ACTIVE OPTICAL CABLE TRANSCEIVER PACKAGING TRENDS AND DIE BONDING CASE STUDIES

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ABSTRACT

The data bandwidth within data server farms continues to grow faster than network user data bandwidth. Applications such as those for consumer shopping require many queries and searches inside a data farm to assemble and compile data before being presented to a user in a simple natural way for making purchasing decisions.

Data farms currently use high speed active optical cables within the data farm to connect servers. Two basic configurations will be discussed in this paper. These technologies use either “Edge Emitting Laser (EEL) + Single-Mode Fiber” or “Vertical Cavity Surface Emitting Laser (VCSEL) +Multi-Mode Fiber”.

Both EEL and VCSEL technologies will be studied from a packaging architectural view with case studies showing high accuracy pick and place of the laser die, photo detector, and lens attachments.

Example cases are presented to show the challenges and solutions to high accuracy die attach active optical cables.

The paper is applicable to process engineers and managers who currently or plan to assemble Active Optical Cable transceivers or other similar packages using high accuracy pick and place systems.

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INTRODUCTION

Opto-electronic transceivers convert electrical signals to optical signals for transmission (Tx) and optical signals to electrical signals for receiving (Rx). Transceiver module designs have continued to evolve to make them more compatible with existing manufacturing tools.

Semiconductor Packaging
Mainstream high volume semiconductor packaging has evolved around planar structures such as leadframes and printed circuit boards for die bond, wire bond, and surface mount technologies (SMT).

Opto-electronic Packaging Progression
Optoelectronic packaging has evolved from actual optical breadboard benches with discrete lenses and lasers, Figure 1 [1], to highly integrated miniature optical benches with miniature discrete optical and electrical components being assembled together as shown in Figure 2 [2].

As designers have been pressured for further cost reductions and performance improvements, they have drawn upon semiconductor manufacturing tools and design guidelines to make the optoelectronic components more like flat planar structures rather than round and odd shaped structures.

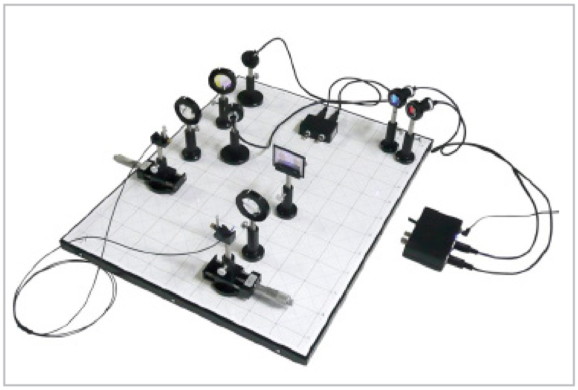


Figure 1: Optical Bench Example.

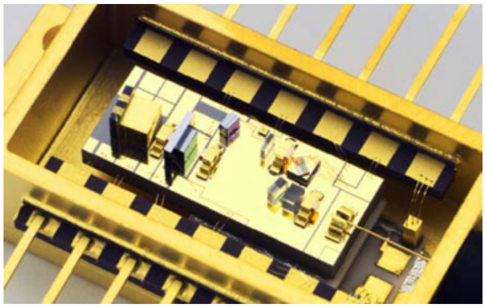
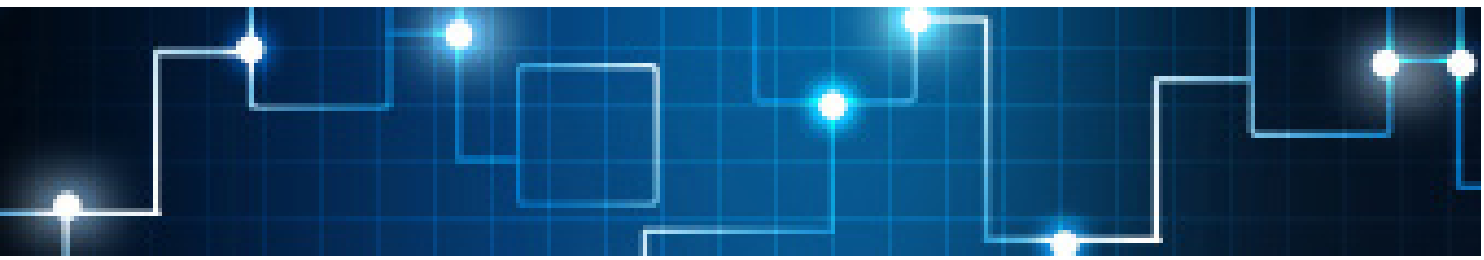


