Qualification &Reliability of Photonic Devices System Perspective

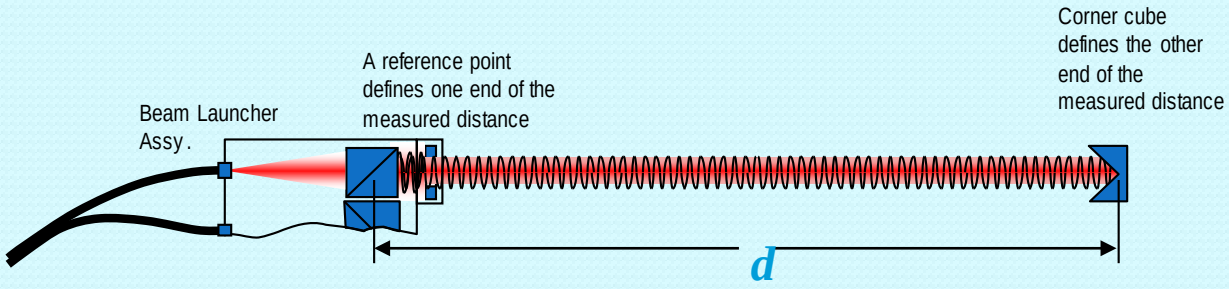
Alireza Azizi, Ph.D.
NASA-Jet Propulsion Laboratory, California Institute of Technology
818-354-0639
Alireza.Azizi@jpl.nasa.gov

NEPP Electronics Technology Workshop (ETW 2018)
June 17-20, 2019
NASA-GSFC

Introduction

- This talk concentrates on photonics devices of a system that JPL is in the process of qualifying
- Unlike electronics parts, standard guidelines for qualification and screening of photonics parts for space application does not exist
- JPL had to develop process for qualify and screening of these photonics parts
- The system is a metrology system capable of measuring displacement with nms accuracy
- This talk focuses only on the photonics part of the system

System Overview Concept



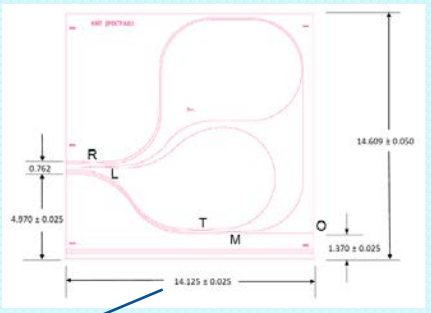
- A Laser Metrology System is a "yardstick," with "nm-marks" provided by the interference fringes of the laser beam
  - Changes in the distance ***d*** between the Beam Launcher (BL) and the Corner Cube (target) are measured as phase shifts between input and output beams
    - Uses heterodyne techniques to measure phase
    - "count fringes" corresponds to the changes in ***d***
- It can be used for alignment and wavefront control of the future NASA segmented telescope such as Luvior or HabEx

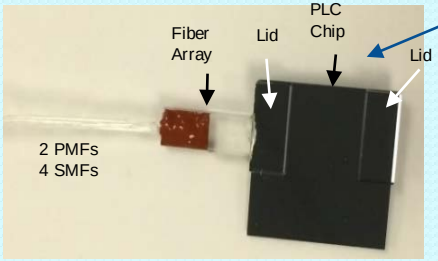
Type of Photonics Devices

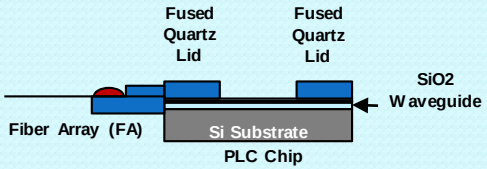
- Two type of photonics devices
  - Passive
    - Buy COTS and put them through environmental requirements
    - 6 thermal cycles
    - Radiation
  - Active
    - Screening and lot qualification using Telcordia and Mil-STD combine

Passive Devices (1/2)

- Waveguide
  - Custom made interferometers integrated photonics on a silicon chip (~14x14x0.7 mm)
  - Perform full Qualification on 3 units
    - Performance (PER, Il, thermal sensitivity)
    - Dynamic test
    - Radiation (100 Krad)



