The Challenges in High Volume Manufacturing of Photonic Devices

Dr. Yi Qian
Vice President, Product Management
MRSI Systems
About the Talk

The Trends

The Challenges

The Opportunities
High Growth Internet and Data Traffic Drive Bandwidth Demand

CAGR = 24%

(1) Cisco Visual Networking Index: Forecast and Methodology, 2016-2021
(2) Cisco Global Cloud Index: Forecast and Methodology, 2015-2020
Global Data Center Traffic >5X of Non-Data Center Traffic

Visual Networking Index (VNI)

- **A** + **B** = 2.3 ZBs
- **A** Non-Data Center Traffic
  - NOT included in GCI
- **B** Data Center-to-User Traffic
  - This is the overlap between VNI and GCI

Global Cloud Index (GCI)

11.7 ZBs

- **B** + **C** + **D** = 15.3 ZBs
- **B** Data Center-to-User Traffic (14%)
  - This is the overlap between VNI and GCI
- **C** Data Center-to-Data Center Traffic (9%)
  - Traffic that flows from data center to data center
- **D** Within Data Center (77%)
  - Traffic that remains within the data center

Hyperscale / Cloud Data Centers Drive Growth

Source: Cisco Global Cloud Index, 2015-2020; Synergy Research.
"Deep Pocket" Cloud Providers Sustain Spending on Data Centers

<table>
<thead>
<tr>
<th>Group average</th>
<th>2Q17 result</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues</td>
<td>Up 16%</td>
<td>Growth accelerating again</td>
</tr>
<tr>
<td>Spending</td>
<td>Up 20%</td>
<td>Double 1Q17 growth rate</td>
</tr>
<tr>
<td>Operating margin</td>
<td>20%</td>
<td>Flat vs. year ago quarter</td>
</tr>
<tr>
<td>Net income</td>
<td>26%</td>
<td>Up sharply, well above long term average of 20%</td>
</tr>
<tr>
<td>Cash &amp; equiv.</td>
<td>$491 billion</td>
<td>Up 23% y-o-y, record high</td>
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**3Q17/3Q16 segment growth**

- Telecom: -3%
- Datacom: 10%
- Equipment: -4%
- Components: -9%

* Includes Alibaba, Alphabet, Amazon, Apple, Baidu, eBay, Facebook, Microsoft, Oracle, PayPal, Sohu, Tencent, Twitter,
Photonics is Essential for Bandwidth Growth

- Lasers
- Detectors
- Modulators
- Transmitters
- Receivers
- Transceivers
- Switches

Longhaul:
Between Data Centers

Metro:
Within Data Center

Access:
5G Wireless
Datacom / Data Center Drives Future Optical Transceiver Growth

CAGR ('16-'22)
19%

CAGR ('16-'22)
3%

LightCounting April-2017
About the Talk

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The Opportunities
### New Cloud-based DC Model
- Controlled operating climate
- Upgrade every 3-5 years
- Low photonics installation costs
- **High** volume
- **Poor** forecast visibility
- Fast project ramp up and tailing down
- Fast pace of innovation
- Extremely sensitive to photonics cost ($<1/Gbps)

### Traditional Telecom-Centric Model
- Stringent operating environments
- Device life time for 20+ years
- High photonics installation costs
- Medium-low level of volume
- Good forecast visibility
- Slow project ramp and tailing down
- Slow pace of innovation
- Reduced sensitivity to photonics cost (field service is #1 cost now)
Photonics Manufacturing Needs to Handle High Volume and High Mix

Optical Transceivers

Unit (in Millions)


LightCounting April-2017
Large Varieties of Parts through Manufacturing Assembly Lines

- Chip & Die
  - FB/DFB/EML lasers
  - Pump lasers
  - PDs
  - Capacitance Thermistor
  - LiNbO3 modulator chip (1/10th to actual)
  - AWG (1/4 scale)
  - Lens Isolator (1/2 scale)
  - VCSEL arrays
  - LD Driver
  - TIA

- Chip on Carrier (CoC)
  - Single die CoC
  - Multi-die CoC
  - Multi-die PIC (SiPh, Glass, etc.)
  - Laser CoC, lens on Baseplate
  - Laser or PD on TO
  - VCSELs-Drivers/PDs-TIAs
    - Lens on AOC PCB

- Open Package Assembly
  - Laser
  - TOSA
  - ROSA
  - Receiver
  - Modulator
  - Complex TO
  - AOC

- Final Module
  - Laser
  - Transceiver
  - Receiver
  - Modulator
  - BOSA
  - TOSA, ROSA
  - AOC

MRSI Systems Proprietary
www.mrsisystems.com
Advanced Products Require Increasingly High Precision Assembly

Higher Density
Smaller Size

Higher Speed
Higher Precision

Need to assemble more parts on smaller carriers/boards and into smaller packages.
Need to manage smaller gaps between parts for low impedance and thus higher speed.
Need to align more precisely between parts on light path for higher power and better yield.
About the Talk

The Trends

The Challenges

The Opportunities
Opportunities Exist with Challenges

Data Center
- High volume
- Fast ramps
- Poor forecast
- Rapid innovation
- Cost sensitive

Photonics
- High volume, elastic capacity
- Advanced products
- Accelerated NPD
- Risk free NPI
- Cost efficient SCM

Automation
- High speed
- High flexibility
- High precision
- High reliability
- ROI on Capex and Opex
Automation Improves Photonics Supplier’s Response to Data Center Demand

