NEXT GENERATION OPTICAL INTERFACES

"Performance Photonics Enabling next Generation Interfaces"

David Lewis, *Lumentum*

TECHNOLOGY EXPLORATION FORUM

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LUMENTUM

Performance photonics enabling next-generation interfaces

David Lewis

January 28th, 2021

Outline

- Possible changes in component performance in the next few years:
  - DML (Directly Modulated Laser) 25 GBd (today) to 50 GBd
  - EML (Externally Modulated Laser) 50 GBd (today) to 100 GBd
  - Coherent Components 64 – 96 GBd (today) to 128 GBd

- These components will enable Ethernet PMDs beyond 400 Gb/s, for example:
  - 8 x 50 GBd DML for 800 Gb/s interface
  - 4 x 100 GBd EML for 800 Gb/s interface
  - 8 x 100 GBd EML for 1600 Gb/s interface
  - 128 GBd with DP-16QAM for 800ZR interface

Leading wafer fab infrastructure

North America

San Jose, California USA
- Gallium Arsenide
- Indium Phosphide
- Lithium Niobate
- Planar waveguides
- Flagship products
  - Pump lasers
  - VCSELs
  - ROADMs
  - Modulators

EMEA

Caswell, UK
- Indium Phosphide
- Flagship products
  - Coherent components
  - Tunable lasers
  - Photonic integrated circuits

APAC

Sagamihara, Japan
- Indium Phosphide
- Flagship products
  - Data center laser chips DMLs
  - PAM4 EMLs

Sagamihara Fab ~50 Years of Innovation in Optical Communications Technology

1971: Room Temperature CW Operation of GaAlAs Lasers
1973: First to realize CW operation of DFB lasers at room temperature
1974: First operation of BH lasers
1975: First operation of DFB lasers under current-injection
1978: First operation of 1.3μm BH lasers
1979; First MP of 1.3μm lasers
1982: MP of 1.3μm BH-lasers for TAT-8 submarine systems
1985: First demonstration of high-speed properties by MQW lasers
1987: Proposal & demonstration of MD-MQW lasers with fr up to 30GHz
1989: Ultrahigh-speed 1.55μm lasers with 17GHz–BW & 16Gb/s modulation
1990: First MP of 2.5Gb/s 1.55μm MQW-DFB lasers
1991: Proposal & demonstration of innovative EML
1992: Record 16λ-WDM 10Gb/s DFB lasers
1994: Record-ultralow threshold current of 1.3μm MQW-DFB lasers with 0.5mA
1995: First demonstration of 40Gb/s EML, proposal and operation of GaInNAs lasers
1996: First MP of innovative 2.5Gb/s 640km EA-DFB lasers
1999: First MP of 10Gb/s-40km EML
2002: First MP of Uncooled 10Gb/s DFB lasers, First MP of 10Gb/s APDs w/GB of 120GHz
2003: First demonstration of uncooled 10Gb/s DFB-LD beyond 115°C
2004: First MP of 40Gb/s EML
2007: First demonstration of uncooled 10Gb/s-80km EML up to 85°C
2008: First demonstration of 1.3um CWDM 4ch 25Gb/s uncooled EML for 100GbE
2010: First MP of LAN-WDM 25Gb/s EML for 100G CFP-LR4
2011: First demonstration of 25Gb/s LISEL and LIPD
2014 : First demonstration of 1.3μm uncooled 50Gb/s DFB-LD beyond 80°C
2015: First MP of 1.3μm uncooled 25Gb/s DML for 100G-CWDM4
2016: First demonstration of 1.3μm 100G-PAM4 (53Gbaud) EML with 10km transmission
2016: First demonstration of 1.3μm uncooled 25Gb/s DFB-LD beyond 120°C
2018: First uncooled operation of 53-Gbaud PAM4 (106-Gb/s) EML from 25°C to 85 °C
2018: First 53-Gbaud PAM4 (106-Gb/s) operation of 1.3-mm DML from 25°C to 80°C

DFB technology origin

BH structure origin

10G-DML foundation

25G-EML foundation

25G-DML foundation

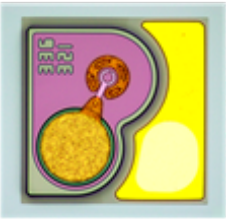
Datacom Optics for 800G and Beyond

Lumentum is the market leader for datacom lasers:

- Scale and performance leader
- Pioneer in uncooled, self-hermetic lasers
- Continued investment in our laser technology

