DATA TO SUPPORT 100G OPTICAL PARAMETER SELECTION

MATT SCHMITT, CABLELABS

SUPPORTERS

- Chris Stengrim, CableLabs
- Clark Scott, ADVA
- Curtis Knittle, CableLabs
- David Lewis, Lumentum
- Eric Menu, Videotron
- George Hart, Rogers
- Haipeng Zhang, CableLabs
- Jeff Finkelstein, Cox
- Jeffrey Maki, Juniper
- John DeAndrea, Finisar
- Jörg-Peter Elbers, ADVA
- Mu Xu, CableLabs
- Peter Noutsios, Fujitsu Optical
- Shawn Esser, Finisar
- Stephan Neidlinger, ADVA
- Tom Williams, Acacia

BACKGROUND

- In an ad hoc presentation to 802.3ct on April 25 (http://www.ieee802.org/3/cn/public/adhoc/19_0425/schmitt_3ct_01_190425.pdf), I built off of the presentation from Stassar, et al (http://www.ieee802.org/3/ct/public/19_03/stassar_3ct_01_0319.pdf) by adding a "*Proposed Strawman*" column to that presentation's tables of optical parameters
- The "Proposed Strawman" column was populated in the following manner:
  - Where G.698.2 and the CableLabs PHYv1.0 spec agree, that value was added to the *Strawman*
  - Where G.698.2 has a value and the CableLabs spec is silent, that value was added to the *Strawman*
  - Where G.698.2 and the CableLabs spec disagree, a "TBD" was added to the *Strawman*

TBD ITEMS

- That exercise identified several areas with TBDs associated with them, including
  - Output/Input power
  - Max/min frequency
  - OSNR
  - Reflectance/Return Loss
  - Laser Linewidth
  - Max PDL
- This contribution provides input into most (but not all) of these areas in an attempt to develop a *Strawman* that is complete enough to adopt as a baseline for the 100G objective

A NOTE ON BER

- The Hard Decision Staircase FEC already adopted as a baseline for the 100G application requires a pre-FEC BER of $\leq 4.5X10^{-3}$ in order to achieve a post-FEC BER of $\leq 10^{-15}$, which is required in the CableLabs specification
  - Target for this specification is a post-FEC BER of $\leq 10^{-12}$, which permits a somewhat higher pre-FEC BER
- Much of the testing referenced by this contribution for required power and OSNR levels has done so relative to achieving a pre-FEC BER of $\leq 4.5X10^{-3}$, as this is easier to test for post-FEC BER
- Suggests that there is some additional margin relative to the numbers used here

POWER AND OSNR LINKAGE

- In the *Strawman* table, we have the following parameters
  - Minimum mean input power [amplified]
  - Minimum OSNR(193.6) [amplified]
  - Minimum mean input power [unamplified]
  - Minimum OSNR(193.6) [unamplified]
- Propose treating power and OSNR for each of "[amplified]" and "[unamplified]" as linked together to create a single measurable data point
  - For example, device must meet BER requirement for amplified case when input signal meets both power and OSNR requirements
- If so, "unamplified" is equivalent to CableLabs "power-limited baseline", and "amplified" is equivalent to CableLabs "OSNR-limited baseline"

