Analysis on Feasibility to Support a 40km Objective in 50/200/400GbE

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Background and Motivation

- In "Beyond 10km Optical PHY - CFI Consensus ":
  - The Call for Interest is the formation of a study group to explore the development of new single mode fiber PHYs with greater than 10 km reach for following speeds 50GbE, 200GbE, and 400GbE.
- The study group will define objective for new PHYs/PMDs for >10 km for 50/200/400GE and filling the gap in current standards

Today's Point-to-Point SMF Ethernet Family

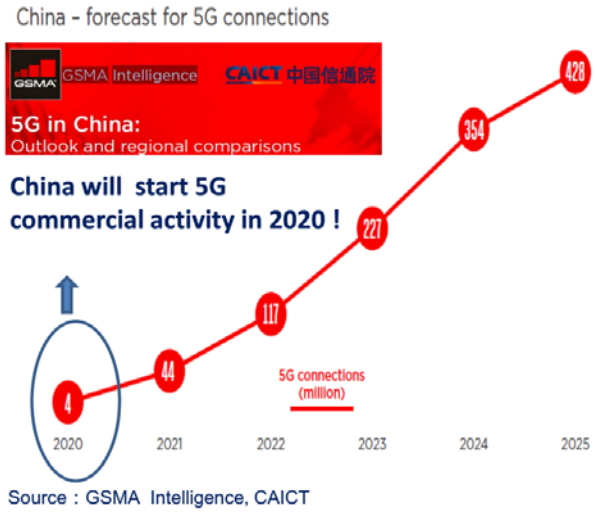
	500m	2km	10km	20km	40km
10GBASE-			L4		ER
25GBASE-			LR		ER
40GBASE-	PSM4	FR	LR4		ER4
50GBASE-		FR	LR		
100GBASE-	PSM4 DR	10X10 CWDM4 / CLR4	LR4 / WDM4-10	WDM4-20	ER4 / WDM4-40
200GBASE-		FR4	LR4		
400GBASE-	DR4	FR8	LR8		

Black Text — IEEE Standard
Red Text — In Standardization
Blue Text — Non-IEEE standard but complies to IEEE electrical interfaces

- This contribution addresses technical and economic feasibility considerations for PHYs/PMDs with up to 40km reach addressing objectives for 50/200/400GE.

Application of 40km Standard to support a broad marketing

- In “wenyu_b10k_01_0917” and “wenyu_400_01_0713”: Expecting to deploy 50/200/400GE 40km from 2020 for 5G mobile backhaul application in China Carrier, furthermore IP Metro will also require 40km reach standard



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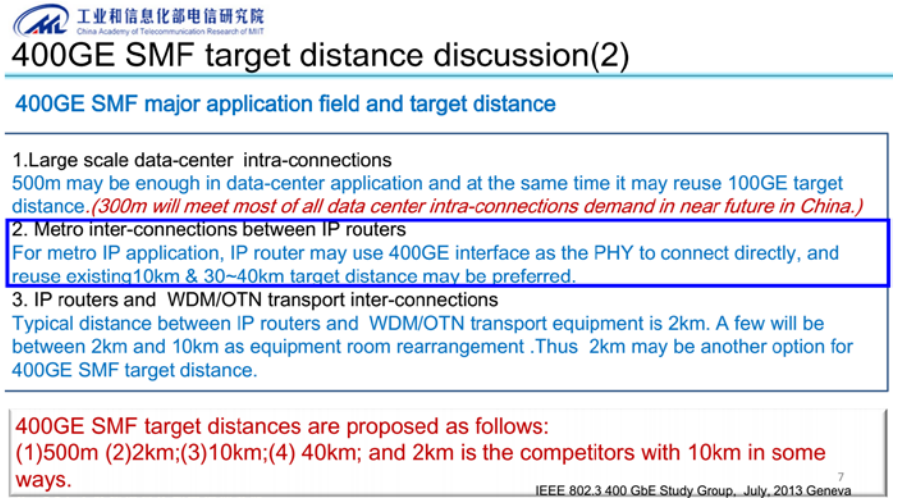
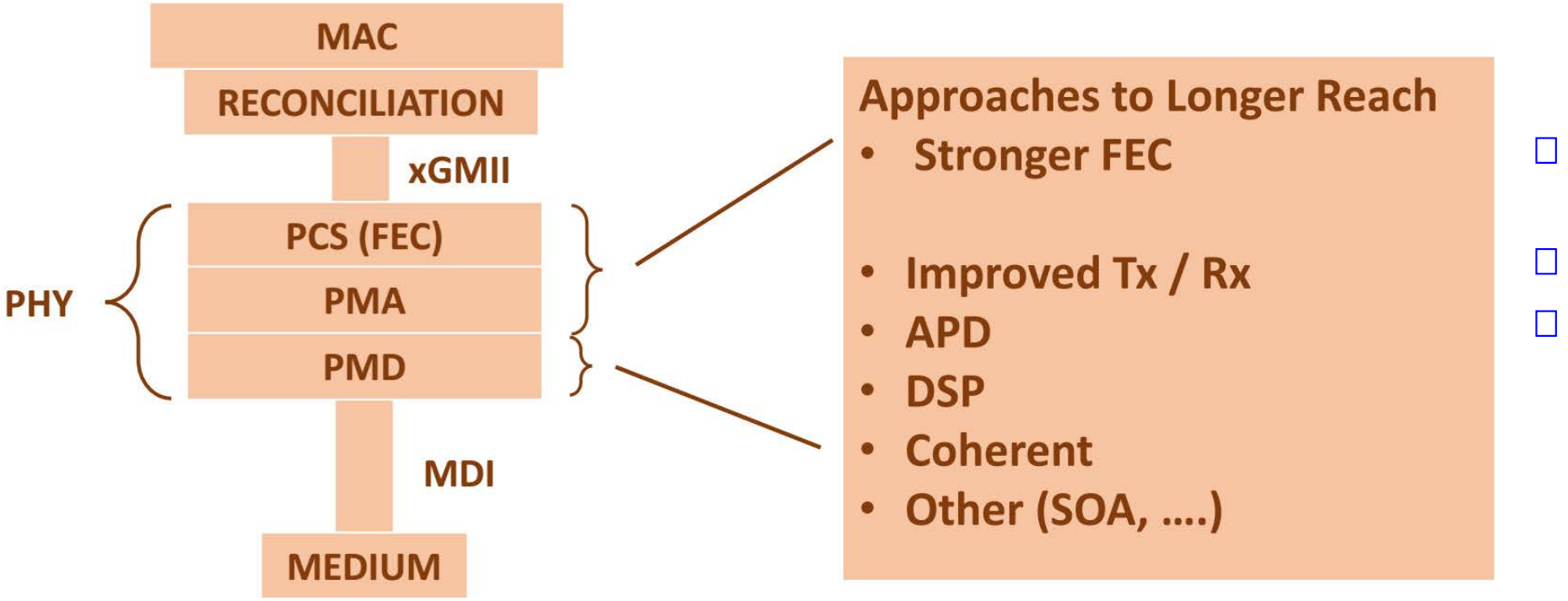


