# Cryogenic Digital Optical Link Testing

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## Agenda

The following slides illustrate room temperature measurement results from selected 1310 nm SFP+ transceivers as well as comparative measurements on the same devices at liquid nitrogen (LN2) temperatures. Devices tested employed both Fabry-Perot (F-P) lasers and Distributed FeedBack (DFB) lasers.

The results include measurements obtained from:

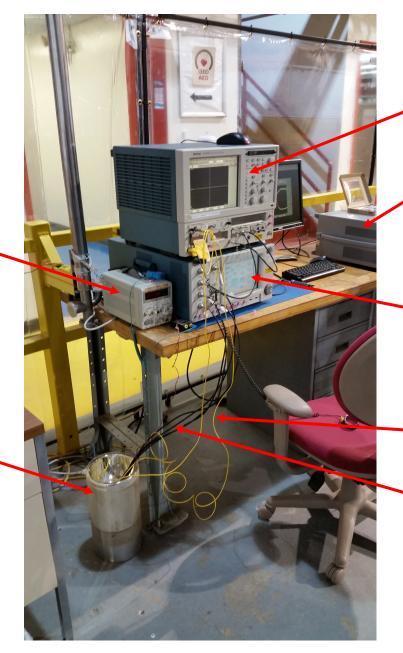
- 1. Optical eye pattern analysis
- 2. Optical jitter analysis
- 3. Optical loopback testing (for tests of BER performance)
- 4. Optical spectra

All measurements were made with PRBS7 data patterns or OMA Patterns (repetitions of ...1111000011110000...) delivered at the data rates indicated on the slides.

BER tests were conducted with the SFP+ Tx in the cold and a complementary SFP+ Rx in the warm over a 3-meter single mode fiber.

All of the data illustrated here were captured at the Proton Assembly Building.

#### Test Stand at PAB



Digital Signal Analyzer (Eye pattern and jitter analysis)

Optical Spectrum Analyzer

Bit Error Rate tester (Pattern Generation and Error Checking)

Single Mode Optical Fibers (yellow)

Coaxial cables for electrical pattern (black)

**Power Supply** 

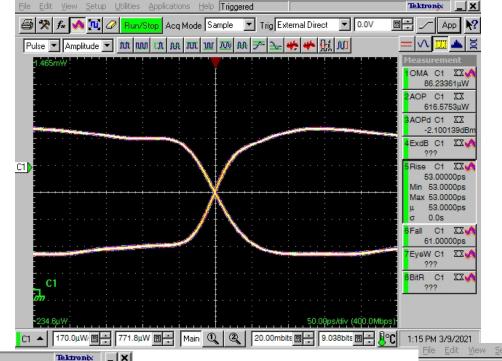
Dewar (Containing Evaluation Board and Test Device)

