Challenges and progress in design of Electical IC's for Analog Drive Optics

2022.12.16

InSiGa

Bridging Technologies

Introduction to InSiGa

InSiGa

Bridging Technologies

- Company started in July 2016
- Focus is on high speed optical communication market -10Gbs to 800Gbs
- Fabless business model
- Differentiation- Low power, small size IC's for 10-800Gbs market

Market Focus

5G Mid haul
5G Back haul
5G Front haul
200G-800G Coherent
100G Datacenter
200G Datacenter
400G Datacenter
800G Datacenter
10G PON (OLT)
50G PON

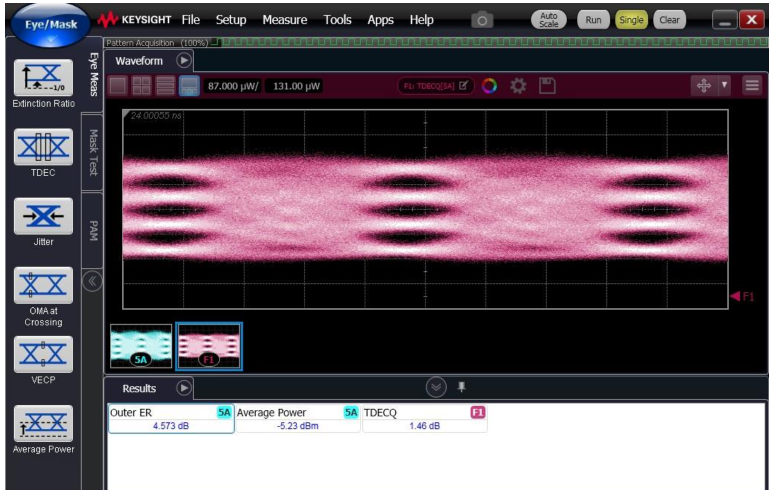
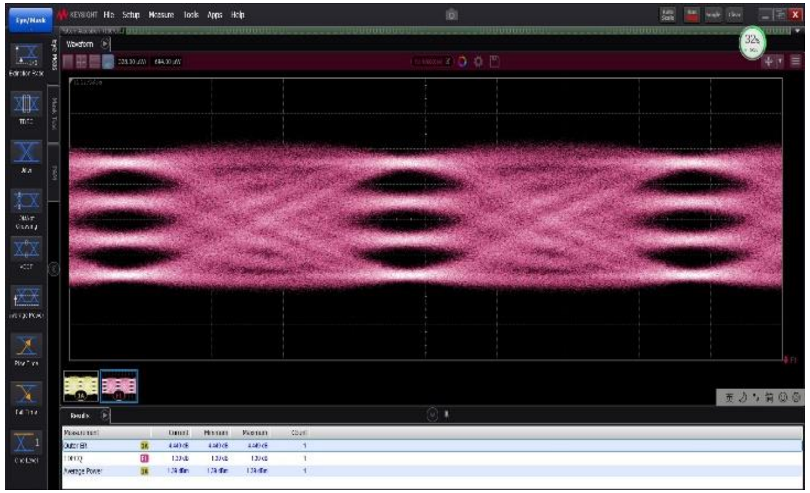
Market Trends

- Accelerated adoption of higher bandwidth modules
- Multi level Modulation schemes (PAM4, QAM) in mass deployment already
- DSP driven modules primarily for PAM4 modulation
- High cost pressures
- Bandwidth doubling almost every 2-3 years
- Silicon Photonics becoming prevalent for high speed modules

Optical Technology Choices – Single Mode Transmitter

- DML (Directly Modulated Lasers)
- EML (Electrically Modulated Lasers)
- Thin Film Lithium Niobate based MZ
- Silicon Photonics based MZ

Comparison of eye @ 53Gbauds

DML@53Gbaud/s	EML@53Gbaud/s	Si Photonics@53Gbaud/s
		
Outer ER=4dB TDECQ=2.2dB	Outer ER=4.5dB TDECQ=1.5dB	Outer ER=4.5dB TDECQ=1.3dB

Optical Technology Choices – Transmitter

For 53Gbaud/s PAM4 (100Gbs/lane)

Parameter	DML	EML	Si Ph	TFLN
Performance	3	2	1	-
Cost	1	3	2	-
Power	1	2	2	-
Scalability	2	2	1	-

Ranking – 1 is best, 3 is worst

Silicon Photonics – Challenges

- Power Dissipation
  - ❑Vpi (high drive)
  - ❑High power lasers
- Optical Coupling
- Controls- Heater, Bias, CW laser

Silicon Modulator Design- Key Parameters

Key parameters for Si MZ Modulator design

- ❑Vpi ↓
- ❑Bandwidth ↑
- ❑Optical Loss ↓
- ❑Length of Modulator (size) ↓
- ❑Impedance of Modulator ↑

