Approach for 40km PMD

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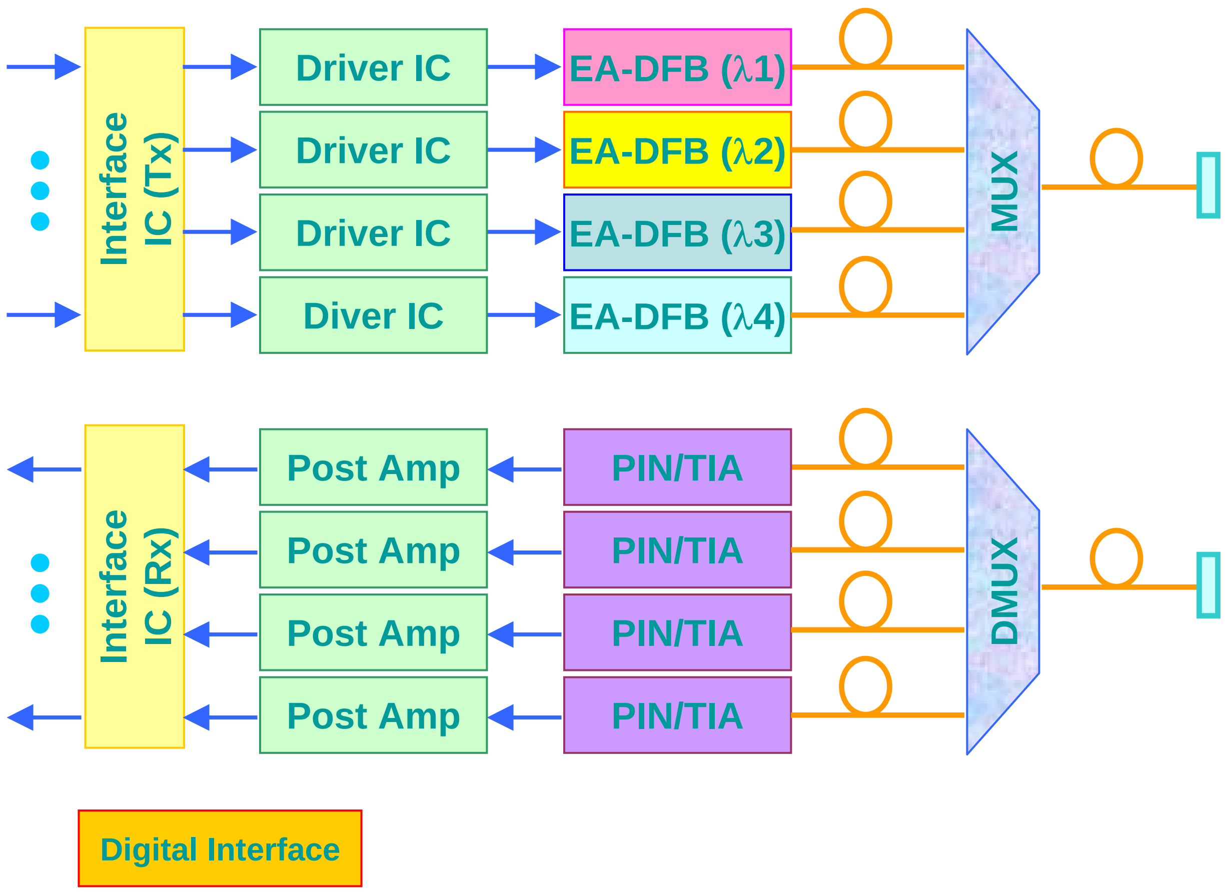
Philosophy for 40km PMD

