Minimum TX OMA Launch Window

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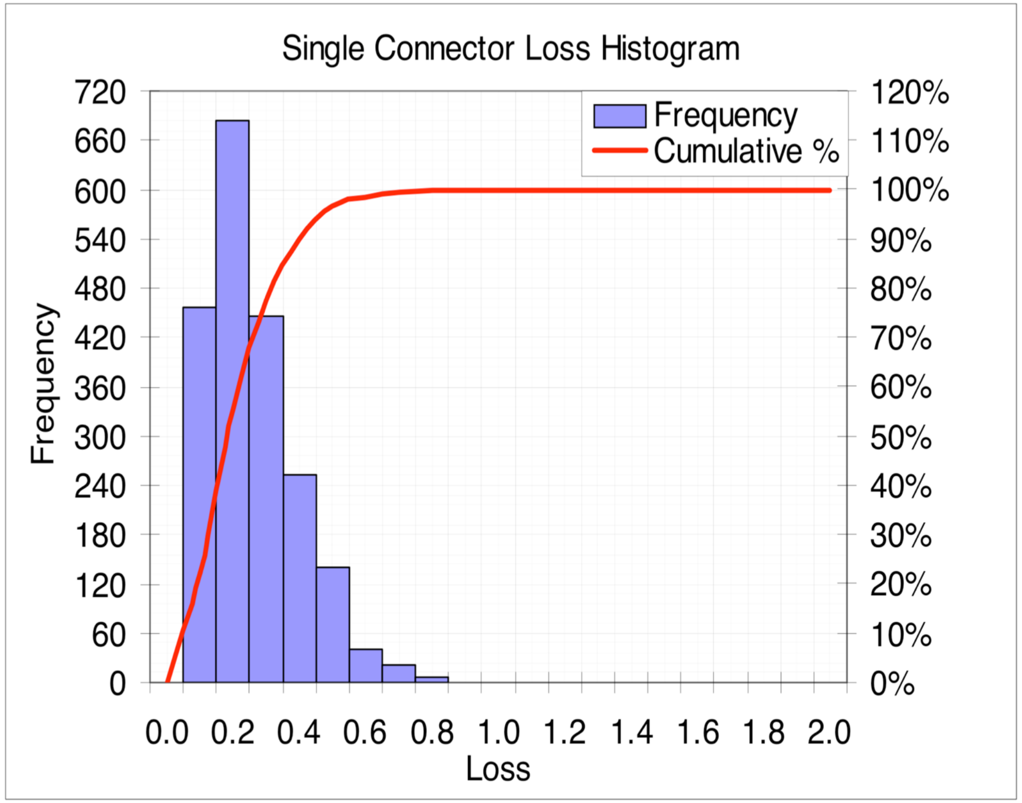
Overview

- LC connector loss distribution
- TOSA bore and ferrule tolerance
- Wiggle test
- BCR test and cross-plug XPR variability
- Min OMA window
- 400GBASE-FR8/LR8 TX OMA launch windows
- Proposed 100G-FR/LR TX OMA launch windows
- Proposed 400G-FR4/LR4 TX OMA launch windows.

Special thanks to Jonathan King and Greg Le Cheminant for providing helpful inputs.

SMF Connector Loss

- **Kolesar_02_0313 reports SMF connector loss as followings:**
  - Good SMF LC have Mean Loss=0.2 dB and Std. Dev.=0.15 dB
  - Good SMF MPO have Mean Loss=0.35 dB and Std. Dev.=0.25 dB
- **King_01_0508 distribution to calculate max (99.8%) for single connector loss based use estimated 2.67xStd. Dev.**
  - Max single SMF LC loss would then be=0.6 dB
  - Max single SMF MPO loss would then be = 1.02 dB
- **The maximum (99.8%) single connector loss are for floating symmetrical connector pairs**
  - SMF transmit receptacle loss with asymmetrical non-floating design the loss could be easily 2x higher!



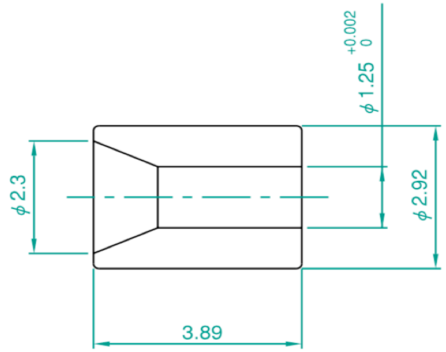
Corning SMF28e+ Characteristics

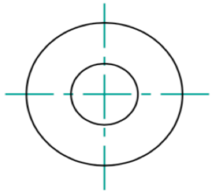
- **Full specifications for Corning SMF28e+ can be found at**
  - http://www.corning.com/worldwide/en/products/communication-networks/products/fiber/smf-28e-.html
- **Corning SMF28e+ fiber is ITU G.652.D compliant**
- **Core Diameter = 8.2 μm**
- **MFD (Mode Field Diameter) = 9.2 ± 0.4 μm**
- **SMF 28 glass geometry**
  - Cladding diameter = 125 ± 0.7 μm
  - Core-Cladding concentricity ≤ 0.5 μm
  - Cladding non-circularity ≤ 0.75%
  - Will assume above items will produce 0.5 μm offset from center.

Tolerance of Ferrule and Sleeve

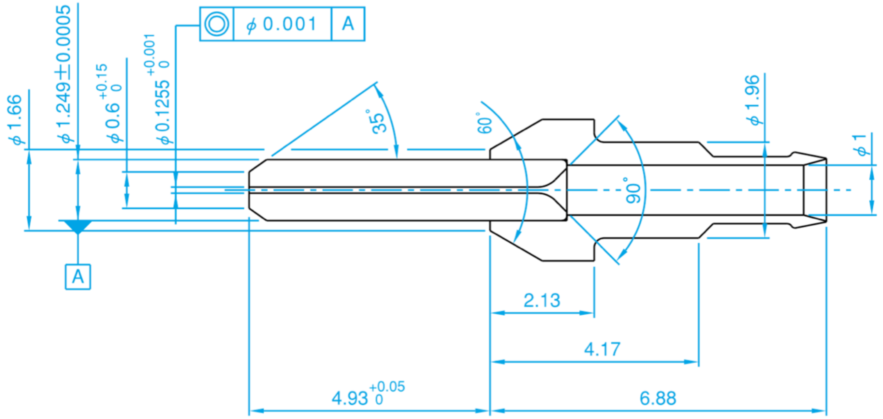
- **Tolerance for Adamant Namiki 1.25 mm zirconia receptacles and connectors**
  - Solid sleeve inner diameter 1.25 +0.001/-0 mm (assuming premium grade, Std grade +0.002/-0 mm)
  - Ferrule outer diameter 1.249 ±0.0005 mm and fiber hole 0.1255 +0.001/-0 mm

