Qualification of Fiber Optic Transceivers for Space Applications ESCCON - March 2016

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Briefing Available Upon Request – Give me Business Card – Write ESCCON briefing on back!

Agenda

- Introductions
- Overview
- Status
- Advanced Technology Developments
- Summary

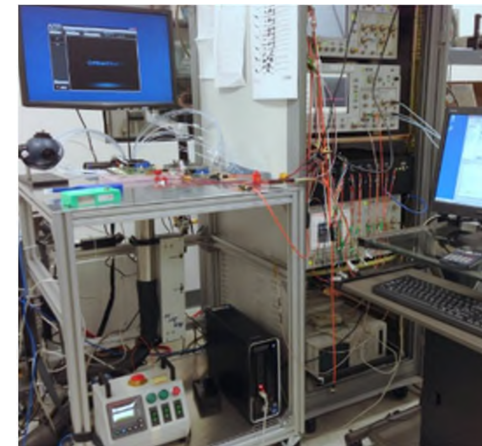
Introductions / Overview

Chuck Tabbert

Ultra Communications Overview

- 2006 Spin-out of Peregrine Semiconductor
  - 18 employees (nine dedicated to manufacturing and quality system)
  - $4.2M revenue 2015 (Real Products & R&D)
- Fiber optic communications for harsh environments
  - Fiber optic component packaging and circuit design
    - Built-in-test (including OTDR)
    - Wide temperature operation & survival
  - Primarily R&D (Gov't and Customers)
  - **Low rate production (50-75 units / month) today**
- Business Sectors
  - Aerospace & Military: Avionics, Ships, Space
  - Embedded computing – Data Center, Automobiles
  - Fiber Sensing Market
  - Single Photon Detection for Quantum Key Distribution (QKD) networks

Finetech Fineplacer
(0.5 micron accuracy)



Transceiver Test Station with unique Optical Power Monitoring During Burn-In

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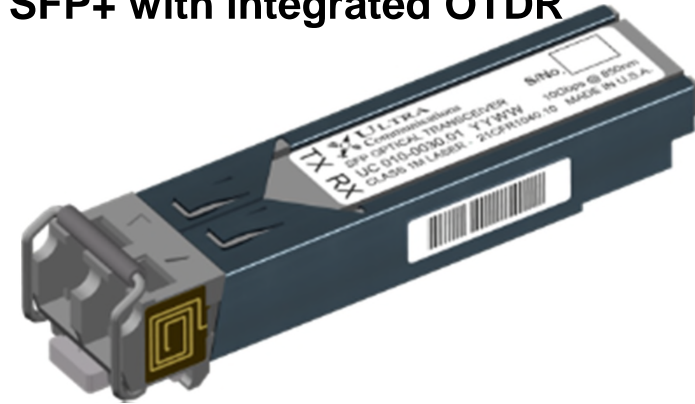
Ultra Comm Roadmap – Size, Data Rate & Functionality

RVCON™ Fiber Connector

SFP+ with integrated OTDR



Commercial Form-Factor

X80-J
JSF 4x4 @ 2.5Gbps/ch

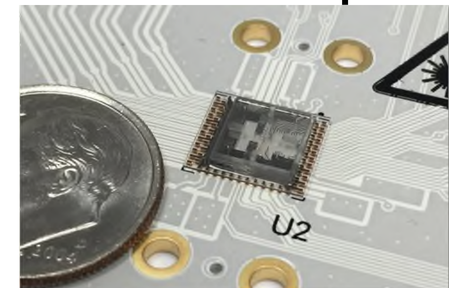
25 mm

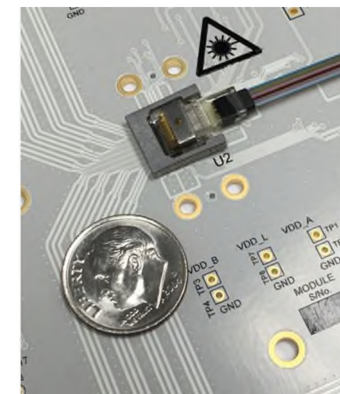
X80-Q
QFN 4x4 @ 10Gbps/ch

12 mm

(OTDR capability in productization)

X200-CSP
CSP 4x4 @ 25Gbps/ch





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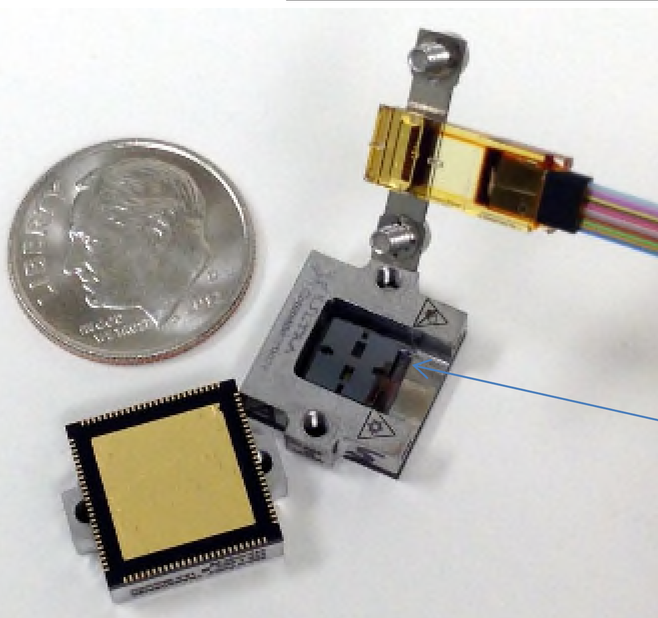
X80-Q Flip-Chip Transceiver Construction

