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:

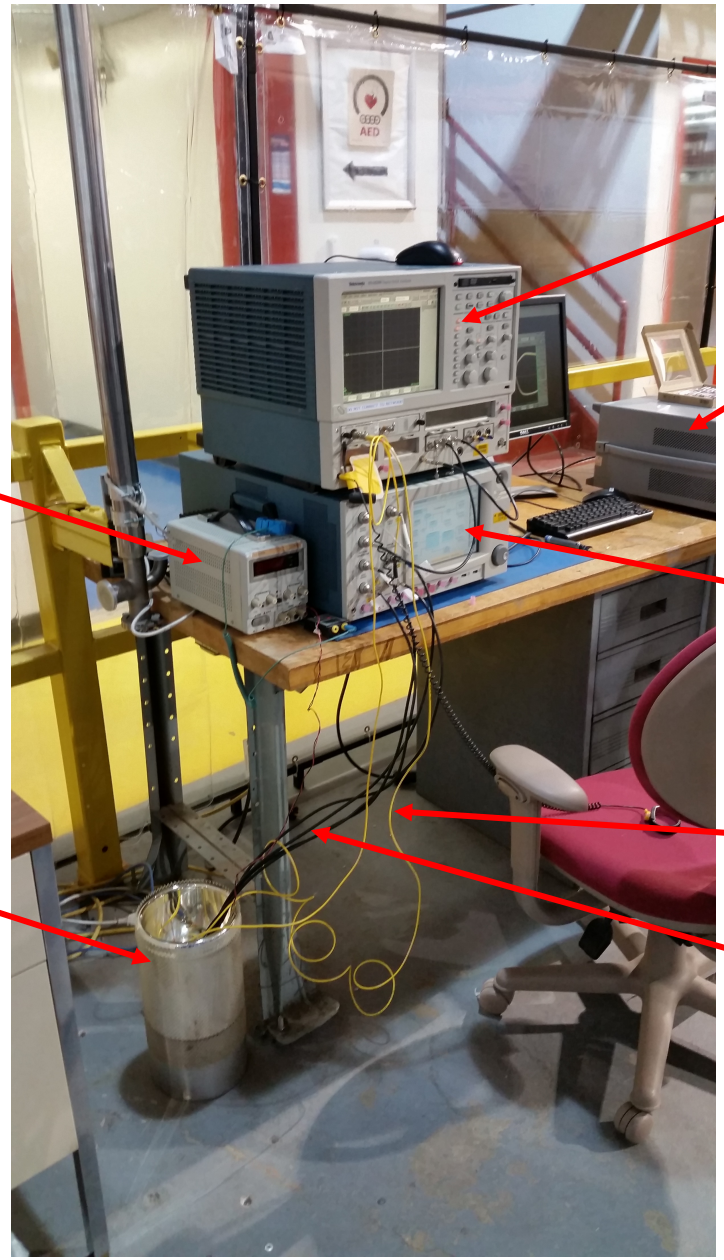
1. Optical eye pattern analysis
2. Optical jitter analysis
3. Optical loopback testing (for tests of BER performance)
4. Optical spectra

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

Power Supply

Bit Error Rate tester
(Pattern Generation and Error Checking)

