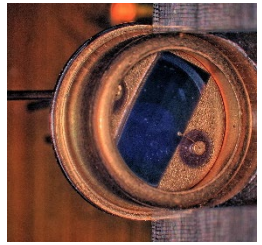
- For over 15 years, the 562 Photonics group has been screening and qualifying optoelectronic components for spaceflight and harsh environments.
- Optoelectronics are components which interface between electrical and optical energy.
  - Sometimes referred to as electro-optical components, but this can sometimes be confused with the electro-optical effect used for devices like laser Q-switches or polarization controllers.
  - It can be included in parallel to 2 other major laser component categories: waveguides (classic optics, fiber optics, etc.) and integrated devices (PICs).
- Key parts to look for that are included in optoelectronics are: sources (LEDs, laser diodes), detectors (photodiodes, pyroelectric detectors), and modulators.
- Due to the optical energy aspect of these components, parts selection, screening and qualification must take into consideration additional requirements not typically used for selection of standard EEE parts. Some of these requirements include, but are not limited to:
  - Wavelength of light
  - Required efficiency (detectors)
  - Required output optical power (sources)
  - Directivity/Beam Profile (sources)
  - Fiber or lens coupling

Optical Modulator

Laser Diode



LED

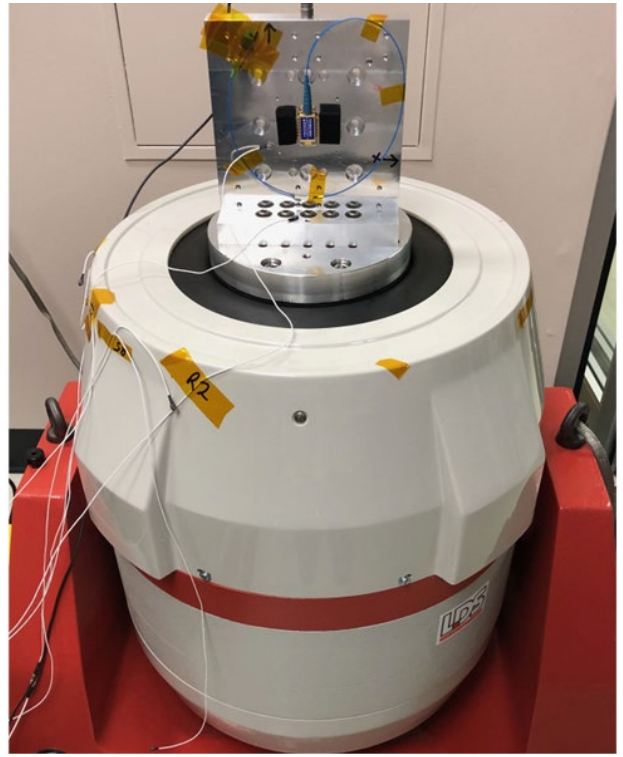


Photodiode

- Special concern for packaging of optoelectronic parts is also required due to the impacts of non-conductive debris on optical performance, cracking of optical components and alignment within the devices.

Screening and Qualification Methodology

- Unless a specific component has been previously screened and qualified in its current configuration, all incoming parts are considered commercial off-the-shelf (COTS) quality, meaning there is no differentiation between automotive-grade (AEC/AC/JEDEC/SAE), military-grade (MIL-STD), and general COTS parts.
  - Even previously qualified components or Telcordia qualified components must undergo lot-level flight screening and qualification testing to certify they continue to meet the current mission's performance standards.
- The most appropriate test plans take care to evaluate the impact of mission-specific parameters (risk, budget, schedule, etc.) when deciding which evaluations to include, highlighting the balance of both cost and schedule with risk.
  - The type of device being considered plays a large role in what style of evaluations are "necessary", leading to a more organic test campaign development process than standard EEE parts.
  - Some examples of what is "necessary" include wavelength stability, or output power at a certain temperature.
  - Often when schedule or cost is driving a screening campaign, testing is driven around known failure modes of the component.
- MIL-STD-883 provides a helpful starting point for test conditions in the absence of strict requirements and should be modified where possible to prevent significant permanent performance degradation or to accommodate the specific requirements of the program. Additionally, the Goddard Environmental Verification Standards (GEVS), can be utilized for guidance where mission requirements appear insufficient.