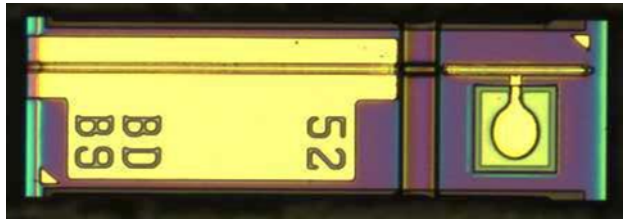
Lasers for 800G and beyond:

- **200G EML**: Enabling high performance, low power consumption for 2km PAM4 modules
- **100G DML**: Lower power, lower cost, smaller footprint than EML
- **100G VCSEL**: Leverage high-volume 3D sensing manufacture foundry for leading performance with the industry's best cost structure and massive production capacity
- **CW lasers for SiPh**: Based on Lumentum's EML chip leadership
- **CW lasers for CPO**: Families of lasers covering 20mW to over 400mW



VCSEL

DML



EML

CW laser

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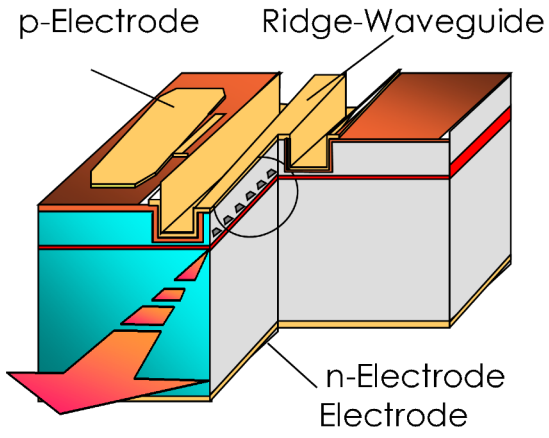
DML Status

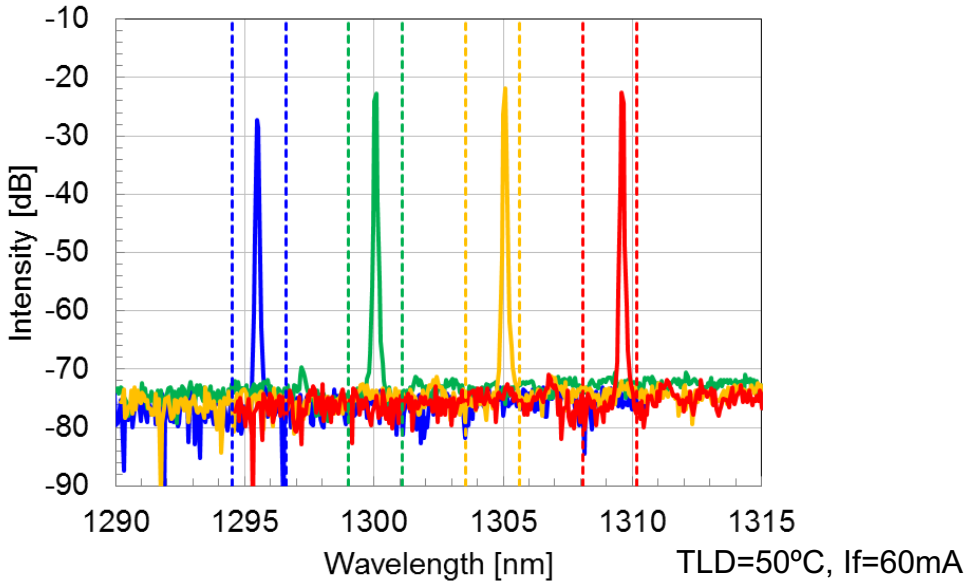
DML Leadership

Design features:

- InGaAlAs MQW active layer for reliable high temperature operation
- Ridge waveguide structure for manufacturability with high yield
- Corrugation Pitch Modulated (CPM) grating and shorter cavity for higher bandwidth - 25G x 4λ
- Sophisticated cavity design for wide temperature operation, high reliability
- Self-hermetic chip for GR-468 damp heat environments
- Grating-pitch designs for CWDM(HL13BF) and LAN-WDM(HL13BE)
- PAM4 DMLs