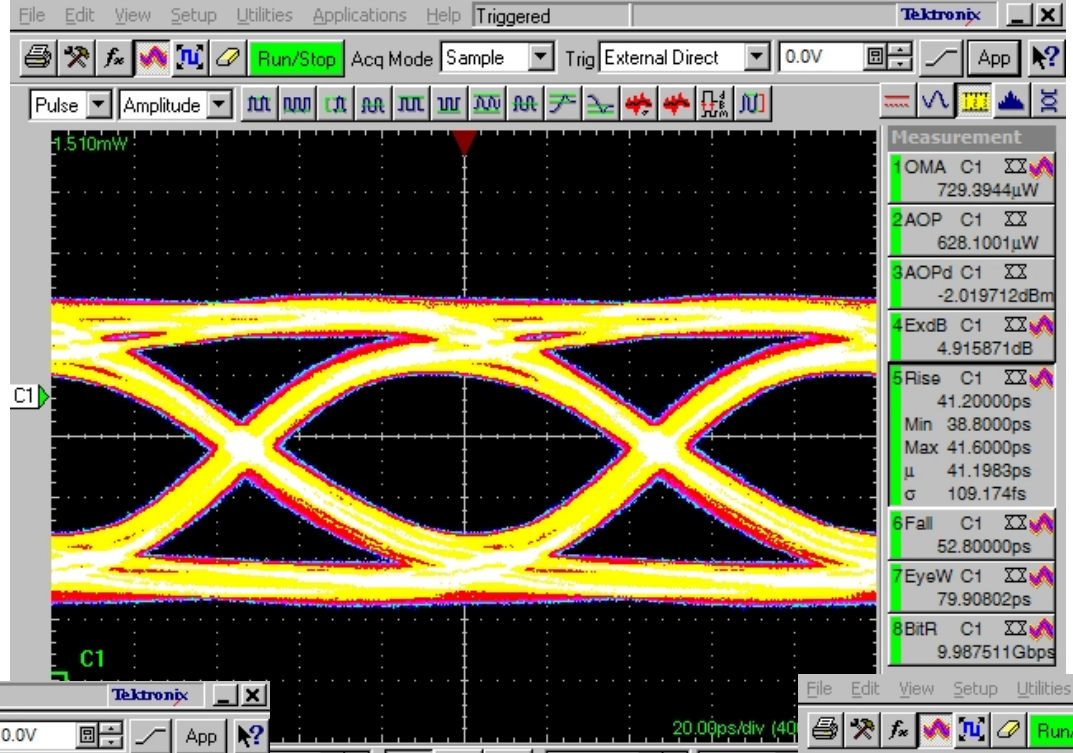
Dewar
(Containing
Evaluation Board
and Test Device)

Single Mode Optical Fibers (yellow)

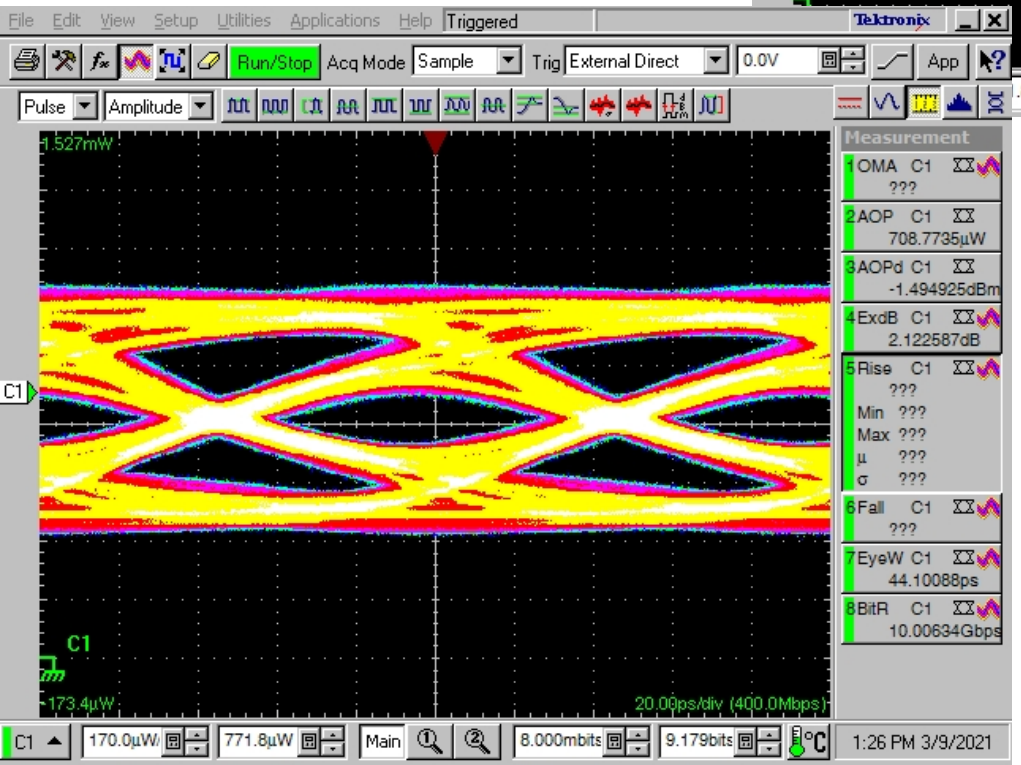
Coaxial cables for electrical pattern (black)