ALC-SSタイプ
＜ϕ1.25mmフェルール用＞
図：ALC-SS-1-20-292-0389





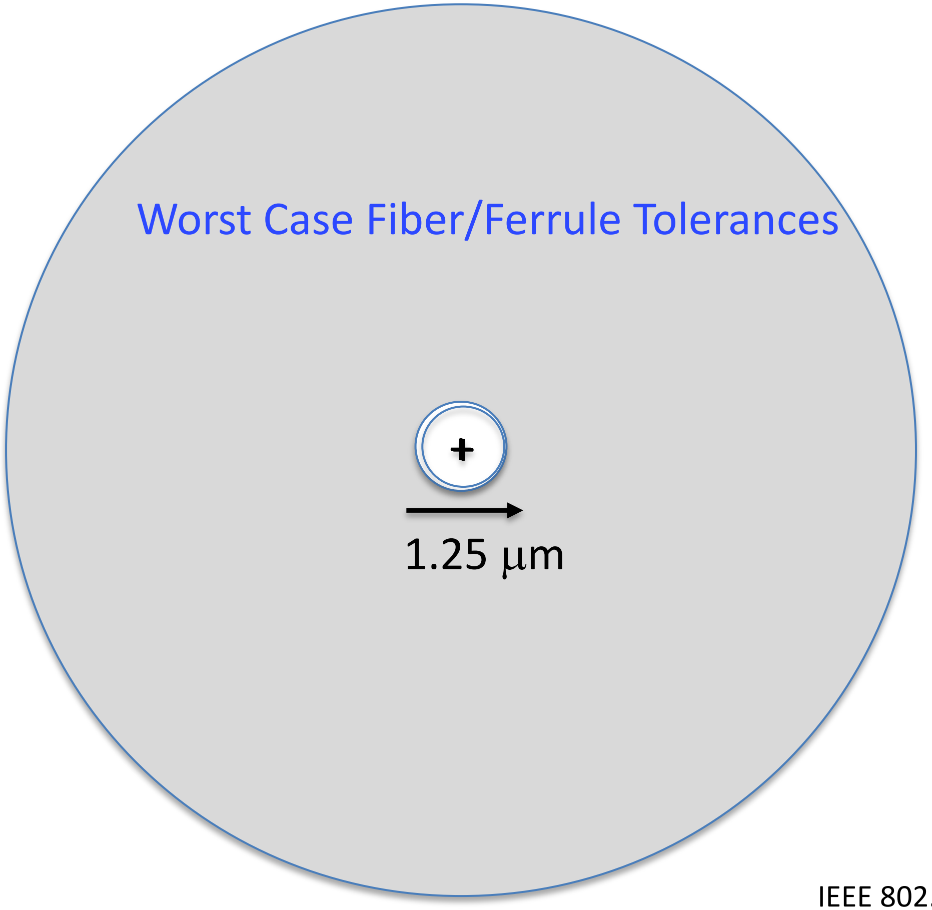
ALC-FSBタイプ＜LCコネクタ用、フラット端面、フランジ付＞

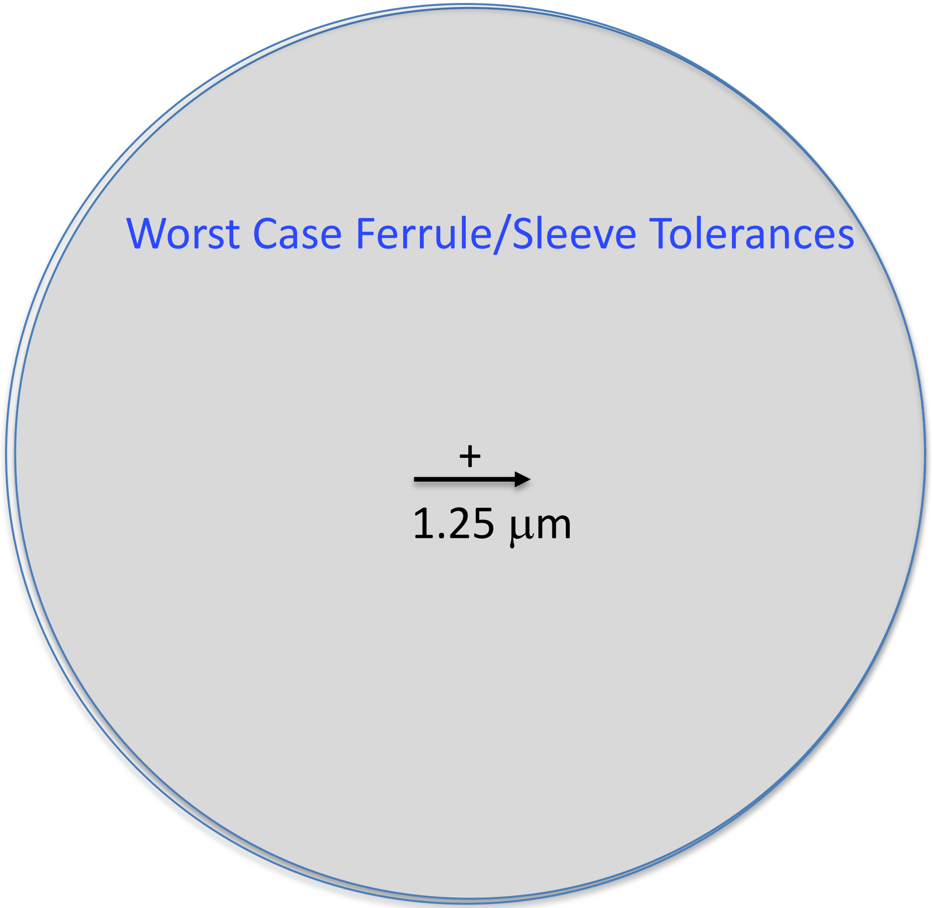


https://www.ad-na.com/en/product/optical/ferrule-sleeve/

Fiber/Ferrule/Sleeve Tolerances

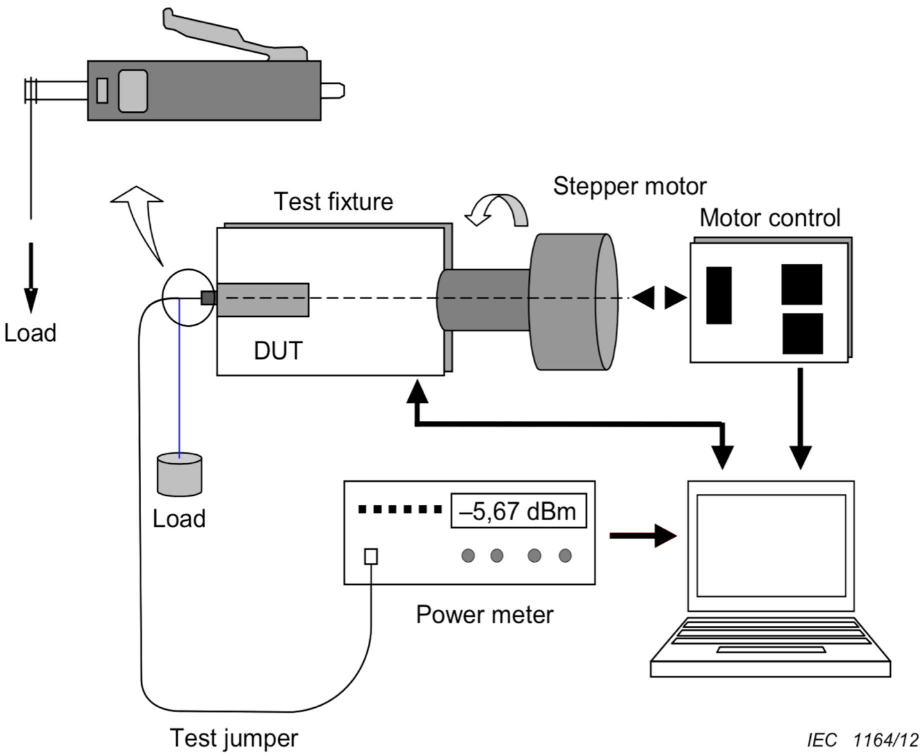
- **Worst case fiber, ferrule, and sleeve tolerance may add up to 2.5 μm offset**
  - A non-floating/non-symmetrical transceiver with fiber stub may add 0.5 to 1 μm to above tolerance
  - Unless one uses a metrology grade connector with fiber offset that is rotated in the receptacle the min/max coupling losses are not be observed.