HL13BF DFB Laser



TLD=50ºC, If=60mA

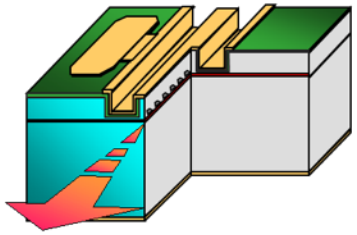
DML vs EA-DFB PAM4 Eye Comparison

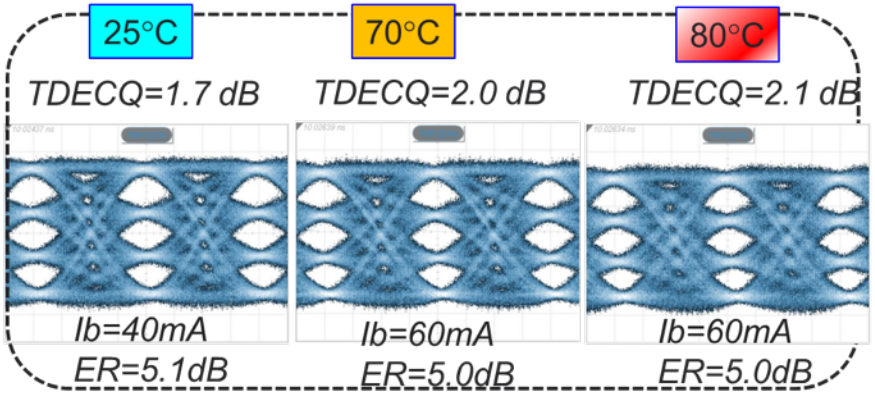
- Choice defines power consumption, dispersion tolerance, and cost
- Lumentum EMLs have historically provided the most cost and power efficient solution for leading edge interface rates
- Lumentum DMLs provide power and cost reduction path as ecosystem matures at a given rate