- As the data above shows 5G Mobile application expect to grow at CAGR OF 154% in China with field trial starting in 2018 and expect the rest of the world is expected to follow similar 5G Mobile growth
- Other key applications are some MSOs, considering to upgrade backhaul network currently serviced by IP Router/Switch with multiple 10GE or 100GE to 200/400GE

Technical feasibility: How to reach 40km?

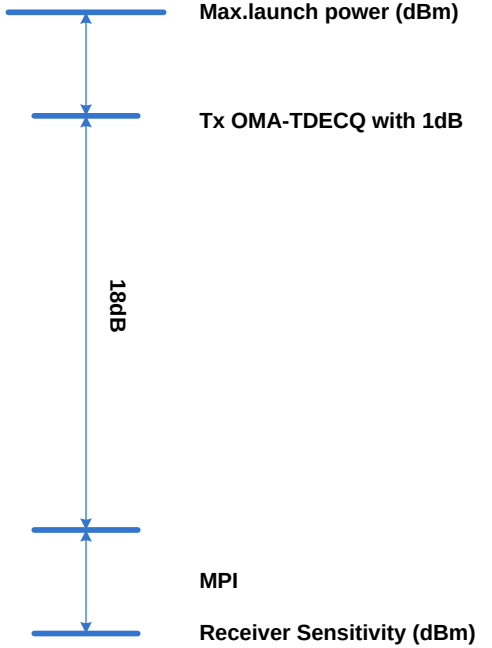
- In "CFI Consensus - Beyond 10km Optical PHYs": An Ethernet Overview of the Problem



- We investigated Transmitter, APD receiver and FEC aspects to share data or information to support 40km objectives at 50/200/400GE in following slides

40km Reach Link Budget

- In the previous presentations, NTT, Lumentum and also Huawei had presented the test result of n*50G PAM4 on BER, transmitter output power, dispersion penalty, oMux/oDemux loss, sensitivity of APD-based ROSA, fiber dispersion and so on.
  - http://www.ieee802.org/3/B10K/public/17_09/lewis_b10k_01_0917.pdf
  - http://www.ieee802.org/3/B10K/public/17_09/yu_b10k_01_0917.pdf
  - http://www.ieee802.org/3/ad_hoc/ngrates/public/calls/17_0502/sone_nea_01a_170502.pdf
  - http://www.ieee802.org/3/ad_hoc/ngrates/public/calls/17_0502/yu_nea_01_170502.pdf
- Further investigation of ways to enhance link budget, based on 200GE with 4X50G PAM4 analysis



	Type 1	Type 2	Type 3
Tx OMA-TDECQ (dBm)	3	1	1
Fiber + Connector Loss (dB)	18	18	18
MPI (dB)	0.5	0.5	0.5
Receiver Sensitivity(dBm)	-15.5 @ 2.4e-4	-17.5 @ 2.4e-4	-17.5 @ ~1e-3
FEC Gain dBo	3.2	3.2	4.5~5.2

- Type 1 approach: With enhanced EML
- Type 2 approach: With enhanced APD
- Type 3 approach: With enhanced FEC

