Intel 100G PSM4 QFSO28 Transceiver

Optical Fiber Transceiver for Datacenter based on Intel's Silicon Photonics

Photonic report by Sylvain HALLEREAU
March 2019 – version 1
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Executive Summary

This full reverse costing study has been conducted to provide insight on technology data, manufacturing cost and selling price of the Intel’s Silicon Photonic 100G PSM4 QFSP28 Transceiver.

- In only a few years, Intel succeeded being number 2 supplier for Si photonics based optical transceivers. Intel has succeeded because they put a lot of effort into the bottleneck: the laser chip integration with its InP chiplet bonding followed by post processing. Intel introduced a silicon photonics QSFP transceiver that supports 100G communications in 2016 and since then, the company has now ships a million units of the product per year into data centers. Intel's 400G products are expected to enter volume production in the second half of 2019. At ECOC 2018, Intel announced new 100G silicon photonics transceivers targeted at 5G wireless fronthaul applications. All these innovations have been allowed with the first generation, the Intel 100G series silicon photonics QSP transceivers featuring laser on chip.

- The transceivers came with two separated line with several dies. The transmitter integrated several InP laser and a CMOS die chiplets are bonded on a main silicon die in flip-chip configuration. On the main silicon die a Mach-Zehnder modulator is added in order to produce the signal. Other components are added to the system in order to focus or isolate the signals. The data are processed using a four channel 25G optical Clock and Data Recovery (CDR) component from MACOM. The receiver function is performed by 4 germanium photodiodes die and a TransImpedance Amplifier (TIA) circuit. The Ge photodiodes are manufactured on a dedicated SOI substrate. A specific fiber optical coupler with focusing lens is used to connect the photodiode die with the fiber optic.

- All of these described in this report shows the potential of Intel in term of packaging, and photonics. In a very small form factor, Intel managed to integrate four lasers, a photonic driver, optical modules, CDR functionality, high performance photodiodes, two advanced substrates and materials for optic. This report will show how implement the chiplet configuration along with a detailed description of the transmitter and receiver line.

- This report constitutes an exhaustive analysis of the main components of the Intel 100G PSM4 connector, including a full analysis of the Silicon Photonic die, the TIA circuit, the Mach-Zehnder Driver circuit, the MACOM circuit and the germanium photodiode along with a cost analysis and price estimate. The 2 fiber optic couplers, focusing lens the isolator are described and the price estimated. Moreover, a comparison with Luxtera silicon photonic circuit is performed.
The reverse costing analysis is conducted in 3 phases:

**Teardown analysis**
- Package is analyzed and measured
- The dies are extracted in order to get overall data: dimensions, main blocks, pad number and pin out, die marking
- Setup of the manufacturing process.

**Costing analysis**
- Setup of the manufacturing environment
- Cost simulation of the process steps

**Selling price analysis**
- Supply chain analysis
- Analysis of the selling price
Summary of the Physical Analysis – Transmitter Block

- The optical connector is disassembled to get dies and optical components data: dimensions, main characteristics, device markings.

- The components of the transmitter line are identified:
  - Pictures of selected area are made in order to understand the connections and the way of light
  - High Resolution Optical photographs to measure the lines dimensions.
  - Cross section of Silicon Photonic die to measure thicknesses.
  - Delaying of the die to observe waveguides, Mach-zehnder modulator, etc
  - Cross section of optical parts to measure thicknesses and EDX analyse of the materials.
    - Lens module
    - Prism
    - Isolator
    - Fiber optic coupler
  - Cross section of MZI Driver and CDR ICs to measure thicknesses.
  - Explanation of the transmitter line
Summary of the Physical Analysis – Receiver Block

- The optical connector is disassembled to get dies and optical components data: dimensions, main characteristics, device markings.