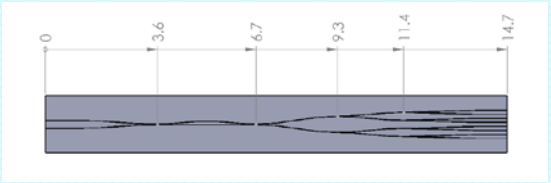




  - Screening other devices after qualification
    - Performance
    - Thermal cycle

Passive Devices (2/2)

- Splitters/coupler 1x2 and 2x8
  - Planar Lightwave Circuits (PLC)
  - Screening
    - Performance (PER, IL, uniformity)
    - Thermal cycle

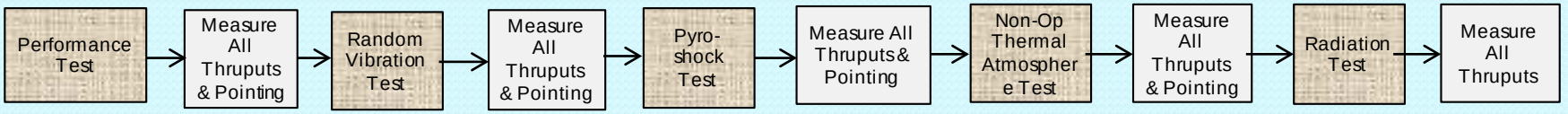


- Fiber optics
  - Single mode (SM)
  - Polarization maintain fiber (PM)
  - Polarizing fiber (PZ)
  - There are plentiful data on most fibers
  - Perform lot qualification

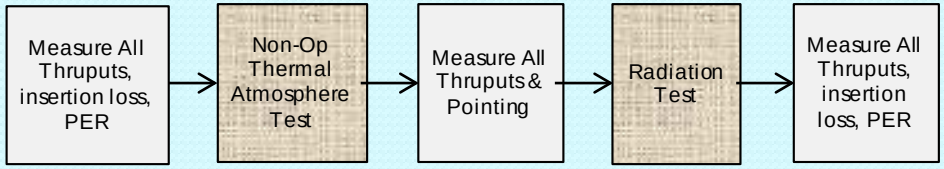
Qualification Process for Passive Devices

- Different process used for passive devices
  - Different performance parameters and different reliability parameters

Interferometer:

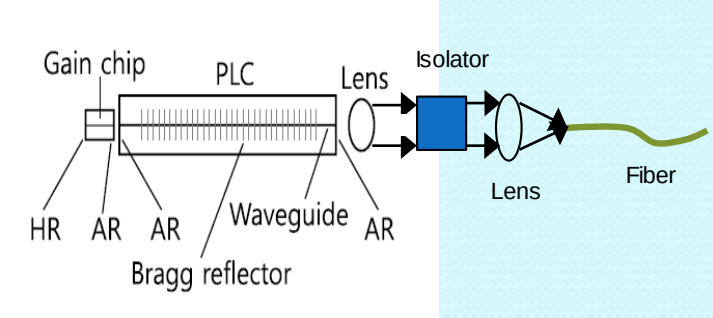


Splitters & Fibers:



Active Devices- Laser

- Laser- 1.5 um external grating semiconductor laser with narrow linewidth
  - COTS laser, with screening and lot qualification
  - Guidelines developed at JPL for screening and qualification
  - 21 lasers were used for lot qualifications



Qualification Process for Laser

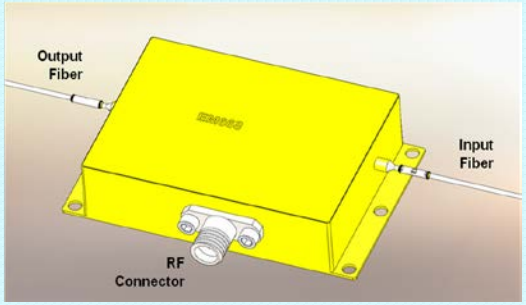
- JPL developed qualification process using Mil-STD and Telcordia