[UNAMPLIFIED] RECEIVE POWER AND OSNR

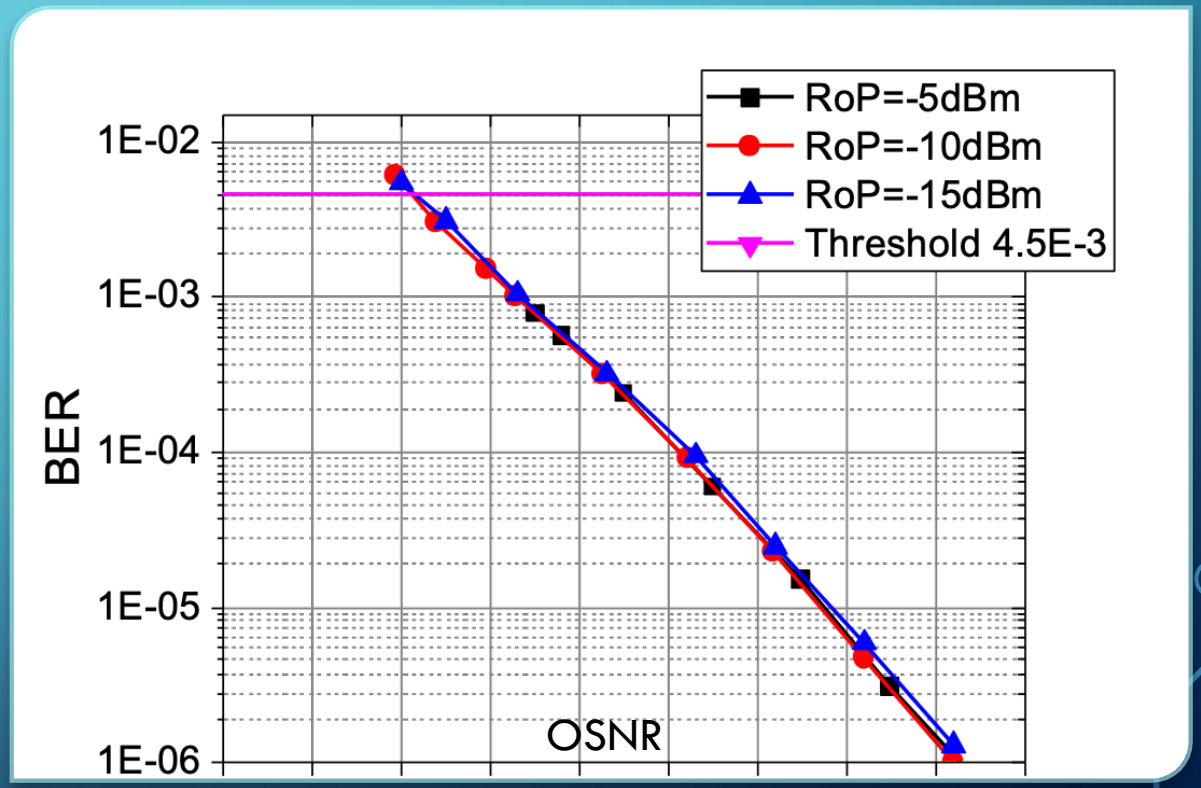
- CableLabs spec power-limited baseline requirement is -30 dBm (EOL) when OSNR is 35 dB (must achieve BER requirement when power is -30 dBm or higher when OSNR is 35 dB)
  - Selection based on survey responses from 6 different manufacturers and consensus from WG of ~18 manufacturers
- CableLabs has since tested 8 different transceiver modules for received power
  - All modules achieved a pre-FEC BER of $\leq 4.5X10^{-3}$ at -31 dBm or lower

[AMPLIFIED] RECEIVE POWER AND OSNR

- CableLabs spec OSNR-limited baseline requirement is 15.5 dB OSNR (EOL) when input power is -10 dBm (must achieve BER requirement when OSNR is 15.5 dB or higher and power is -10 dBm)
  - Selection based on survey responses from 6 different manufacturers and consensus from WG of ~18 manufacturers
- CableLabs has since tested 4 different transceiver modules for received OSNR
  - All modules achieved a pre-FEC BER of $\leq 4.5X10^{-3}$ at 14.5 dB OSNR and input power of -10 dBm

CONSIDERATIONS FOR [AMPLIFIED] INPUT POWER

- CableLabs also tested a transceiver module for impacts to received OSNR performance at different received power levels
  - -5, -10, and -15 dBm
- Results showed virtually no differences between them
  - Suggests some flexibility in choosing value
- Manufacturer feedback suggests optimal sensitivity ~-10 dBm is common



PROPOSAL FOR RECEIVED POWER AND OSNR

- Based on manufacturer inputs and test results, propose adopting the following:

- Unamplified (power limited) case
  - Minimum mean input power [unamplified]: -30 dBm
  - Minimum OSNR(193.6) [unamplified]: 35 dB
- Amplified (OSNR limited) case
  - Minimum OSNR(193.6) [amplified]: 15.5 dB
  - Minimum mean input power [amplified]: -10 dBm