Sample: DFB2

Pattern: PRBS7
Bit Rate: 10 Gbps
Room Temperature



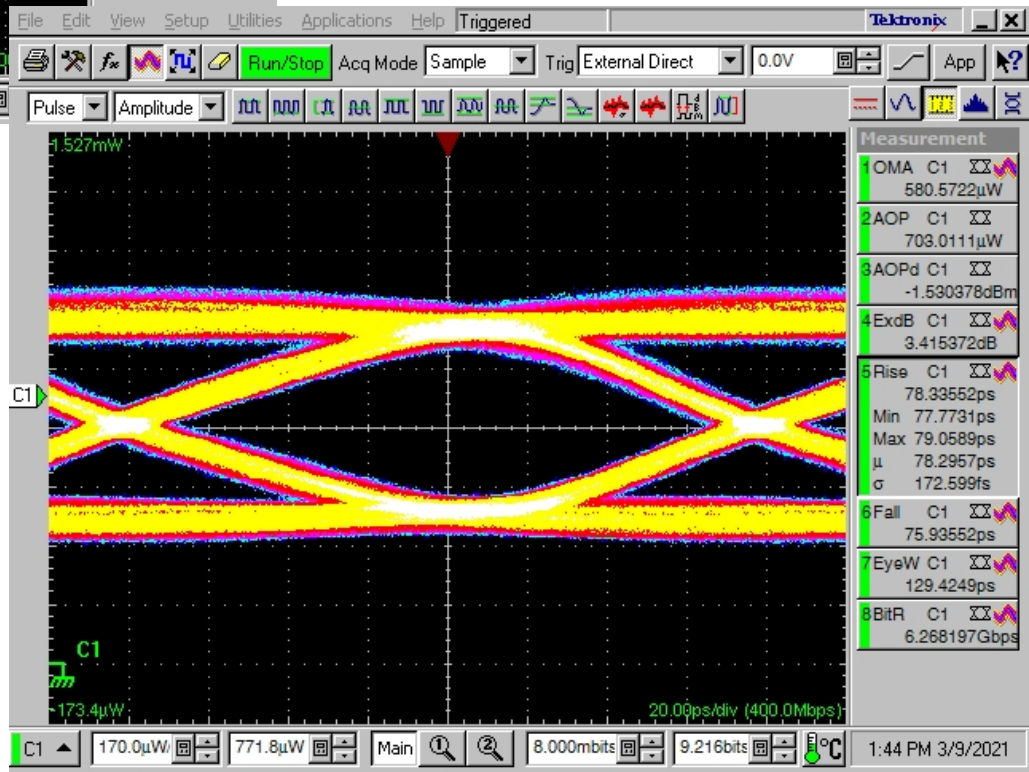
Pattern: PRBS7
Bit Rate: 10 Gbps
LN2



Bit Error Rate tests at
10 Gbps and 6.25 Gbps
resulted in no errors
in 10e12 transmitted bits

