

White Paper

Reliability Issues for Optical Transceivers

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Introduction

Optical transceivers & transponders are an integral part of fiber optic networks for data communication and Ethernet applications. By definition, they are co-packaged transmitters (Tx) and receivers (Rx) along with control electronics; transceivers and transponders have serial and parallel electrical interfaces, respectively. The Tx subcomponents are typically fixed wavelength, and offered for each coarse or dense wavelength division multiplexing (CWDM or DWDM) channel, so that multiple transceivers can be operated simultaneously on a single optical fiber. However, in the last 10 years, tunable transponders have become available, capable of operating on each of 100-200 channels centered on the telecom wavelengths of 1310 and 1550 nm.

Product	Package	Center Wavelength (nm)	Typical Maximum Reach (km)
Transceiver	SFP	850, 1310, 1550	200
	SFF		80
	XFP		80
Transponder	XPAK (datacom)	1310, 1550	10
	X2 (datacom)		80
Tunable Transponder	300 pin	1550	200

For fixed wavelength transceivers and transponders, the Tx and Rx components are rather simple, but a variety of technologies can be used for each. Transmitters can employ, depending on the center wavelength and required optical power, vertical cavity surface emitting lasers (VCSELS), light emitting diodes (LEDs), or edge-emitting laser diodes (either distributed feedback (DFB) or Fabry-Perot (FP)), along with a monitor photodiode for output power control. Receivers use either PIN or avalanche (APD) photodiodes, both in conjunction with transimpedance amplifiers (TIA). The devices are based on GaAs (850 nm) or InP (1310 and 1550 nm) materials. Both are typically packaged in hermetic TO cans, which are then soldered onto printed circuit boards with flex cables and mounted into metal enclosures.

Center Wavelength (nm)	Tx	Rx (all with TIA)	Application
850	oxide VCSEL	PIN	Datacom
1310	VCSEL LED DFB laser diode FP laser diode	PIN APD	Datacom Telecom
1550	DFB laser diode FP laser diode	PIN APD	Telecom

Market

The worldwide market for optical transceivers & transponders was greater than \$2 billion in 2007, based on a total volume of ~ 40 million units (with substantial variation based on market, wavelength, reach, and data rate). Roughly 5% of that volume was in tunable transponders. Sales were projected to increase to nearly \$3 billion in 2012, but that is clearly questionable with the recent economic crash. Major companies in the transceiver market include Avago, Avanex, Bookham, Emcore (which recently acquired assets from Intel), Finisar, Fujitsu, Hitachi, JDS Uniphase, Mitsubishi, NEC, Opnext (Stratalight), and Source Photonics (Luminent-Fiberxon merger). There has been significant consolidation recently, coupled with steady improvements in costs and yields, suggesting that transceiver profitability will continue to increase despite significant pricing pressure from OEMs.

Reliability Issues

Key infant mortality and wear-out failure modes for fixed wavelength transceivers are summarized below at the chip, package, and module level. This list is by no means comprehensive, but is based on failures that the author and other DfR staff have directly observed on fielded devices. Tunable transponders are subject to the same failure modes, but have a number of additional, technology specific device & packaging failure modes that will not be discussed here.

Chip

- Defect generation and propagation in the active region (dark spot and dark line defects)
- Catastrophic optical damage (COD) of the mirror facets
- Dielectric cracking
- Metallization cracking/peeling
- Active layer dopant diffusion
- N- and p-metal diffusion through pin holes or insufficient barrier layers
- ESD-induced damage

Package

- Shorting or corrosion due to trapped water vapor and subsequent condensation
- Possible oxide depletion of the diode facets due to inert filling gas (not an issue for certain facet passivation and AR coating materials)
- Corrosion and/or optical surface contamination due to reactions between volatile gases or surface migration of non-volatile species; typical sources include:
 - Trapped hydrogen in metalized Kovar packages due to insufficient annealing
 - Oxygen, carbon dioxide, hydrogen, and water vapor from incomplete epoxy curing or outgassing
 - Non-volatile residues, particularly dimethyl siloxane, from materials processing, subcomponent packaging material, cleaning (ironically), and numerous other sources
- Shorting due to electro-chemical migration, arising from anions on the surface (from handling or insufficient cleaning) combined with water vapor and electrical bias
- Solder/adhesive voiding and subsequent thermal runaway of the chip
- Wirebond fatigue (excessive loop length), fracture (process issues, IMC formation, Kirkendall voids), and delamination (surface contamination)

Module

- Delamination or damage to flex connector due to handling/insufficient support during assembly
- PCBA contamination, leading to either surface (general ECM) or subsurface (conductive anodic filament)-induced shorting
- Many other material and component (active & passive) issues, that are heavily dependent on Pb-based vs. Pb-free processes (PCBA blistering/cracking; via cracking; board glass transitions; component moisture sensitivity and popcorning; mechanical or thermal cracking of ceramic capacitors; bulging and migration in electrolytic capacitors; tin whisker formation; black pad; etc.) – please see other white papers on DfR Solutions' website for details

How DfR Can Help

DfR Solutions works with component suppliers, OEMs, and end users to identify designs, materials, processes, and qualification test methods that enable the reliable operation of components and systems. For transceivers, the following services are particularly relevant

- Guidance on material & process selection, particularly die attach materials (solders & adhesives), reflow/cure process optimization, hermetic sealing methods, and Pb-free conversion issues
- Destructive physical analysis, for competitive analysis or vendor selection, highlighting strengths and weaknesses of designs, materials, and processes
- Vendor reliability assessments: on-site reviews of vendor manufacturing facilities with an emphasis on procedures, processes, and/or test methods that may compromise the reliability of the product (not to be confused with vendor quality audits)
- Qualification test plan development: many OEMs require additional testing beyond Telcordia, MIL-STD, and IPC/JEDEC standards; conversely, many small vendors don't have the resources to perform all of these tests, and may require guidance on the most relevant tests to win new customers
- Contract qualification services:
 - Environmental exposure testing (shock, vibration, thermal cycling & shock, high temp/high humidity, high & low temperature storage)
 - Solderability, wirebond pull, and die shear
 - Residual gas analysis
 - Non-volatile residue analysis
 - Ion chromatography analysis of components and PCBAs
- Failure analysis & corrective action development: DfR has successfully resolved over 500 failure analysis cases for telecom, military, industrial, and commercial partners, providing detailed guidance on the necessary actions to substantially reduce or eliminate lifetime-limiting failure modes

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