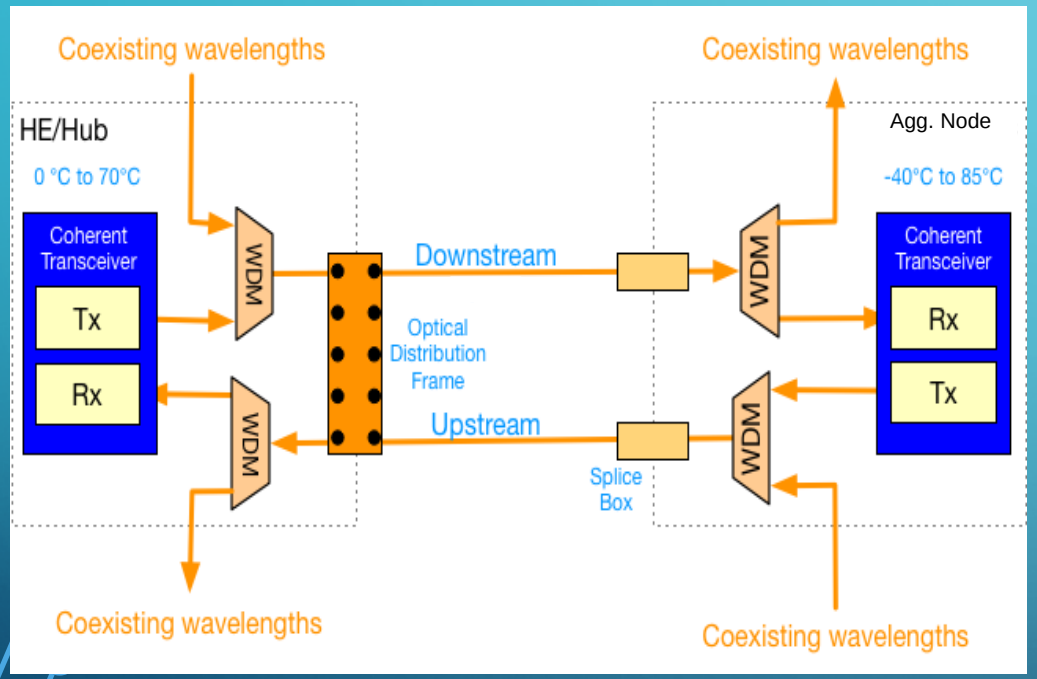
MINIMUM TRANSMITTER OSNR

- CableLabs specification defines a minimum transmitter OSNR of 35 dB
  - Based on surveys of 6 manufacturers, and consensus of ~18 manufacturers in CableLabs working group
- CableLabs has tested output OSNR from several transceiver modules
  - All results were in excess of 40 dB OSNR
- Since G.698.2 does not have a direct equivalent, propose adopting value of 35 dB OSNR for "Minimum Transmitter OSNR" parameter

MINIMUM TRANSMITTER OUTPUT POWER

- In *Strawman* table, G.698.2 and CableLabs PHYv1.0 have following values
  - G.698.2: -8 dBm
  - CL PHYv1.0: -6.5 dBm
- Either should allow low cost implementations
  - G.698.2 allows a bit more flexibility, at the potential expense of the reach/link budget in a "power limited" case
- Following slide shows impact in an example "power limited" case
  - Assumes adoption of proposed receiver power and OSNR values from previous slides

POWER LIMITED DWDM LINK BUDGET EXAMPLE



	G.698.2	PHYv1.0
Minimum Tx Output Power (dBm)	-8	-6.5
Link Impairments (dB)	1.7	1.7
Optical Equipment Loss (dB)	11	11
Rx Power w/Loss (dBm)	-20.7	-19.2
Minimum Rx Input Power (dBm)	-30	-30
Min Link Budget (dB)	9.3	10.8
Reach (km) (0.25 dB/km)	37.2	43.2

TRANSMITTER OUTPUT POWER PROPOSAL

- Based on these results, while -6.5 dBm would be preferred, -8 dBm would be acceptable based on the following assumptions:
  - The reduced reach will still be acceptable for the majority of cable operator applications
  - Most transceivers (if not all) will likely exceed the minimum
  - End users can therefore select higher output power transceivers if they need them
  - Allows more opportunity for product differentiation
- Therefore, propose adopting -8 dBm (EOL) for Minimum mean channel output power

OPTICAL REFLECTANCE

- CableLabs specification initially adopted same value as G.698.2 for maximum reflectance of transmitter and receiver: -27 dB
- This defines the maximum discrete reflectance between points S and R, in order to minimize the effects of multiple reflections