Edit View Setup Utilities Applications Help Triggered Tektronix 画 ノ 🞒 🎌 🏂 🌠 🚺 🖉 Run/Stop Acq Mode Sample 🔻 Trig External Direct 🔽 0.0V Sample: DFB2 = 🕶 🚾 📥 💆 Pattern: PRBS7 OMA C1 XX Bit Rate: 10 Gbps 729.3944µW AOP C1 XX 628.1001µW Room Temperature AOPd C1 XX -2.019712dBr 4ExdB C1 XX 4.915871dB Rise C1 XX 41.20000ps Min 38.8000ps Max 41,6000ps 41.1983ps 109.174fs Pattern: PRBS7 Pattern: PRBS7 52.80000ps Bit Rate: 6.25 Gbps Bit Rate: 10 Gbps 'EyeW C1 XX 79.90802ps LN2 LN2 BitR C1 XX 9.987511Gbps Edit View Setup Utilities Applications Help Triggered Tektronix View Setup Utilities Applications Help Triggered 😂 🥍 🏂 🌠 🗸 🥒 Run/Stop Acq Mode Sample 🔽 Trig External Direct 🞒 💸 🏂 🚺 🗸 Run/Stop Acq Mode Sample 🔽 Trig External Direct .8μW 🖫 🖟 Main 🔍 🝳 8.000mbits 🖫 9.181bits 🖫 Pulse T Amplitude T Int no th AA Int no AA F T S S S S NO OMA C1 XXV 580.5722µW Bit Error Rate tests at AOP C1 XX AOP C1 XX 703.0111µW 708.7735µW 10 Gbps and 6.25 Gbps AOPd C1 XX AOPd C1 XX -1.530378dBr -1.494925dBn resulted in no errors ExdB C1 XX ExdB C1 XX⊌ in 10e12 transmitted bits 3.415372dB 2.122587dB Rise C1 XX Rise C1 78.33552ps Min 77.7731ps Power cycle test while cold 78.2957ps failed 172.599fs Fall C1 XX Fall C1 75.93552ps TEyeW C1 XX EyeW C1 XX 44.10088ps 129.4249ps BitR C1 XX BitR C1 XX 6.268197Gbps 10.00634Gbps C1 ▲ 170.0µW 🖫 771.8µW 🖫 Main 🔍 🍳 8.000mbits 🖫 9.179bits 🖫 🖟 🖟 🕻 🕻 🕻 C1 ▲ 170.0µW, 🖶 771.8µW 🖶 Main 🔍 🍳 8.000mbits 🖳 9.216bits 📑 👂 🕻 1:44 PM 3/9/2021 1:26 PM 3/9/2021