- Stack of flip-chip bonded wafer-processed materials
  - Advanced submicron flip-chip bonder
  - 10 flip-chip bonding steps

- Rugged Vertical Connector (RVCON™)
  - Ribbon fiber connector
  - <0.5dB loss from laser to end of pigtail <u>over temp -120C to 180C</u>



RVCON™

Lens guide

Collimating optics

Transparent carrier

Transceiver ASIC

1 x 4 PIN array

2nd ASIC Options:
- uController
- OTDR ASIC

CORE
Wafer Scale Stack

1 x 4 VCSEL array

CORE

Ceramic Interposer

Status

Transceiver Status

- Baselined configuration in fabrication for qualification testing to both avionic and space requirements
  - Both markets are requiring MIL-PRF 38534 Class L testing
    - Element Evaluation - in evaluation at customers
    - Module Screening (Group A)
    - Qualification (Group C,D Testing – UC performs in-line Group B on every lot)
  - Avionic Qual Testing to began December 2015
  - Space Qual Testing to begin March 2016
    - **X80-Q baselined into 7 space programs worldwide**
  - Core is common to both packaging configurations
- Recent Customer Space Environmental Testing
  - Shock/vibration / Thermal Vacuum – Space Qualification Testing Completed
  - Radiation – Space Qualification Radiation Testing (TID, Proton & SEE) Completed
  - **Summary Data available upon request with Test Conditions!!**
- Quality Systems Installation
  - Full time Quality Engineer hired and have concluded initial customer audits
  - Activity to continue through qualification phase. **Plan to certify to MIL-PRF-38534 Class L**
- Worldwide demand outpacing supply
  - Capacity expansion being finalized for mid 2016 implementation ramping to volume production
  - In preparation, new hires in operations, multiple shifts
  - Rigorous “fab sizing” for 2016 & 2017 – Need Customer Expectations

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Summary Results– Radiation

Radiation Testing

- Test environments
  - 10 MeV/amu beam cocktail from Lawrence Berkeley National Laboratory
    - Flux from 1E4-1E5 p/cm^2/s with total fluence of 1E7 p/cm^2
    - Ions Used
      - Ag – 48.1 MeV-cm^2/mg; E=1039 MeV; Range(Si) = 90 µm
      - Kr – 30.2 MeV-cm^2/mg; E=906 MeV; Range(Si) = 113 µm
      - Ar – 9.74 MeV-cm^2/mg; E=400 MeV; Range(Si) = 130 µm
      - Si – 6.1 MeV-cm^2/mg; E=291 MeV; Range(Si) = 141 µm
      - Ne – 3.5 MeV-cm^2/mg; E=216 MeV; Range(Si) = 174 µm
  - 200 MeV Protons from Loma Linda University Medical Center Synchrotron
    - Flux ~1.48E8 p/cm^2/s with total fluence up to 1E12 p/cm^2
      - TID/DDD on 3 samples
        - 46.7 krad
        - 8E11 p/cm2

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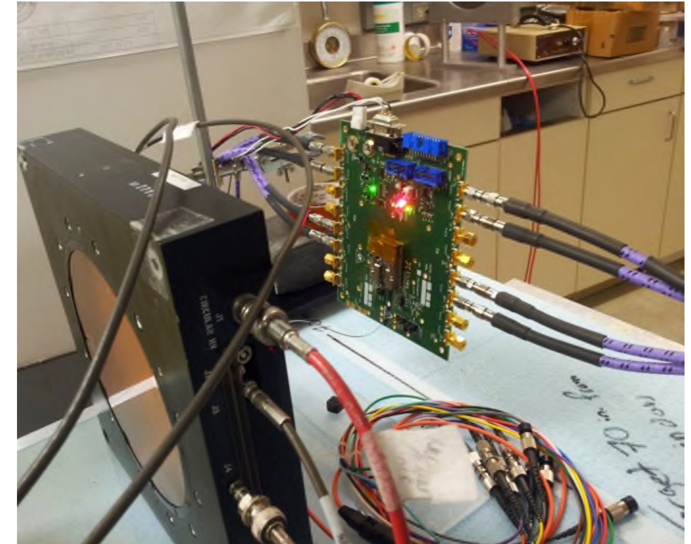
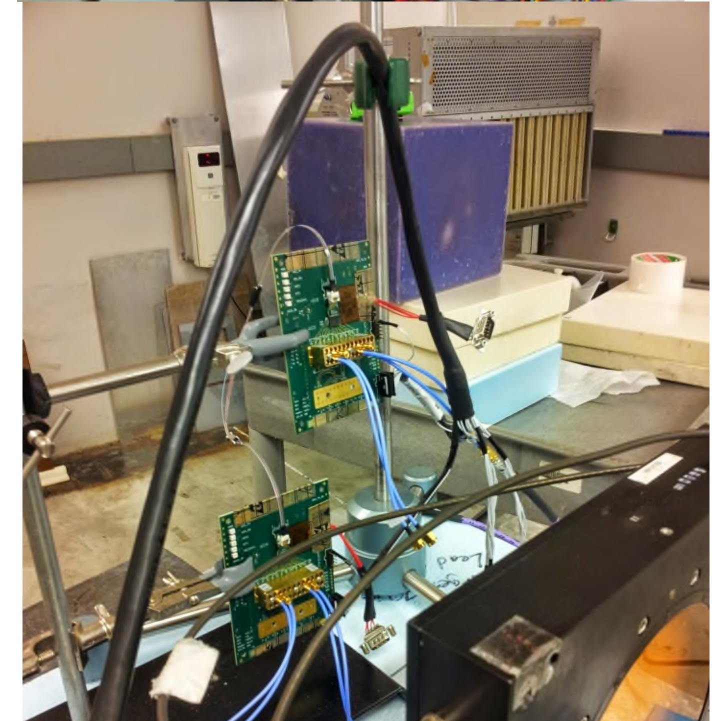
Radiation Testing