Silicon Photonics Modulator Driver- Key parameters

Key parameters for Si Photonics Modulator Driver design

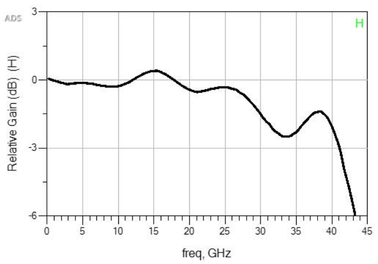
- ❑Output Swing ↑
- ❑Bandwidth ↑
- ❑Size ↓
- ❑Gain ↑
- ❑Linearity (THD ↓)
- ❑Impedance of Driver ↑
- ❑Power Dissipation ↓

Silicon Photonics Modulator Driver

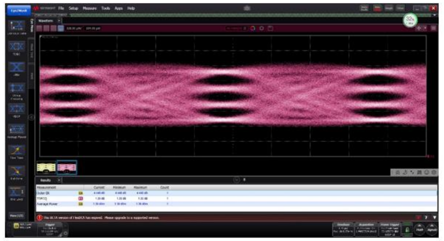
InSiGa 400Gbs Driver- ISG-D5640 (Technology – SiGe)

- Output Swing- 3.5Vpp
- Bandwidth > 40GHz
- Die Size – 1.7x3.7mm
- Gain – 17dB
- THD < 3%
- Driver Impedance- Very high
- Power Dissipation/ch- 260mW

- ❑ Output Swing ↑
- ❑ Bandwidth ↑
- ❑ Size↓
- ❑ Gain ↑
- ❑ Linearity (THD ↓)
- ❑ Impedance of Driver ↑
- ❑ Power Dissipation ↓



Bandwidth > 40GHz



Application – 400Gbs DR4

Outer ER =4.5dB
TDECQ=1.3dB
SSPRQ

Silicon based Receiver- Key Parameters

Key parameters for Receiver design

- ❑ Bandwidth ↑
- ❑ Optical Loss ↓
- ❑ Dark Current ↓
- ❑ PD Responsivity ↑
- ❑ PD Parasitic Capacitance ↓

Key parameters for TIA design

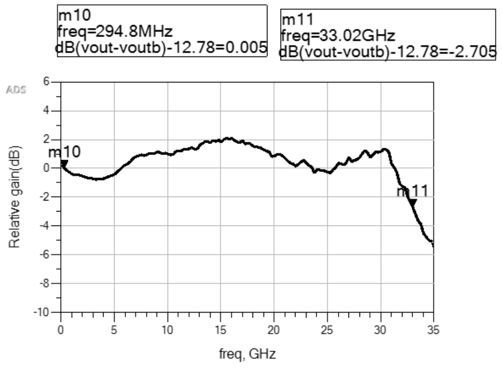
- ❑Noise↓
- ❑Bandwidth ↑
- ❑Size↓
- ❑Gain ↑
- ❑Linearity (THD ↓)
- ❑Power Dissipation ↓

TIA

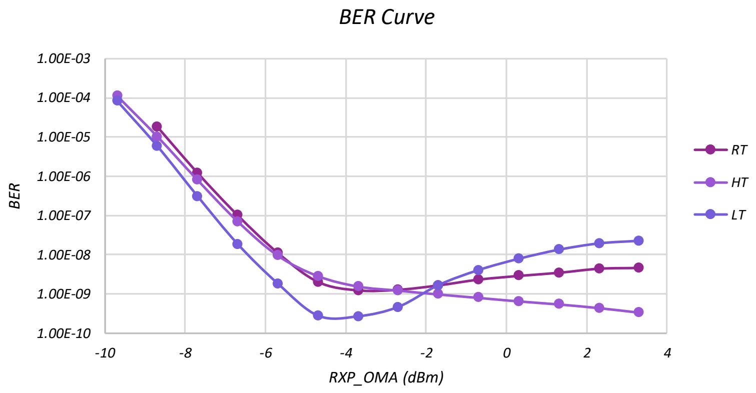
InSiGa 400Gbs TIA- ISG-T5743 (Technology – SiGe)

- Input Noise- 2.2uA
- Bandwidth > 30GHz
- Die Size – 1.3x2.35mm
- Gain – 4.5kohm
- THD < 3%
- Power Dissipation/ch- 160mW

- ❑ Noise↓
- ❑ Bandwidth ↑
- ❑ Size↓
- ❑ Gain ↑
- ❑ Linearity (THD ↓)
- ❑ Power Dissipation ↓



VDD=3.3V, IDD=39mA, GC=2.5V,
PD Cap=80fF, Rpd=10ohm, Lbw=0.5nH



ANALOG DRIVE OPTICS (ADO)

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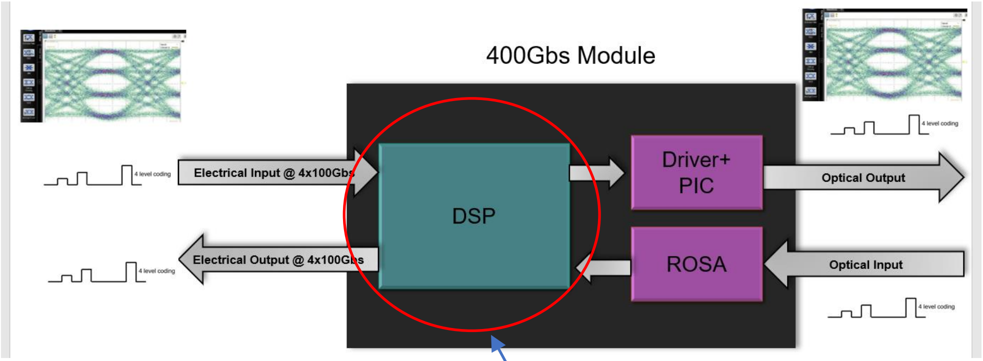
What are Analog Drive Modules (ADM)?