Pattern: OMA Pattern

Bit Rate: 10 Gbps

LN2



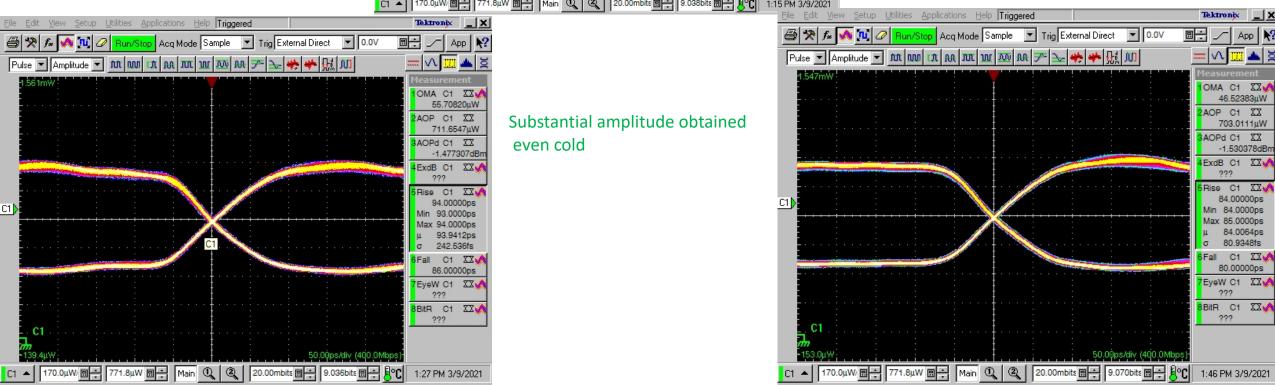
Pattern: OMA Pattern

Bit Rate: 10 Gbps

Room Temperature

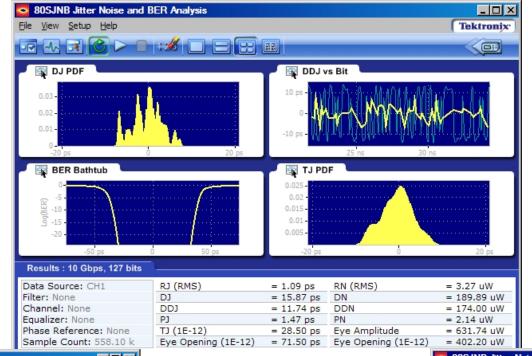
Pattern: OMA Pattern

Bit Rate: 6.25 Gbps



Pattern: PRBS7
Bit Rate: 10 Gbps

LN2



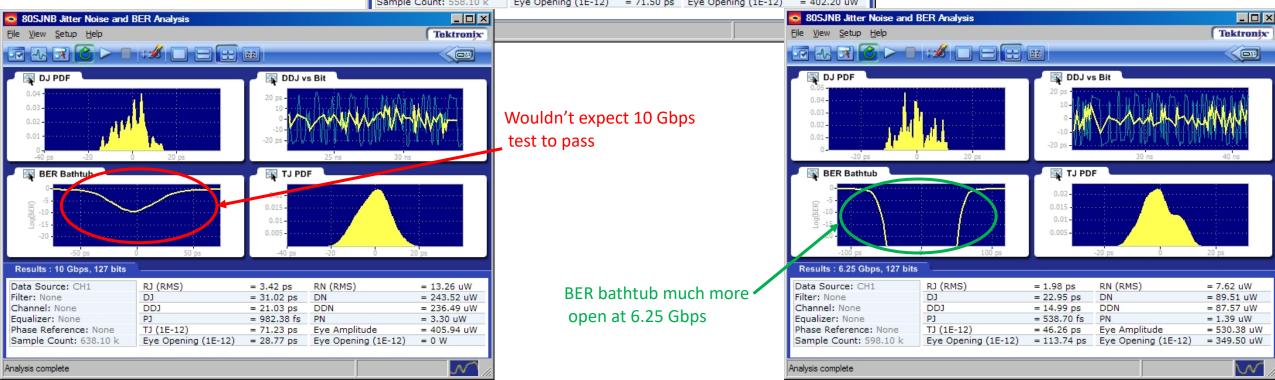
Pattern: PRBS7