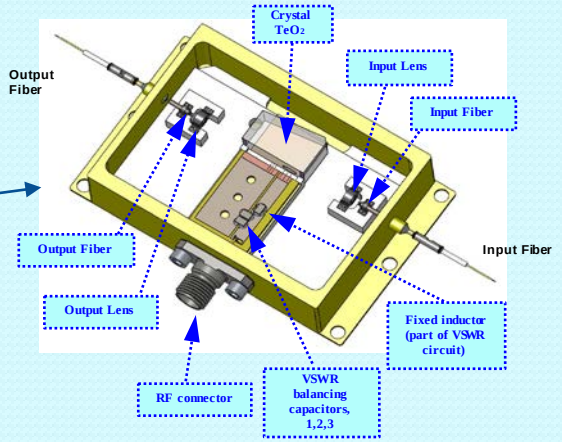
Qualification Steps for Laser

Qualification Step Number	Test	Method	Conditions	Quantity Accept (Failure No.)
Subgroup 1	Environmental Stress Tests			
1	Performance Tests	Per Table VII	Tests 1-12 of Table VII	13 (0)
2	Mechanical Shock	TM 2002	A, Y1 direction, 500G	
3	Performance Tests	Per Table VII	Tests 1-8 of Table VII	
4	Vibration	TM 2026	Condition A, 20G, 20 Hz to 2000 Hz	
5	Performance Tests	Per Table VII	Tests 1-8 of Table VII	
6	Thermal Shock	TM 1011	Condition A, 0°C to 100°C, 20 cycles	
7	Seal	TM 1014	Method compatible with pigtailed module	
8	Performance Tests	Per Table VII	Tests 1-8 of Table VII	
9	High-Temp Storage	3.3.2.1 and Table 4-4 in Telcordia GR-468	+85°C, 2000 hrs	
10	Performance Tests	Per Table VII	Tests 1-8 of Table VII	
11	Low-Temperature Storage	3.3.2.1 and Table 4-4 in Telcordia GR-468	-40°C, 72 hours	
12	Performance Tests	Per Table VII	Tests 1-8 Table VII	
13	Temperature Cycling	GR-468, Table 4-4	Condition C, 100 cycles per Table 4-4 in Telcordia GR-468, -45°C to +85°C	
14	Performance Tests	Per Table VII	Tests 1-12 of Table VII	
15	Fiber Pull	Telcordia GR-468	1 kg	
Subgroup 2	Package Tests			
1	Solderability	TM 2003	Steam aging not required	3 (0)
2	Metal Package Isolation	RIO defined	600 VDC, 100nA maximum	
3	Lead Integrity	TM 2004 - B2	B2 lead fatigue	
4	DPA, including PIND, RGA, Wire Bond Strength and Die Shear	MIL-STD-1580	Performed by JPL Permissible to use samples used for Solderability, Package Isolation and Lead Integrity	
Subgroup 3	Accelerated Aging			
1	Accelerated Module Life Test via Temperature Cycling	Table 5-1 in Telcordia GR-468	-40°C to +85°C Continue Temperature Cycling tests (Subgroup 1, step 12) using devices that have completed Subgroup 1 testing to accumulate a total of 500 cycles.	5 (0)
2	Performance Tests	Per Table VII test 1-12	Perform Tests 1-8 at the end of every additional 100 cycles, and Tests 1-12 at the end of 500 cycles.	
3	Accelerated Aging Tests via High Temperature Storage (Operation?)	Table 5-1 in Telcordia GR-468	+85°C, Continue High Temperature Storage Test (Subgroup 1, step 8) using devices that have completed Subgroup 1 testing to accumulate a total of 5000 hrs	5 (0)
4	Performance Tests	Per Table VII test 1-12	Perform Tests 1-8 at the end of every 1000 hrs and Tests 1-12 after the 5000hrs.	