Analog Drive Modules -Modules without DSP

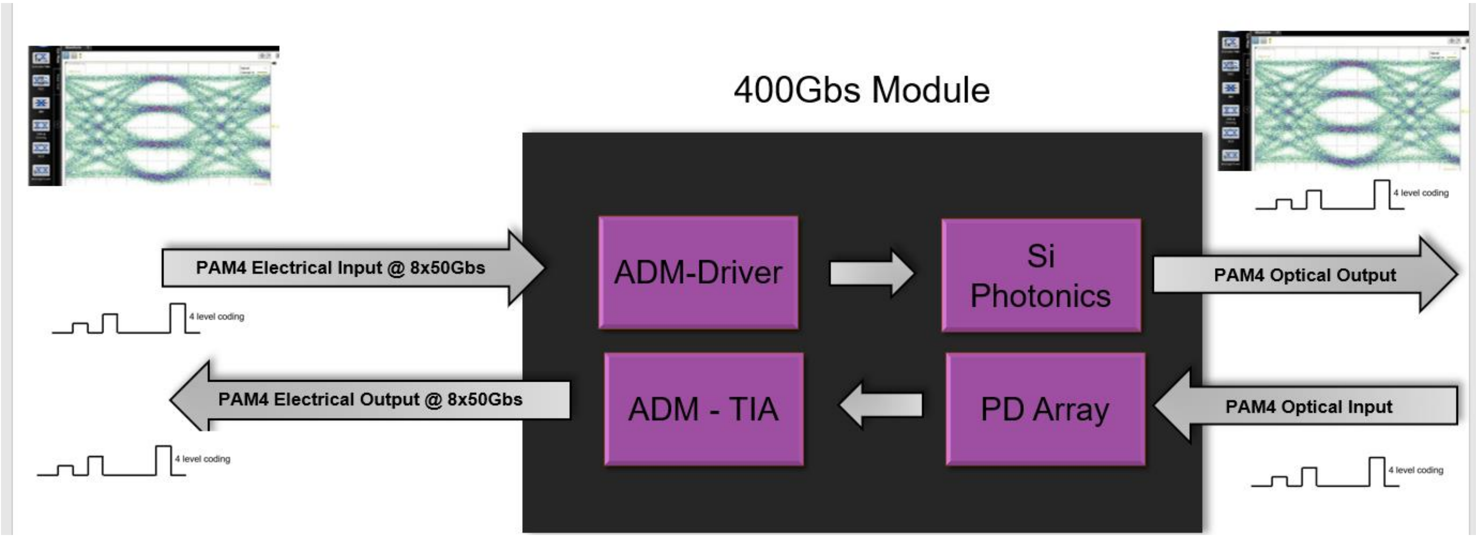


Remove DSP from Module

When are Analog Drive Modules (ADM) possible?

No gearbox requirement

- Input Signal rate and modulation is same as optical output



Analog Drive Modules -Modules without DSP

Analog Drive Modules -Modules without DSP

Advantages

- Low Cost
- Low Power Dissipation
- Higher channel/bandwidth density
- Low Latency

Analog Drive Modules -Modules without DSP

Challenges

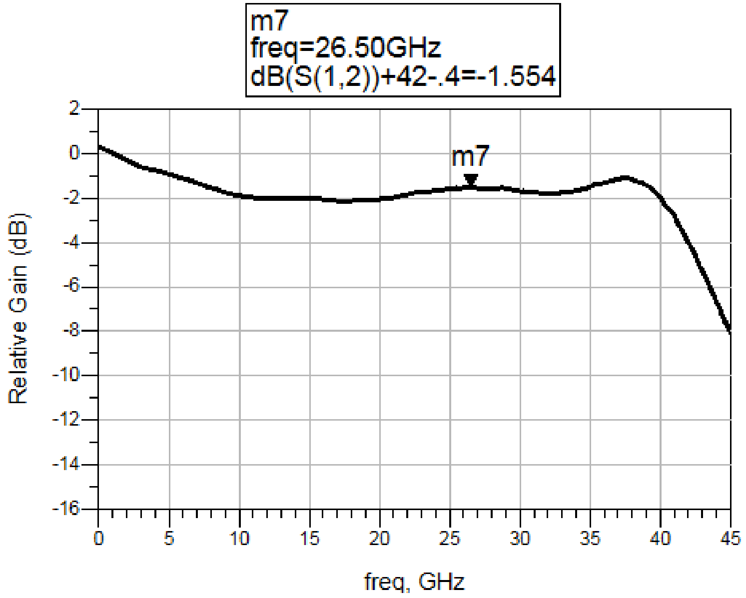
- Overcoming channel Loss on host/module
- Connector Mismatch issues (No resonance in band due to connector and module interface)
- Phase/Group Delay Compensation