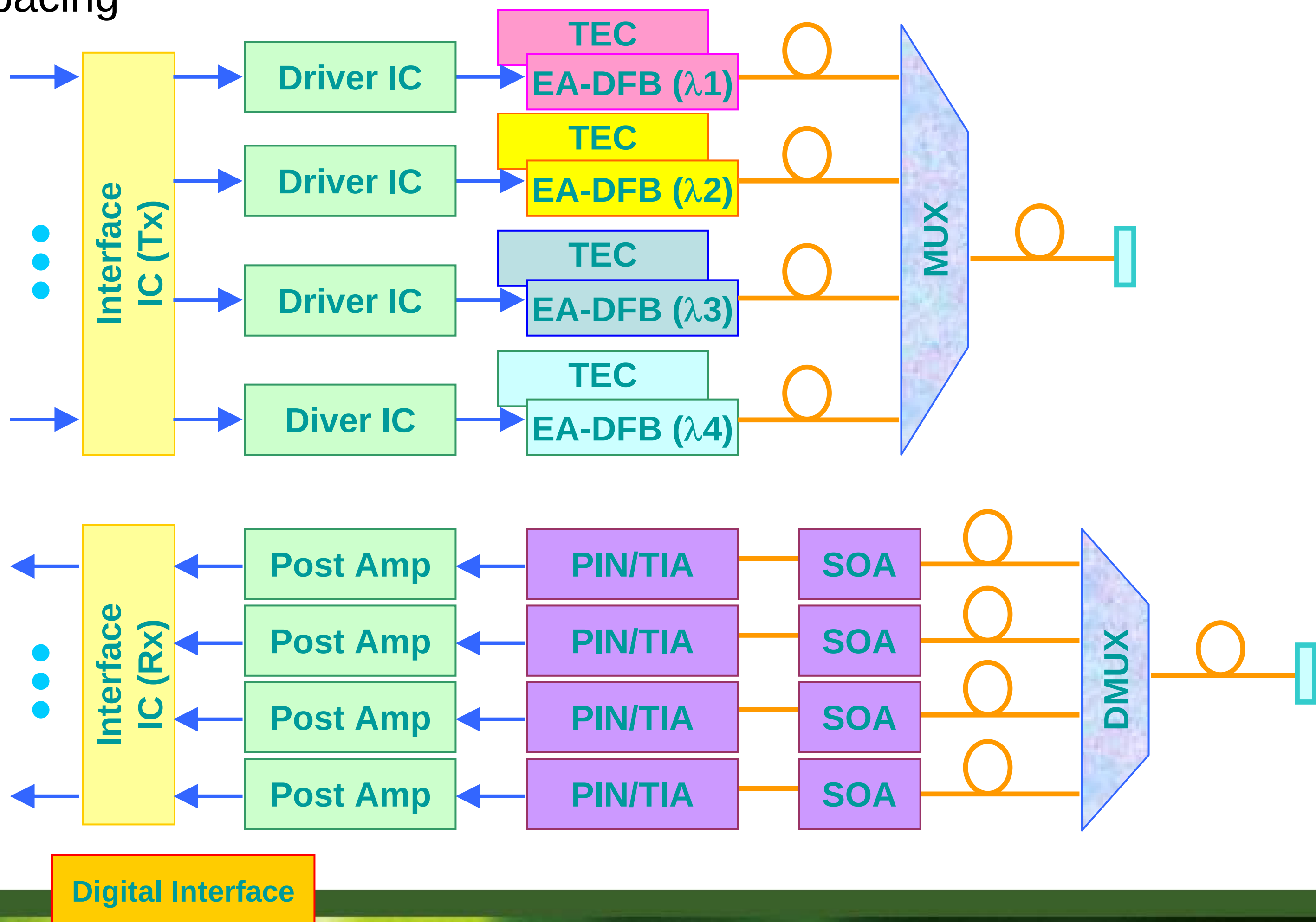
- Borrow key block diagram items from 10km Module
- Leave 1550nm band for implementation of WAN
- Use 1310nm band near the zero dispersion point for standard single mode fiber
- Build amplification into the PMD receiver to compensate for attenuation
  - SOA or APD example technologies that could be used in the Rx chain
- This presentation assumes a 4 λ solution

1st Gen Module Structure for 10km 100GbE Application



Module Structure for ≥40km 100GbE Application

Use temperature controlled lasers for improved transmission characteristics and tighter wavelength spacing



Wavelengths

- Select narrower channel spacing, eg. 400GHz (2.2 nm) – no active wavelength locker
- Center channels near lambda zero of SMF-28 for best chromatic dispersion performance
  - Use G.652 clause 7 tables for values for Sellmeier constants:
- Requires use of cooled light source
- Open to alternate wavelength proposals – these chosen to be centered about G.652 lambda-zero
- Open to alternate spacing – tight spacing makes future integration somewhat simpler

Unit = nm	200GHz Spacing
CH0	1308.7
CH1	1310.9
Ch2	1313.1
Ch3	1315.3
Channel pitch	2.2
Channel bandwidth	2.0

Wavelengths & Dispersion

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- Transmission distance using EA-DFB with 1-dB dispersion penalty with narrow wavelengths are calculated as below.

