Silicon Photonics Wafer-Level Test & Measurements

Technical Consultant / FormFactor Inc.
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Bio Data

- Support Customer Applications & Production Solutions, Marketing
- 10 Years with Cascade Microtech Inc. prior to Formfactor Inc. Merger
- Ph.D. in RF Device Design and Modelling
- Worked with International Semiconductor companies, foundries as well as renowned Research Institutes & Universities in the world
- IEEE MTT-11 Microwave Measurement Committee
  - Measurement Best Practices, Emerging Technologies & IEEE Workshop
- IEC TC47 – Technical Expert representing Singapore
  - Sponsored by Singapore Standards, Productivity and Innovation Board
  - Leading Wafer-level Device Reliability Tests & Standards
- EECE Technical Committee, Institution of Engineer Singapore (IES)
- Research Interests:
  - DC, AC, 1/f noise, Power Device Characterization
  - Wafer-Level Optical Measurements, THz Calibration & Characterization of Devices
Agenda

- Why Silicon Photonics?
- Why Wafer-level Photonics Test?
- FormFactor Integrated Wafer-Level Photonics Probing Solution
- Key Advantages of FormFactor’s Photonics Solution
- RF Wafer-Level Solutions to Support Optical-Electrical Tests
- Conclusions
Why Silicon Photonics?

- Demands for high bandwidth & big data
- Improvements in Thin Film technologies
  - Overcoming lattice mismatch
  - Very High Quality III/V semiconductor material on Silicon substrate
- Exploiting Silicon Technologies
  - High Volume Production = Low Cost
  - 300mm wafers
  - Ultra Low Power Logic devices
  - High Performance RFCMOS devices
  - Higher Integration
    - Higher interconnect density/Layers
    - More embedded functionalities
Other Photonics Applications
LIDAR (Light Detection and Ranging)

Leddar Tech

Military Payload
>1K Units

Geographical Survey
>20K Units

Robotics
>100K Units

Construction & Industry
>250K Units

Autonomous Navigation
>1M Units

3D Drone Mapping

High Volume

Low Volume
Imaging for Automotive Applications

- LIDAR will become key sensors for autonomous vehicles
Imaging for Automotive Applications – Solid-State LiDAR

Analog Photonics is developing the next generation chip-scale Light Detection and Ranging (LiDAR) sensor solutions using proprietary and patented silicon photonics and optical phased array technology.

Advantages

- Miniaturized
- Low-cost
- Aesthetic
- Eye-safe
- Chip-scale
- Lens free
- No moving parts

Applications

- Advanced driver assistance systems (ADAS)
- Autonomous driving
- Parking assistance
- Cabin monitoring
- Laser mapping
- Robotics
- Mobile-device
LIDAR on UAV

- **Solid-State LIDAR**
  - Higher Imaging Precision
  - Lighter Payload
  - Longer Time in the Air

- **Applications**
  - Environmental & Coastal 3D Mapping
  - Agriculture Precision Forestry
  - Civil Engineering & Surveying
  - Defence & Emergency Services
  - Highway & Road Networks
  - Logistics – courier services
General Photonics Devices

- **Passives**
  - Low loss waveguides
  - Splitters
  - Wavelength selective combiners/splitters
  - Isolators/Circulators
  - Comb generators

- **Actives**
  - Lasers (single frequency, tunable, mode locked)
  - Modulators
  - Switches
  - Amplifiers
  - Photodetectors
Why Wafer-Level Photonics Test?

- **R&D**
  - Process Development
  - SPICE Model Development

- **Production**
  - Wafer Acceptance Test
  - Known Good Die Test

- **Reduce Development & Production Costs**

- **Faster Time to market**
FormFactor Integrated Wafer-Level Photonics Test Solution

- Joint partner integration between
  - FormFactor (formerly Cascade Microtech)
  - Keysight
  - Physik Instrumente

- Integrated solution provides optical alignment and measurement capability
Optical Probing System

- Z displacement sensor driver
- Optical positioner controller
- N7744A Optical power meter #2
- B2901A SMU
- N7786B Polarization synthesizer
- 81608A Tunable laser source
- Optical power meter #1
- CM300xi Probe Station
- Optical probe positioners
Optical Positioning Systems

XYZNano Positioners

HexNano Positioners

Fine Align
Long Travel
Precision Align
Long Travel Angular Align
Fully Automatic Wafer-level Photonics Test Solution with CM300
**Probe Design**