- The components of the receiver line are identified:
  - Pictures of selected area are made in order to understand the connections and the way of light
  - High Resolution Optical photographs to measure the lines dimensions.
  - Cross section of Germanium photodiode die to measure thicknesses.
  - Cross section of optical parts to measure thicknesses and EDX analyse of the materials.
    - Fiber optic coupler
  - Cross section of TIA and CDR ICs to measure thicknesses.
  - Explanation of the transmitter line
Intel 100G PSM4

Overview / Introduction
Company Profile & Supply Chain
Market Analysis

Physical Analysis
- 100G PSM4 Teardown
  - Transmitter Block
    - View, Dimensions, Cross-Section, Fiber Optic Coupler
  - MZI Modulator Driver Die
  - Die View & Cross-section
  - Silicon Photonic Die
    - InP Laser Cross-Section
    - MZI Modulator Cross-Sect
    - Mirror Cross-Section
    - Waveguide Cross-Section
  - Receiver Block
    - Fiber Optic Coupler
    - Ge Photodiode Die
      - View & Process
      - Die Cross-Section
    - TIA Die
    - Macom M37049G Die

Physical Comparison
Manufacturing Process Flow
Cost Analysis
Related Reports
About System Plus

Dimensions
- Height: 120 mm
- Width: 18.5 mm
- Thickness: 8.6 mm

Weight
- 69g

Intel 100G PSM4 Overview
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Intel 100G PSM4 Front, Side and Back View
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Intel 100G PSM4 Teardown

- The metal cover contains several pieces realizing the data to the light features.
- This is made with four main components:
  - The silicon photonic die
  - The modulator driver
  - The light guide
  - The fiber coupler
Intel 100G PSM4 – Transmitter Block
InP Laser Diode – Silicon Photonic Die

Physical Analysis
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    - Fiber Optic Coupler
    - Ge Photodiode Die
      - View & Process
      - Die Cross-Section
    - TIA Die
    - Macom M37049G Die

Physical Comparison
Die Delayering – 4x Ge Photodiode Die

Physical Analysis
- 100G PSM4 Teardown
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  - TIA Die
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Physical Comparison

Manufacturing Process Flow

Cost Analysis

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Silicon Photonic Die Wafer Process Flow Epitaxy

- SOI etching: Lithography 1
- SOI etching: Lithography 2
## Handle Wafer Front-End Cost

<table>
<thead>
<tr>
<th>Handle Wafer for the Chiplet</th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
</tr>
</tbody>
</table>

### Cost Analysis
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- Yields Explanation & Hypotheses
- Transmitter Block
  - Si Photonic Die
    - Wafer Cost
    - Step cost
    - Die Cost
  - MZI Driver Die
  - MACOM M37049G
  - Optical Elements
  - Assembly
- Receiver Block
  - Ge Photodiode Die
  - TIA Die
  - MACOM M37049G
  - Optical Element
  - Assembly

### Related Reports
- About System Plus
## Transmitter Block Cost

### Assembly Cost

<table>
<thead>
<tr>
<th></th>
<th>Low Yield</th>
<th></th>
<th>Medium Yield</th>
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<th>High Yield</th>
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<td>Breakdown</td>
<td>Cost</td>
<td>Breakdown</td>
</tr>
</tbody>
</table>

- **Adhesive Deposition**
  - Photonic Die placement

- **Transmitter Block**
  - Si Photonic Die
    - Wafer Cost
    - Step cost
    - Die Cost
  - MZI Driver Die
  - MACOM M37049G
  - Optical Elements
    - Assembly

- **Receiver Block**
  - Ge Photodiode Die
  - TIA Die
  - MACOM M37049G
  - Optical Element
  - Assembly

### Related Reports

- Cost Analysis Summary
- Yields Explanation & Hypotheses
- Transmitter Block
- Receiver Block

**Cost Analysis**

**Company Profile & Supply Chain**

**Market Analysis**

**Physical Analysis**

**Physical Comparison**

**Manufacturing Process Flow**
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- Luxtera Silicon Photonic Die
- Mobile Camera Module Comparison 2019
- STMicroelectronics’ Near Infrared Camera Sensor in the Apple iPhone X
- Apple iPhone X – Infrared Dot Projector
- Orbbec’s Front 3D Depth Sensing System in the Oppo Find X

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