SMF Wiggle Test

- **Wiggle test has been widely used to test receptacle and connector mating for power coupling variations**
  - As the transmitter OMA window is reduced guaranteeing min/max OMA across fiber jumpers distribution with varying degree of ferrule sizes, fiber offset, and eccentricity become challenging
- **Figure is from IEC 62150-3 but GR-326 also defines similar test method**
  - IEC wiggle test perform 360 degree rotation
  - GR-326 wiggle test is at 0, 45, 90, 135, 180, 225, 270, 315 degree instead of full rotation.



NOTE The details of the loading point are described in Annex C.

Figure 1 – Equipment setup of Method A for Tx interfaces

Beam Centrality Ratio (BCR) is a Scientific Wiggle Test

- **Optoelectronics for Data Communication book by Ronald Lasky, Ulf Osterberg, and Daniel Stigliani, Academic Press 1995, have defined Beam Centrality method**
  - Where BD is receptacle bore diameter (2.5025 μm)
  - FD is the ferrule diameter (2.5 mm)
  - FCE is the master fiber core offset (1.6 μm)
  - BC is receptacle beam offset (1.6 μm)
  - ψ is the fiber offset in relationship to receptacle beam offset
  - LMFD is the laser receptacle/fiber stub mode field diameter (11.5 μm)
  - FMFD is the fiber mode field diameter (10 μm)

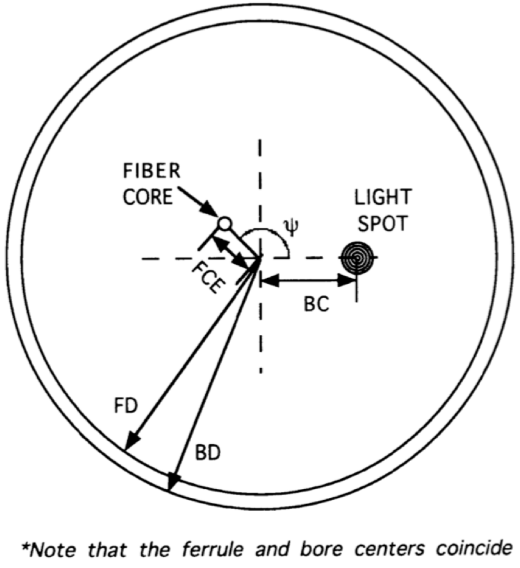
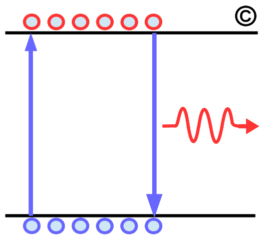


FIGURE 5.6 Beam centrality (BC) and ferrule/core eccentricity (FCE), exaggerated scale.

- **Beam Centrality Ratio (BCR) for ψ =180 and gives maximum BCR of 4.3 dB**
  - $$\text{BCR (dB)} = \frac{8\times 20\times \log(e)\times 2BC\times\left[FCE+\frac{1}{2}(BD-FD)\right]^2}{LMFD^2+FMFD^2}$$

BCR and Cross-plug (XPR) Distributions



- **The Weibull distribution indicate 3-sigma limit (99.73%) is > 3 dB**
  - About 2% of the 16 jumper and TOSA combinations exceed 3 dB XPR
  - Unless there has been substantial improvement the 1.2 dB XPR assumed here results in 25% of TOSA-Jumper combinations failing!

Lasky Measured BCR for 16 TOSA's

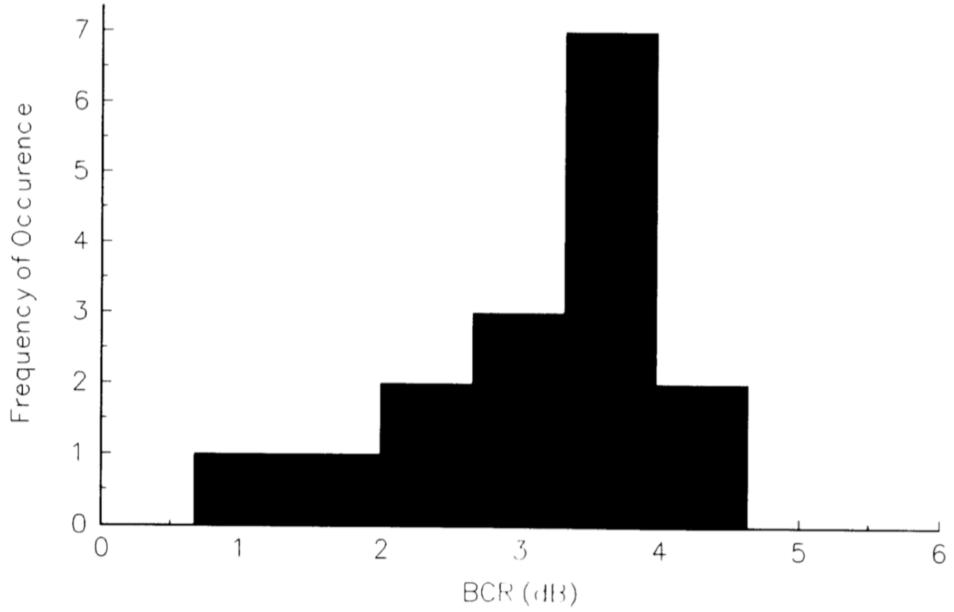


FIGURE 5.23 The BCR test results.