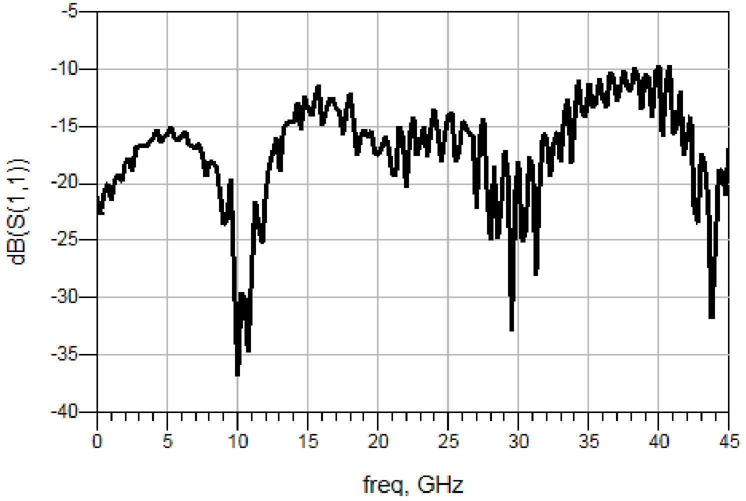
What are challenges for Modulator Driver for ADM?

Challenges for Modulator Driver Design

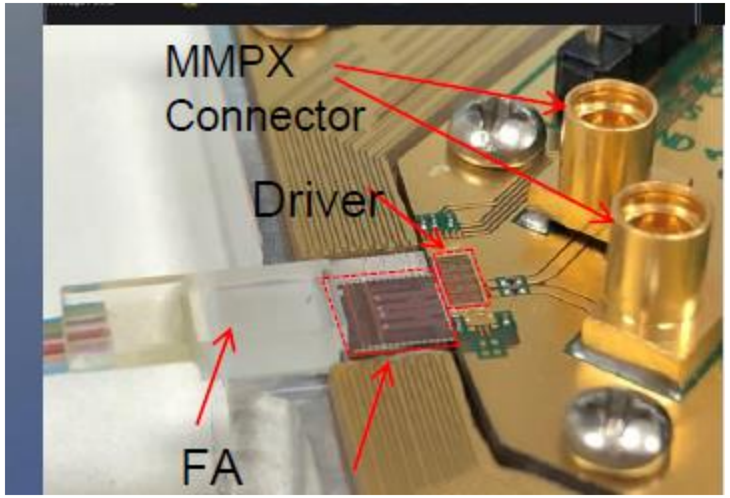
- Equalization capability to compensate for losses
- Good Input return loss to minimize reflection issues
- Good Phase response (Group delay)
- Good linearity