- Test Configurations
  - Heavy Ion - Berkeley
    - Tx/Rx Chipsets
      - Stand alone chipsets processing 3.125 Gb/s data stream
      - Elevated temperature - 85C
      - Monitoring I_S, BER, and register states
    - VCSEL/PIN
      - Devices flight-like biased during irradiation – destructive investigation only
  - Proton - LLU
    - Full compliment of optics and Tx/Rx processing 3.125 Gb/s data stream
    - Monitoring I_S, BER and register states-RT
    - VSEL/PIN devices tested for DDD/TID degradation





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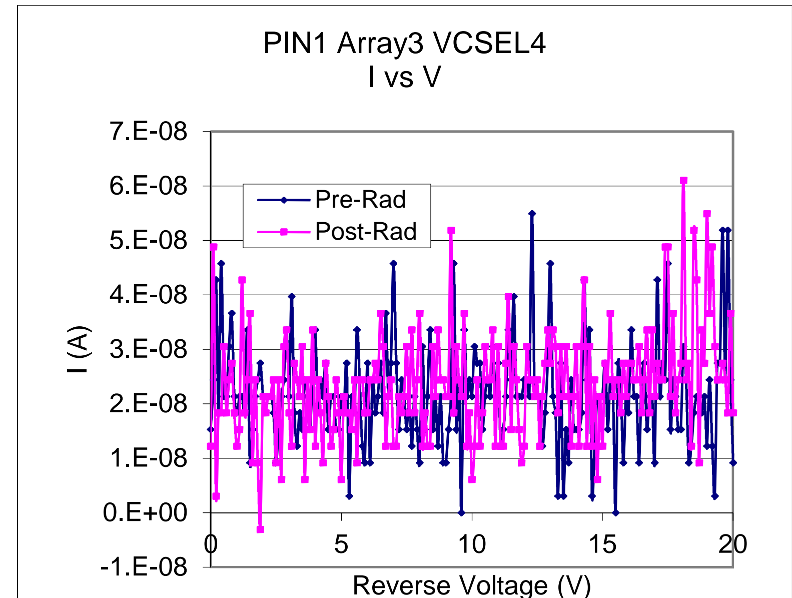
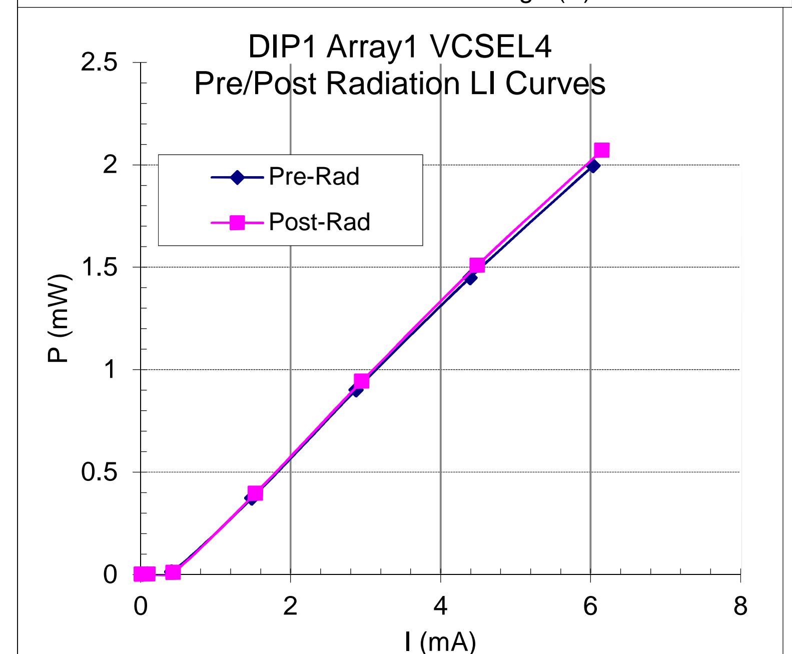
Results – X80 Board Mount