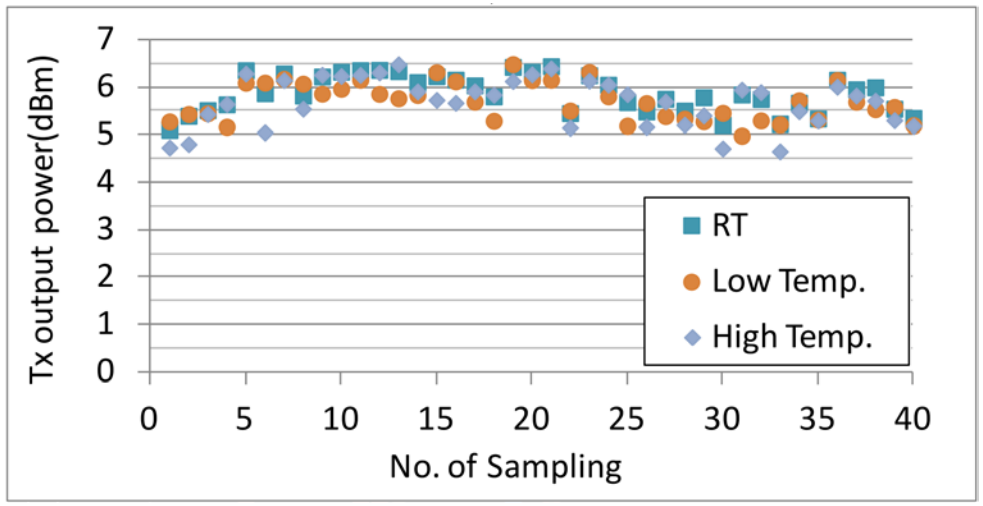
Table 88–14—Fiber optic cabling (channel) characteristics

Description	100GBASE–LR4	100GBASE–ER4		Unit
Operating distance (max)	10	30	40	km
Channel insertion loss[a, b] (max)	6.3	18	18	dB
Channel insertion loss (min)	0	0		dB
Positive dispersion[b] (max)	9.5	28	36	ps/nm
Negative dispersion[b] (min)	–28.5	–85	–114	ps/nm
DGD_max[c]	8	10.3	10.3	ps
Optical return loss (min)	21	21	21	dB

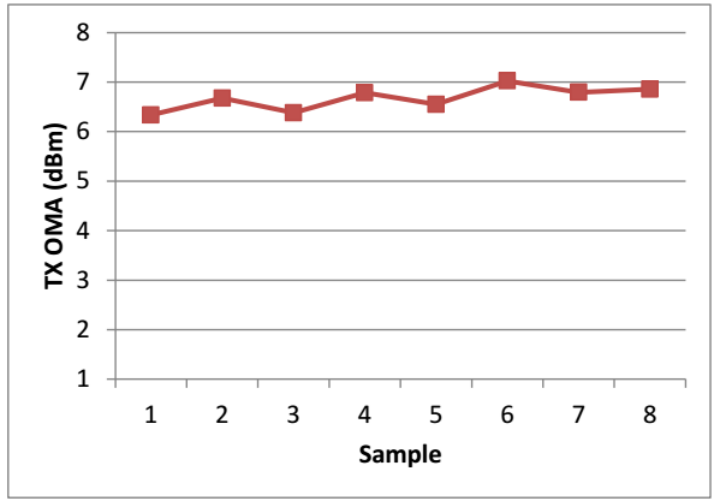
[a]These channel insertion loss values include cable, connectors, and splices.
[b]Over the wavelength range 1294.53 nm to 1310.19 nm
[c]Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

- Refer to 802.3ba 100GBASE-ER4

Type 1: High Power EML to Achieve 40km



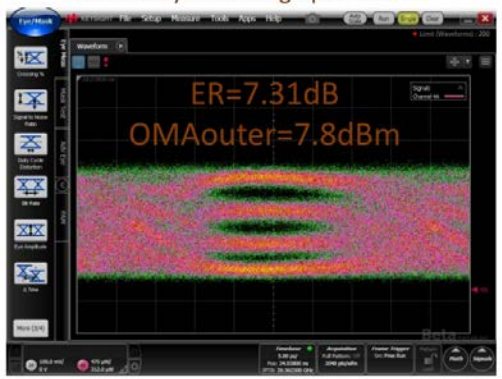
Vendor 1



Vendor 2

Evaluation result using high power EML and APD-ROSA
Link-budget=24.9dB (1ch B2B, KP4 FEC limit)

PAM4 tx eye with high power EML



7.8dBm (EML)

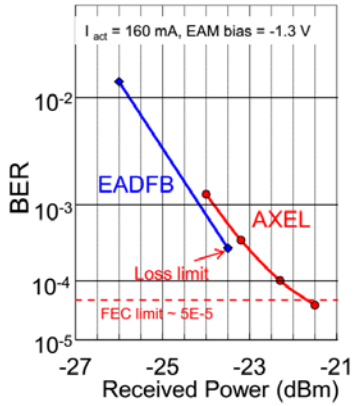
24.9dB* (1ch-B2B) 20.9dB** (4ch-B2B) 18.9dB** (8ch-B2B)