Data Center Provider’s cloud-based business model
- Project based, Just-In-Time Procurement
- Qualified suppliers compete for the best delivery and lowest cost

Challenges for photonic device suppliers
- Need reasonably large manufacturing base for the size of each order
- Can’t ramp fast enough for short lead time when getting an order
- Can’t reduce labor cost fast enough when missing an order
- CM model is sometimes challenged to respond due to capacity competition for the same projects from multiple photonics customers at one time

Response of photonic device suppliers
- “Elastic” capacity model for
  - High Quality, Low Cost manufacturing with Fast Switch on-and-off of capacity
- More automation for R&D&E and Manufacturing
  - Lower dependence of labors to reduce variable cost (labor hiring, training, and retention)
  - Minimize risks for NPI by using the same automation platform and processes
  - High precision automation enables processes and thus advanced products that could not be achieved manually
Flexible Automation for High Volume and High Mix Manufacturing

High Mix Automation Costs

- **Production Cost**
  - (given volume, over given period of time)

- **Manual production**

- **Robot production**
  - (including tooling + changeovers)

- **Robot production**
  - Flexible fixture

- **High Mix**
  - Lots of:
    - Changeovers
    - New Product Introduction

For Photonics
- **HVM**
- **High Volume, Delivery**
- **Low Cost**
- **Rapid Innovation**

Approved to use by ROBOTIQ
A Case Study - Automation

MRSI-HVM3

A New Class of Automatic Die Bonding Machine for Photonics High Volume Manufacturing
Target the Highest Volume Applications – Multi-CoS per Transceiver

Chip & Die
- FB/DFB/EML lasers
- Pump lasers
- PDs
- Capacitance Thermistor
- LiNbO3 modulator chip (1/10th to actual)

Chip on Carrier (CoC)
- Single die CoC
- Multi-die CoC
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- Laser CoC, lens on Baseplate

Open Package Assembly
- Laser or PD on TO
- VCSELs-Drivers/PDs-TIAs /Lens on AOC PCB

Final Module
- Laser Receiver Modulator
- Modulator
- Complex TO
- AOC

Solder or epoxy joint
High Flexibility

Enables Multi-Chip Multi-Process CoS Assembly In One Machine

- Photonics CoS assembly involves lots of different types of parts (size, geometry) that can’t not be picked/placed by single fixed tool

- MRSI-HVM3
  - Integrated “On-the-fly” tool change module with up to 13 vacuum tips/collets
  - Spacious working areas for large variety of materials handling (up to 30x 2” Waffle-Pak/Gel-Pak, and 2x 4”or 6” wafer tape)
High Precision Improves Manufacturing Yield and Enables Advanced Products

• Photonics HVM needs high precision for higher yield, higher speed and more complex products

• MRSI-HVM3 provides future-proof assembly with $\pm 3\mu m@3\sigma$ die bonding precision
  – Built based upon long proven MRSI-M3 ($\pm 3\mu m@3\sigma$)
  – Current photonics HVM tightens front end (e.g. CoS) packaging tolerance to have better yield in later packaging steps to reduce total assembly cost
  – Next generation photonic packaging designs require $3\mu m$ die bonding precision for $5\mu m$ post-processing accuracy
  – Some of silicon photonics assembly steps need $3\mu m$ die bonding precision to work with self-alignment mechanics built on parts using semiconductor nanofabrication in order to achieve submicron post-processing accuracy
• Photonics HVM needs high speed equipment to be flexible and precise

• MRSI-HVM3’s speed is the fastest in class (<7µm) for photonic CoS HVM, without sacrificing precision or flexibility, realized by optimizing assembly steps
  – “on-the-fly” tool change
  – Parallel material handling and final bonding steps using dual head/gantry/stage
  – Ultrafast temperature ramping & cooling of eutectic hot stage
High Reliability Proven by MRSI’s Long Track Record Serving Manufacturing


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Recap

The Trends
Data Center Drive; High Volume; High Mixes; JIT

The Challenges for Photonics
High volume high mix; Quick delivery; Rapid innovation; Make profit

The Opportunities in Automation
Speed; Flexibility; Precision; Reliability

A Case Study with MRSI-HVM3
The fastest in class (< 7µm) fully automated die bonder with 3µm high precision, superior flexibility and long proven reliability for high volume manufacturing of photonic chip-on-submount
Thank You!

MRSI Systems Proprietary

www.mrsisystems.com

yi.qian@mrsisystems.com
Sales@mrsisystems.com
About the Company: MRSI Systems

History – 33+ Years of Precision Automation Solutions

MRSI was founded in Massachusetts in 1984. We are the leading provider of automated solutions for dispense and assembly of microelectronic and optoelectronic devices.

1984 – 2002
Micro Robotics Systems, Inc. (MRSI)

2002-2014
Newport Corporation

2014 –
MRSI Systems
About the Speaker: Dr. Yi Qian

• VP Product Management, MRSI Systems
  – Automating photonics manufacturing
  – Ph.D. in Physics + B.S.E.E.

• A veteran of lasers and photonics for multi-markets
  – Developed high power pump lasers and high speed EML/DFB lasers for optical communications
  – Managed 40G/100G transceiver product lines for optical communications
  – Managed high speed laser scanner product lines for multiple industries (medical, industrial, etc)
  – Led a startup’s engineering and developed 3D laser sensors for medical and industrial