- Heavy Ion Results
  - No destructive events recorded in Tx/Rx Tx/Rx chipset or any of VCSEL/PIN devices tested for all ions
  - Exceeds 40 MeVcm^2/mg requirement
  - No register upsets
- Proton Results
  - No significant parametric changes in TX/Rx (I_S) or VCSEL/PIN devices
  - Single bit errors in X80 module calculated to be 1 per 6 yrs
  - No register upsets
- All BER impacts negligible





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AVFOP Reliability Panel
Santa Barbara, CA – NOV 2015

Two Important Points:

VCSEL Reliability

Packaging Reliability

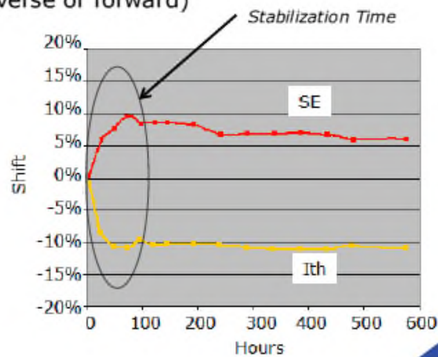
VCSEL Reliability

- VCSELs Stabilize with Burn-In
- Require Reverse Bias Testing on VCSELS from manufacturer

Elimination of Manufacturing Defects

- Device testing (Wafer level testing & Burn-in)
  - Device parameter stabilization rather than light-bulb effectiveness
- Visual inspection (process defects, mishandling)
  - Scratches, metalization step coverage defects, debris
- Reverse voltage-current (Vrb) measurements
  - Detection of EOS events (ESD reverse or forward)

Wafer-level testing



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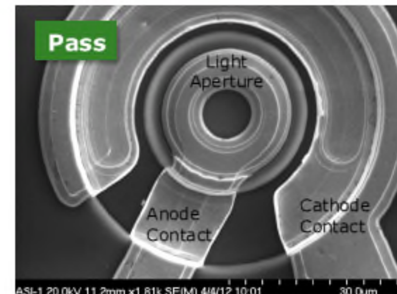
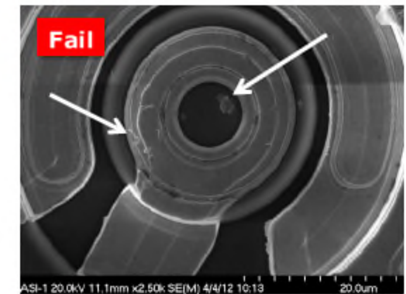
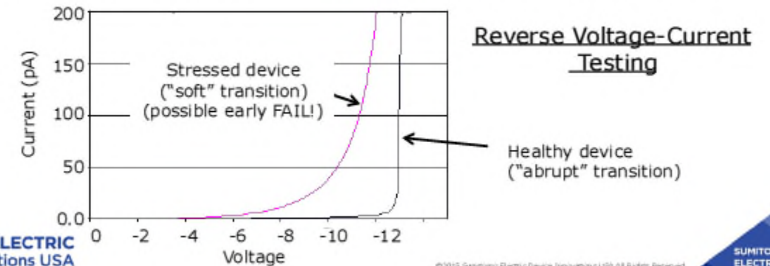
Screens to Minimize Early Life Failures

Visual Inspection







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- US Space Customers looking at post VCSEL assembly screening
  - Photo Luminescence Test
  - Power Spectral Density Test

Package Reliability Metrics

- Package reliability centers around the stability / reliability of the package interfaces:
  - Connector to Transceiver Interface
  - Active Devices to Carrier Interfaces
  - Transceiver package to PCB bonding
  - OE Component Health Post Assembly