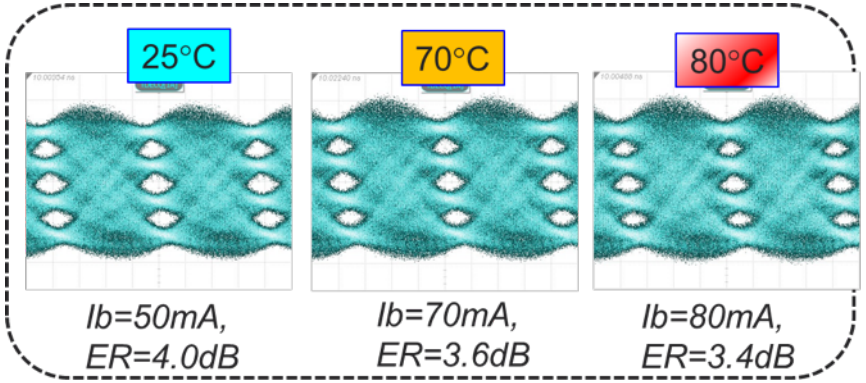
26 Gbaud

53 Gbaud

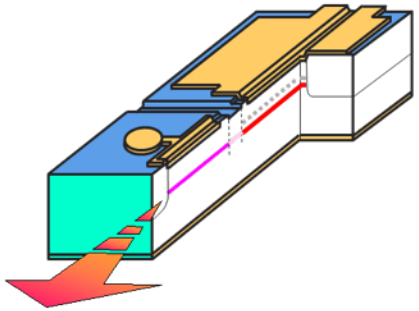
DML

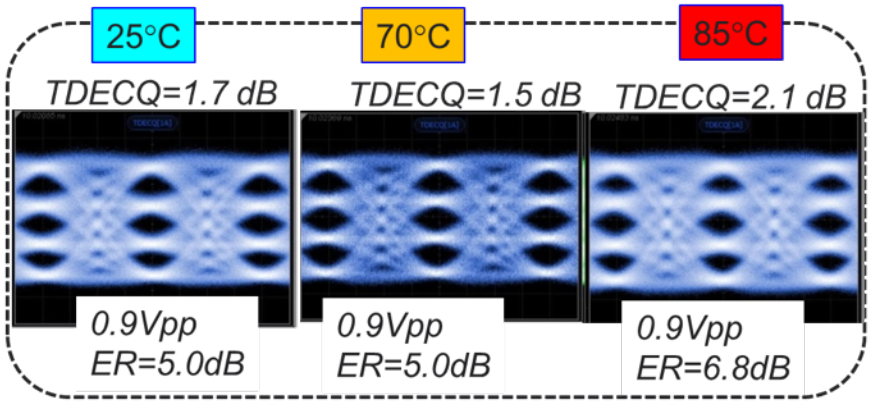


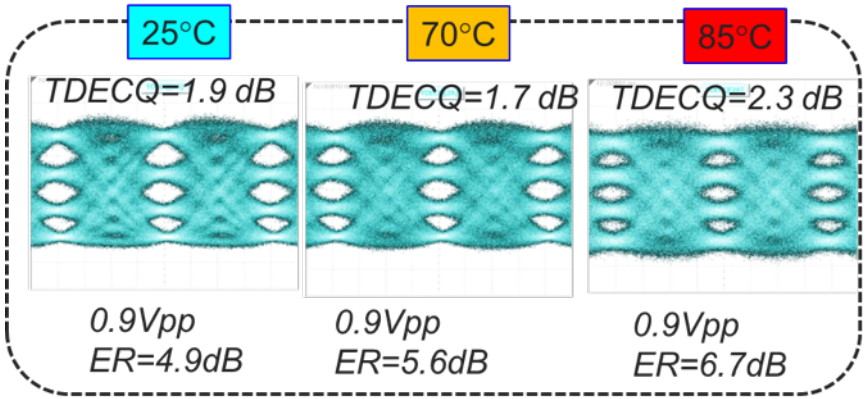




EA-DFB







50 GBd (100 Gb/s PAM4) DML Progress

Lumentum Announces Industry-First 100G PAM4 DMLs Available For Sampling

Advanced Indium Phosphide (InP) laser technology enables lower cost solutions for hyperscale data center speeds of 400G and beyond

NEWS PROVIDED BY
Lumentum →
Dec 07, 2020, 03:00 ET

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SAN JOSE, Calif., Dec. 7, 2020 /PRNewswire/ -- Lumentum Holdings Inc. ("Lumentum"), an industry-leading provider of high-speed optical transmission solutions, today announced a new addition to its broad datacom laser chip portfolio, the 100G PAM4 (53 Gbaud) directly-modulated laser (DML) for hyperscale data center applications. This breakthrough product complements Lumentum's existing 100G PAM4 externally modulated laser (EML) products and offers transceiver designers a lower cost alternative.

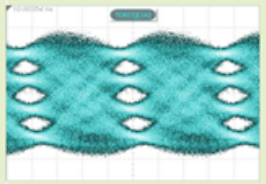
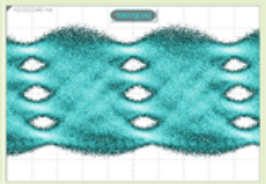
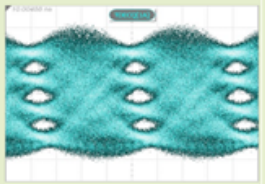
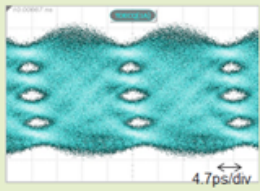
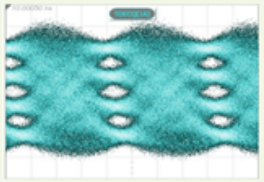
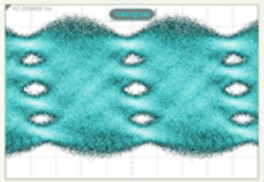
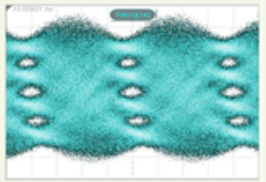
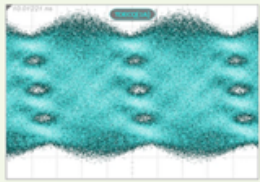
In response to the rapid growth of intra-data center traffic and the resulting need for higher speed, capacity, and reliability, Lumentum has begun sampling its 100G PAM4 DMLs to customers seeking a cost-effective approach for 400G DR4 and future 800G PSM8 transceiver module applications.

"This latest advancement helps to significantly reduce the cost of 400G DR4 modules in data center infrastructures," said Walter Jankovic, Lumentum Senior Vice President and General Manager, Datacom. "The 100G PAM4 DML goes beyond servicing the current need for cost-effective and innovative InP laser solutions at mass volume by enabling future intra-data center interconnects as the industry moves to 800G."

About the Product

The newly developed 100G PAM4 DML joins Lumentum's portfolio of best-in-class laser chips that enable a wide-range of MSA-compliant transceiver modules operating at multiple data rates and wavelengths. Manufactured with Lumentum's internal wafer production capabilities, the 100G PAM4 DML leverages advanced InP technology, using a sophisticated cavity design to operate with the same high-bandwidth performance of an EML in 100G and 400G applications, but in a small, simple, and cost-effective footprint. The latest DML can lower the cost of 400G DR4 compared with current laser alternatives. Additionally, 800G PSM8 modules can benefit from the capabilities of the new 100G PAM4 DML, which is important as data centers transition to these modules in future top-of-rack and leaf layer applications.

To sample the 100G PAM4 DML, contact a Lumentum representative at customer.service@lumentum.com.

