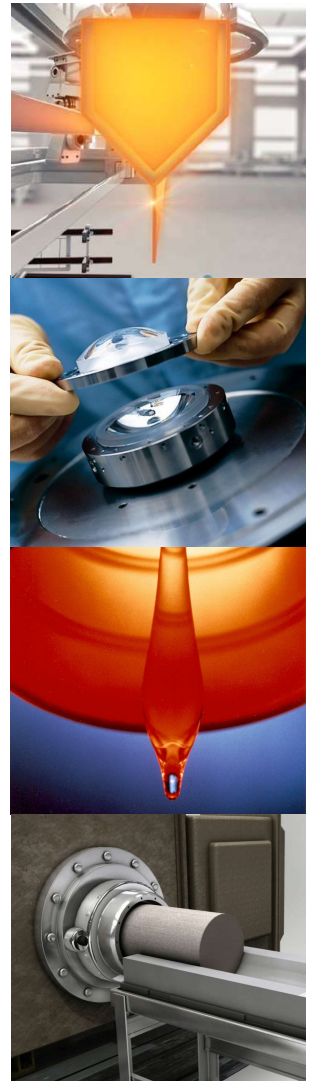# Fiber Requirements for 802.3cz: GI-POF

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Outline

1. Challenges for incorporating GI-POF fiber into 802.3cz

2. Challenges for including GI-POF and OM3 fiber in same standard

SUMMARY

The OM3-VCSEL option for 802.3cz is based on 20 years of experience with OM3 in data centers and a history based on round-robin testing and validation. OM3 has been successfully incorporated into 802.3 projects for 10Gb/s to 400Gb/s

The GI-POF option is not ready.

20+ years of OM3/VCSEL experience in data centers

Reference: Pepeljugoski et al., "Development of System Specification for Laser-Optimized 50-μm Multimode Fiber for Multigigabit Short-Wavelength LANs", *IEEE J. Lightwave Technology*, Vol. 21 No. 5, May 2003 p.1256-1275.

The performance of an optical link depends on complementary specifications on the laser source and the optical fiber, **so that the optical fiber will work with any laser and the laser will work with any fiber**. The complementary specifications were developed in 1999-2003 in a collaboration of manufacturers and end-users, including modeling and extensive experimentation/validation.

Summarized in 802.3cz:

https://www.ieee802.org/3/cz/public/may_2021/abbott_3cz_02_0521_Laser_Optimized_Fiber.pdf

~20 years of OM3/VCSEL development

IEEE multimode projects
https://www.ieee802.org/3/archive.html

802.3ae-2002 10Gb/s Ethernet original round robins, DMD & EF development
802.3ba-2010   40Gb/s and 100Gb/s Ethernet (100=10x10 NRZ)
802.3bm-2015 40Gb/s and 100Gb/s Fiber Optic (100=4x25 NRZ)
802.3cd-2018   50Gb/s, 100Gb/s, 200Gb/s Ethernet (200=4x25 PAM4)
802.3cm-2020 400Gb/s over Multimode Fiber (400=8x25 PAM4)
802.3db in progress 100Gb/s,200Gb/s, 400Gb/s over MM Fiber (100=1x50 PAM4)

1st Missing Piece with GI-POF -- worst-case VCSEL EMB

IEC A4i bandwidth specification is based on OFL BW and does not address worst-case VCSEL launch (EMB)

The bandwidth of the fiber depends on the mode delays (a fiber property) and the mode power distribution (a laser / launch property). VCSELS meet an encircled flux spec. There is no provision in the A4i specification for how the GI-POF bandwidth depends on the VCSEL launch.   This is in contrast to OM3.

2nd Missing Piece with GI-POF -- short length BW

IEC A4i specification does not address the effect of mode coupling on the worst-case BW for short lengths.

Researchers at Lucent and Asahi Glass Company measured pulse broadening as roughly increasing like $L^{0.57}$
White et al., *IEEE Photonics Technology Letters* Vol. 11 No. 8 August 1999.

Measurements seem to show that the coupling length is approximately 30m, so that $L^{0.5}$ from 30m to 100m and $L^{1.0}$ from 0 to 30m.
Polley and Ralph, *IEEE Photonics Technology Letters* Vol. 19 No. 16 Aug 2007

So 100m BW measurements will overpredict the 15m BW by a factor of 1.8-2.0+

We need more data on EMB of short length fibers.

3rd   Missing Piece with GI-POF -- worst case components

It is the norm within IEEE 802.3 to design the standard so that it always works.

The standard is not designed to work with nominal components left to the discretion of the manufacturer and customer.

The fiber needs to work with all "compliant" VCSELs

The VCSEL needs to work with all "compliant" fibers

It is not sufficient to demonstrate a working link with components, since most fiber will be better than worst case and most transceivers will be better than worst case.

It is not clear what is meant by a "compliant" GI-POF.

Recommendations

1. Develop a better way to estimate 15m performance of a specific GI-POF fiber with any compliant VCSEL meeting current encircled flux spec.
2. Consider either reducing the link length from 15m to 7.5m (or less) or increasing the 100m BW spec from 350MHz.km to 700MHz.km (or more) to accommodate a worst case L^0.5 relation. Need more data before any specific proposal. Update as we get more data; need to get a handle on VCSEL EMB.
3. More work is need for a rigorous GI-POF option. Unlike the OM3-VCSEL option, it is not ready for incorporation into the task force drafts.

