Advances in PIC – Using DenseLight’s HIPP™ Platform to Deliver Integrated Sensing Optical Engines & Interrogator Systems

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Presenter: Lam Yee Loy, CTO, DenseLight Semiconductors Pte Ltd
DenseLight – Powering Your Future Through Light

Innovative Singapore company providing state-of-the-art optoelectronics products for photonics sensing and datacom

- Founded May 2000 on NTU photonics integration technologies, VC-funded
- Engaged in the design, manufacture, and marketing of optoelectronic devices and photonic integrated circuits
- Industries served: active photonics components for photonics sensing & datacom
- M&A acquisition by POET Technologies in May 2016, a Toronto-listed developer of integrated photonics platform

✓ Product Design and manufacturing
✓ Optoelectronics Semiconductor Wafer Fab
✓ Discrete & Integrated Photonics Manufacturing
✓ Assembly, Packaging & Test
✓ Global sales & technical marketing footprint

Respectable global installed-base of >150,000 photonics sensing equipment worldwide

Operationally ready wafer fab and Assembly & Test capacity, ISO 9001:2015, Telcordia qualified, and certified (TuV, BS, UL)
Data Centres Driving Future Solutions

Mega data centers require new technology
Need smaller, faster, cheaper and lower power integrated photonic transceivers

Mega Data Centers built by

Amazon  Google  Facebook  Others

A single Mega data center (500,000 sq. ft.) is estimated to require
~700,000 100G long reach transceivers @ $250 ASP = $175M

Source: Needham & Co., Research Note on AAOI, May 22, 2017
Growth of Integrated Photonics

Integrated photonic transceivers will dominate the market

Integrated transceivers forecast to

$20 Billion by 2025

from $3.2 Billion today

surpassing current discrete-based devices in 2021

Source: Oculi, Inc.
Why Integration Matters

Our approach to “integration” is through the use of Optical Interposers

- Packaging and testing are a large fraction of BOM cost of conventional Photonics devices
- Integration of devices onto a single chip (monolithic) or within a package (hybrid) is the only effective means to:
  - Improve size, power, cost, speed, reliability and scalability
  - Enable new functionalities
  - Drive disruption in optical communications
Combining the Best Technologies for Superior Performance

Hybrid integration combines the best, market-ready solutions:
- InP for Active Devices (light generation, modulation and detection)
- DIP dielectric for Passive Devices (light splitting, filtering and interference)
- Si or dielectric for Bench and Packaging (optical alignment, thermal management, electrical, encapsulation)

<table>
<thead>
<tr>
<th>BUILDING BLOCK</th>
<th>PERFORMANCE</th>
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<tbody>
<tr>
<td>Indium Phos. (InP)</td>
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<td>Silicon (Si)</td>
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<td>Dielectrics (DIP)</td>
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<td>Passive Components</td>
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<td>Lasers</td>
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<td>Modulators</td>
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<td>Switches</td>
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<td>Optical Amplifiers</td>
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<td>Detectors</td>
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<td>Bench</td>
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Integration platform leverages the optimal technology for individual components to deliver the highest performing complete solution.

HIPP™: Hybrid Integration Photonics Packaging using POET Optical Interposer Technologies
HIPP™ with POET Optical Interposer Platform

Optical Interposer

- Electrical Die 1
- Electrical Die 2
- Optical Die 1
- Optical Die 2
- Waveguides
- Optical Axis
- Z-height Alignment Stops
- Wafer Level Hermetic Cap Seat (Optional)
- Active Die
- Waveguide Layer
- Solder Bump on Die Side
- Metal
- Wirebond Pad
- Active Die Attach
- High Resistivity Silicon Substrate
- Multi-level (Optical) Cu backend. Interposer can include passives such as resistors, MIM caps, etc.
- Scribe Street and Fiber Groove
Chip-scale Integration with Optical Interposer Technology

A multi-purpose integration platform with unique benefits for transceiver manufacturers in datacom and telecom

Proprietary Dielectric Waveguides eliminate costly components and “active” alignment
- Ultra-low loss material improves coupling efficiency
- Athermal – not sensitive to temperature changes
- Passive devices embedded in dielectric at no added cost

System Architecture allows optimal power/performance/cost
- Small form factor and elegant lateral optical axis design
- High scalability for multiple protocols and increasing data rates
- High flexibility platform for customized applications

Full Wafer-level Integration of all components
- Fabrication, test, packaging all at wafer level
- Hundreds of modules vs. one module at a time
- Known good device assembly improves yield and lowers cost