Temp.	25°C	55°C	70°C	80°C
Ib	50 mA	60 mA	70 mA	80 mA
ER	4.0 dB	3.9 dB	3.6 dB	3.4 dB
BTB with equalizer				
After 10 km (+8ps/nm)				

Presented by N. Sasada et al., ECOC2018 Th3F.3 (2018)

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EML Status

EML Leadership

30 years of EML technology expertise dating back to Hitachi

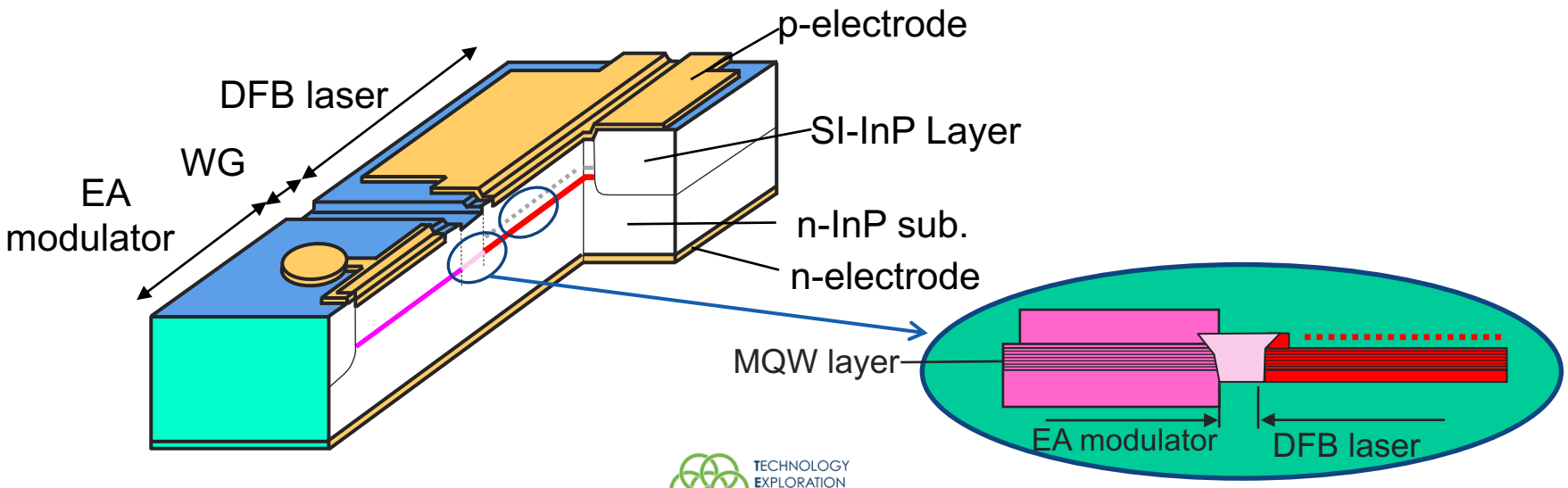
- Leadership position in high-speed EMLs since 2.5G and 10G era
- World's first uncooled EML, now GR-468 self-hermetic devices in production

Best support for the 200G/400G PAM4 module applications

- 1.3um LAN-WDM/CWDM wavelengths, cooled LAN-WDM and uncooled 28GBaud/53Gbaud PAM4
- Bare chip for cost effective design and COC for quicker evaluation and production usage

Design features

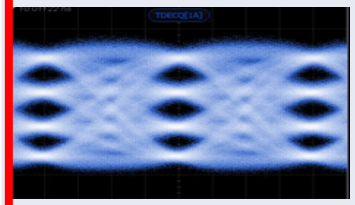
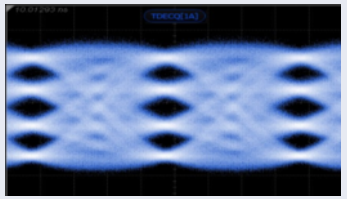
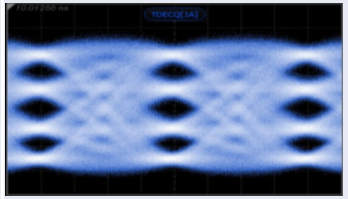
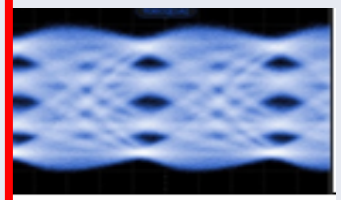
- Butt-joint structure for designing LD and EA independently
- Buried Heterostructure with semi-insulating InP layer for high speed
- High temperature operation for low power consumption TEC, or "coolerless"
- Optimized p-i-n structure in EA modulator for higher extinction ratio



HL13B6: 53Gbaud uncooled EML performance snapshot

- Basic design is based on HL13B5 with high reliability and high productivity.
  - Achieved high BW of 42GHz and high Po at 85°C compared to HL13B5
  - MQW structure is optimized to achieve low TDECQ over the temperature range