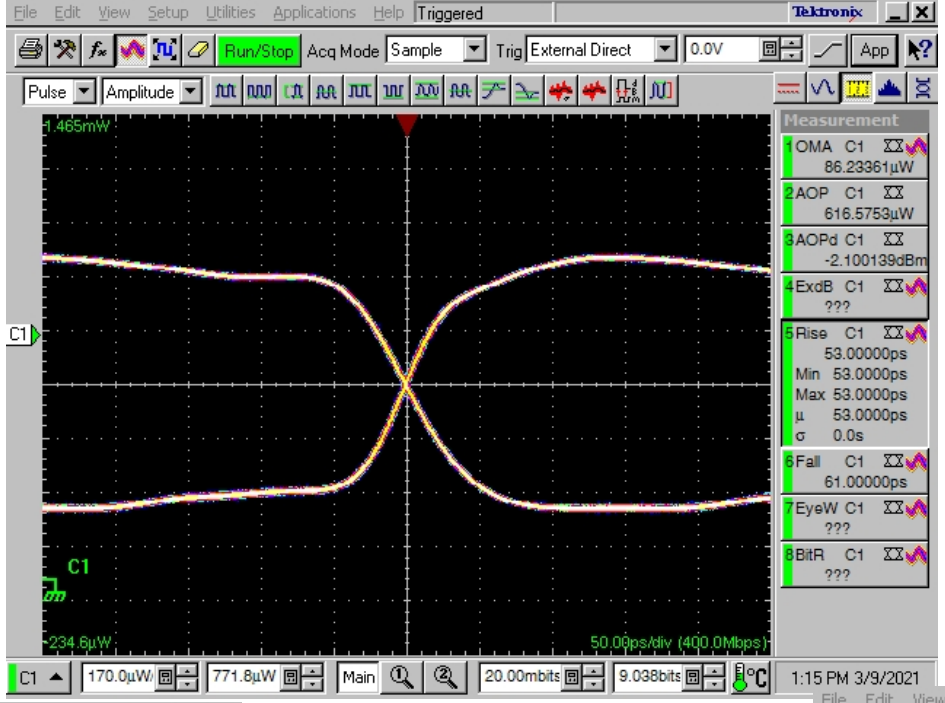
Power cycle test while cold failed

Pattern: PRBS7
Bit Rate: 6.25 Gbps
LN2

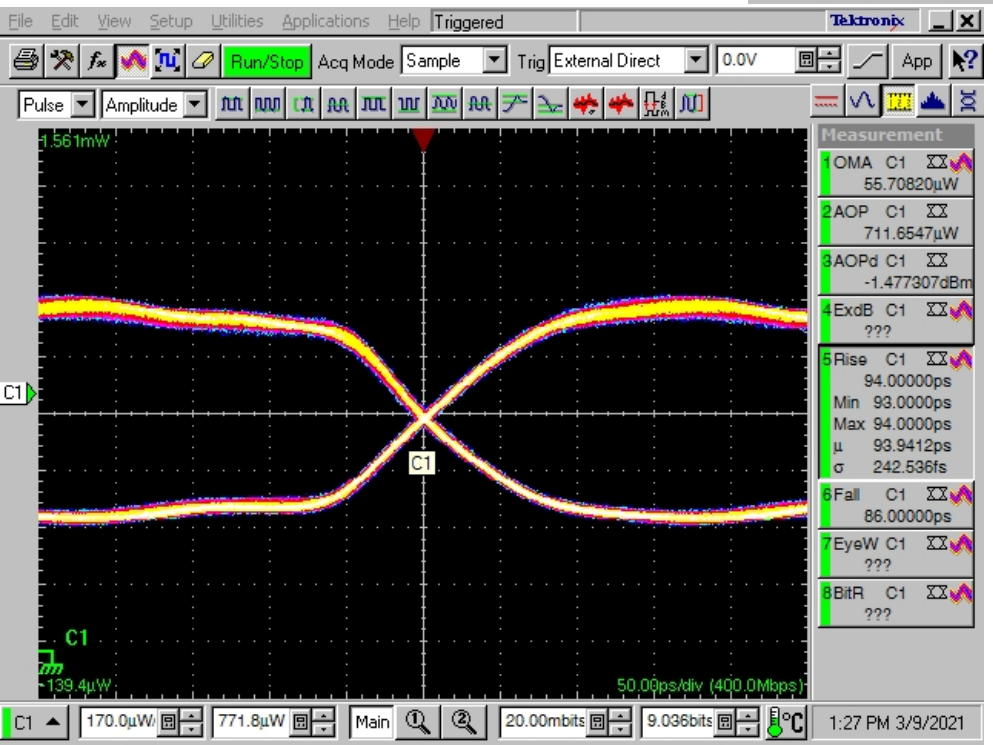


Sample: DFB2

Pattern: OMA Pattern