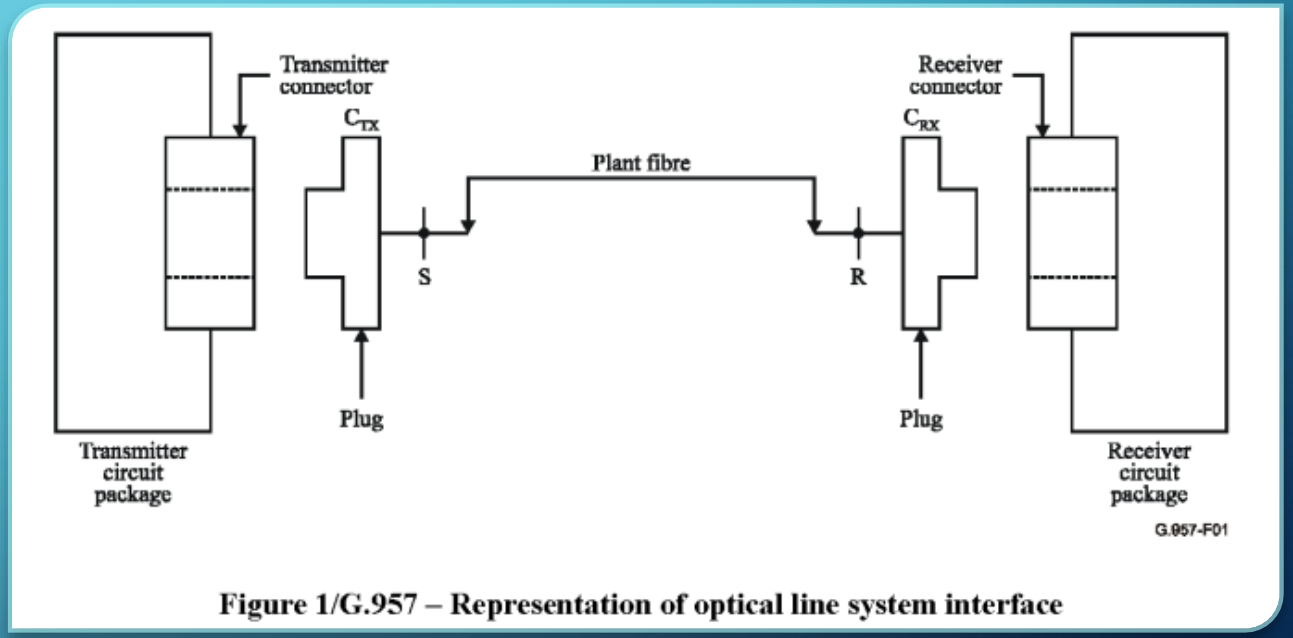


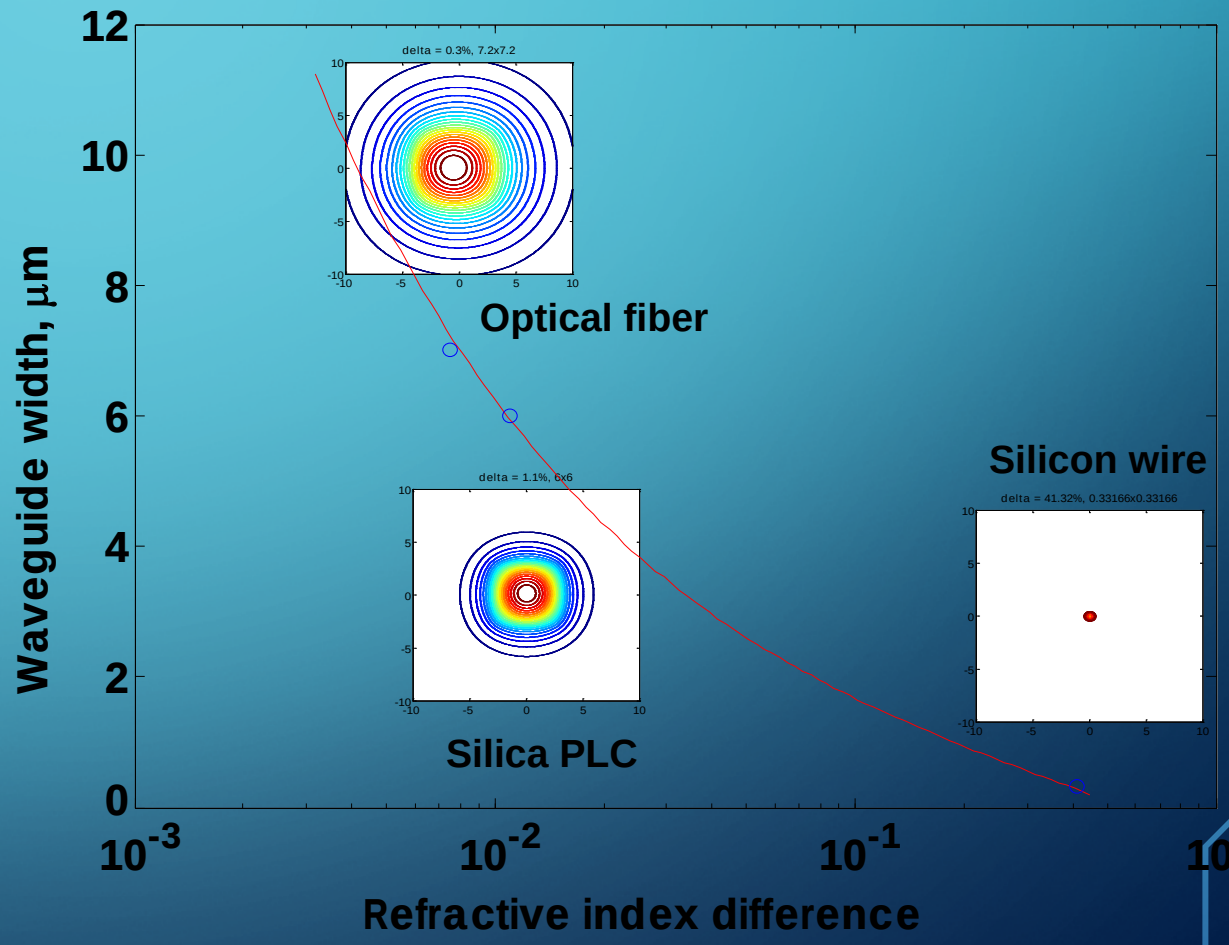
Figure 1/G.957 – Representation of optical line system interface