Figure 2: Micro Optical Bench Examples

HISTORY

This paper will review a narrow history of optoelectronic transceiver designs to show the progression over time. All of the designs require positioning of electro-optical components such as EELs and VCSELs to an optical system which will ultimately couple to and from a fiber.

Transceiver examples from the public domain are covered to show a progression of designs. Many of these design changes have allowed semiconductor packaging equipment to serve the opto-electronic packaging market.



EDGE EMITTING LASER (EEL) BASED TRANSMITTER (TX)

One example of an edge emitting laser based transmitter design is shown in Figure 3 [3] and Figure 4 [3].

The system is composed of a light source subassembly, Figure 3. This subassembly gets attached to a CMOS chip, Figure 4. The light source assembly is composed of mostly planar structures except the ball lens which is easily picked and placed using a round pick tool with center hole sized to secure and center over the top portion of the ball.

Edge emitting lasers emit light out the end of the laser and are typically attached with AuSn to achieve high thermal transfer of heat through the base of the chip. Package designs must orient the laser beam accordingly through the rest of the system.

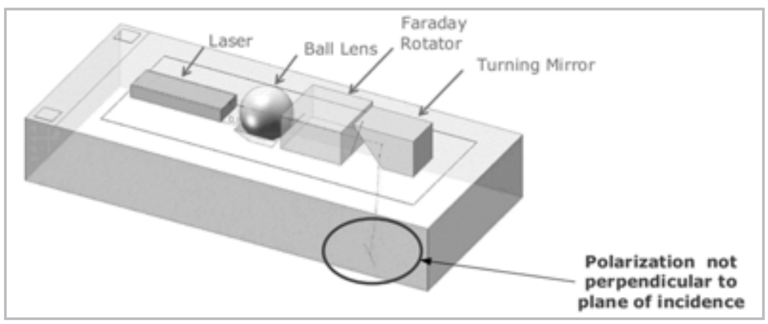


Figure 3: Luxtera EEL Light Module

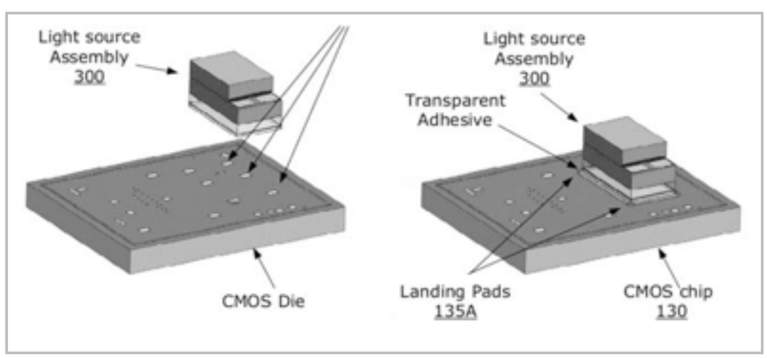


Figure 4: Luxtera EEL TxRx Module

VERTICAL CAVITY SURFACE EMITTING LASER (VCSEL) BASED TxRx

VCSEL based lasers emit light through the top surface. Package designs must also orient the VCSEL laser beam to be the correct orientation in the package and off the package.

VCSEL based TxRx designs require less power dissipation and allow usage of epoxy and PCB materials and structures which are more common in higher volume electronic manufacturing. The designs in Figures 5 and Figure 6 capture an evolution of designs.

Package designs have migrated to fewer process steps over time to reduce costs. The package in Figure 5 shows a design that focused on the Transmitter Optical Subassembly (TOSA) and Receiver Optical Subassembly (ROSA) manufacturing and testing and then integration into the overall package. The TOSA and ROSA. assemblies were composed of multiple components such as a base, circuit card, housings, VCSEL, PD, and lenses [5].