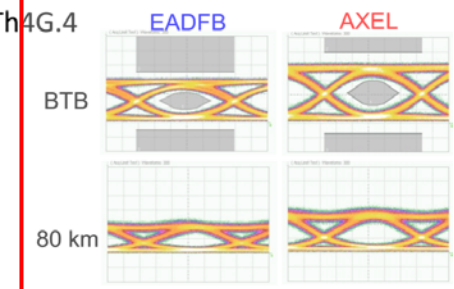
-17.16dBm (APD=ROSA)

* WDM mux/demux loss is not included
** 4:1 Ratio 2 dB, 8:1 Ration 3 dB mux/demux loss (see

Vendor 3

Hasebe et.al, OFC2017, paper Th4G.4



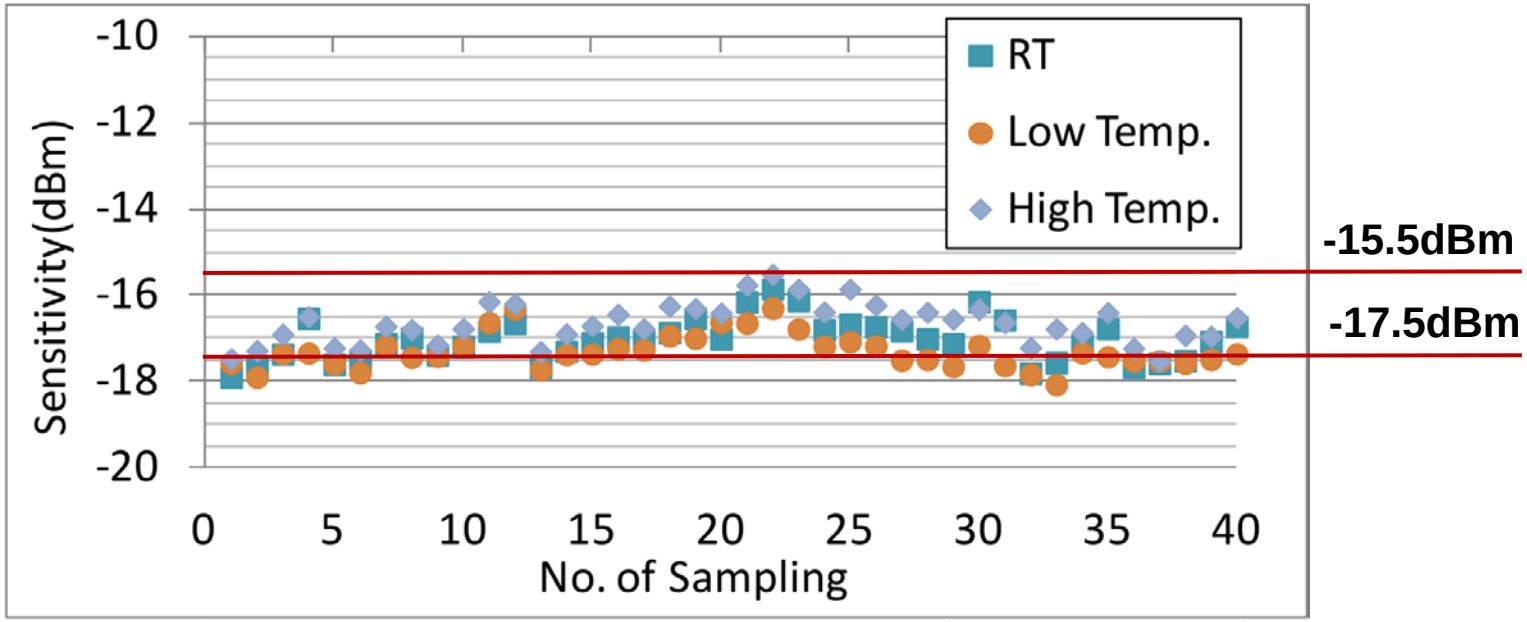


	EADFB	AXEL
Output power(dBm)	5.7	8.7
Extinction ratio (dB)	8.5	8.9
OMA (dBm)	7.5	10.4
Mask margin	8%	9%

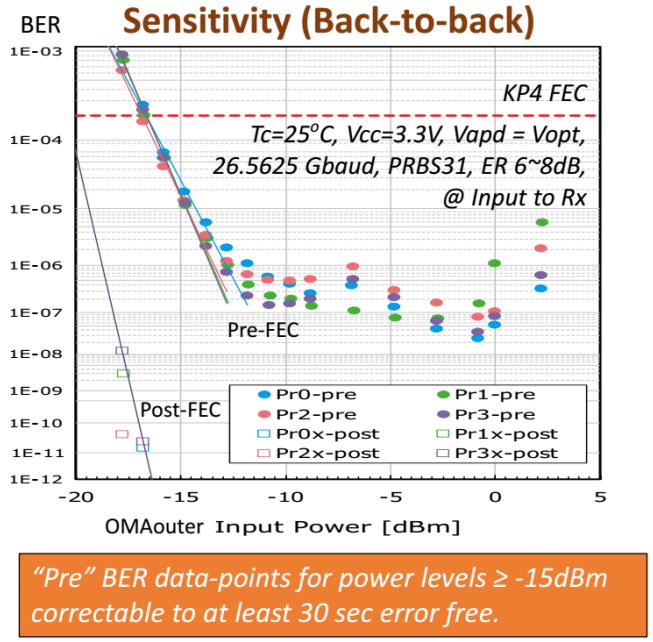
Achievement: 28 Gbit/s, 80-km transmission
Modulated average power P_{avg} = 8.7 dBm