Measured Driver + PIC Performance on EVB





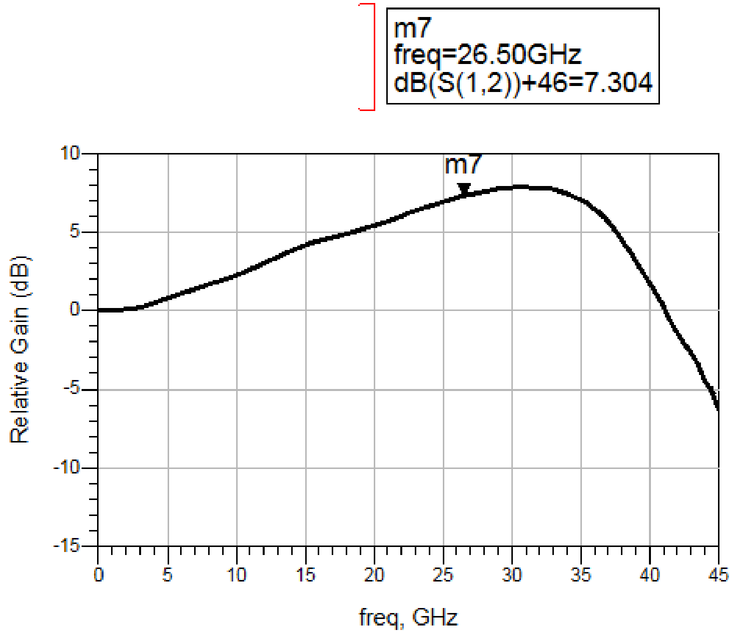
Test Setup

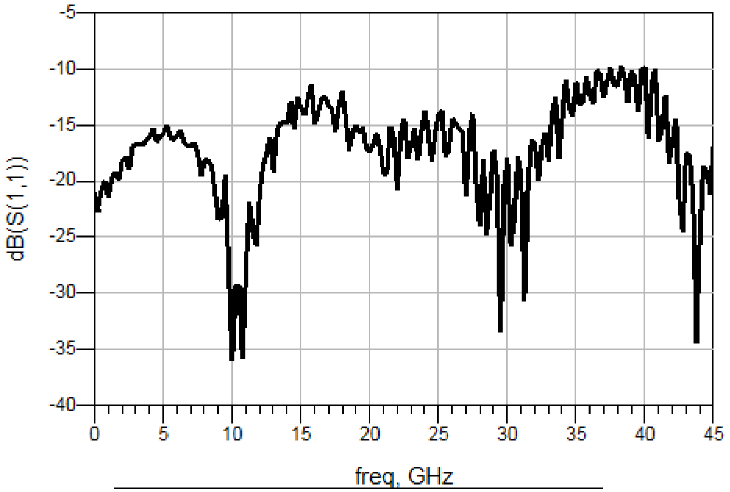


Si PIC

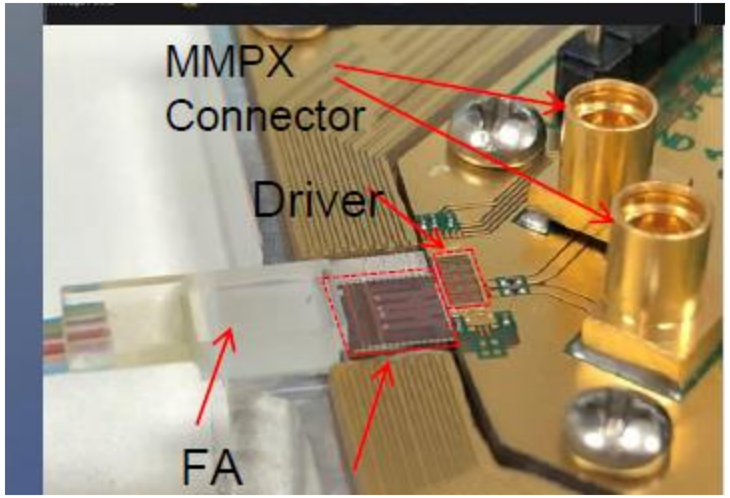
Lowest Equalization from InSiGa Driver- ISG-D5640