Challenges for including GI-POF and OM3 in the same standard

1. There are major differences between OM3 and GI-POF
   a. OM3 fiber readily available for 20+ years from multiple vendors, based on several round-robin tests of DMD and BW, as well as characterization of VCSELs.
   b. A4i GI-POF fiber has not been characterized thoroughly, no round-robins, fiber is not available. We do not know the worst-case short-length performance with VCSELs.
2. 802.3cz objective and 802.3 norms specifically limit options for overlapping solutions.
   a. Same VCSEL source;
   b. Roughly same core diameter (i.e. connector tolerance)
   c. Proven, established product: High volume production of OM3 by multiple manufacturers for 20+ years, higher BW OM4 has now been made for years making OM3 the choice for lower BW requirements. OM3 is a lower BW MM option while A4i is a high BW POF option.

BACKUP SLIDES from abbott_3cz_02_0521_Laser_Optimized_Fiber.pdf

Length Dependence of Pulse Broadening in GI-POF
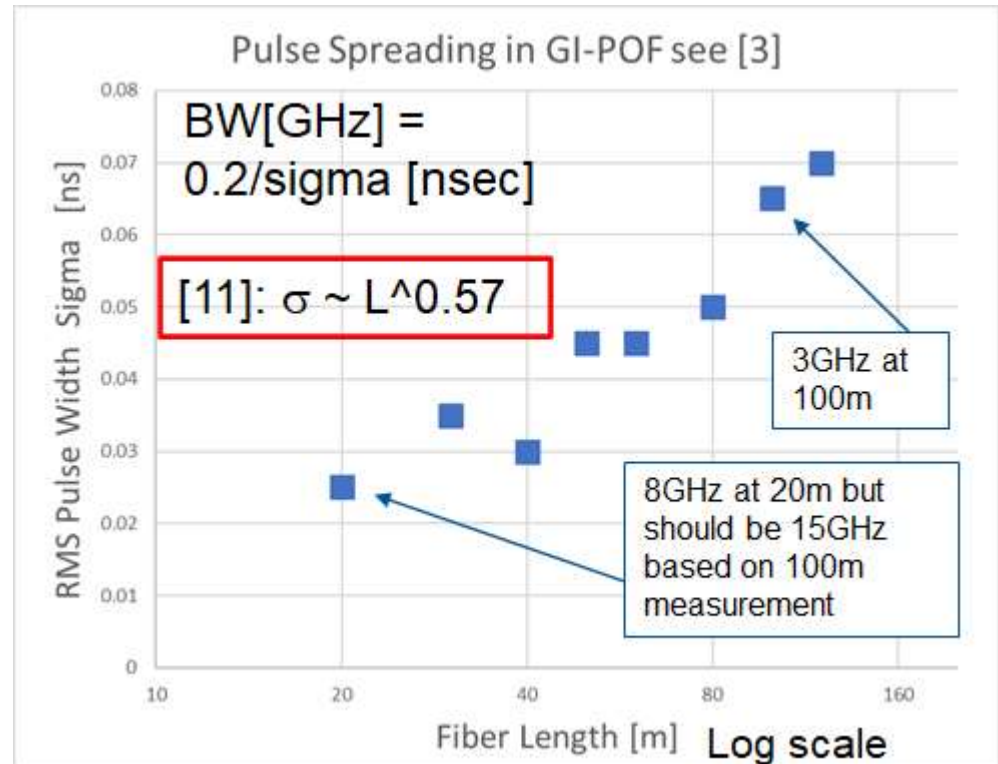
See Slide 21 in
https://www.ieee802.org/3/cz/public/may_2021/abbott_3cz_02_0521_Laser_Optimized_Fiber.pdf

20+ years of 10+ Gb/s Multimode Fiber in Data Centers

Reference: Pepeljugoski et al., "Development of System Specification for Laser-Optimized 50-μm Multimode Fiber for Multigigabit Short-Wavelength LANs", *IEEE J. Lightwave Technology*, Vol. 21 No. 5, May 2003 p.1256-1275.

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The fiber is tested with the differential mode delay (DMD) measurement, scanning a small spot across the fiber core and recording the change in the output pulse.

The laser is tested by launching into a fiber and recording the relative power as a function of radius – the so-called "encircled flux".
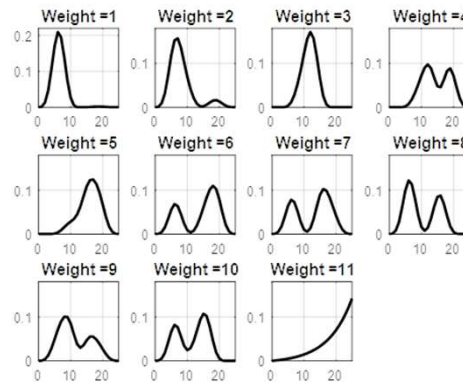
20+ years of 10+ Gb/s Multimode Fiber in Data Centers

Optical Fiber Test

VCSEL Test

DMD
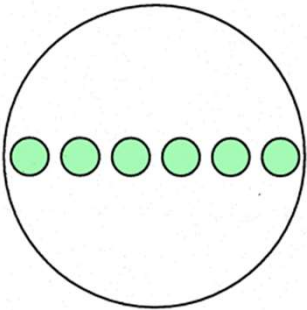
Encircled Flux

Combined to generate minEMBc