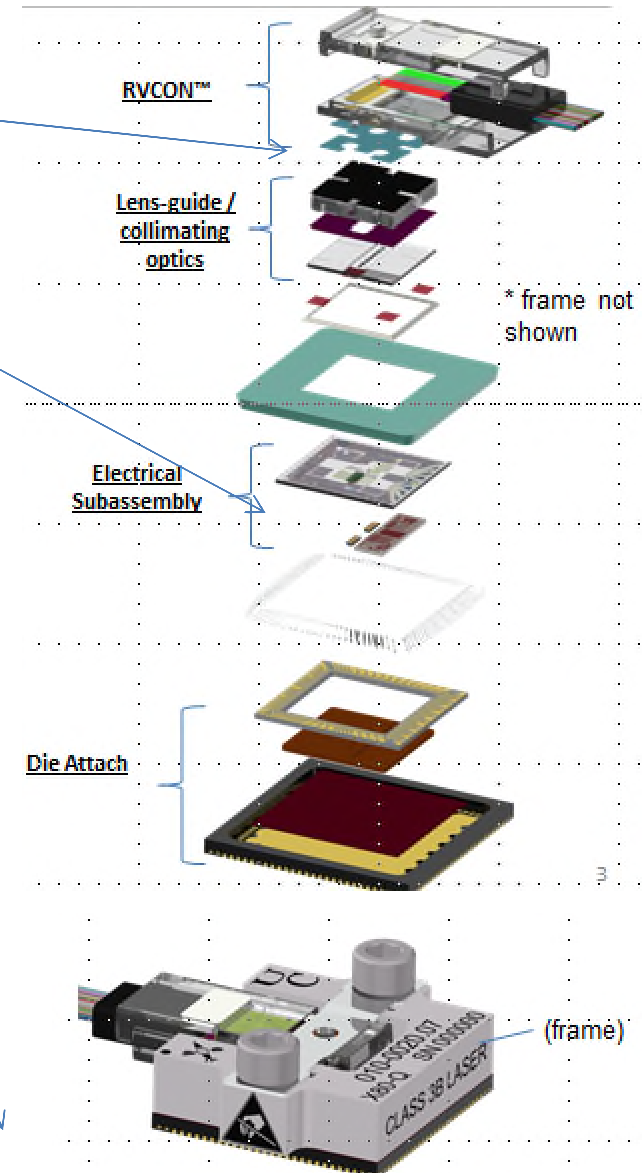
- The most telling acceleration tests to date has been rapid, long duration, thermal cycling and Highly Accelerated Stress Test (HAST) for humidity testing
  - Mil Std 883 Method 1010 Condition B Cycles done in a two chamber system Hot chamber is 128C Cold chamber at -58C Transfer time is less than 30 seconds for the shuttle Hold parts, after reaching temperature, for 12 min for 1000 cycles
  - HAST – per JESD-22 A110

    130C

    85% Relative Humidity (RH)

    96 hours

    Devices electrically biased



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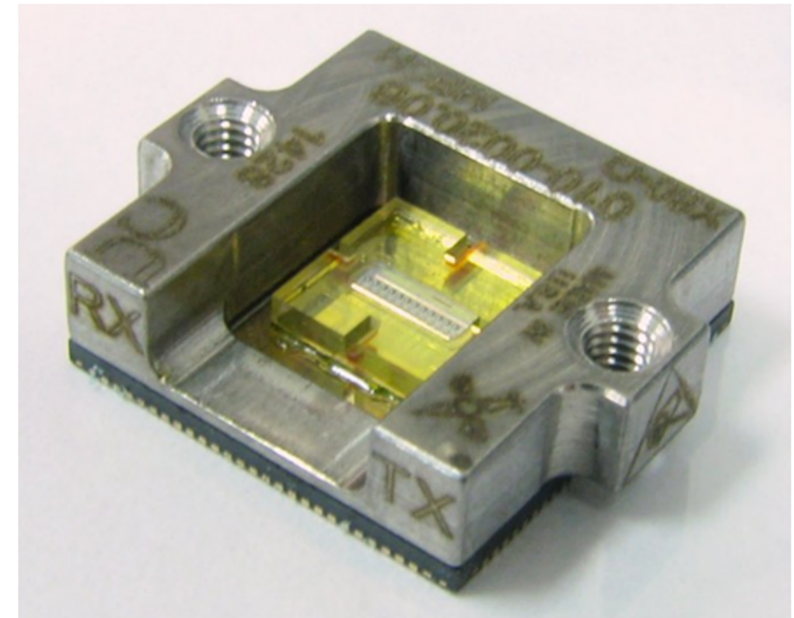
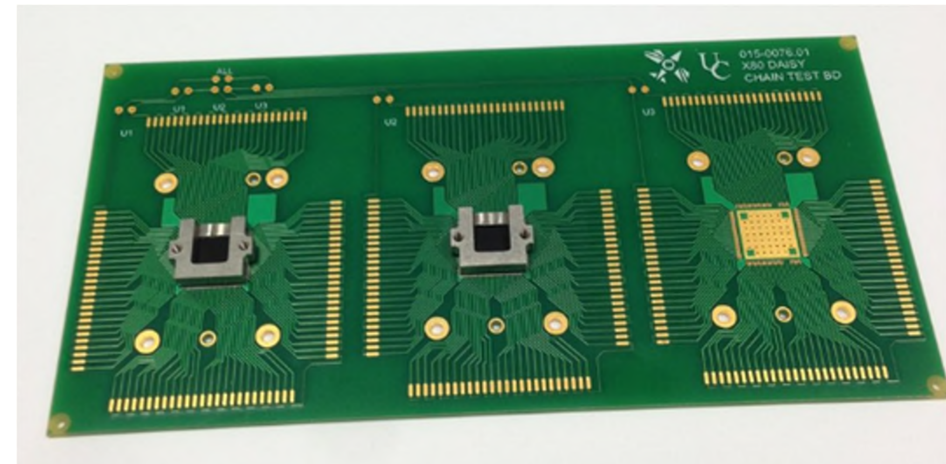
Transceiver package to PCB bonding

- #1 asked customer question – not familiar with large leadless quad flat-pack package