Lasky Cross Plug XPR for 16 TOSA's with 16 Jumpers

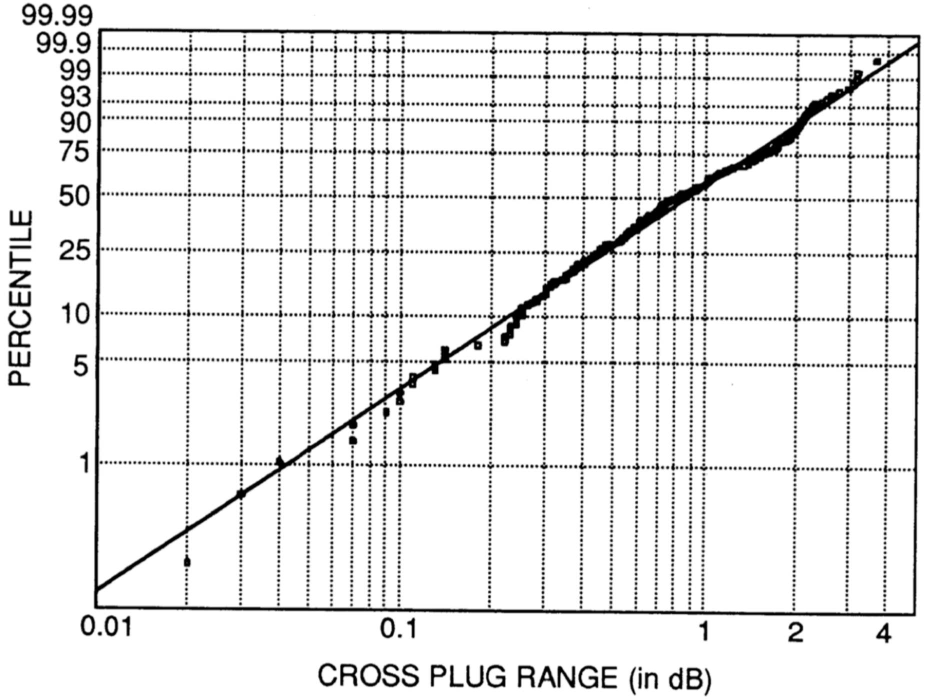
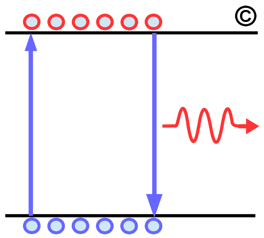
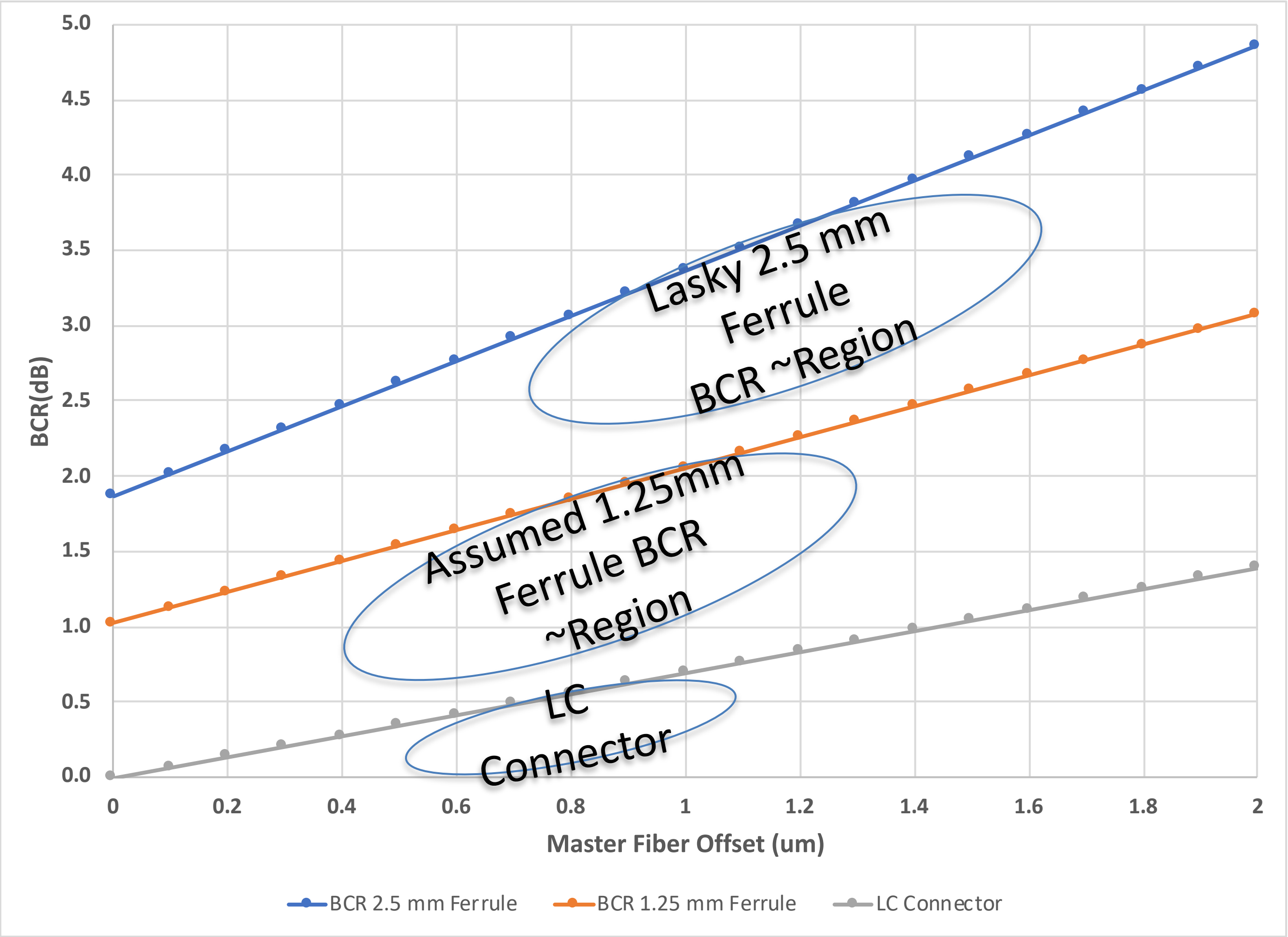


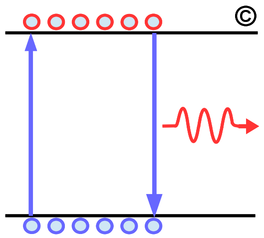
FIGURE 5.24 Weibull probability plot of XPR results.

BCR as function Master Offset Jumper



- BCR for Lasky 2.5 mm ferrule reported as high as 4.5 dB
- Lets assume BCR for LC receptacle with premium grade bore and fiber stub has improved by 60% from Lasky measurement, resulting in BCR<1.8 dB
  - Lets also assume cross plug has improved by 60%, where XPR=1.2 dB
- To meet BCR≤ 1.8 dB or an XPR ≤ 1.2 dB may require testing with master jumper and accept some yield loss
- From LC connector max loss 99.87% the BCR would be 0.6 dB and the master jumper offset would be 0.8 μm.





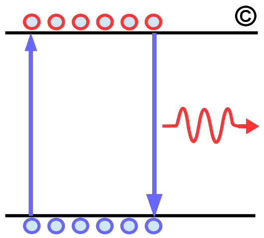
Fiber/Connector Coupling Efficiency

- **Fiber/connector loss due to lateral offset can be approximated by [Marcuse, Bell Tech Journal 1977]**

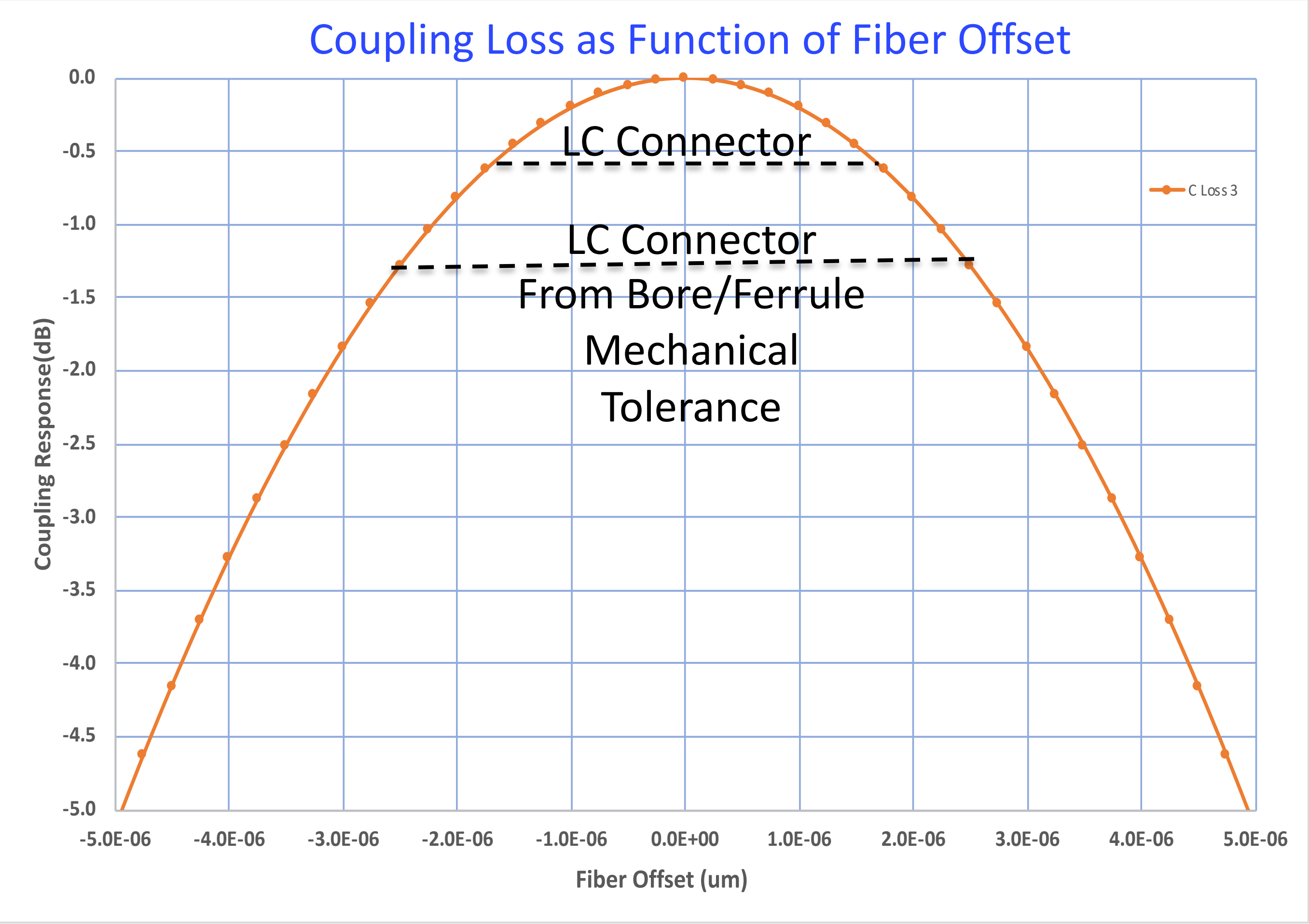
$$C(dB) = 10 \times LOG\left\{\left(\frac{2w_1w_2}{w_1^2 + w_2^2}\right)^2 exp\left[-\frac{2d^2}{w_1^2 + w_2^2}\right]\right\}$$