IF=100mA

	HL13B6-b			HL13B5
	20°C	70°C	85°C	85°C
with equalizer (5tap)				
Vpp (V)	**1.2**	**1.2**	**1.2**	**1.2**
Vmid (V)	**-2.5**	**-1.3**	**-1.1**	**-0.4**
OuterER (dB)	**3.5**	**4.6**	**6.2**	**10.4**
PoAve. (dBm)	**10.5**	**7.1**	**4.2**	**2.0**
TDECQ (dB)	**2.2**	**2.2**	**2.6**	**unmeasurable**

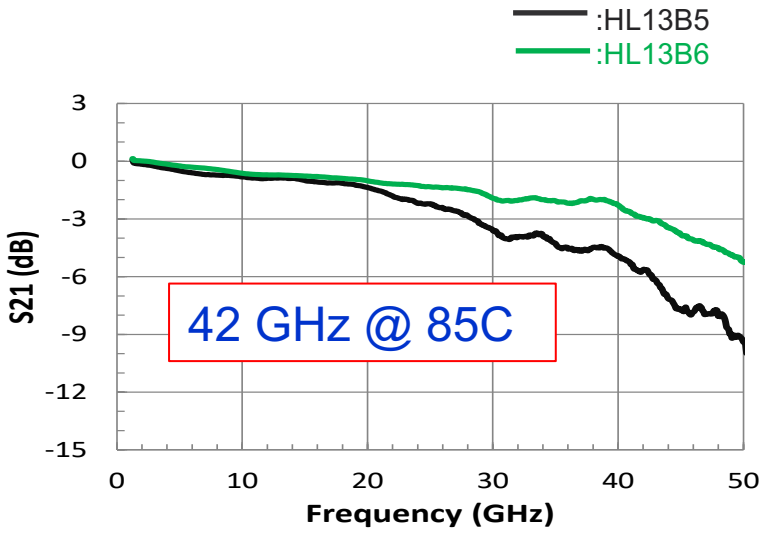


Fig. S21 @85°C

100 GBd EML Progress

Ref: K. Adachi et al, Mo.2.B.6, ECOC2020

Wide-temperature-range 100-Gbaud Operation of a Lumped-electrode-type EA-DFB for an 800-Gb/s Optical Transceiver

K. Adachi, S. Yamauchi, H. Asakura, A. Nakamura, K. Naoe, and S. Tanaka

Lumentum, 4-1-55 Oyama, Chuo-ku, Sagamihara, Kanagawa, 252-5250, Japan
koichiro.adachi@lumentum.com

Abstract *A lumped-electrode-type EA-DFB with a short-length modulator packaged by using an ultra-short wiring technique achieved bandwidth over 60-GHz in a wide-temperature range, and 100-Gbaud NRZ eye opening up to 80°C was demonstrated for the first time.*

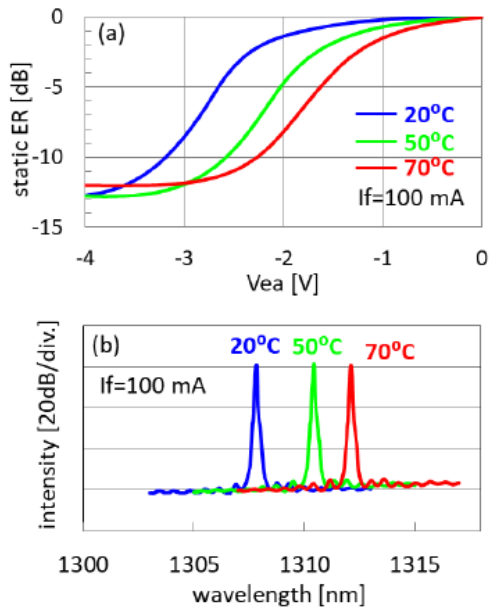


Fig. 2: Static extinction ratio and spectrum at 20, 50, and 70°C under DFB applied bias of 100 mA.

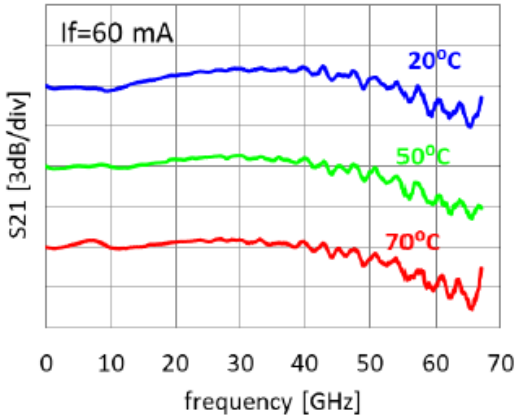


Fig. 3: S21 characteristics at 20, 50, and 70°C under DFB applied bias of 60 mA.