Sellmeier Equation (*2)
S_{0max}= 0.092 ps/nm
λ_{0max} = 1324 nm
λ_{0min} = 1300 nm

$$\frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\max}}{\lambda}\right)^4\right] \le D(\lambda) \le \frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\min}}{\lambda}\right)^4\right]$$

Wavelength dependent transmission distance L at bit rate of B is obtained using the formula below in the most simple model. D_0: dispersion tolerance at bit rate of B_0.

$$L = \frac{D_0}{D_{CH}} / \left(\frac{B}{B_0}\right)^2$$

	Outer Channels	Notes
CH0, λ, min	1309 nm	
Dispersion for CH0	0.82 to -1.4 ps/nm	
CH3, λ, max	1315 nm	
Dispersion for CH3	1.36 to -0.84 ps/nm	
Distance (*1)	203 km	Chromatic Dispersion Only

(*1) D_0 = 1600 ps/nm for B0=10.7 Gbit/s (ITU-T P1L1-2D1), B=100Gbit/s * (66/64) / 4 = 25.8Gbit/s
(*2) Values from constant obtained from G.652 clause 7

IEEE Related Specification

- Test Point (TP2, TP3) [1] Figure 52-2, "Std 802.3ae-2002"

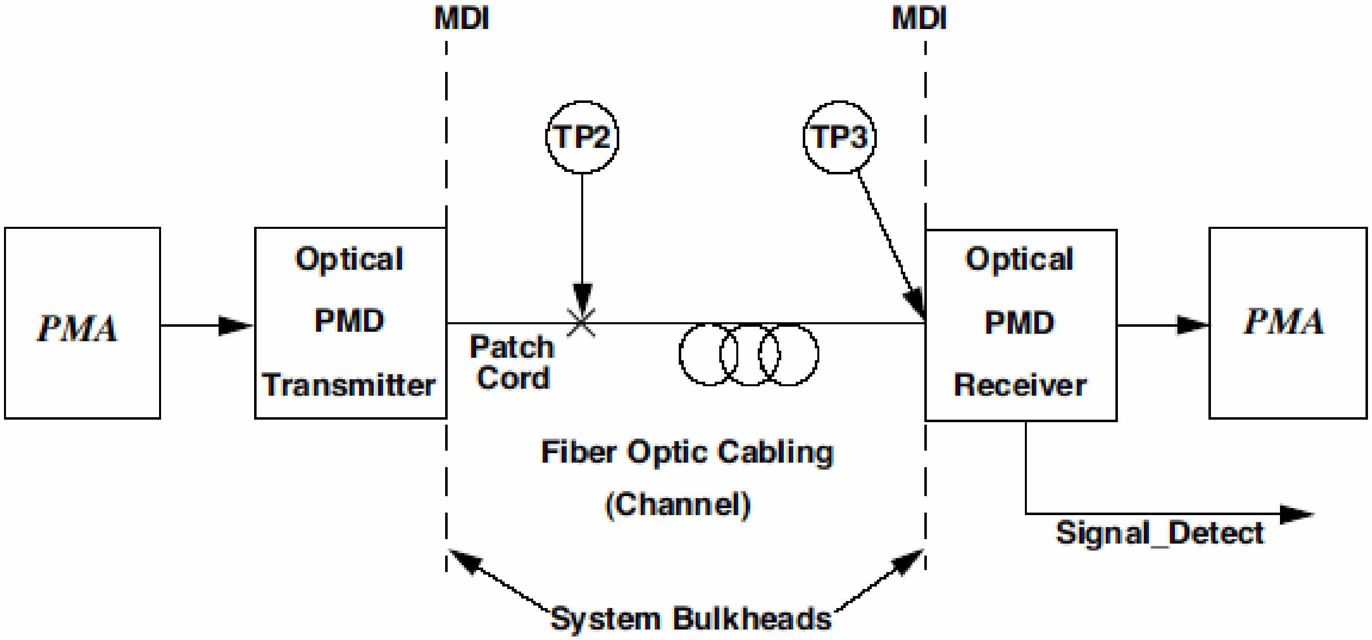


Figure 52–2—Block diagram

Receiver Sensitivity

- Hypothesis
  - Commercial available 10Gbit/s receiver *OMA* is around -14.9dBm_{max} (This is equivalent to -17.0dBm P_{avg} sensitivity with 10dB extinction ratio. Typical 10Gbit/s receivers record sensitivities from -17.0 to -19.0 dBm)
  - Sensitivity decrease from 10 Gbit/s to 25Gbit/s is calculated to be 4 dB (*1)
  - Optical DMUX loss is 3.5 dB_{max} + Splicing loss in the PMD is 0.2 dB
  - Aging degradation + Accuracy of measurement is 0.5dB_{max} + Interoperability penalty is 1.0 dB

Per lane	*OMA* (dBm)	Loss (dB)	
10 Gbit/s	-14.9		BOL_{max}
25 Gbit/s	-10.9	(4.0)	Using Approximation
DMUX + Splice		3.7 (*2)	
Aging + Accuracy + Interoperability		1.5	
Internal Gain		-20	SOA
TP3	-25.7		EOL