Bit Rate: 10 Gbps
Room Temperature

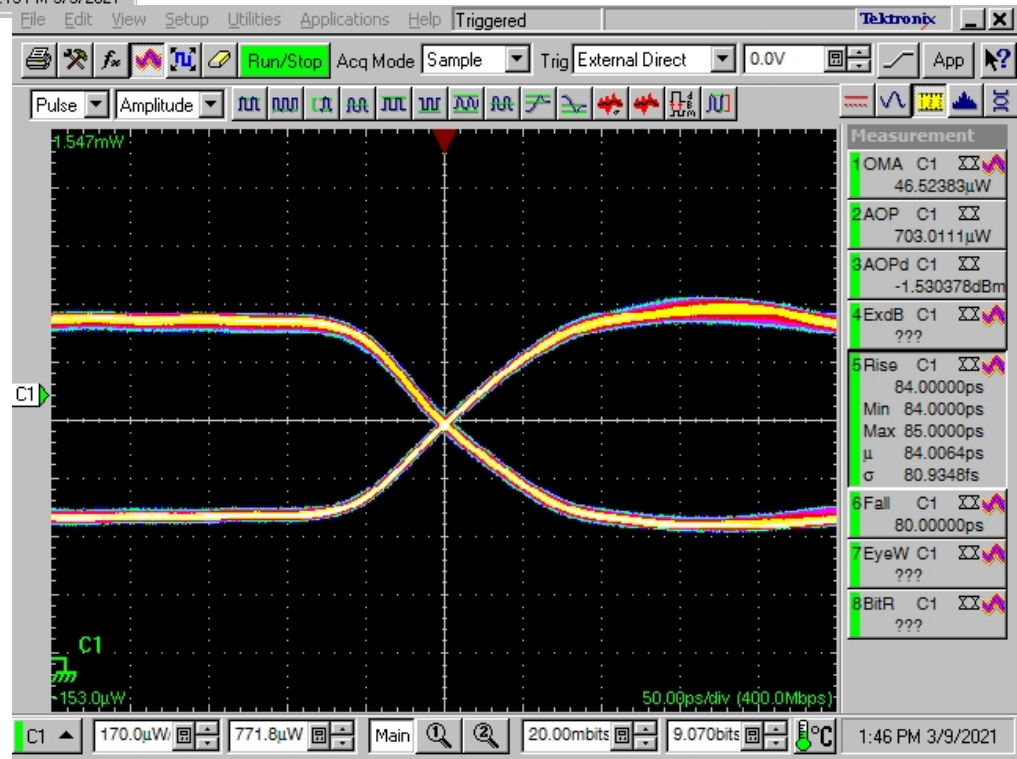


Pattern: OMA Pattern
Bit Rate: 10 Gbps
LN2



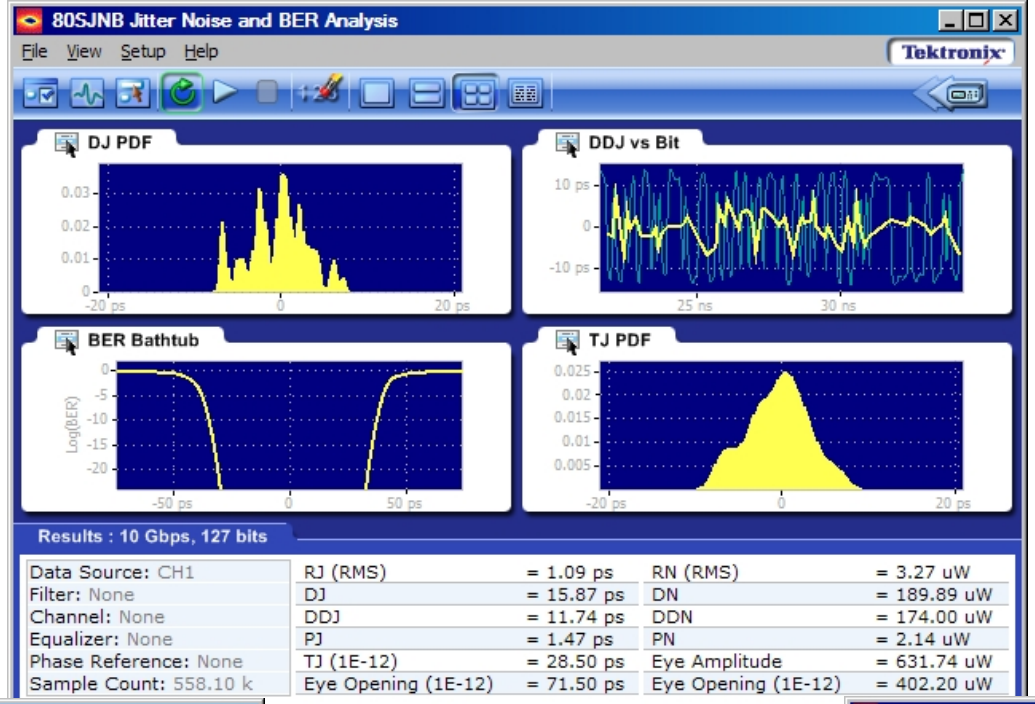
Substantial amplitude obtained even cold