NEL PROPOSAL

- NTT Electronics (NEL) provided the CableLabs Working Group with the following input (shared here with NEL permission):
  - "To our knowledge, ITU-T traditionally specifies the value of – 27 dB for reflectance. Note it covers system specifications without forward error correction (FEC)."
  - "To prevent error floor over 10^{-12}, lower reflectance is mandatory for systems without FEC."
  - "Digital coherent systems employ FEC, and relaxing reflectance is possible for [CableLabs] specifications."

ADDITIONAL NEL INPUT

- "Silicon photonics (SiP) and Indium phosphide (InP) are essential technologies for small form factor transceivers."
- "They have larger refractive index and core size differences compared with optical fiber, and which make difficult to achieve comparable reflectance performances of silica PLC based devices."
- "Use of different materials including silicon photonics will reduce the cost of transceivers and benefit the industry."



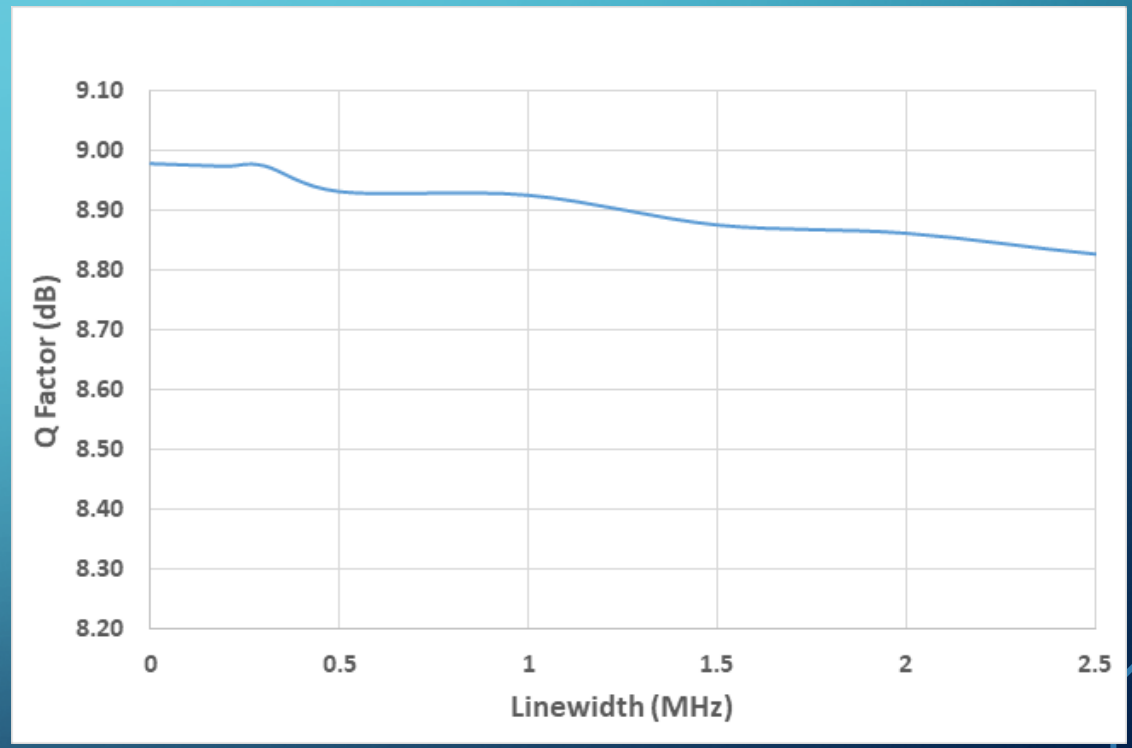
MAXIMUM REFLECTANCE PROPOSAL

- Based on input from NEL regarding potential cost savings of relaxing the Maximum Reflectance without impacting performance, propose adopting the following:
  - Maximum reflectance of receiver: -20 dB
  - Maximum discrete reflectance between S_s and R_s: -20 dB

LASER LINEWIDTH

- During CableLabs spec development, Acacia provided the following input (shared here with permission from Acacia):

- Penalty is relatively small well above 1 MHz
  - Some trade-off between sensitivity and linewidth
- Simulation Assumptions
  - 100G QPSK
  - Staircase FEC
  - -28 dBm input power
  - 1600 ps/nm dispersion
  - Nyquist Shaping



SC FEC Threshold ~8.4 dBQ

LASER LINEWIDTH PROPOSAL

- Relaxing the laser linewidth requirement relative to ITU creates the opportunity to use lower cost lasers in compliant devices
- Given minimal impact to performance, CableLabs Working Group decided to adopt 1 MHz (1000 kHz) for maximum laser linewidth requirement
- Propose doing the same for 100G objective in 802.3ct
  - Adopt 1000 kHz for Maximum laser linewidth

MIN AND MAX CENTRAL FREQUENCY

- Based on previous discussions, there appears to be some disagreement or misunderstanding regarding what the Min and Max Central Frequency parameters mean
  - Is it defining the range of frequencies/channels that all *transceivers* are required to support? Or just the range those transceivers are permitted to support?