- The approximate analysis assumes PC contact with no Fresnel loss and no angular misalignment
- The parameters assumed are::
  - w_1=w_2=Mode Field Radius=MFD/2, Corning SMF28e+ has MFD=9.2 μm
  - d is the lateral offset
- Coupling loss as function of offset d for range of ±5 μm is shown on the next page.

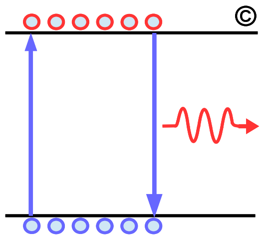
LC and MPO Connector Coupling



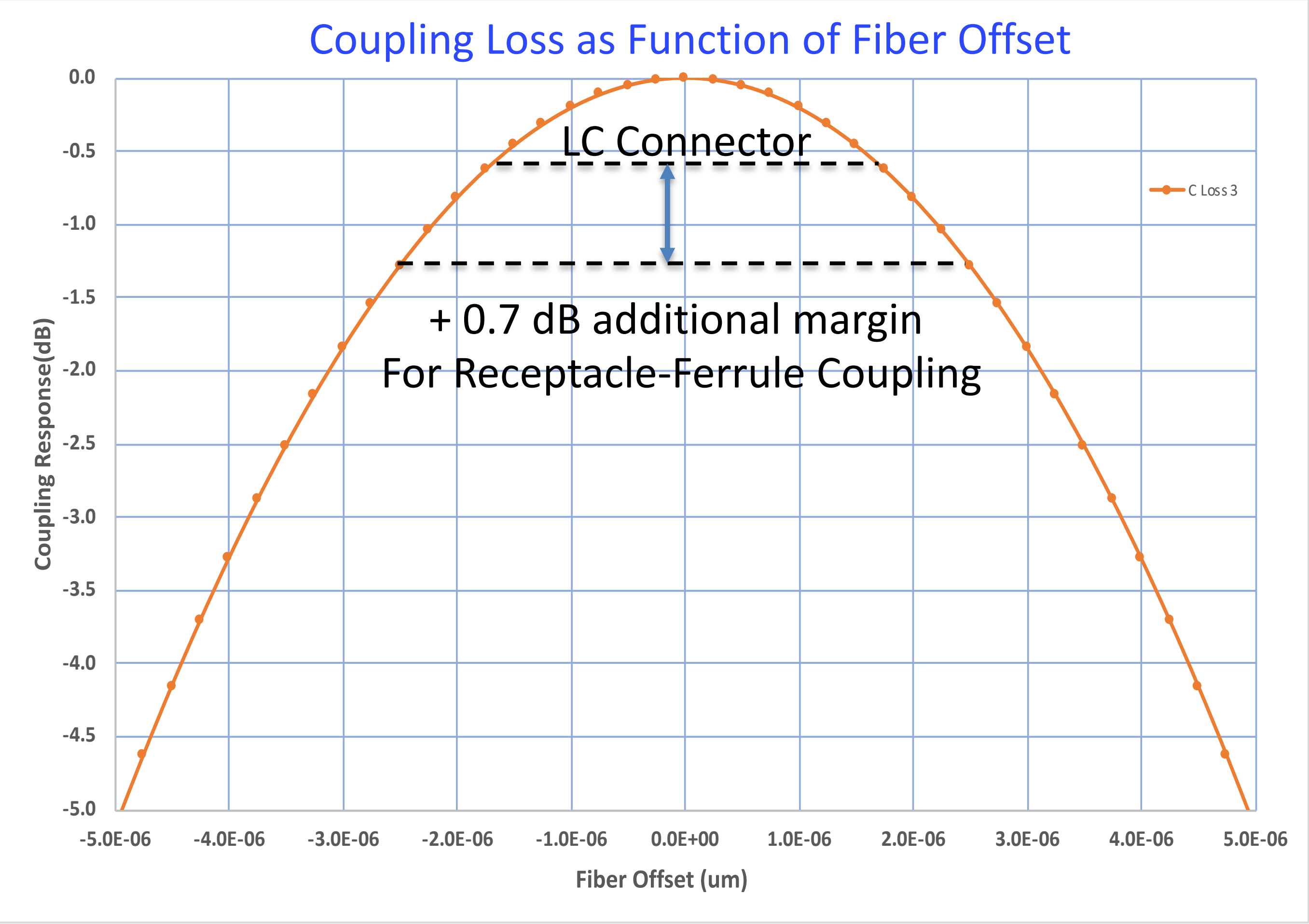
- From Kolesar_02_0313 and King_01_0508 max connector loss can be estimate for
  - LC connector =0.6 dB (99.8%)
- Using analysis from Marcuse connector loss as function of lateral x offset is shown on the graph
  - LC connector loss of 0.6 dB (99.8%) correspond to an offset of 1.75 µm
  - But worst case LC bore/ferrule may have up to 2.5 µm offset resulting in 1.3 dB.



Transmitter Output OMA Inaccuracies

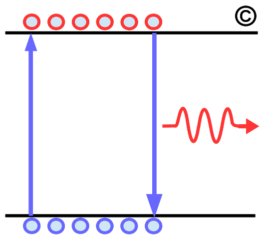


- **XCVR receptacles are non-floating/non-symmetrical and likely will have additional ~0.5 µm of slop and the receptacle coupling loss is expected to be:**
  - ~ 1.2 dB for LC
- **Additional source of TX OMA inaccuracies:**
  - OMA /ER tracking over life ~0.6 dB
  - Scope OMA accuracy ~0.4 dB*
- **Total mechanical, measurement accuracy, and OMA tracking require the transmitter to have 2.2 dB OMA window to avoid higher cost.**