True Silicon CMOS compatibility a disruptive advantage
- On-chip integration with electronic devices
- Competitive waveguides (glass, silica, SiN) NOT compatible with CMOS
- Multiple applications beyond transceivers

POET WDM Optical Engine in Transceiver Assembly
100G LAN WDM Transceiver Optical Engine
- Scalable to 400Gbps
- Single Mode Fiber (SMF) with Wavelength Division Multiplexing (WDM)
- Eliminates costly fibers using WDM
- Longer reach (10m – 2km) than PSM4
- Integrated with proprietary dielectric photonic technology for lowest-cost integration and packaging
- Sustainable cost advantage compared to all incumbent technologies
- Low Loss, Low Power
- Potential to reach economic goal of $1/Gbps cost

400Gbps Data Center Interconnects

10/26/2018
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Markets - Photonics Sensing

**Test & Measurement (10b)**
- Component and material testing
- Distributed temperature sensing
  - Fibre Bragg Grating Sensors

**Structural Health Monitoring (6b)**
- Smart-grid sensors
- Transport-related sensors
  - Monitoring of civil infrastructure
  - Fibre-optic sensing

**LIDAR (3b)**
- LIDAR Wake Steering in Wind Farms
- Self-driving cars

**Medical & Healthcare (2.5b)**
- Optical coherent tomography (Biomedical imaging)
- Non-invasive blood glucose monitor
- Patient monitoring
- Pulse oximeters

**Guidance & Navigation (4.5b)**
- Unmanned aerial vehicles
- Fibre-optic Gyrocompass
- Industrial robotic automation
- Tunnelling

**Distributed Acoustic Sensing (1B)**
- Railway network
- Leak Detection in Oil Pipes

Market size numbers represent projections/forecasts/estimates.
Source: MarketsandMarkets, LaserFocusWorld, Allied Market Research, Photonics Industry Report by Photonics.org, Light Counting 2016 Reports (FTTX, Data Centers)
Applying HIPP™ to Transform Sensing Optical Engine (SOE) and Interrogator Systems

Transformation for Success

SOE subsystem

SOE in Backward Compatible Packages

SOE enabled Integrated Module System Solutions
Potential application examples: Transmit Sensing Optical Engines (SOE)

Super-broadband Incoherent Lightsource

8-channel Multi-Wavelength Sensing Lightsource
Potential application examples: Interrogator System Application

Automotive LIDAR Optical Engine

State of Art → Pulsed-laser Time-of-Flight Direct Detect (905nm or EDFA-1550nm)
Next Generation → Coherent Automotive LIDAR (e.g. FMCW LIDAR)

CHALLENGE: Complex optical circuitry with many different types of components
SOLUTION: Integration Photonics for very compact, high reliability, very low cost, high volume market

Chart: Coherent detection versus conventional pulse power direct detection: 10,000 times lower laser power requirements

Adv of SOE-FMCW LIDAR over state-of-art Direct Detect method:
✓ Eye-safe 1550nm emission
✓ 10000 times lower laser power needed
✓ Longer range: >400m
✓ Higher accuracy: <5 millimetre
✓ Robust all-solid state construction
✓ Significant Lower cost at high volume (wafer scale mfg)
✓ Inherent Cross-talk immunity: major issues with current pulsed-laser Lidar as more lidar traffic increases

Ref: Daniel J, et al, Optics Express, vol26, no12, June 2018


HIPP™-SOE for FMCW LiDAR

Fig. 4. Block diagram for homodyne self-chirped detection.


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DenseLight Value Add

- Established since 2000, first supplier to get *SLED Telcordia qualification*. Remaining few independent InP foundry and the expertise to operate R&D and manufacturing.
- Invested > USD50M in a design centre, wafer fab, assembly and test Singapore facility run by group of experienced photonics experts.
- Strong global market reputation— shipped *over 150K units (sensing only)* since inception. Lead supplier for biomedical imaging (OCT) applications.
- Supplier to major private & defense companies – Viavi (JDSU), Leica, Wuhan HTX, Connect Fiber, ELOIRA, Huawei, Optolink, Molex, Singapore Defense.....
- IP encompasses competency across fields of III-V optoelectronics design, assembly, test and packaging and box assembly to system.
- Since POET acquisition have embarked on a organization transformation process to achieve next level of success in the existing sensing and the new data center markets.
- In house *vertical integration* allows us to become a first choice, flexible and dependable partner.