Vendor 4

Type 1: Receiver Sensitivity of APD



Vendor 1

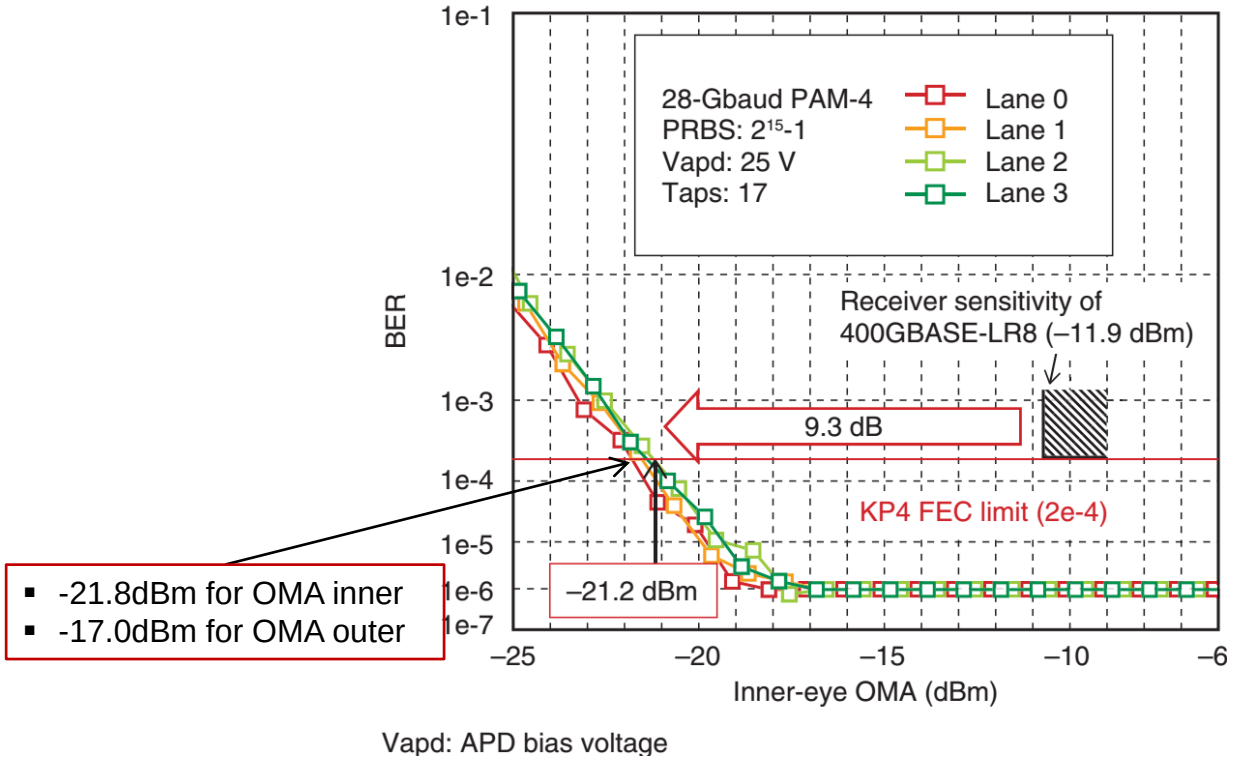


"Pre" BER data-points for power levels ≥ -15dBm correctable to at least 30 sec error free.

Vendor 2

- Different APD vendors test data show the feasibility to satisfy the type 1 system parameters for at least 200GE with 4X50G PAM4 with 40km transmission
- Further improvement of EML and APD together can extend to support 400GE 40km

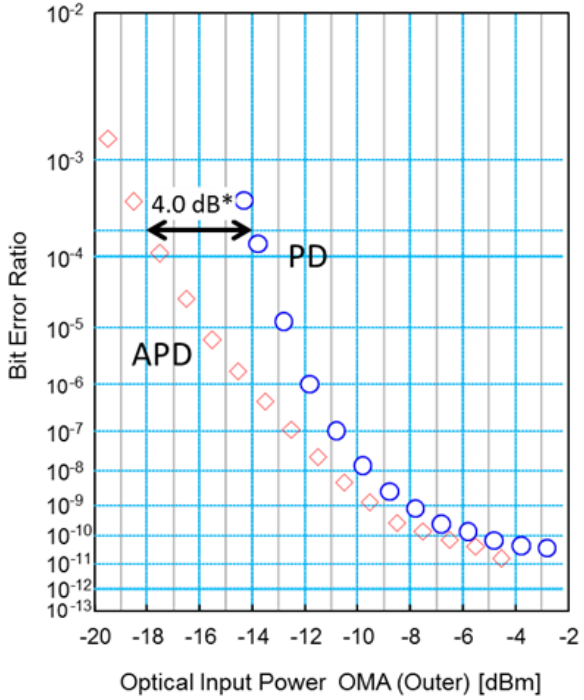
Type 2: Further Enhanced Receiver Sensitivity of APD