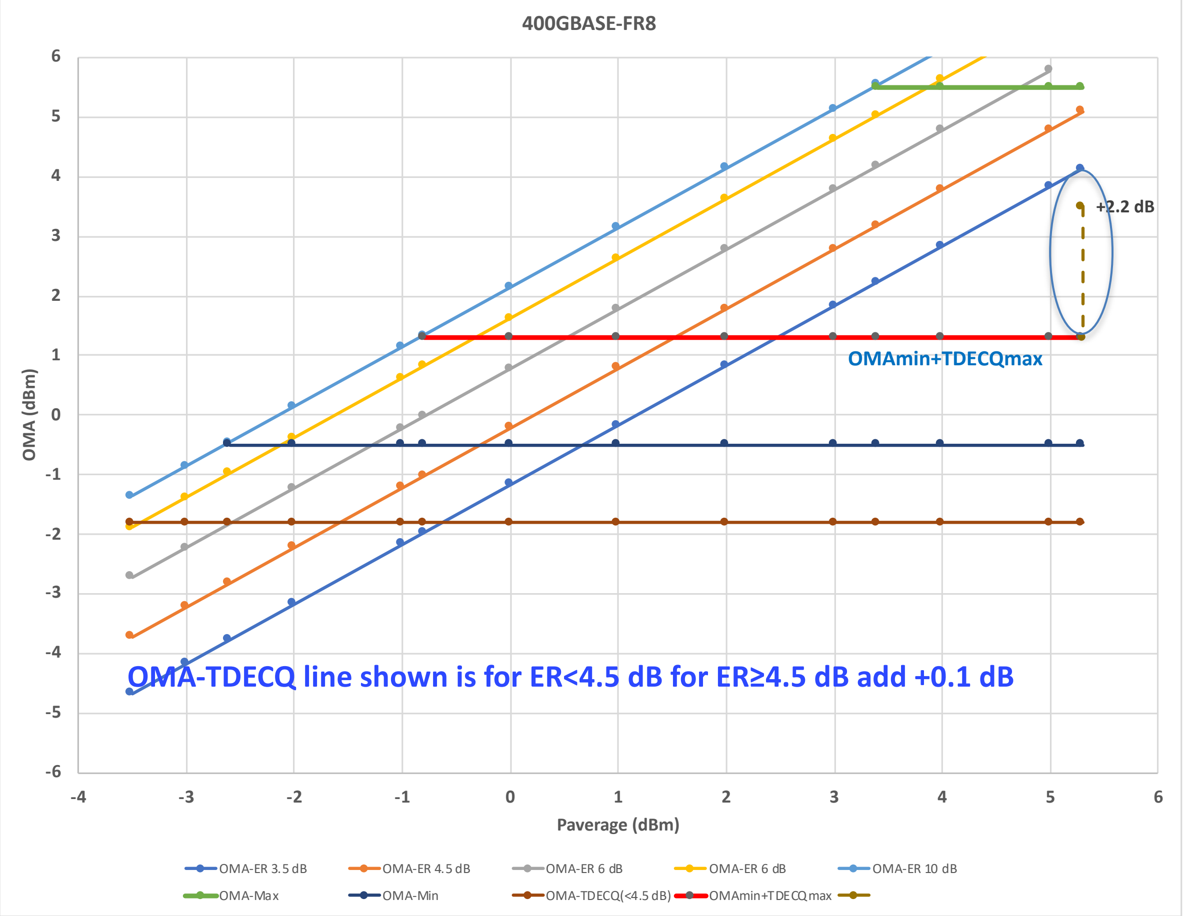


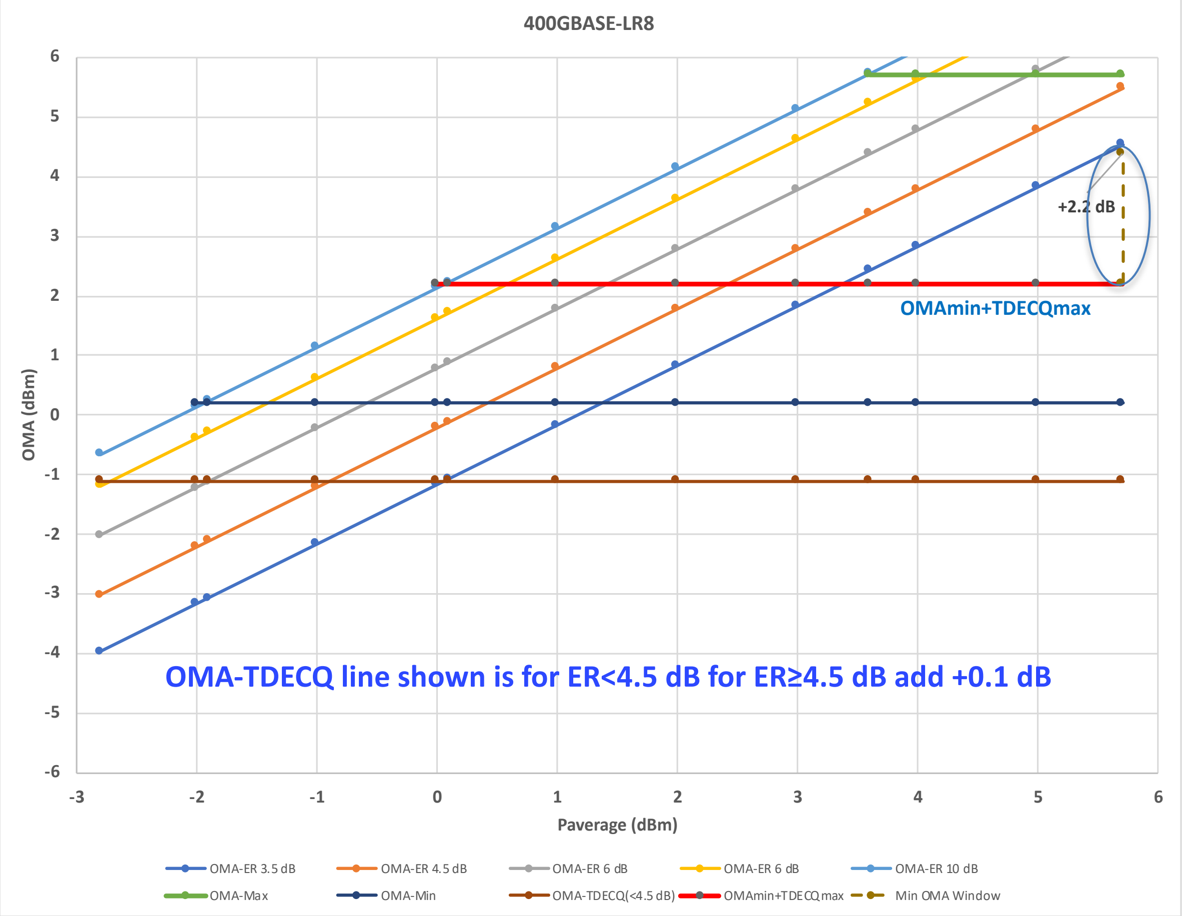
* Scope plugging assumed Keysight 86116C .

400GBASE-FR8/LR8 Allowed TX OMA Launch Window

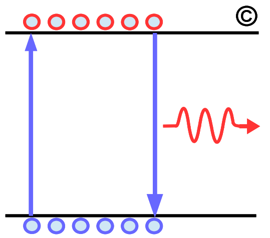


- Depending on the Extinction Ratio (ER) 400GBASE-FR8 provides 2.8-4.2 dB and 400GBASE-LR8 2.3-3.5 dB for TX OMA window and exceeds min TX window of 2.2 dB!