Pattern: OMA Pattern
Bit Rate: 6.25 Gbps
LN2

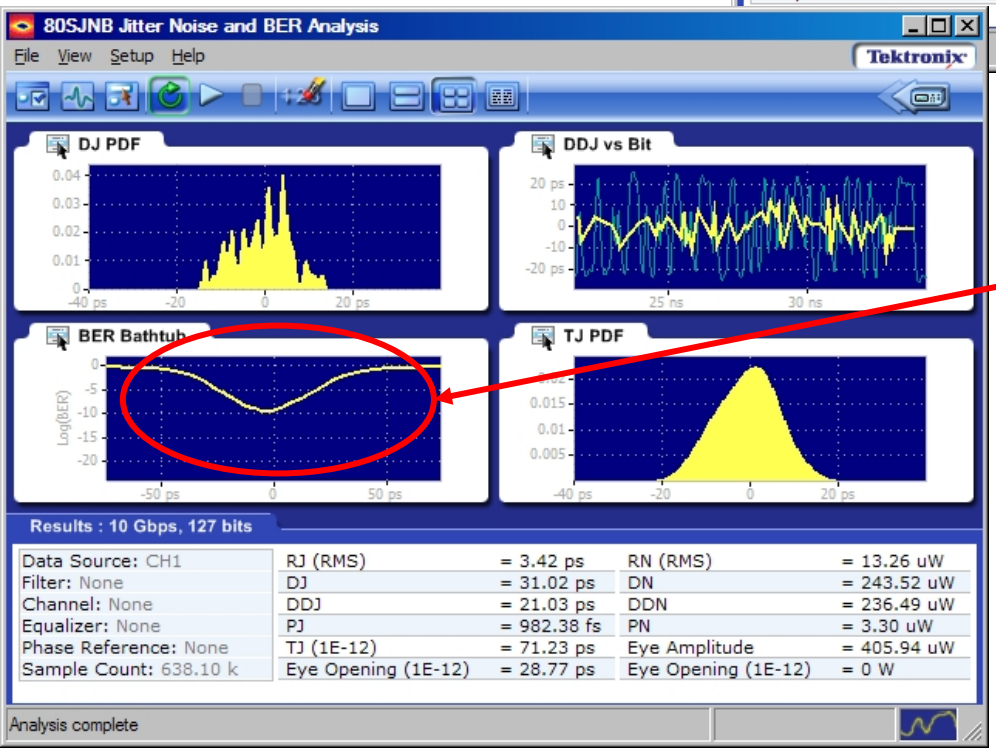


Sample: DFB2

Pattern: PRBS7
Bit Rate: 10 Gbps
Room Temperature



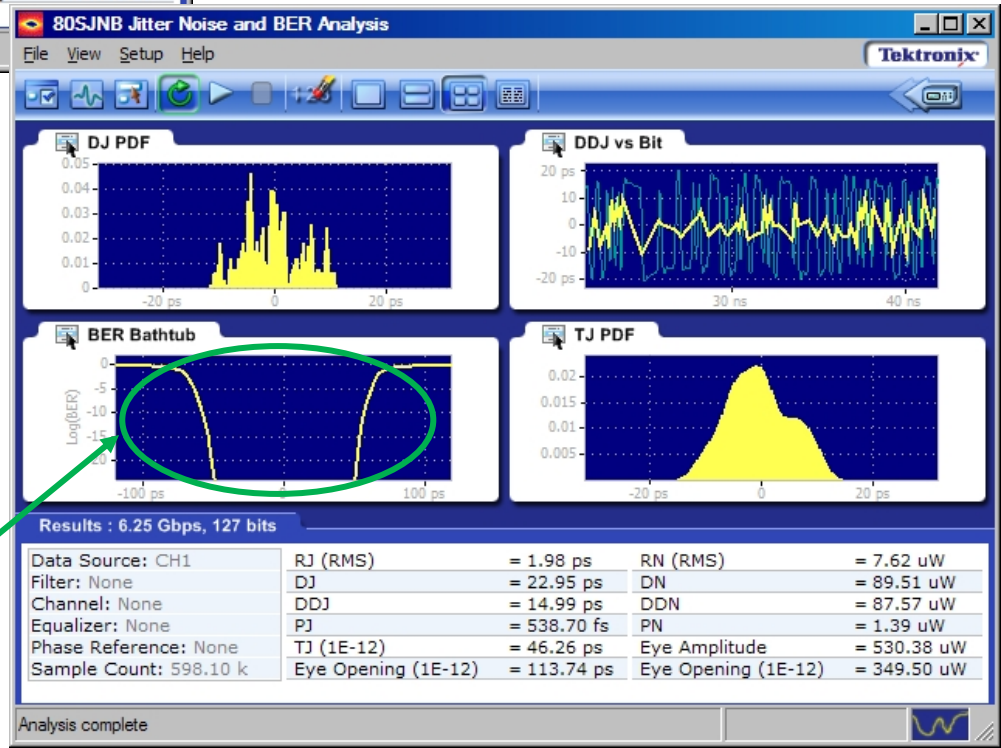