(*1) Using bipolar TIA that the sensitivity is proportional to the bit rate.
(*2) Used AWG maximum insertion loss – probably overly severe

Transmit Power Output

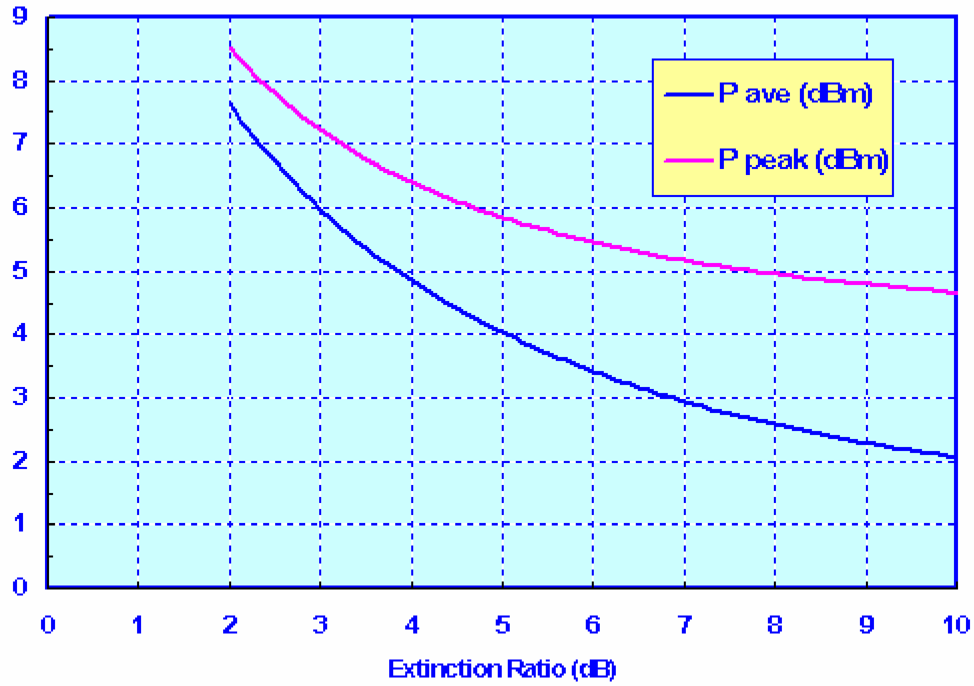
- Hypothesis
  - Receiver sensitivity *OMA* is -3.3 dBm_{max}
  - Link loss is 24 dB
  - Dispersion penalty is 1.0dB
  - Optical MUX loss is 3.5 dB_{max} + Splicing loss in the PMD is 0.2 dB
  - Aging degradation + Accuracy of measurement is 0.5

Per lane	*OMA* (dBm)	Loss (dB)	
TP3	-25.7		EOL
TP2 connector		0.2	
Link loss		24.0	0.6dB/km
Penalty		1.0	Dispersion etc.
TP2	-0.5		EOL
MUX + Splice		3.7 (*2)	
Aging + Accuracy		1.0	
EML out	+4.2		BOL

(*2) Used AWG maximum insertion loss – probably overly severe

Extinction Ratio

- Transmit OMA of +4.2dBm is equivalent to output peak power depending on extinction ratio (Er) shown below.
- Er equal or larger than 7 dB is obtained with realistic output power of BOL=4 dBm with 1dB margin.



Transmit Power Output

- Transmitter

	min	Proposal	10GBASE-L	10GBASE-LX4
***T_OMA min* , per lane**	**dBm**	**+0.5**	**-5.2**	**-6.25**
***T_OMA max* , per lane**	**dBm**	**+3.5**	**NA**	**-1.25**
***T_Avg max* , four lanes**	**dBm**	**+9.5 (*1)**	**0.5**	**5.5**
***Er* min**	**dB**	**7.0**	**3.5**	**3.5**

- Receiver

	min	Proposal	10GBASE-L	10GBASE-LX4
***R_OMA min* , per lane**	**dBm**	**-25.7**	**-12.6**	**-14.45**
***R_OMA max* , per lane**	**dBm**	**TBD**	**NA**	**NA**
Dispersion Penalty max	**dB**	**1.0**	**(1.0)**	**(1.0)**

- Link Budget

	min	Proposal	10GBASE-L	10GBASE-LX4
Link Power Budget	**dBm**	**25.2**	**7.4**	**8.2**
Channel Insertion Loss	**dBm**	**24.2**	**6.2**	**6.2**
Margin for Penalty min	**dB**	**1.0**	**1.2**	**2.0**

Note (*1): Limited by Eye safety