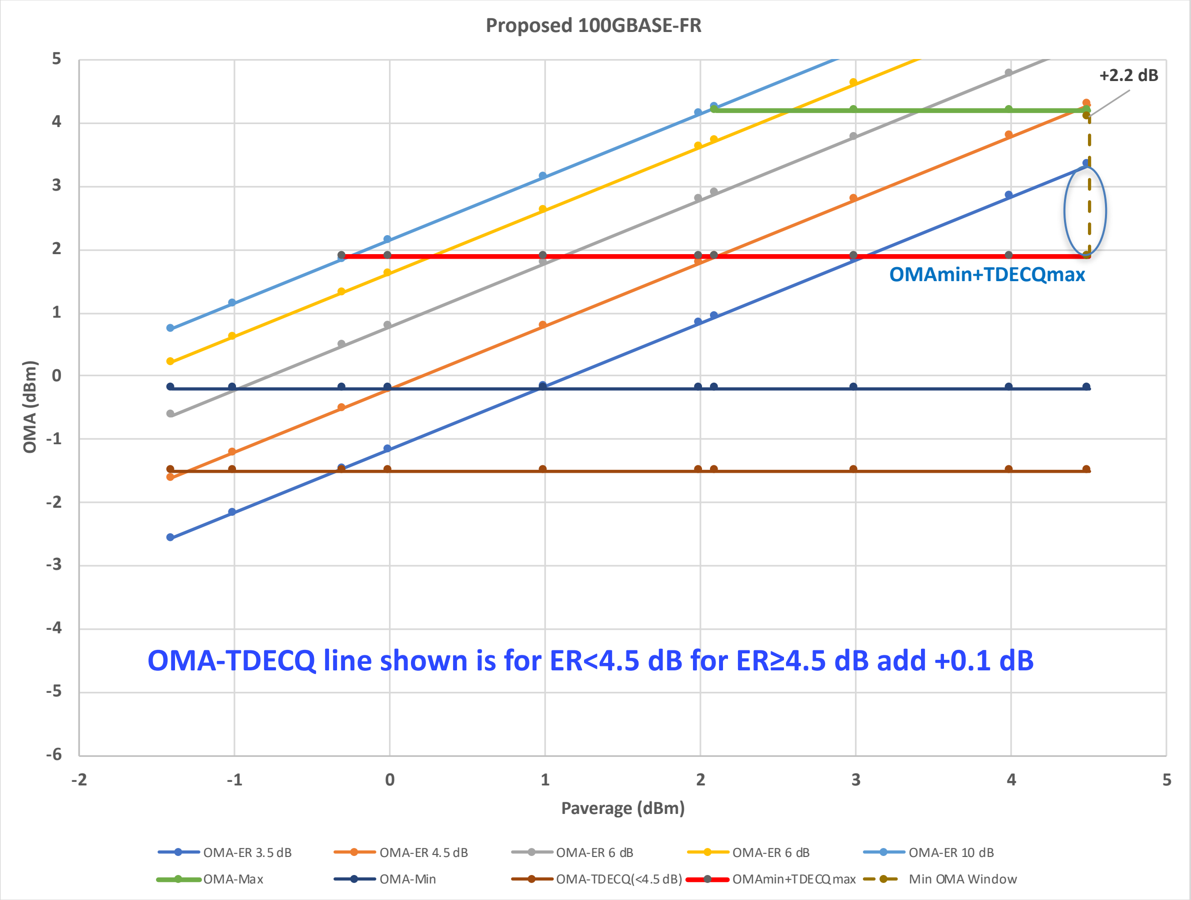


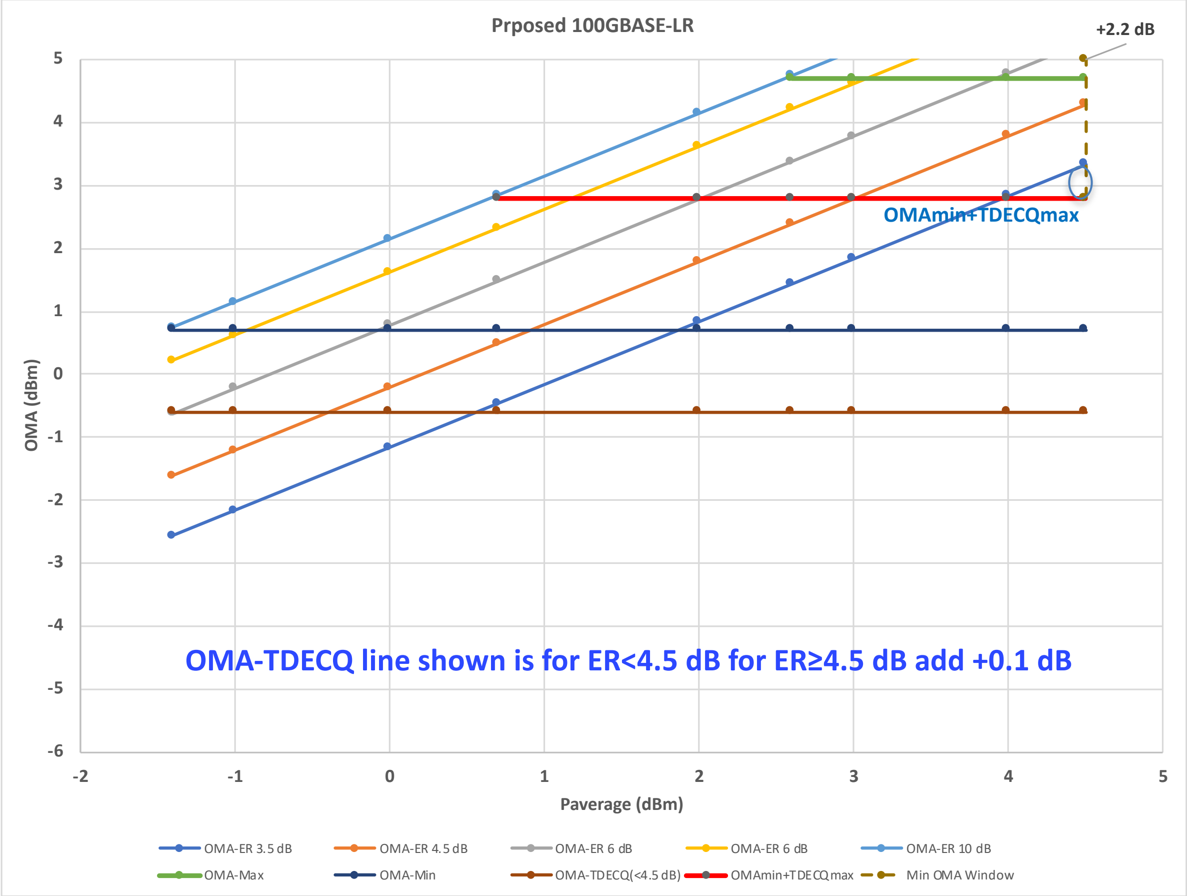


Proposed 100G-FR/LR Allowed TX OMA Launch Window

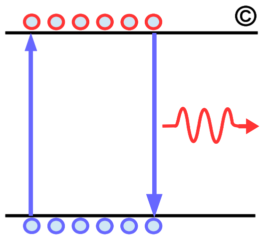


- **Depending on ER 100G-FR provides 1.4-2.3 dB and 100G-LR 0.5-1.9 dB fails min TX OMA window of 2.2 dB!**
  - See welch_3cu_adhoc_050119.