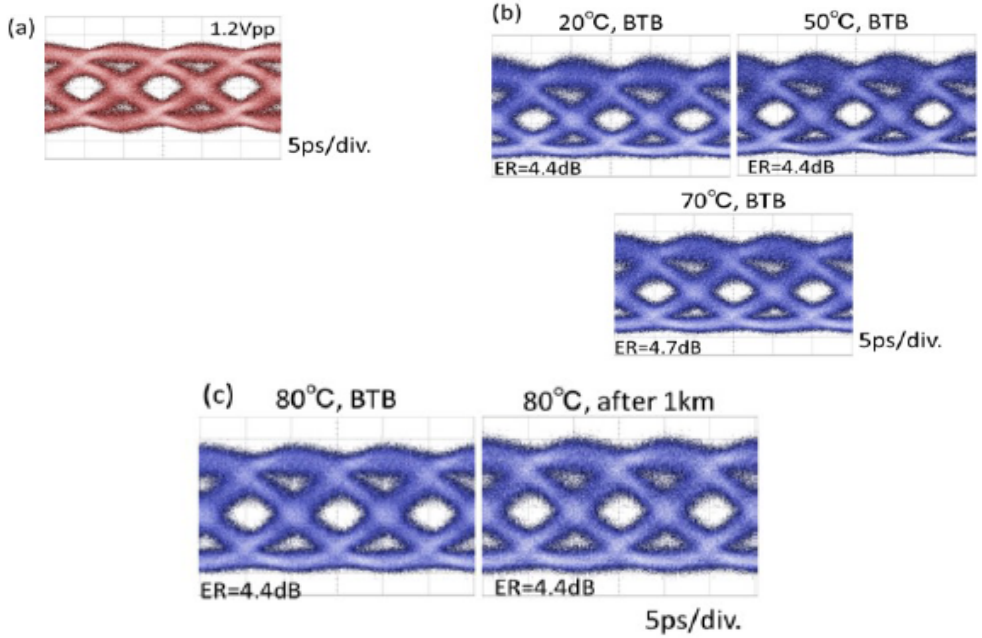


Fig. 5: 100-Gbaud NRZ eye waveforms: (a) input electrical signal, (b) measured optical signal at 20, 50, and 70°C, and (c) measured optical signals of BTB and after 1km at 80°C.

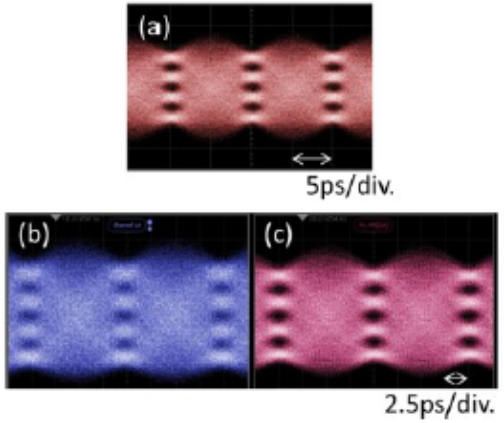


Fig. 6: 100-Gbaud PAM4 eye waveforms: (a) input electrical signal, (b) raw data of measured optical eye, and (c) optical eye with 5-taps FFE.