Tunable laser diode in vibration testing

Typical Screening and Qualification Flow for Optoelectronic Parts

General Flow for LEDs and Laser Diodes

Test Phase	Step ID	Activity Performed
Screening	10	Incoming Visual Inspection and Serialization
Screening	20	Electro-Optical Characterization (Full)
Screening	30	DPA (Destructive Physical Analysis/Construction Analysis)
Screening	40	Temperature Cycling (unpowered, 10-20 cycles, 12 cycles typical)
Screening	50	Electro-Optical Characterization (Partial)
Screening	60	Powered Temperature Testing
Screening	70	Burn in (120-240 Hours typical)
Screening	80	Powered Temperature Testing
Screening	90	Electro-Optical Characterization (Partial)
Screening	100	Vibration (GEVS 9.8 Grms typical)
Screening	110	PIND (Particle Impact Noise Detection)
Screening	120	Electro-Optical Characterization (Full)
Screening	130	Hermeticity
Screening	140	Final Visual Inspection
Screening		Report Generation

Test Phase	Step ID	Activity Performed
Qualification	1.10	LIV
Qualification	1.20	Vibration (GEVS 14.1 Grms typical)
Qualification	1.30	Thermal Cycling
Qualification	1.40	LIV
Qualification	1.50	Hermeticity
Qualification	2.10	LIV
Qualification	2.20	Life Test (1000-2000 hours)
Qualification	2.30	Power Cycling (6000 cycles)
Qualification	2.40	LIV
Qualification	2.50	Hermeticity
Qualification	3.10	Gamma Radiation
Qualification	3.20	Proton Radiation
Qualification	3.30	LIV
Qualification	4.10	IGA (Internal Gas Analysis)
Qualification	4.20	Construction Analysis
Qualification		Report Generation

Full Electro-Optical Characterization:
- LIV (Light, Current, Voltage)
- Spectrum
- K Factor
- Thermal Impedance
- Reverse Bias
- Directivity/Beam Profiling

Partial Electro-Optical Characterization:
- LIV
- Spectrum
- Thermal Impedance (optional)
- Reverse Bias (optional)

All parts (100%) go through screening.

Small subset of screened parts are divided into four groups for qualification testing.

Testing parameters, temperatures, levels, durations, etc. are customized for the intended use conditions and exact part type and packaging.

Flight Part Selection

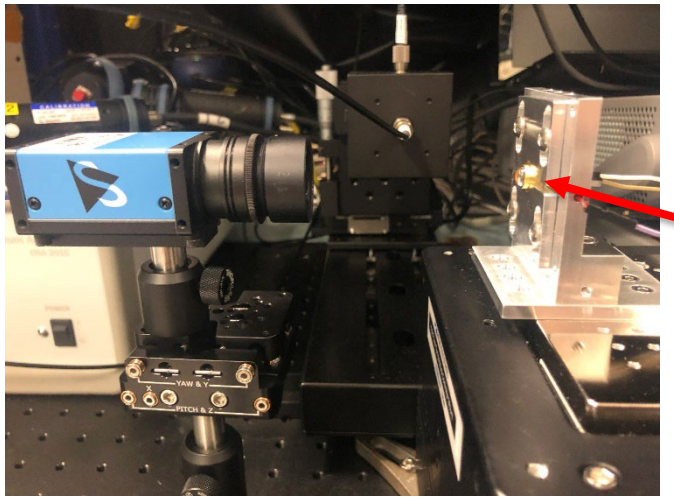
- Optoelectronics part lots are qualified by proto-flight method: flight parts are chosen from the lot that is qualified, not the parts that have been qualified.
- Optoelectronic component screening and qualification testing typically does not see absolute part failures, outside of packaging failures, i.e. PIND and hermeticity.
  - Infant mortalities of optoelectronic screening are seen but are commonly parts that either have lower performance at the first power on or degrade significantly faster than the rest of the lot.
- Screening and qualification campaigns are designed to trend the optical and electrical performance of the parts over the required environments specified by the test campaign.

(Left and right images): Testing setups are designed to allow testing a wide variety of parts with independent drive and monitoring of each part at specified temperature, while trending performance throughout burn-in and life testing.

