Considerations on wavelength choices for 400GBASE-LR4

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Introduction

- This presentation provides considerations towards wavelength choices for the 400GBASE-LR4 optical interface specification.

- Practical options are a choice between operating the 4 transmitter wavelengths on a 20 nm spaced CWDM grid or on an 800 GHz spaced DWDM grid (also known as LAN-WDM).

- Other choices for grid spacing, e.g. 12.5 nm, are theoretically possible but would not be practical because they would require significant investment in the development of suitable laser chips and cooling would always be required.

- During similar discussions on LR4 wavelength choices in previous projects for 100GBASE-LR4 (.3ba project) and 200GBASE-LR4 (.3bs project), an 800 GHz grid spacing was chosen.

Wavelength selection criteria

- While the preference for a 20 nm spaced CWDM grid appears obvious (because of the anticipated lowest device cost) at the same time it will be necessary to obtain stable and “plug-and-play” capable BER performance.

- The key question to be answered is whether at two wavelength extremes the chromatic dispersion penalty is sufficiently low.

- Therefore in this presentation chromatic dispersion effects for the single-mode fiber type under consideration, G.652 fiber, are analyzed for several conditions appropriate for 10 km distance.

- Furthermore, available results from chromatic dispersion penalty testing for 100 Gb/s PAM4 devices are used as a reference point.

G.652 chromatic dispersion characteristics

- In-force IEEE 802.3 specifications use the following formula and fiber parameters to calculate worst case chromatic dispersion (from e.g. Clause 122.8.5.2, Table 122-16) for the specification of the transmitter compliance channel for a 10 km link:
  - Minimum CD: $0.2325 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$
  - Maximum CD: $0.2325 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$
  - For the minimum CD a worst case (highest) zero chromatic dispersion wavelength of 1324 nm (according G.652) is used together with a dispersion slope of max 0.093 ps/nm.nm.km.
  - For the maximum CD a worst case (lowest) zero chromatic dispersion wavelength of 1300 nm (according G.652) is used together with a dispersion slope of max 0.093 ps/nm.nm.km.
- According to data (not public) from some telecom operators for 98% of deployed (over many years) G.652 fibers the zero dispersion wavelength is between 1305 and 1320 nm. This information is consistent with the fact that it appears virtually impossible to purchase test fibers outside of that range.