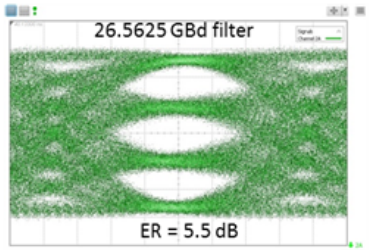
- -21.8dBm for OMA inner
- -17.0dBm for OMA outer

Vapd: APD bias voltage

Vendor 1



TOSA Waveform

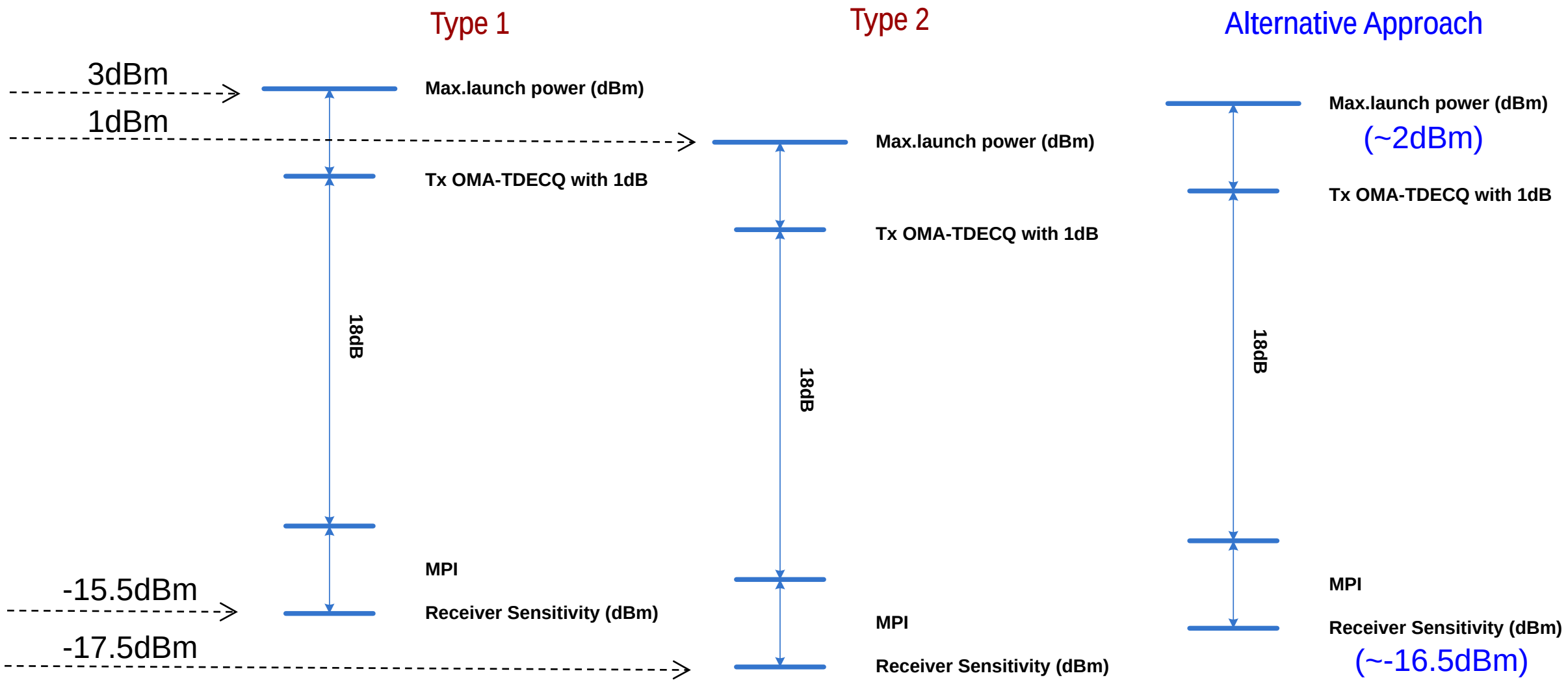


- Data Rate: 26.5625 Gbaud
- Pattern: PRBS15
- Tx: EML
- Rx: APD or PIN + DSP

Vendor 2

- The requirement for Type2 Transmitter is 2dB lower than Type1, additional required on further enhanced sensitivity of APD.
- Different vendors test data of further enhanced receiver sensitivity of APD show the capability with ~1.5dB enhanced, further improvement expect to fulfill Type 2 system requirement