Flight Part Selection

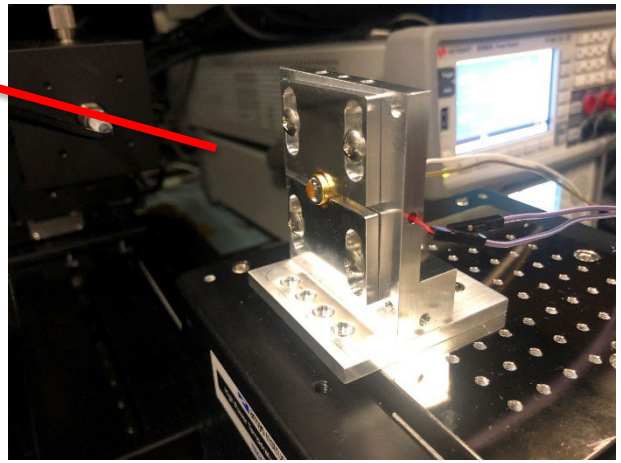
- The selection of flight parts is then done by analyzing the performance over the entire lot of components.
  - The lot of components is first assessed for flight candidacy based on flight requirements, historical data on similar components and results of construction analysis.
  - Flight parts are then ranked within the lot based on the in-family performance in key areas.
    - What qualifies as in-family is typically 2-3 standard deviations of the mean for the lot, but this can be modified based on project requirements or lot performance.
  - Parts with out of family performance (that still pass screening) are typically delivered to the project and used for bench top or ETU testing.

Initial screening and setup calibration



Stable and repeatable setup for measuring optical beam pointing, divergence along with LIV, K factor, thermal impedance, and reverse leakage current.

TO can LED in a temperature-controlled mount.



Is it required?

- Opto-electronics (electro-optical components) are the 4th E of EEEE acronym.
- GSFC code 562 Photonics Group has been successfully using this screening and qualification flow for over 15 years, with modifications based on mission requirements and incorporating lessons learned.
- However, no official standard captured this accepted practice, primarily due to the large variety of optoelectronic parts and use conditions.
  - For example, an indicator light has very different needs than a source in an on-board calibration system.
- Telcordia qualification only applies to the manufacturer's processes, not the actual procured lot of parts. Lot screening and qualification testing must still be performed for flight use.
- That is about to change with the upcoming release of NASA Standard 8739.11 (still in review).
  - Incorporates this general flow for optoelectronics into several sections of the standard.
  - Additions to the general flow for Class A missions.
  - Severely reduced required testing for Class D missions.

- Using the component in an unusual manner will require additional testing.
  - Large electrical drive current ranges (use at extremely low current).
  - Frequencies and modulation outside of the manufacturer's specifications.
  - Temperatures outside of the manufacturer's specifications.
  - Anything else outside of the "normal" intended use.

Summary

- Optoelectronic components interface between electrical and optical energy. All screening and qualification testing must include testing of the optical performance of the parts.
  - Typical EEE test plans cannot be used for optoelectronic parts without modification.
- Optoelectronics components are typically treated as COTS.
  - Even if the same configuration was previously tested to the same requirements, due diligence should be done to ensure the vendor's process still meets these requirements.
- Test programs for optoelectronics components are based on MIL standards but are tailored to the individual program based on part type, schedule, cost and specific program requirements.
- Absolute failures of optoelectronic components are rare outside of packaging. Test campaigns must trend the optical and electrical performance over time.
- Flight parts are typically selected by ranking parts within a qualified lot.
  - Flight parts are chosen from the lot that is qualified, not the parts that have been qualified.

Thank you for your time!

Questions?

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Acronyms

- AC = Automotive-grade Components
- AEC = Automotive Electronics Council
- COTS = Commercial Off the Shelf
- DPA = Destructive Physical Analysis
- EEE = Electrical, Electronic, and Electromechanical
- EEEE = Electrical, Electronic, Electromechanical and Electro-Optical Components
- ETU = Engineering Test Unit
- GEVS = Goddard Environmental Verification Standards
- GSE = Ground support Equipment
- GSFC = Goddard Space Flight Center
- IGA = Internal Gas Analysis
- JEDEC = Joint Electron Device Engineering Council.
- LED = Light Emitting Diode
- LiDAR = Light Detection and Ranging
- LIV = Light-Current-Voltage
- MIL-STD = Military Standards
- NASA = National Aeronautics and Space Administration
- NEPP = NASA Electronic Parts & Packaging
- PIC = Photonic Integrated Circuit
- PIND = Particle Impact Noise Detection
- SAE = Society of Automotive Engineers
- TEC = Thermoelectric Cooler
- TO = Transistor Outline