Bit Rate: 10 Gbps

Room Temperature

Pattern: PRBS7

Bit Rate: 6.25 Gbps



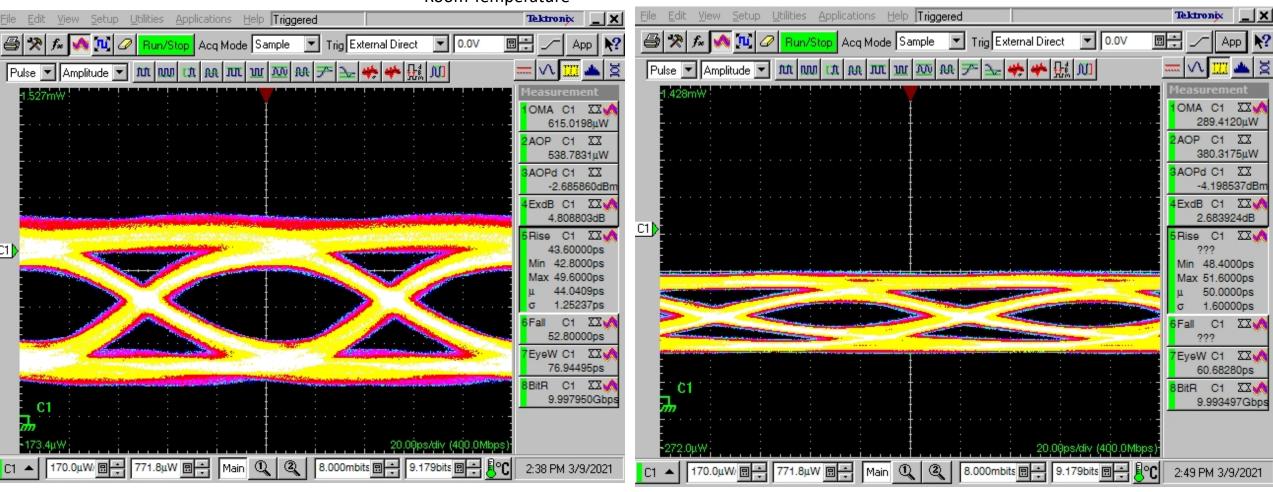
Pattern: PRBS7

Bit Rate: 10 Gbps

**Room Temperature** 

Pattern: PRBS7 Bit Rate: 10 Gbps

LN2



Bit Error Rate tests at 10 Gbps resulted in no errors in 10e12 transmitted bits

Power cycle test while cold failed