Measured Driver + PIC Performance on EVB





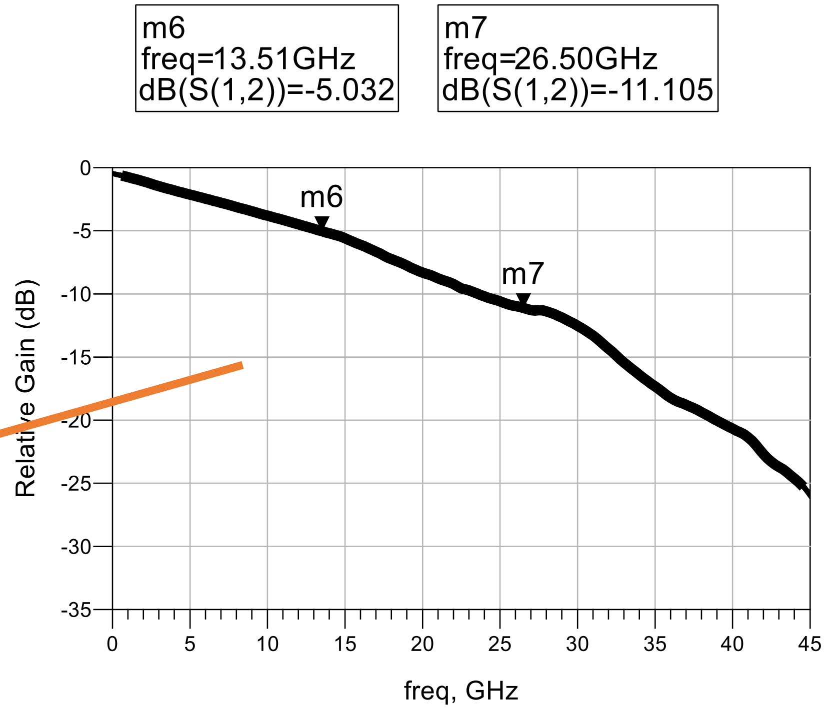
Test Setup



Si PIC

Maximum Equalization from InSiGa Driver- ISG-D5640

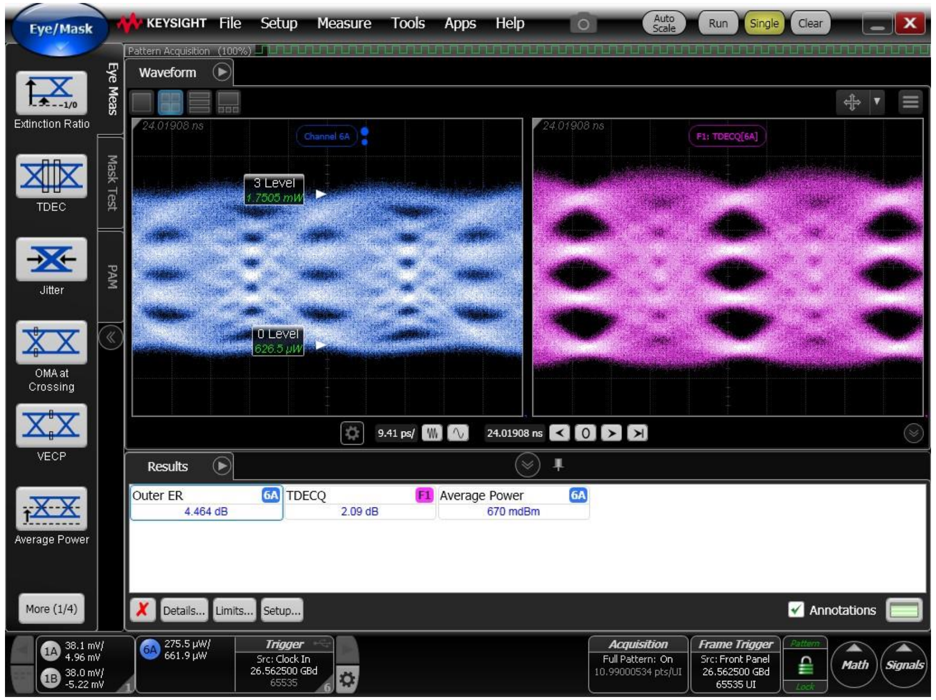
Test Setup with PCB loss



Loss of PCB – 14cm trace

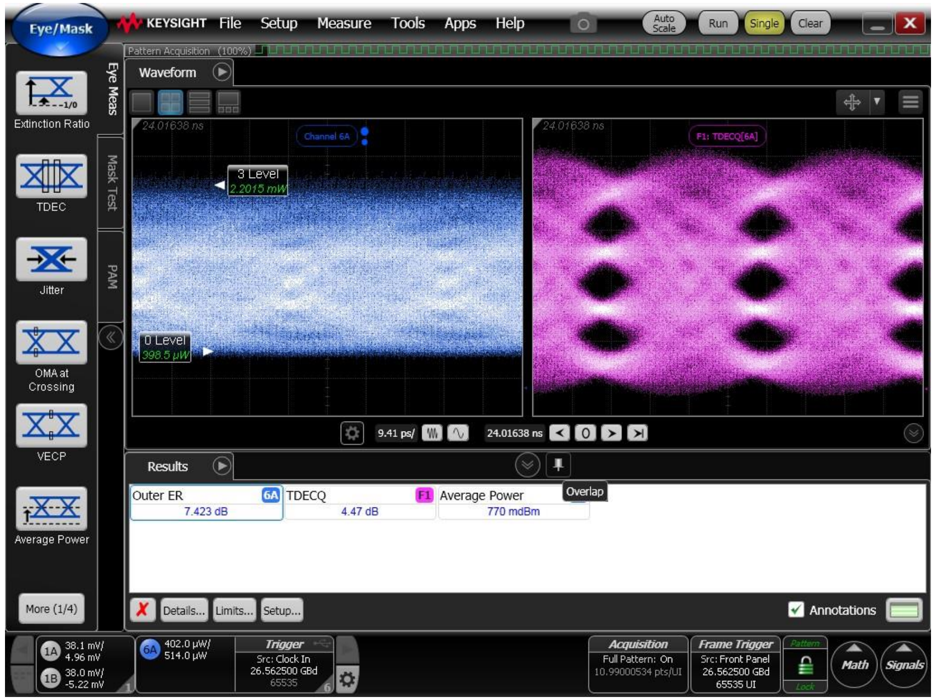
Measured Eye at 26.5Gbaud/s

TDECQ=2.09dB



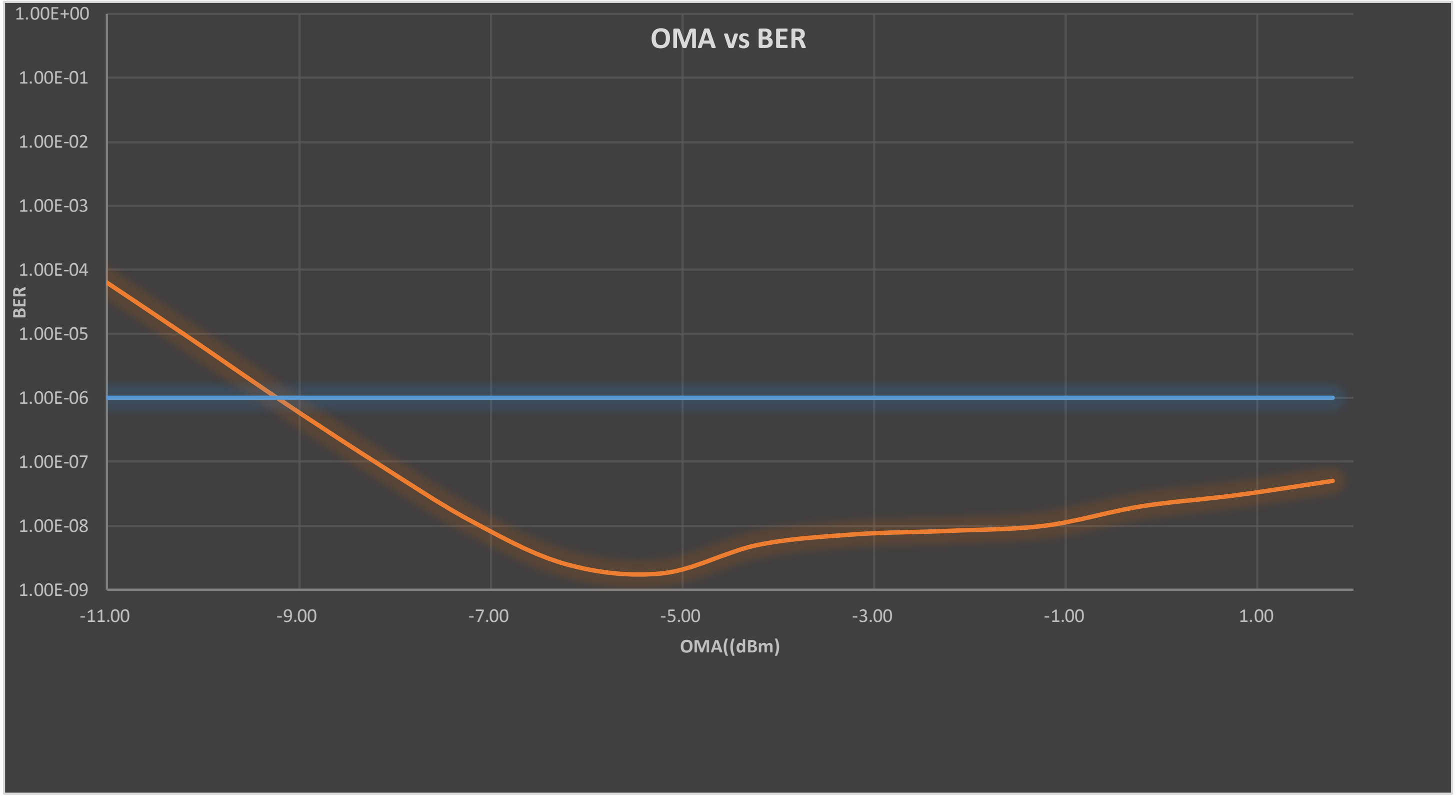
With Equalization from Driver

TDECQ=4.5dB



Without Equalization from Driver

Measured BER with Loss

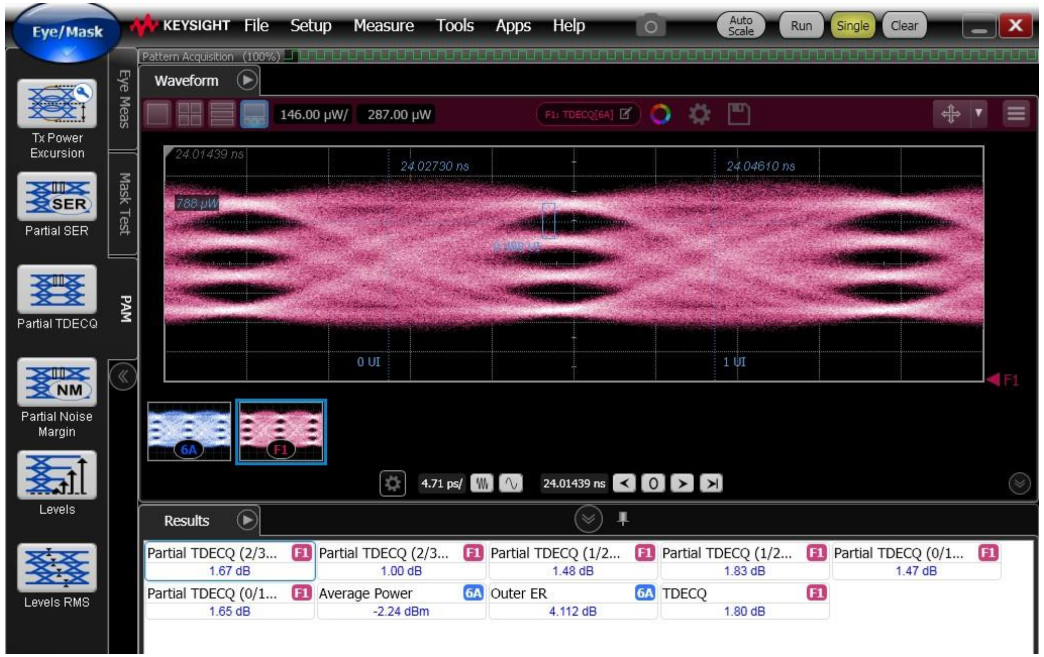


14cm of PCB loss at TX input
14cm of PCB loss at RX Output

RX side uses InSiGa's TIA ISG-T5713 inside a TO

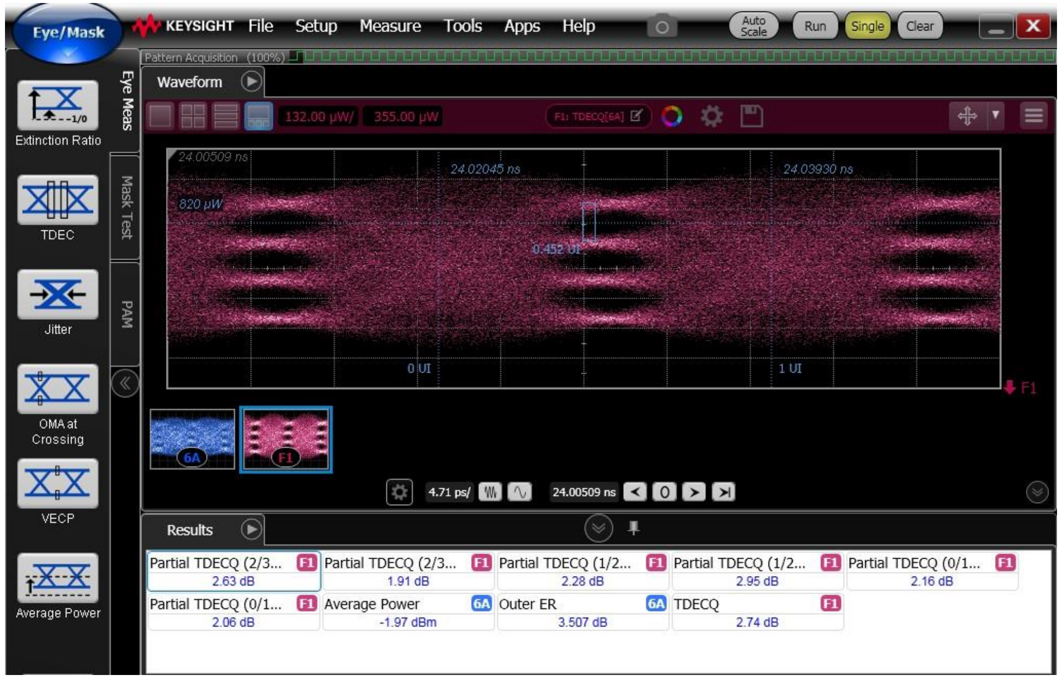
Measured Eye at 53Gbaud/s

TDECQ=1.8dB



With No loss at TX input

TDECQ=2.7dB



With Equalization after loss at TX input

ADM - applications

AOC – Eg. 400G (50Gx8)

Advantages

- The Equalization from TX can be optimized to get best BER- can compensate for RX side by over-equalization on TX
- High number of channels bring out true value of Silicon PIC's
- Length of Cable can easily reach >100m