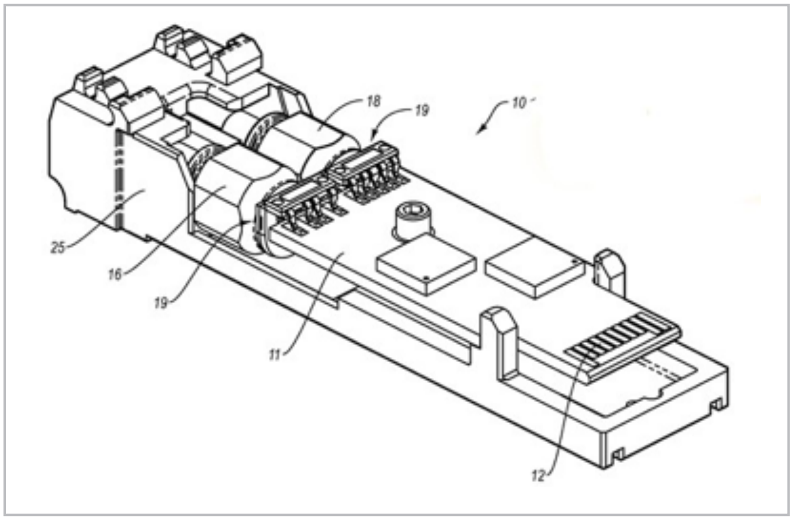


Figure 5: Finisar Discrete TOSA/
ROSA Subassemblies 16&18

Another evolution of package design focused on minimizing the number of components in the TOSA and ROSA subassemblies by combining the two into a molded lens+housing combination as shown in Figure 6. This design still contained separate circuit cards, housings, and lenses, but fewer than in Figure 5. The pick and place requirement is the VCSEL and PD to PCB location such that the lens will align when secured to the housing. Its constraint is one Tx and one Rx.

The next assembly in Figure 7 minimized the number of circuit boards to one and included a molded lens that would fit two Tx and two Rx channels into the same space as single channels previously using a ribbon of fibers [6]. The planar lens in this design has a mirror to bend the light signals 90 degrees. It is also a fiber array spacer to secure the fibers in line with the VCSEL and PD signals.

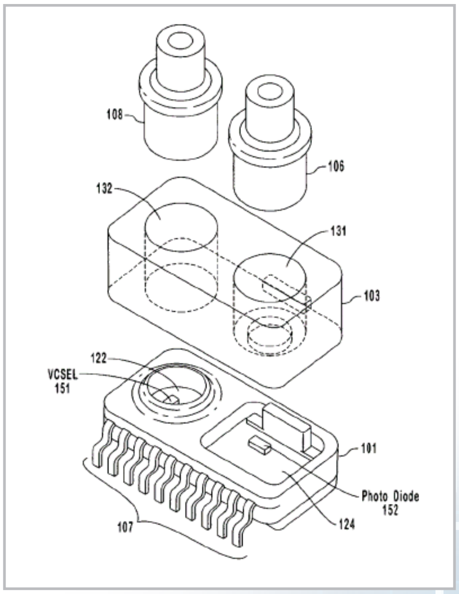


Figure 6: TOSA/ROSA Integrated
Module – VCSEL Alignment to Lens

VERTICAL CAVITY SURFACE EMITTING LASER (VCSEL) BASED TxRx Continued

The next design in Figure 8 and Figure 9 shows a molded plastic lens and molded optical connector housing combination. The molded lens, fiber (114), mirror (124), and VCSEL or PD focus point (104) detail is shown in Figure 9. This design allows even more Tx and Rx channels in the same space and relies on arrays of VC-SELs or PDs similar to that shown in Figure 11, later in this paper.