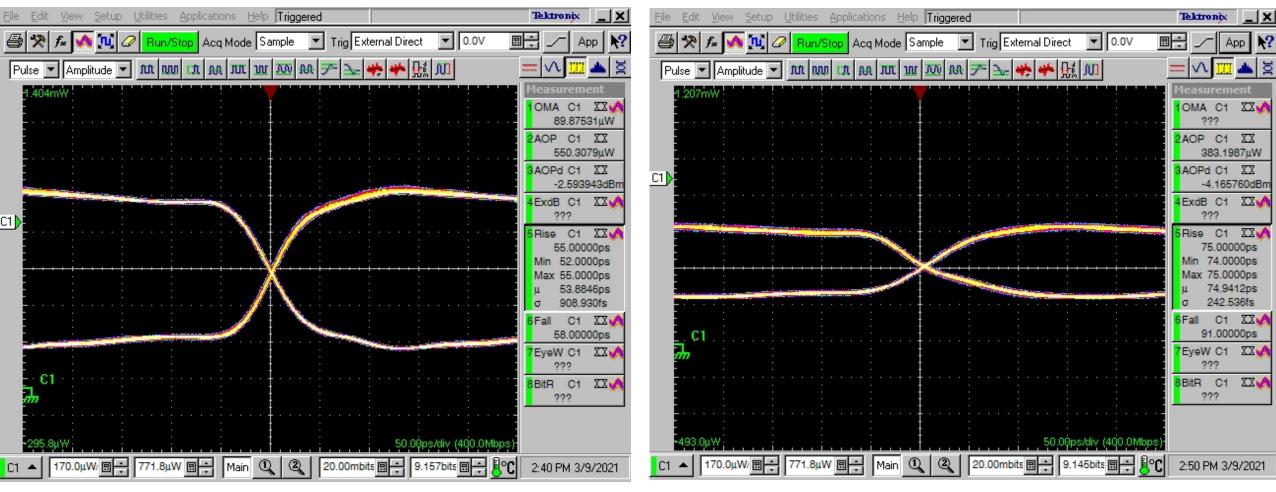
Pattern: OMA Pattern

Bit Rate: 10 Gbps

Room Temperature

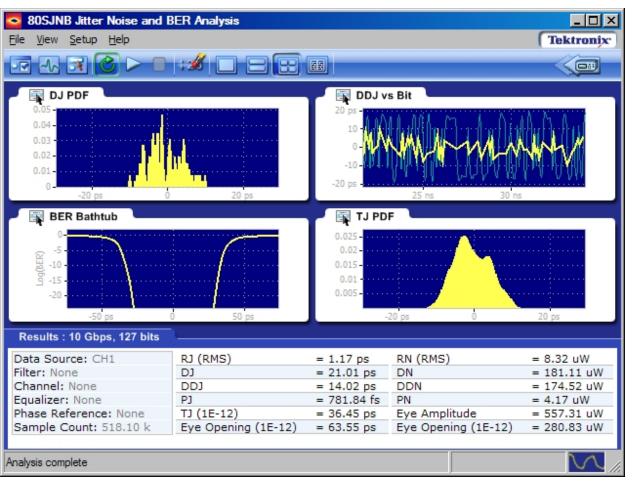
Pattern: OMA Pattern Bit Rate: 10 Gbps

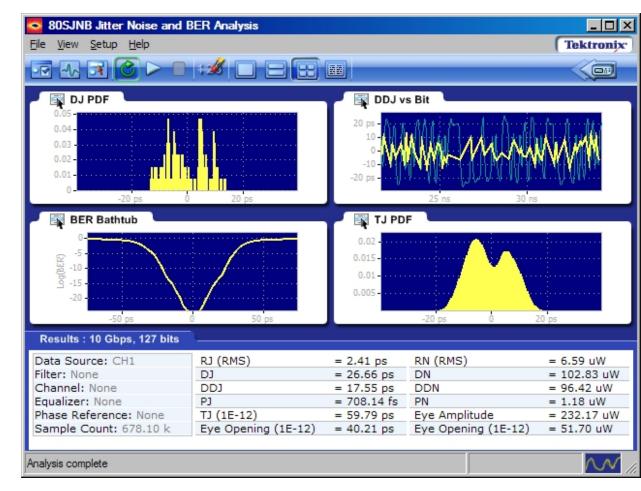
LN2



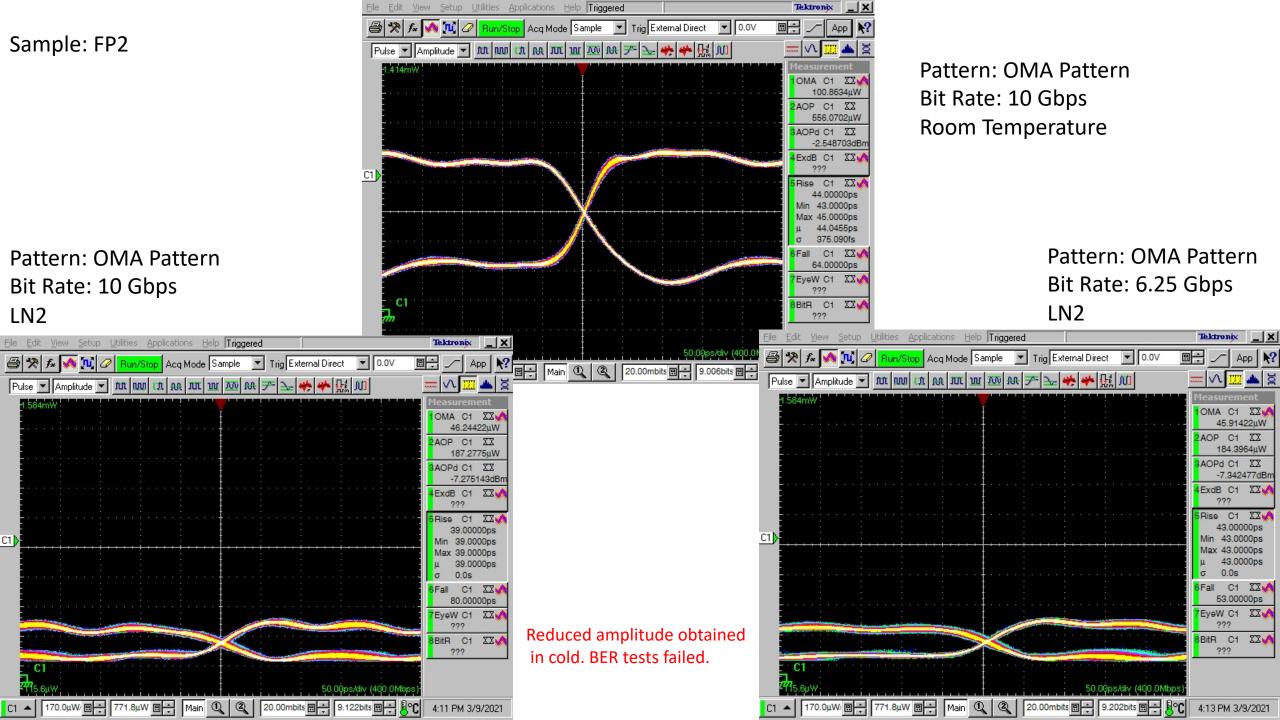
Reduced amplitude obtained in cold. Even so, BER tests succeeded.