- **Top view**
  - Fine XYZ piezo positioner
  - Coarse XYZ/θ_{x,y,z} hexapod positioner

- **Bottom view**
  - Z displacement sensor
  - Fiber tip
  - Optical coupling point
  - Z displacement sensor provides precise realtime fiber height measurement

- **Side view**
  - Fiber angle
  - Fiber height

- **Fiber tip visible for coarse alignment with on-board eVue vision system**
Mixed Signal Probing

- Optical-Optical (O-O)
- Optical-Electrical (O-E)
Software

- Standard *Velox* probe station software controls Wafer Chuck and Vision System
- FormFactor developed *SiPTools* application bridges the gap between Velox and 3rd party applications such as Keysight Photonics Application Suite, also running on Probe Station PC
- Data flows through central Message Server hub through a single interface to end user’s Test Executive (e.g. Keysight Test Automation Platform)
Optical Scans to find Coupling Points

Sinusoidal Scan

- XY axes represent XY position of piezo (fine) positioner during scan, 0-100um range
- Z axis represents optical power meter signal transmitted through DUT
- Coordinates of optical “coupling point” is defined by the peak of this surface

Spiral Scan
Insertion Loss Measurements

- **IL Measurements**
  - Insertion loss vs. wavelength
  - Fixed polarization

- **IL/PDL Measurements**
  - Insertion loss vs. wavelength
  - Variable polarization
Silicon Photonics Command Set

- AlignOpticalProbes
- CalibrateCapSensor
- CalibratePositioner
- GetLaserPower
- GetPolarizationState
- GetProbeControlVal
- GetWavelength
- ILPDLsweep
- ILSweep
- MeasureFiberAngle
- MoveOpticalProbe
- MoveOpticalProbeZ
- MovePZT
- OpticalScan
- OpticalTracking
- PolarizationSearch
- PolarizationStabilize
- ReadBiasCurrent
- ReadFiberHeight
- ReadOPCPower
- ReadOpticalProbePos
- ReadPowerMeter
- RotateOpticalProbe
- SetBiasVoltage
- SetFiberHeight
- SetLaserPower
- SetOpticalProbeHome
- SetPivotPoint
- SetPolarizationState
- SetProbeControlVal
- SetWavelength
- SetWorkingFolder
- StopSiPTools
- TrackFiberHeight
Alignment & Measurement Demonstration
Key Advantages of FormFactor’s Photonics Solution

- Designed for Flexibility from Engineering to Production.
- Easy to use, Fast & Flexible firmware driven Alignment Algorithms implemented in Controller Hardware.
- Closed-loop control to hold Position Stably without Needing to Track to stay Coupled.
- Know-how to Determine, Calibrate and Set Fiber Height Accurately.
  - Planarity of Chucks today cannot handle 10μm Fiber Hover Height
- Integrate Seamlessly with Keysight Optical Instruments for IL and IL/PDL Measurements
RF Wafer-Level Solutions to Support Optical-Electrical Tests
Infinity GSG, GSSG, GSGSG RF Probe

- Best Electrical Performance
- Thin Film Microstrip
- Nickel Alloy Tips
- Low & Stable Contact Resistance
InfinityQuad, Multi-Contact Probe

- Configurable Probe Family
- 4 to 25 Probe Tips
- Any Tips can be configured as:
  - Ground, Power, 500 MHz logic, 20 GHz RF
- Any 4 Tips can be configured as:
  - 40, 50, 67 or 110 GHz
- Small Test Pads, 30x50um
- Low Probe Contact Resistance
- >250,000 touchdown lifetime
Tip Construction
Tip Construction
RF Performance
Premium RF Performance
X-Talk Performance

landed on dual load

-20
-25
-30
-35
-40
-45
-50

0 5 10 15 20 25 30

GHz

-20
-25
-30
-35
-40
-45
-50

0 5 10 15 20 25 30

GHz

GSG × TALK (S21)  SGS × TALK (S21)

FormFactor™
Calibration Software & Calibration Substrates
Conclusions

- **Strong Demands for Photonics Integrated Circuits on Silicon Technology.**
  - High Bandwidth, Big Data
  - Solid-State LIDAR

- **FormFactor provides a Market-Leading, Proven, Photonics Wafer-level Test Solution through Seamless Integration with Keysight & PI.**
Thank You!
Questions?

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