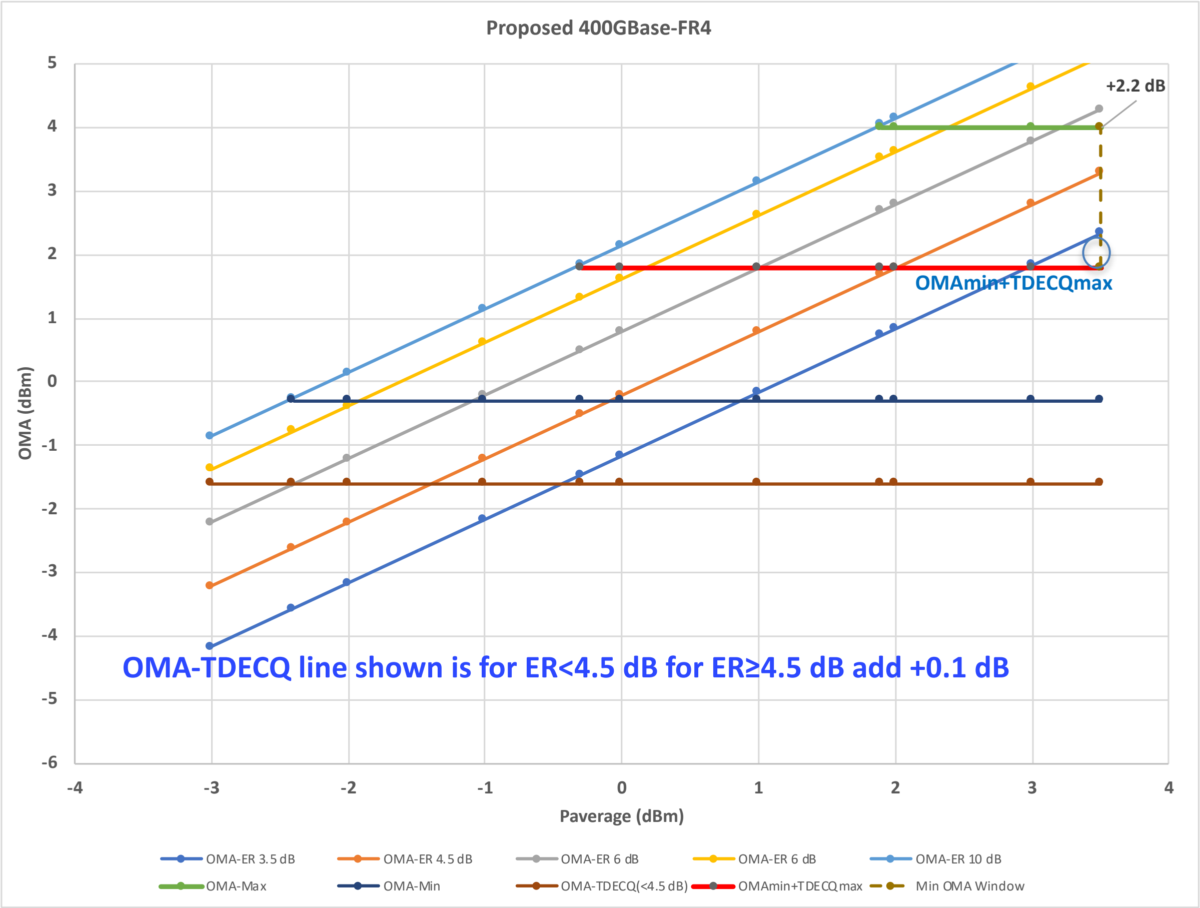


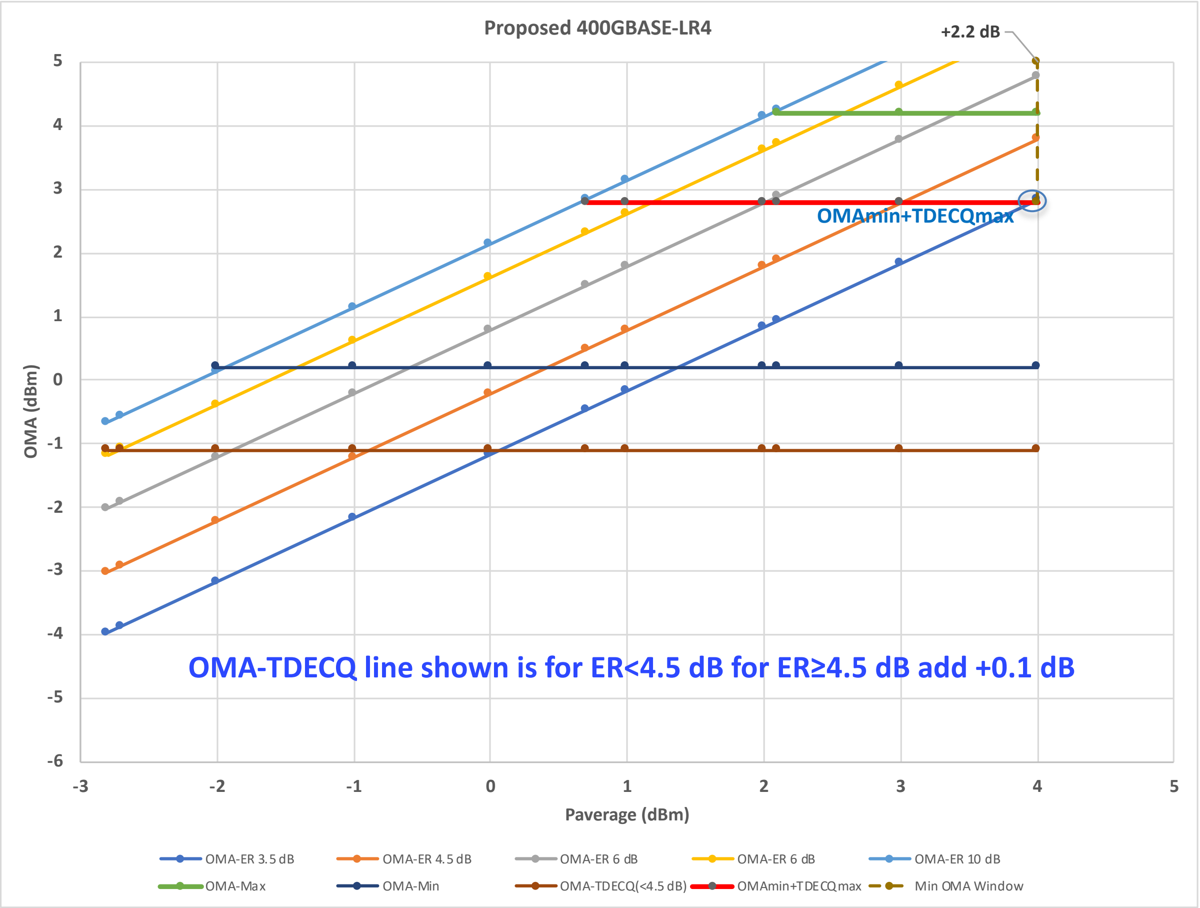


400G-FR4/LR4 Allowed TX OMA Launch Window

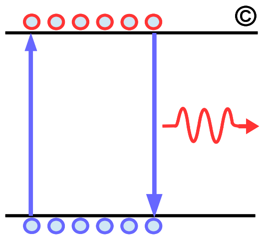


- **At Min ER 400G-FR4 provides 0.5-2.2 dB and 400G-LR4 0-1.4 dB fails min TX OMA window of 2.2 dB!**
  - See liu_3cu_adhoc_050119 and lewis_optx_01a_0319.





Summary



- **Assuming that BCR and cross-plug XPR repeatability can be improved by 60% compare to Lasky results**
  - Receptacle/jumper XPR variability contributes 1.2 dB OMA window
  - Additional 0.6 dB assumed for OMA control over life and 0.4 dB for OMA measurement accuracy
- **Minimum of 2.2 dB OMA window is necessary to support TOSA/jumper mechanical tolerances, OMA control level over life, and OMA measurement accuracy**
- **400GBASE-FR8/LR8 PMDs provide a very healthy 2.8-4.2 dB / 2.3-3.5 dB OMA launch windows over a wide range of extinction ratios**
- **Proposed 100G-FR with 1.4-2.3 dB OMA launch windows marginally fails min of 2.2 OMA window**
- **Proposed 100G-LR with 0.5-1.9 dB OMA launch windows fails min of 2.2 OMA window**
- **Proposed 400G-FR4 with 0.5-2.2 dB OMA launch windows fails min of 2.2 OMA window**
- **Proposed 400G-LR4 with 0-1.4 dB OMA launch windows is badly broken**
- **802.3cu PMDs need to have robust and sufficient OMA window comparable to 400GBASE-FR8/LR8**
  - Task force shouldn't define PMDs with insufficient OMA window that may require testing for complex Wiggle/BCR test or even worse define a set of marginal PMDs that may fail occasionally
  - If increasing OMA is not an option then need to consider reducing reach/power budget.