Dispersion value calculations for 802.3 and restricted fiber

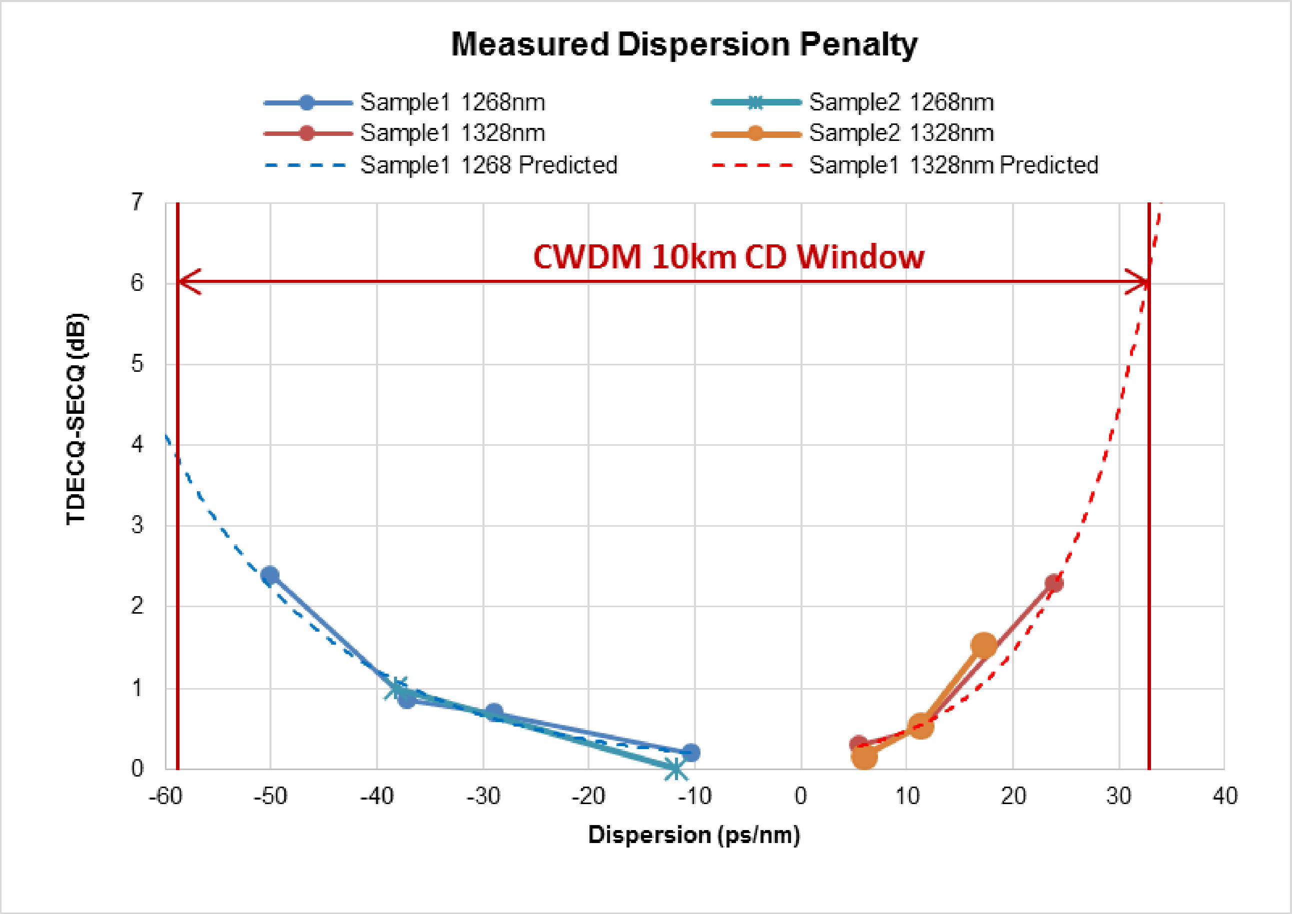
	Wavelength [nm]	Dispersion [ps/nm] for 10 km	
Grid	Lowest and highest wavelengths out of 4	***Standard SMF in IEEE 802.3 with λ_0 = 1300 to 1324 nm and S_0 = 0.093 ps/nm².km***	***Restricted SMF with λ_0 = 1305 to 1320 nm and S_0 = 0.092 ps/nm².km***
CWDM	1264.5 to 1277.5	**-59.4** to -45.7	**-54.5** to -41.1
CWDM	1324.5 to 1337.5	22.2 to **33.4**	17.5 to **28.8**
CWDM restricted	1271.5 to 1277.5	**-51.9** to -45.7	**-47.2** to -41.1
CWDM restricted	1324.5 to 1330.5	22.2 to **27.4**	17.5 to **22.8**
800 GHz	1294.53 to 1296.59	**-28.4** to -26.3	**-24.1** to -22.1
800 GHz	1308.09 to 1310.19	7.5 to **9.4**	2.8 to **4.7**

Notes:

- For CWDM restricting the fiber specification provides a reduction in CD of 8.2% at 1264.5 nm and 13.7% at 1337.5 nm. To obtain the same positive dispersion reduction with standard SMF requires reducing the max length from 10 km to 8.6 km. If the CWDM wavelength range is reduced from ±6.5 nm to ±3 nm CD further reduces. To obtain the same positive dispersion reduction with standard SMF requires reducing the max length from 10 km to 8.3 km.
- For comparison for 800 GHz grid restricting the fiber specification provides a reduction in CD of 14.4% at 1294.53 nm and 49% at 1310.19 nm

Tolerable maximum chromatic dispersion for 10 km

One data set from experiments at room temperature, shown at the meeting in Vancouver, http://www.ieee802.org/3/100G_OPTX/public/Mar19/yu_optx_01a_0319.pdf, showed the relationship between TDECQ minus SECQ versus chromatic dispersion for 2 devices. It is assumed that TDECQ minus SECQ equals chromatic dispersion (CD) penalty.