Pattern: PRBS7 Bit Rate: 10 Gbps Room Temperature Pattern: PRBS7 Bit Rate: 10 Gbps





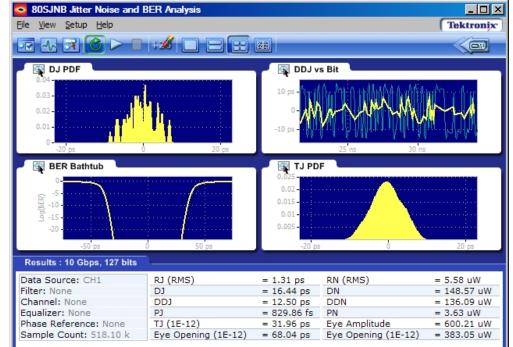
View Setup Utilities Applications Help Triggered Acq Mode Sample Trig External Direct 🔽 0.0V App ▶? Sample: FP2 **二 ペ 🎹 🗻** 💆 Pattern: PRBS7 OMA C1 XX 673.1084µW Bit Rate: 10 Gbps AOP C1 XX 561.8326µW **Room Temperature** AOPd C1 XX -2.503930dBr ExdB C1 XX 5.116459dB 32.40000ps Min 32,0000ps Max 35.6000ps 32.4127ps Pattern: PRBS7 Pattern: PRBS7 55.60000ps 'EyeW C1 XX⊌ Bit Rate: 6.25 Gbps Bit Rate: 10 Gbps 79.23024ps BitR C1 XX LN2 LN2 9.986272Gbp View Setup Utilities Applications Help Triggered View Setup Utilities Applications Help Triggered 😂 🥍 🏂 🌠 🗸 🖉 Run/Stop Acq Mode Sample 🔽 Trig External Direct 771.8μW 🖫 📮 Main 🔍 🍳 8.000mbits 🖫 📫 9.193bits 🖫 Pulse Amplitude Tut wo tit an out w Am F 🛬 🤲 👫 OMA C1 XX 149.1760µW 256.2623µW Bit Error Rate tests at AOP C1 XX AOP C1 XX 187.2775µW 198.8023µW **10 Gbps and 6.25 Gbps** AOPd C1 XX AOPd C1 XX -7.275143dBn failed. -7.015786dBm ExdB C1 XX 4.422598dB 5Rise C1 XX Rise C1 Min 46.8000ps Power cycle test while cold failed C1 XX C1 XX EyeW C1 XX EyeW C1 XX 110.3475ps BitR C1 XX BitR C1 6.250000Gbp С1 🔺 170.0µW, 🖫 🕂 771.8µW 🕮 Наіп 🔍 🍳 8.000mbits 🕮 9.201bits 🖫 🖟 🕻 C1 ▲ 170.0µW 🕮 771.8µW 👺 Main 🔍 🍳 8.000mbits 🕮 9.222bits 🖫 🖟 🕻 ℃ 4:08 PM 3/9/2021 4:09 PM 3/9/2021