Tradeoff on Optical Solution in Type 1 and 2

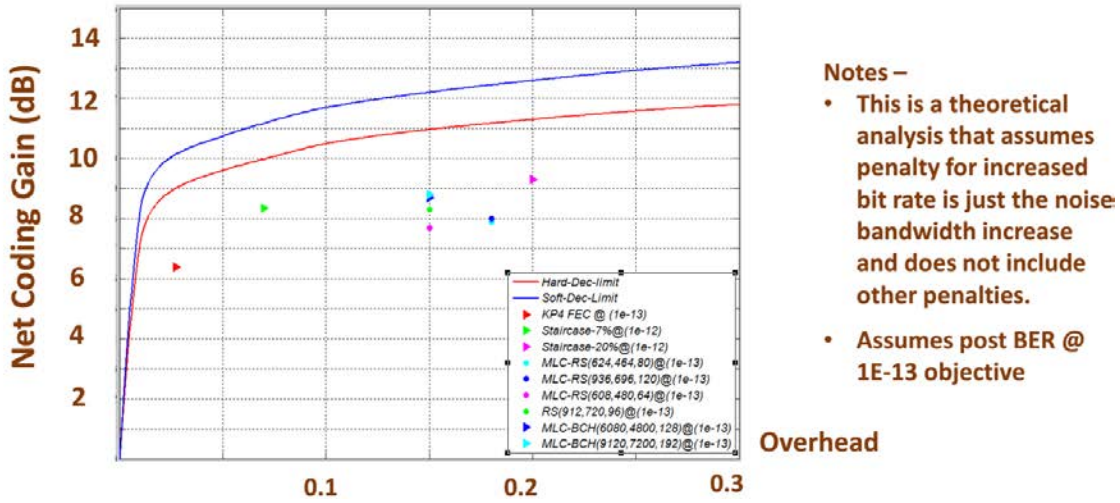


- Alternative approach to balance capability of transceiver is also feasibility and relax parameter of transmitter or receiver can be further investigated in Task Force

Type 3: Aspect of Stronger FEC, Technical Feasibility

- More capability from FEC to compensate link loss with APD receiver as in "effenberger_3ca_2_0316", assume Gain dB(Optical) = 0.75 Gain dB(Electrical/FEC)
- KP4 FEC with 6.4dB NCG and BER@2.4E-4 is assumed for 50/200GE-40km with 1X/4X 50G PAM4
- Stronger FEC offers 9-10 dB NCG or 3~4dB higher NCG compare to KP4 FEC
  - A FEC operating at BER@~1E-3 is off-the-shelf, agnostic to PMDs and can be used for PAM4 or Coherent
  - With the help of stronger FEC, the requirement for optical components could be relaxed by at least 2dB
  - The stronger FEC should be considered as backup option but does require a new design in silicon

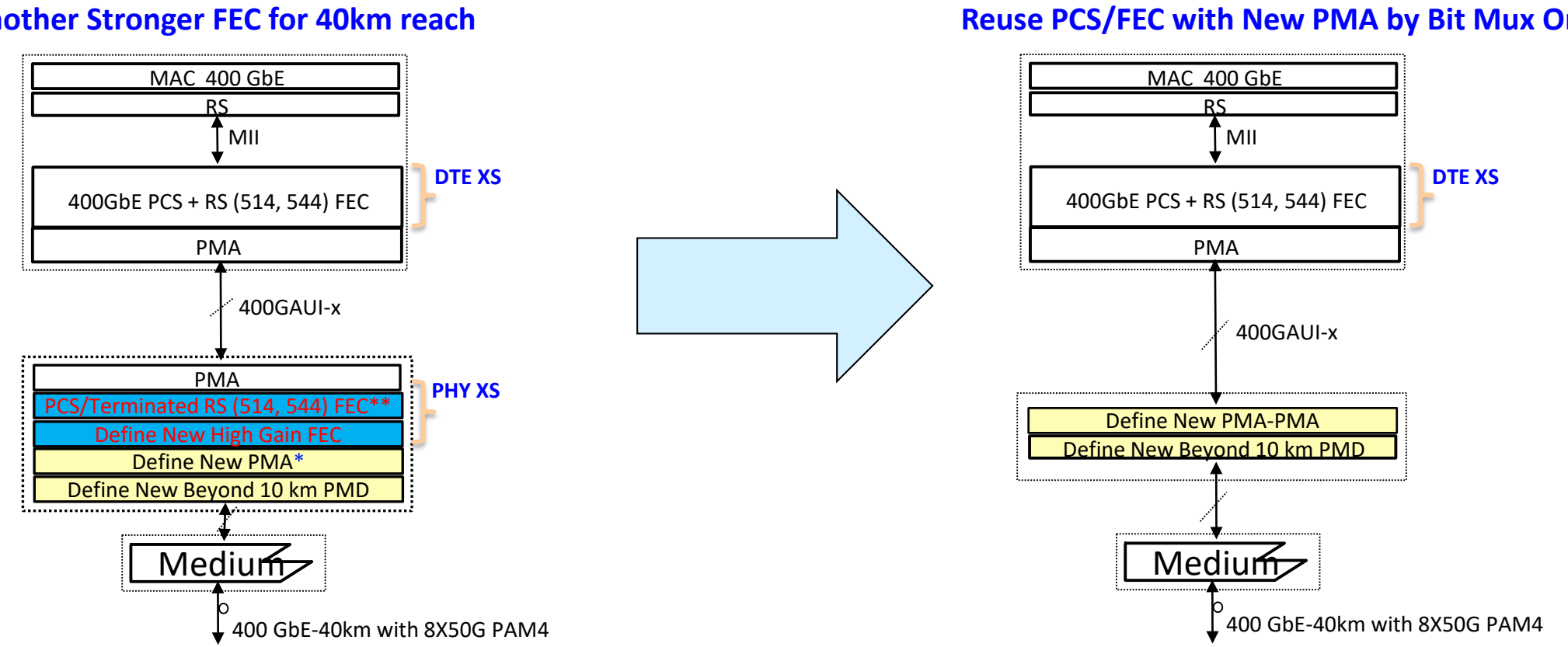
Several Potential HD-FECs can help to achieve beyond 10km 400GbE RS-FEC, BCH-FEC, MLC-FEC or Staircase FEC. (wang_ecdc_01_0316)