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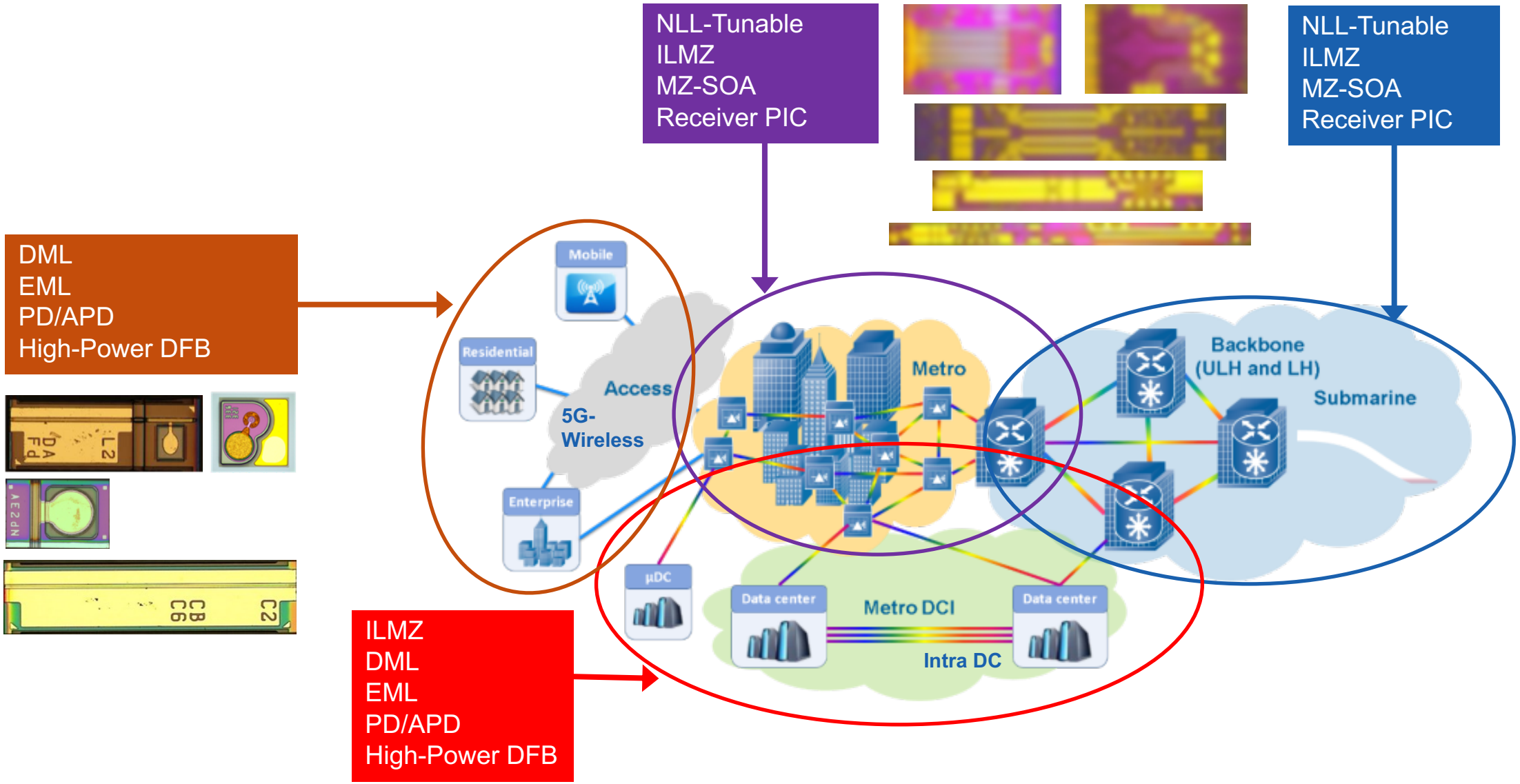
InP PIC and Coherent Components

InP Optical Devices Technology for Moving Networks Forward Faster



Coherent InP PIC Trends

	Today	Next
TL 	100kHz LW, 17dBm fibre, 100ch	▪ Reduced power dissipation ▪ High temperature operation ▪ 50kHz LW, 18dBm fibre ▪ 120ch operation
MZ 	64-96 Gbd dual-IQ fold-MZ with SOA (40GHz BW)	▪ 128Gbd (70GHz BW) ▪ Reduced power dissipation ▪ High temperature operation / Uncooled ▪ Reduced Vpi / Driverless
Rx 	64Gbd dual-IQ Rx with VOA (45GHz BW)	▪ 128Gbd ▪ Smaller chips for lower cost
ILMZ 	25Gb/s NRZ-ILMZ Hermetic die	▪ 100Gbd PAM4 (60GHz BW) ▪ 1300nm PICs as capable as 1500nm ▪ Smaller chips for lower cost

Coherent InP OSA Trends

	Today	Next
HB-CDM 	64Gbd, 96Gbd (OIF IA class 40 & 60)	▪ 128Gbd and beyond (OIF IA class 80) – Very high-speed RF transition & interconnections ▪ Increased thermal dissipation
TROSA 	43Gbd, 64Gbaud	▪ 64Gbaud ▪ 96Gbd and beyond – Very high-speed RF transition & interconnections ▪ Reduced power dissipation
ROSA 	32Gbd	▪ 128Gbd and beyond – Very high-speed RF transition & interconnections ▪ Improved responsivity

Summary

- The components for the next speed are coming:
  - DML chips for the module industry
  - EML chips for the module industry
  - InP PICs for coherent transmission
  - InP packaged components for coherent transmission

- Timeframe is aligned with other components:
  - Switch / SerDes / DSP silicon

Thank you

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For our TEF 2021 on-demand content go to bit.ly/EATEF2021-OD

If you have any questions or comments, please email **admin@ethernetalliance.org**

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