  - Is it defining the range of frequencies/channels that all *links* are required to support? Or just the range that those links are permitted to support?
- The answer to those two questions has a dramatic impact on the implications of different choices
  - If we cannot agree on these points, we will never be able to reach an agreement on the parameter values

DEFINITION IMPLICATIONS

- For the transceiver
  - If the range of central frequencies defines the range that all devices must support, then we will want to keep the range as narrow as possible to keep costs down
  - If the range of central frequencies defines the range that compliant devices can support, but any subset is also compliant, then a wide range should be favored as there is no cost implication
- For the link
  - If the range of central frequencies defines the range that all links – including all of the equipment that comprises the link – are required to support, similarly the range should be as narrow as possible to keep costs down
  - If the range of central frequencies is establishing the permissible range for links (and the equipment in them) to support, and any subset is also compliant, then a wide range should be favored as there is no cost implication

PROPOSAL FOR MIN/MAX CENTRAL FREQUENCY

- Propose adopting the latter definition for both devices and the link
  - That the specification is defining the permissible range
  - That transceivers, the link, and any device that comprises the link can support any subset of the permissible range
- This will provide the greatest possible flexibility for suppliers to align costs and capabilities with customer requirements
- If we agree on that definition, propose adopting the widest range option
  - Minimum Central Frequency of 191.3 THz
  - Maximum Central Frequency of 196.2 THz

CONCLUSION

- At previous meetings, there have been requests to provide additional data to support 100G optical parameter selection for a baseline proposal
- This presentation has provided background and testing data for most of the optical parameters listed as TBD in the most recent 100G strawman proposal
  - For example, does not address system optical return loss or max polarization skew
- If we can agree on values for other parameters using this data, we should (hopefully) have eliminated enough TBDs to be able to agree on a baseline proposal to keep us on schedule so that we can meet market needs
  - This presentation is intended to spark the discussions needed to enable that

THANKS!