Notes –
- This is a theoretical analysis that assumes penalty for increased bit rate is just the noise bandwidth increase and does not include other penalties.
- Assumes post BER @ 1E-13 objective

Type 3: Aspect of Stronger FEC, Economic Feasibility

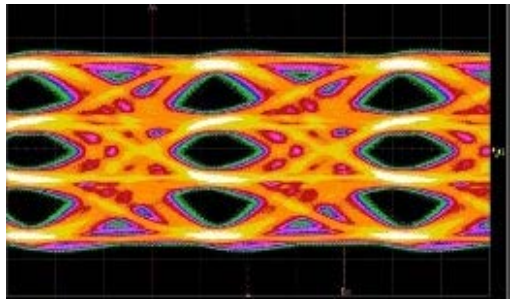
- Introducing stronger FEC will require new silicon inside optical module adding penalty on economic feasibility as new investment on PAM4 chip and potential power issue

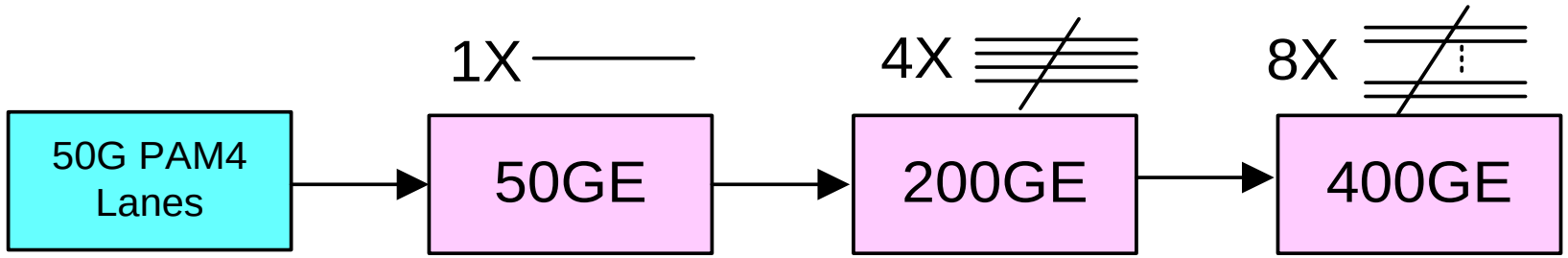


- Prefer to reuse KP4 FEC and bit transparent in PMA mechanism to support 40km reach, further friendly to support reuse in OTN Framer with broad marketing application

Unified Platform to Achieve Economic Feasibility of 10/40km Reach

- History and the success of IEEE 802.3 10/40/100/25GE proves a unified solution with common FEC and reuse of key components in more applications increases overall market and economic feasibility
- Unified 50G PAM4 platform in 50/200/400GE-10/40km





- Given that the market volume of 10km will be higher than 40km, screening can be used early on to get higher power EMLs and more sensitive APDs while avoiding yield losses and cost increases to achieve economic viability

Summary

- Beyond 10km optical PHYs for 50/200/400GbE technical, broad market potential, compatibility, economic feasibility, and distinct identity can be best met and consistent with the reference to 25GBASE-ER, 40GBASE-ER4, and 100GBASE-ER4 link budget
- Objective for Beyond 10 km PHY can be met with following:
  - **PHYs:**
    - **Provide physical layer specifications which support 50 Gb/s operation over at least 40km of SMF**
    - **Provide physical layer specifications which support 200 Gb/s operation over at least 40km of SMF**
    - **Provide physical layer specifications which support 400 Gb/s operation over at least 40km of SMF**
  - Further work to balance technical solution from industry capability on transmitter output power, receiver sensitivity and FEC etc., especially the tradeoff for 400GE-40km is part of ongoing investigation


thank you
danke
謝謝
ngiyabonga
teşekkür ederim
gracias
спасибо
Баярлалаа
рахмат
dank je
bedankt
dziękuję
hvala
mauruuru
obrigado
sukriya
kop khun krap
go raibh maith agat
mochchakkeram
tapadh leat
arigatō
takk
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