Active Devices- AOM

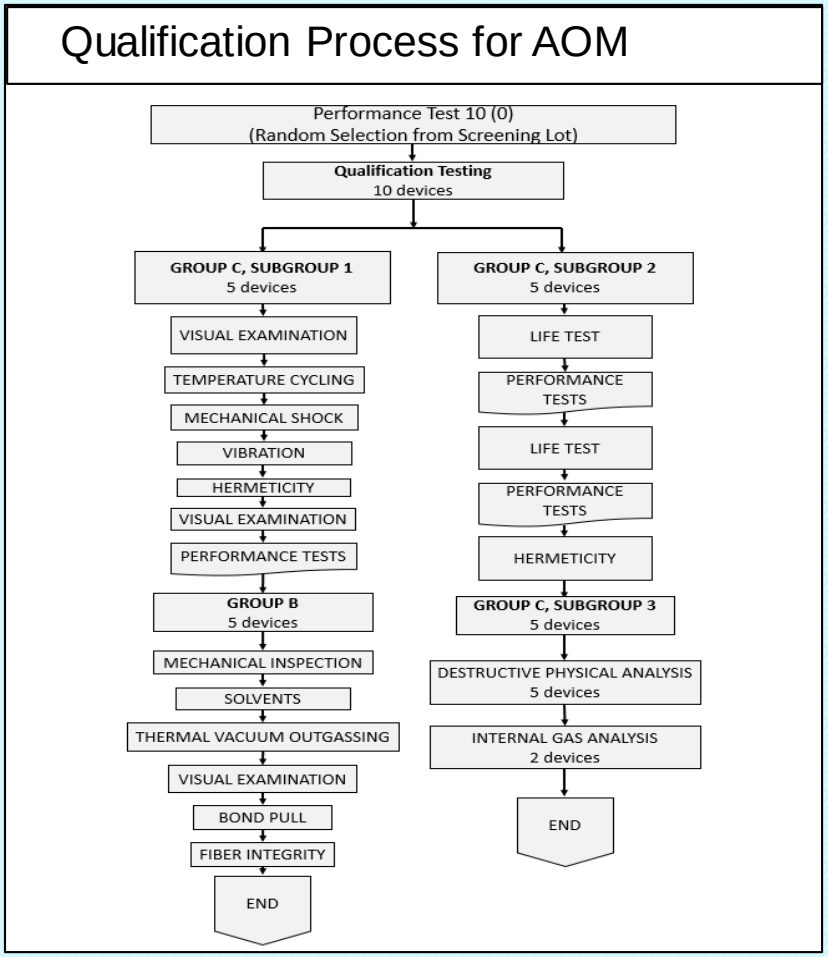
- Acousto-Optic Modulator (AOM)- provide frequency shift (modulation) to the laser light
  - Custom made, with screening and lot qualification
  - Guidelines developed at JPL for screening and qualification
  - 10 AOMs were used for lot qualification





Qualification Process for AOM

- JPL developed qualification process using Mil-STD and Telcordia



In closing

- Photonics market is a growing market, in some estimate it is expected to be over $900 billions by 2024.
- Space application is a portion of this growth with its unique need and requirement.
- More photonics parts are being used or considered for space application due to its benefit, small mass, small size and low power
- Need to develop guidelines and methodology on how to qualify photonics devices for space application
- Need to have a good understand of failure modes of photonics devices
- Goddard has done some great work in this area, and ESA has been also working on this area as well.

Strategy for Qualification

- General strategy- Test according to Mil-STD and Telcordia
- Standard tests are generally not suited for the photonics devices
- Some considerations and constrains
  - Cost reduction
    - Smaller number of devices per test groups
    - Reduction in the characterization parameters at each steps
  - Small procurement volume
    - Not very attractive for COTS manufacturers
  - Reliability and failure data
    - Development of photonic devices are moving fast and not enough time to have complete reliability and failure data for FM
  - Challenge of space environments, vacuum, hermeticity, radiation, temperature range

Recommendations

- Establish a collaboration with other NASA centers, universities , industries and other institutions
- Prioritize parts that are being considered for near term missions
- Develop methodology for evaluation and space qualification of the photonics devices
- Develop guideline on how to bring photonic devices from TRL1 to TRL6

Thank You