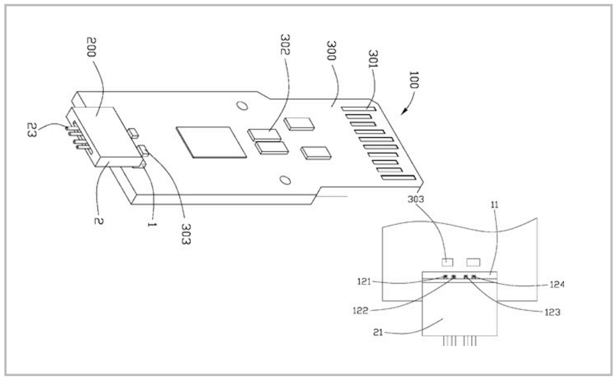


Figure 7: Arrayed Planar TOSA/ ROSA – VCSEL & PD on PWB with Planar Lens

ASSEMBLY CASE STUDY

The fundamental conversion of electrical to optical has to occur in the VCSEL and PD Array. However, the output through the fibers is based on mechanical positioning of the fiber, optic, VCSEL, and PD elements in X, Y, Z, dx, dy, and Tz as shown in Figure 10 [8]. For multimode fiber, the XY positioning requirement is approximately 5µm and better. Z positioning is typically controlled with benching surfaces and height of components. Purely electrical components such as TIAs and Drivers only require 35µm or better accuracy since there is no optical coupling.

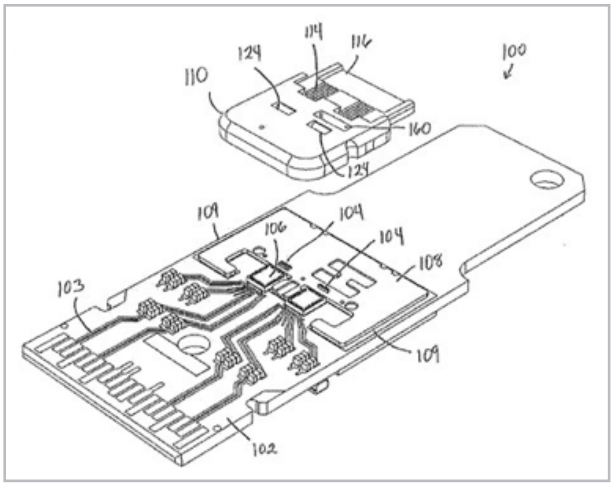


Figure 8: Integrated Planar Plastic Molded Lens Design

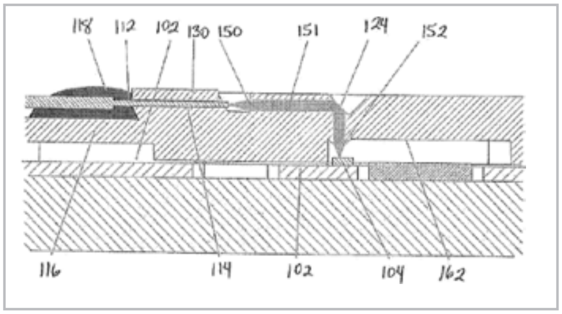


Figure 9: Integrated Plastic Molded Lens Cross Section

The example assembly in Figure 8 is divided into separate process flows, i.e.:

High Placement Accuracy Geometry

– Translation dX, dY

– Rotation Tz

– Levelness Tx, Ty

– Bondline dZ

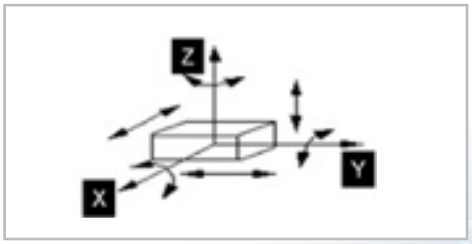


Figure 10: Placement Degrees of Freedom

ASSEMBLY CASE STUDY Continued

1. *PCB SMT Population – Populate the PCB with lower accuracy components that are typically attached with solder reflow. Examples include capacitors and resistors which can be mounted on both sides of the boards.*
2. *High accuracy pick and place of the PD Array and VCSEL Array using solder paste including cure. TIA and Driver chips may also be included at this step.*
3. *Wire Bond*
4. *High accuracy pick and place of the plastic molded lens above the PD and VCSEL arrays. This is typically done using UV adhesive.*

The mechanical schematic layout for the high accuracy pick and place of the PD and VCSEL arrays (step 2) is shown in Figure 11 with critical dimensions for aperture locations along a line. Figure 12 includes VCSEL to PD gap measures. Figure 13 shows Y-axis measures for aperture misalignments of the sample.