- SM Fiber array cost cheaper than MM fiber array
- Power Dissipation lower than DSP/CDR driven modules

Measured BER data shows high probability of this solution being able to meet system requirements

AOC – 400G (100Gx4)

Advantages

- The Equalization from TX can be optimized to get best BER- can compensate for RX side by over-equalization on TX
- Length of Cable can easily reach >100m
- SM Fiber array cost cheaper than MM fiber array
- Power Dissipation lower than DSP/CDR driven modules

FFE capability on RX side for 100G IO (switch and NIC) will be important factor in determining performance

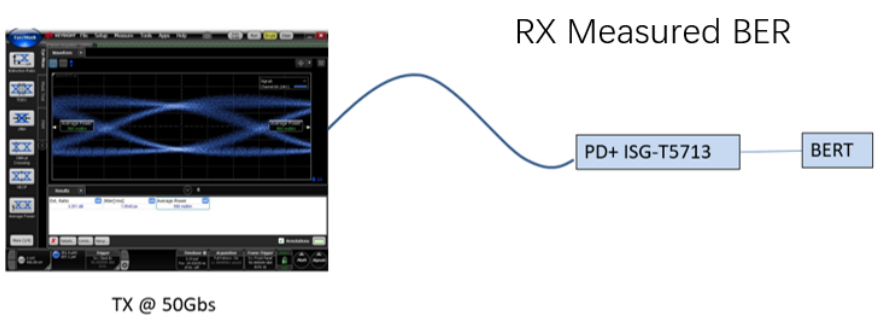
ADM – applications

High Performance Computing (HPC) – Low Latency requirements

Advantages

- The solution can be based on high speed NRZ modulation without FEC （50Gbs NRZ) to achieve high bandwidth- Eg. 50Gbs x 8 for 400G requirements
- Lowest latency

50G NRZ



Error free operation from -9dBm to 2dBm OMA

ADM - applications

400G DR4

Challenges

- TX and RX need to be independently optimized
- Higher Loss budget compared to AOC
- Gain of TIA needs to be higher
- Pre-emphasis capability from TIA?

Need testing with 100G I/O on Switch/NIC to determine exact TX and RX requirements

Analog Drive Optical Engines

CPO – Co-Packaged Optics

Challenges

- Density (Area)
- Power Dissipation (Heat Management)
- Packaging (2.5D vs 3D)
- Cost

CPO – Co-Packaged Optics

Electrical IC direction

- Density (Area)
  - ❑ Equalization capability
  - ❑ 8 channels/die (pitch 375um)
  - ❑ Integrating Si PIC controls like CW laser bias control, heater control, MPD monitoring etc, with Driver IC
- Power Dissipation
  - ❑ (Removal of DSP, Low Power Driver- 260mW/ch)
- Packaging
  - ❑ Tight Pitch Cu Pillars for Flip-chip assembly

Why is Si based PIC best technology choice for ADO?

Advantages of Si PIC’s

- Best linearity (DML, VCSEL have asymmetric rise/fall, EML single ended drive)
- High level of integration – no. of channels, MPD etc.
- Bandwidth roll-off very linear- easier to equalize
- Temperature of Operation
- Cost

Thank you!

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Questions?