Sample: FP2

Pattern: PRBS7 Bit Rate: 10 Gbps

LN2



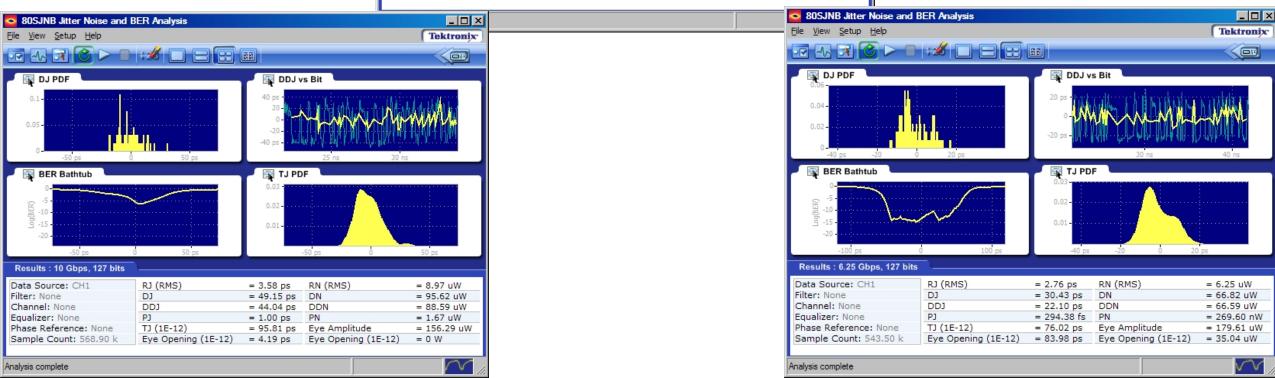
Pattern: PRBS7

Bit Rate: 10 Gbps

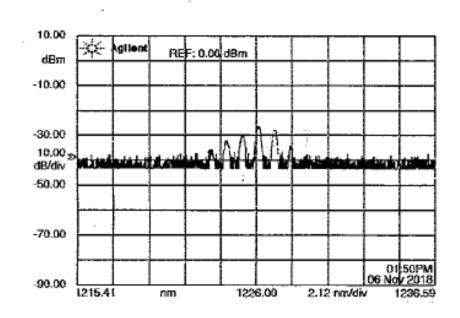
Room Temperature

Pattern: PRBS7

Bit Rate: 6.25 Gbps



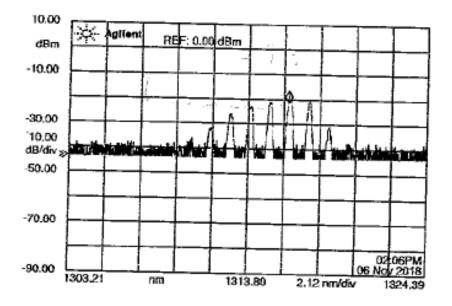
Sample: FP2



LN2 Temperature (PAB)

Peak Wavelength: 1226 nm

Optical Power at Peak: -26 dBm



Room Temperature (PAB)

Peak Wavelength: 1316 nm

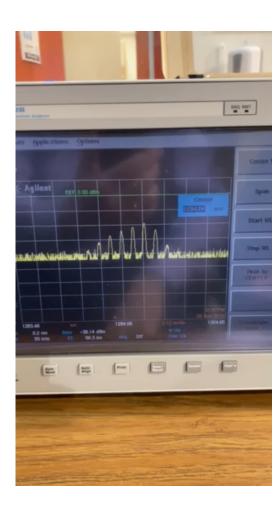
Optical Power at Peak: -18.6 dBm

Original Measurement (FCC, Room Temperature)

Peak Wavelength: 1319 nm

Optical Power at Peak: -18.4 dBm

# **Optical Spectra**



## Summary and Next Steps

Three DFB laser equipped 1310 nm SFP+ transceivers were seen to "survive" being immersed in LN2 while powered on.

These devices exhibited eye patterns which did not fully collapse but were reduced in opening and increased in jitter.

Two of these devices were able to sustain error-free transmission of PRBS7 patterns for over 10e12 bits. One has yet to be tested for this behavior.

Two FP laser equipped 1310 nm SFP+ transceivers were tested. One produced no discernable eye pattern while the other exhibited a severely compromised eye that would not pass BER tests.

None of the devices tested were able to recover from a power cycle while cold. Even when operating "successfully", once the power was shut off and returned, none of the devices could be operated in a BER test.

We will complete the testing on the devices that we have now.

We plan to pursue a more detailed investigation of the specific components and mechanisms by which the modules are failing (we suspect this may be "electronic" rather than "optical" in nature). We plan to have a dialogue with colleagues at Southern Methodist University and CERN to draw on their experience regarding optical and electronic details upon which we may want to focus.