High accuracy pick and place of the plastic molded lens (step 4) typically occurs using a high accuracy pick and place with look up camera referencing of the lens housing. An upside down view of a lens is shown in Figure 14 shows two groups of four lenses that will align with the VCSEL array and PD array in Figure 11. The lens housing is fixed using UV adhesive while being held in place.

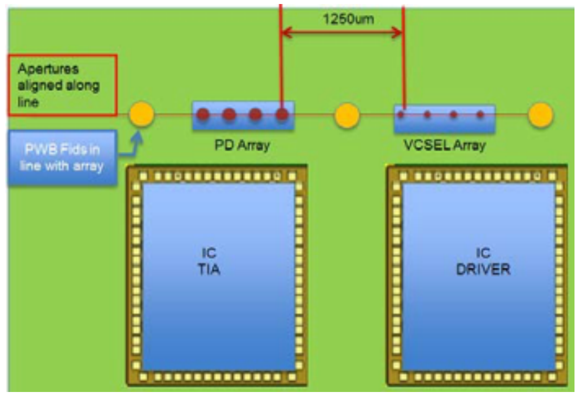


Figure 11: VCSEL/PD Array Assembly Example – General Layout

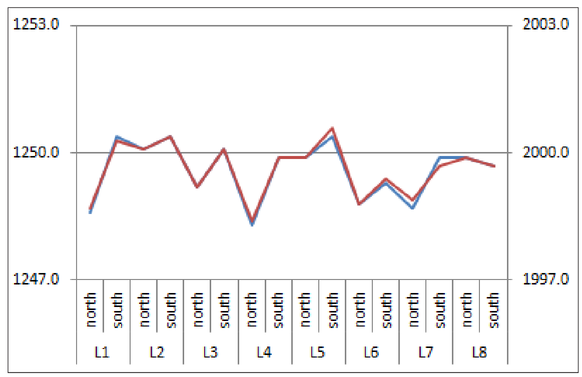


Figure 12: VCSEL to PD Gap, μm

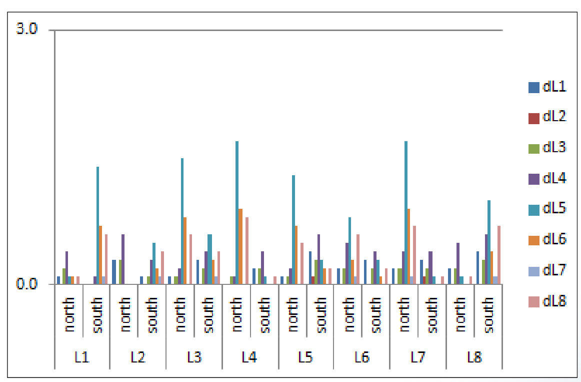


Figure 13: VCSEL & PD Line Error, μm

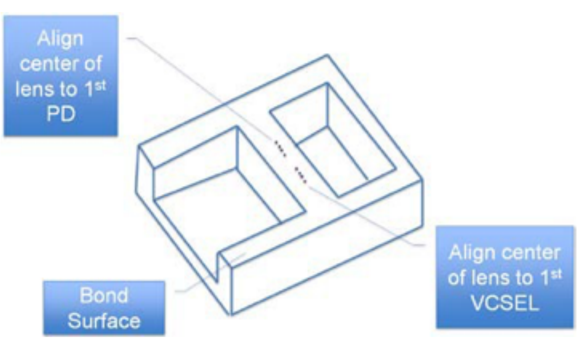


Figure 14: Plastic Molded Lens Example (Upside Down)

SUMMARY

This paper has reviewed background and historical progression of EEL and VCSEL based designs for TxRx optical transceivers. The progression of designs shows how designs have continued to reduce the number of assembly steps and subassemblies over time.

PAPER ABBREVIATIONS & ACRONYMS

TIA Transimpedance Amplifier to convert PD to Electrical signals.

Driver Drives the VCSEL laser power based on electrical high frequency input signals.

The author would like to give recognition and thanks to the very capable staff in Palomar Technologies' Assembly Services and Applications departments.

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