- **Pick & place assembly development**
  - The X80-Q is a 12 x 12 mm QFN dissipating 1.2 watts.
  - Military customers have raised concerns about the reliability of these packages soldered to PCBs in harsh environments.
  - Solder assembly process developed with Dimation Inc. Burnsville, MN.
- Assembly test vehicle #1
  - 10 parts were assembled to a 2-layer PCB
  - **Passed 1,000 thermal cycles** (-55 C to 125 C)
- Assembly test vehicle #2
  - Repeating with 10 parts assembled to a 10-layer PCB
  - **Passed 1,000 thermal cycles** (-55 C to 125 C)

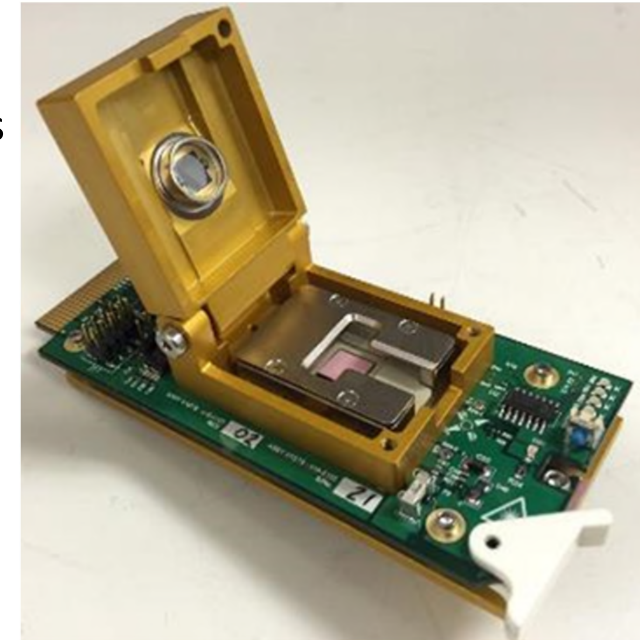
- **Manufacturing Process Instructions provided**





OE Component Health Post Assembly

- Burn-In Systems can be built to look at these issues
  - 100% burn-in (and HTOL) of both electrical and optical functionality
    - In-situ monitoring of optical output is key to manufacturability
    - Traditional thermal chambers do not allow for optical monitoring
  - System consists of racks of DUT boards
    - Local heating of DUT to 125°C
    - Local measurement of optical and electrical parametrics
    - DUT boards networked to PC for real-time logging



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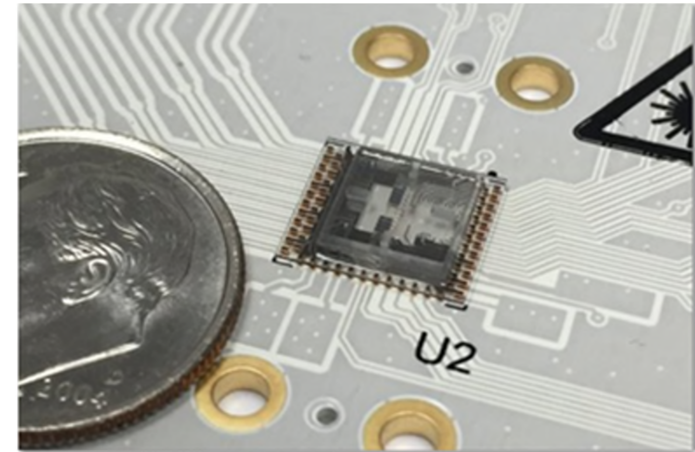
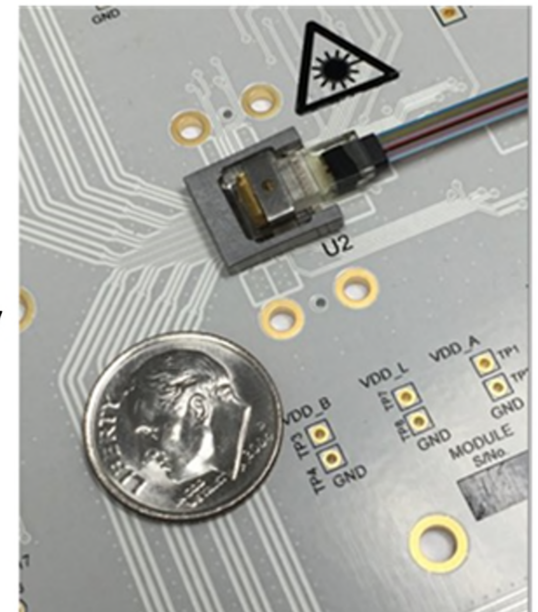
Advanced Technology Developments

- UltraComm Embedded 100G Optical Transceiver Project (LITECHIP™)
- MT to MT Connector Saver (MT Saver)

X200-CSP LiteChip ™

- Emerging need for embedded optical transceivers
  - On the board near the central processor ASIC
  - Difficultly of electrical routing at 28G and beyond
- UltraComm technology to address this need
  - Chip-scale-packaging and flip-chip assembly
- Value for the customer
  - **Low transceiver cost**
    - minimum BOM and wafer level assembly testing
  - **Ease of use**
    - mass solder assembly onto the customer board (no electrical connector).
  - **Minimum PCB footprint**
    - Electrical I/O density matched to PCB technology (*not* defined by bulky connector).
  - **Performance advantages**
    - Maximal bandwidth (no wire-bonds)
    - Efficient coupling of optical modes into multi-mode fiber
  - **Compatibility with immersion cooling**