http://www.ieee802.org/3/100G_OPTX/public/Mar19/yu_optx_01a_0319.pdf

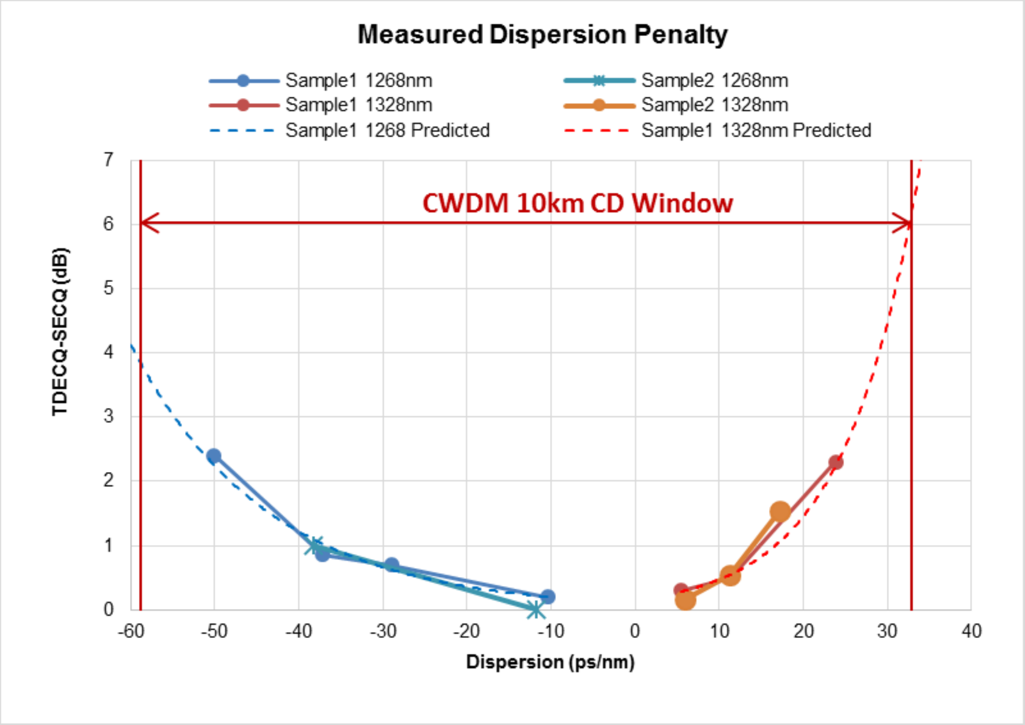
For a CD penalty above 2 to 2.5 dB the penalty starts to increase strongly for small increases of chromatic dispersion, which is a region of operation which should be avoided.

Above this CD penalty range TDECQ seems unmeasurable and significantly higher than currently assumed in various IEEE 802.3 specifications.

If a max CD penalty of 2 dB is assumed then the maximum tolerable dispersion range would be ~ -47 to 23 ps/nm

If a max CD penalty of 2.5 dB is assumed then the maximum tolerable dispersion range would be ~ -52 to 25 ps/nm

Because these tests are at room temperature a conservative approach suggests
2 dB as starting point and ~-47 to 23 ps/nm max



Assessment CD penalty for 802.3 and restricted fiber

- **Assumed limit: ~-47 to 23 ps/nm max**

	Wavelength [nm]	Dispersion [ps/nm] for 10 km	
Grid	Lowest and highest wavelengths out of 4	***Standard SMF in IEEE 802.3 with λ_0 = 1300 to 1324 nm and S_0 = 0.093 ps/nm².km***	***Restricted SMF with λ_0 = 1305 to 1320 nm and S_0 = 0.092 ps/nm².km***
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Observations:

- Assuming a max fiber chromatic dispersion range of ~-47 to 23 ps/nm only the 800 GHz spaced configuration comfortably supports these dispersion levels for both the standard IEEE 802.3 and the fiber with restricted dispersion characteristics.
- Only when restricting the CWDM wavelength ranges from ±6.5 nm to ±3 nm AND restricting the fiber dispersion characteristics, can the assumed maximum dispersion limits just be met.

Questions/suggestions

Is the assumption of ~ -47 to 23 ps/nm in association with a max CD penalty of 2 dB or ~ -52 to 25 ps/nm in association with a max CD penalty of 2.5 dB sufficiently conservative or way too conservative?

What is the behaviour of CD penalty versus CD for similar devices measured over temperature?

- Additional data sets for similar devices are needed, including measurements over temperature.

What is a reasonable maximum TDECQ value? The “common” in-force value of 3.4 dB or up to 3.9 dB, as suggested in http://www.ieee802.org/3/100G_OPTX/public/Mar19/lewis_optx_01a_0319.pdf?

- Need information (test results) that for TDECQ = 3.9 dB CD penalty may not be higher than a range of 2 to 2.5 dB.

Can we do without an additional requirement that TDECQ minus SECQ < ~ 2 to 2.5 dB?

- Do we know of cases where TDECQ is max (e.g. 3.4 dB) while SECQ is 0.9 to 1.4 dB?
- Would such an additional requirement not be more effective than the requirement for “TDECQ – $10\log_{10}(C_{eq})$ max” adopted in IEEE Std 802.3cd™-2018?

Thanks!