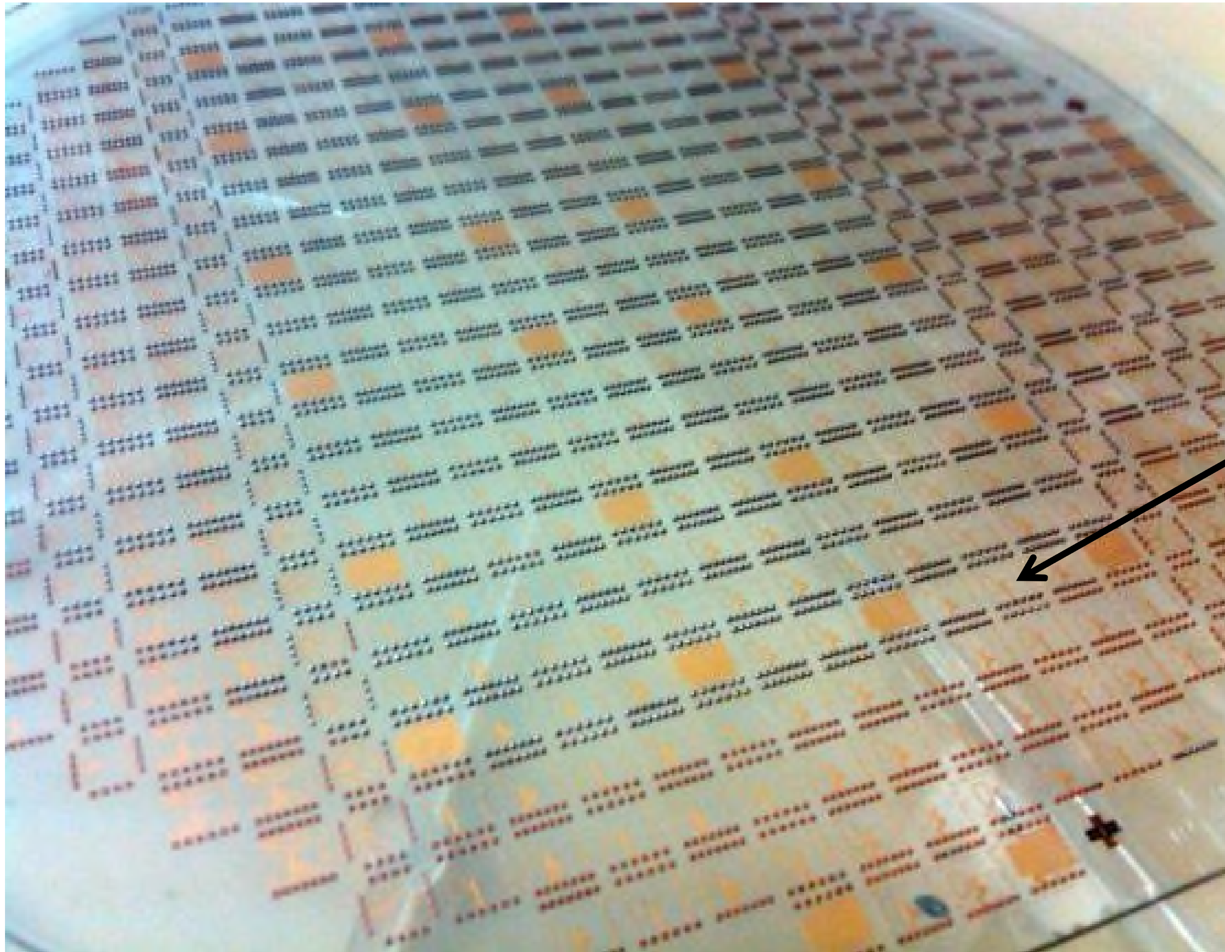


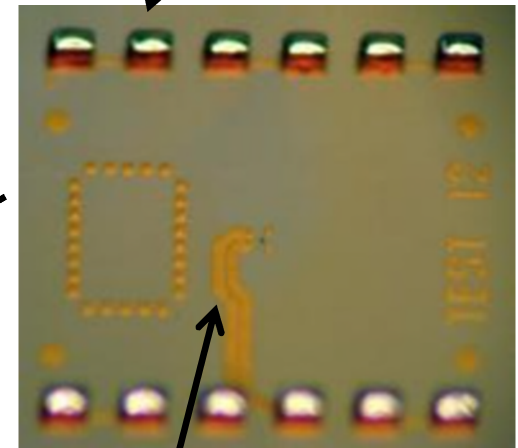
Wafer Scale Production Example

- Wafer scale components
  - Backside metallization of lens wafer

Copper post (300 um height with solder cap)

$4 \times 4\ mm^2$





Gold metallization for flip-chip attach of VCSEL/PIN and active circuits

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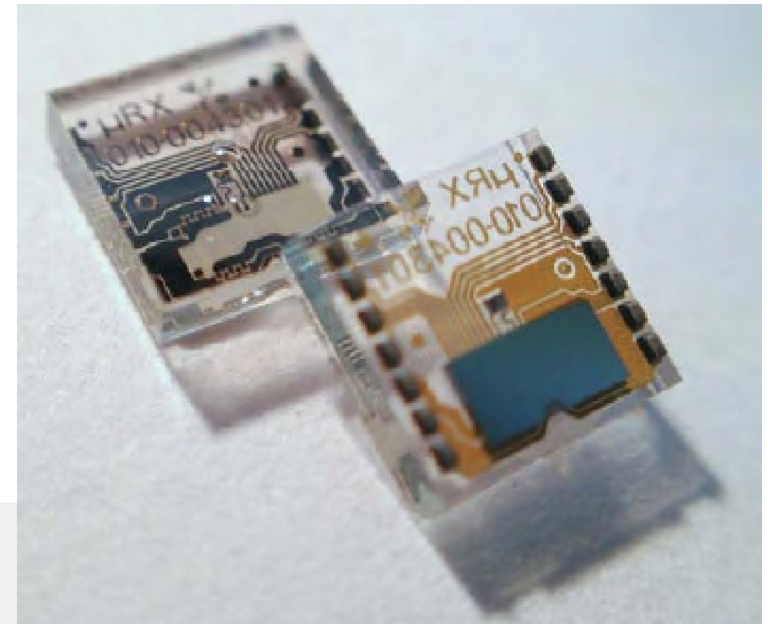
Scaling

- Next generation systems are targeting 56 Gbps per channel line rates
  - Finisar and VI Systems have demonstrated 56G VCSEL operation over 50 meter fiber links.
- Imperative to control the electrical parasitics inside the package
  - Especially at the ASIC-to-OE device interface.
- ASIC-to-OE interface in the LITECHIP™
  - SOS carrier with excellent dielectric properties
  - lithographically defined traces
  - OE devices are flip-chip bonded (no wire-bonds)
  - CSP -> electrical I/O directly to PCB



UltraComm dual-metallization process
- both flip-chip bumps (for the OE devices) and copper pillars for the electrical I/O.

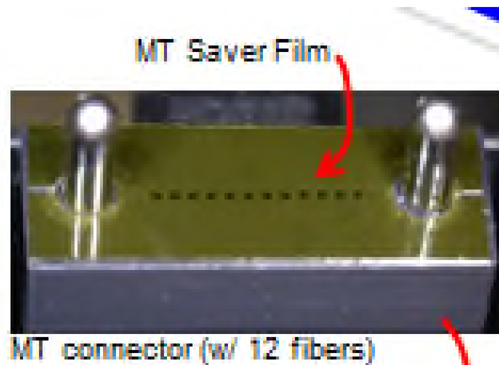
MT Saver

MT Saver

TECHNOLOGY DESCRIPTION

Film protector for MT connectors

- Seals the gap in connectors
- Protects the fiber end-faces
- Low optical loss (0.08 dB)
- Fully operational optical connector w/ film in place
- Removable



MT Saver Film

MT connector (w/ 12 fibers)

F-35 GP Module (courtesy LMCO)

MT fiber connectors (6)

CUSTOMER NEED & REQUIREMENT

Fiber pigtails are prone to damage during assembly and flight, creating maintenance expense and reduced weapons availability

Affordability Issues This Tech Solves

- Vibration Failure: MT Savers are *currently in use* for sub assembly production to eliminate damage in vibe (affecting 50% of units – see photo - MT Saver are removed after vibe).
- Contamination During Flight: MT Savers seal the optical pathways
- Fiber Damage During Assembly: Protection thru production / assembly.

vibe damage to fiber

(courtesy LMCO-Owego)

Program Goal

- Expand for light-use and throughout production. Eliminate vibe-damage, and seal fiber within connectors
- Issues/Hurdles: Environmental tests are a new, but low risk

Transition Plan

- MT Savers are used in contractor F-35 production line to enhance yield during vibe test. We will leverage this success to expand across entire line and to fiber backplane assembly
- Installation at contractor ransceiver manufacturers
- Contractor will provide aircraft requirements for MT Saver flight-use testing (i.e., define environment and acceptance testing)

FUNDING / PROGRAM (18 mos $750K Base + 6 mos $250K Option)

Phase	Task	Description
BASE TASKS (18 mos)	Production Development	Develop production, handling, and inspection processes for MT-Savers
	Environmental Testing	Environmental testing to ensure MT Saver is compatible with flight
	Expand Application	Install the MT Saver throughout the avionic supply chain (transceivers, modules)
OPTION (6 mos)	Production Tooling	Tooling for high-rate production and to ease MT Saver installation/removal

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Summary

- Ultra Comm is presently immersed in qualification of fiber optic transceivers for harsh environments
- Ultra Comm is also bringing up audited quality system and is expanding capacity in 2016 - 2017
- Ultra Comm’s advanced technology development remains strong and an integral part of company’s product development efforts