Pattern: PRBS7
Bit Rate: 10 Gbps
LN2



Wouldn't expect 10 Gbps test to pass

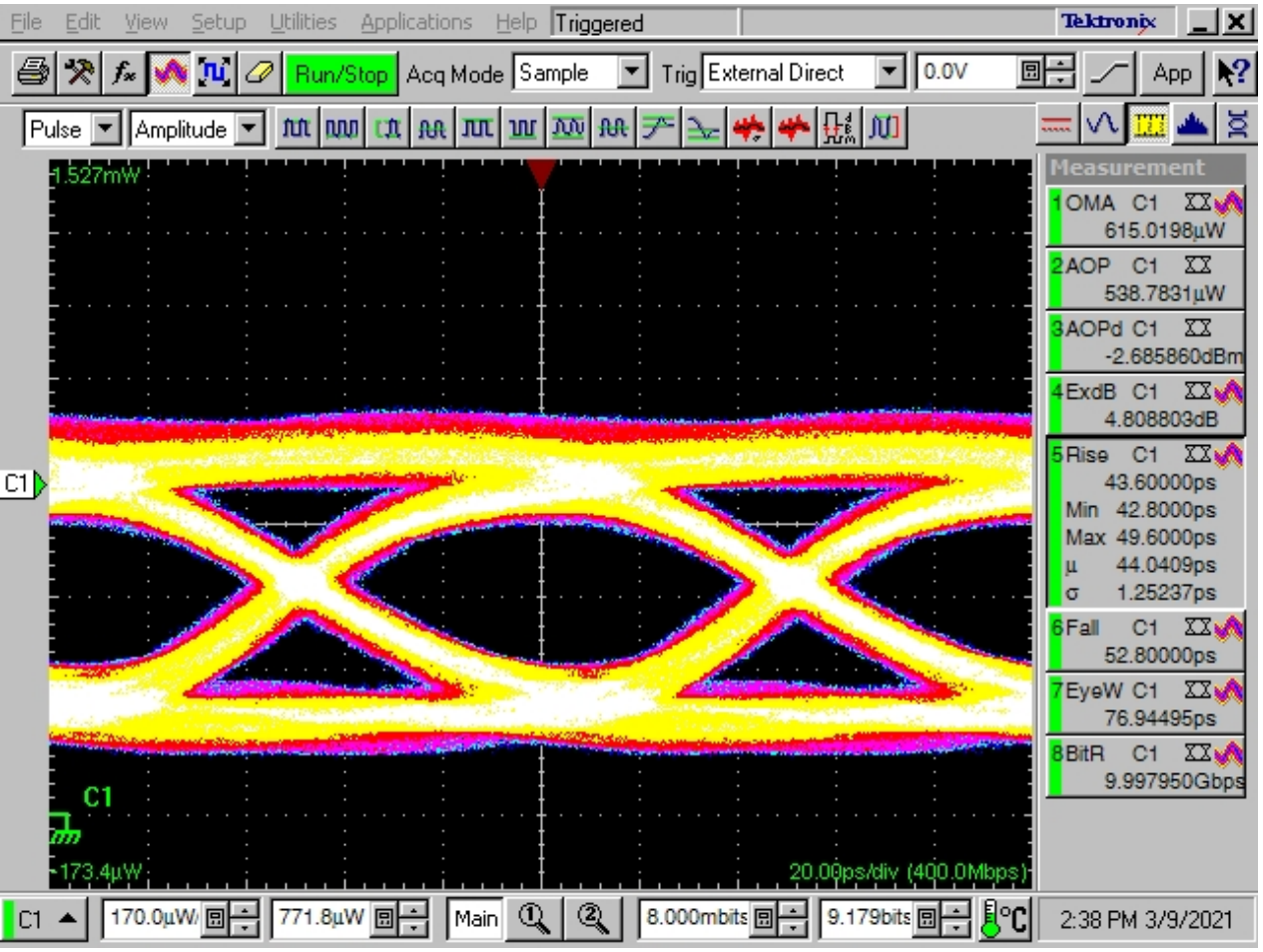
BER bathtub much more open at 6.25 Gbps

Pattern: PRBS7
Bit Rate: 6.25 Gbps
LN2

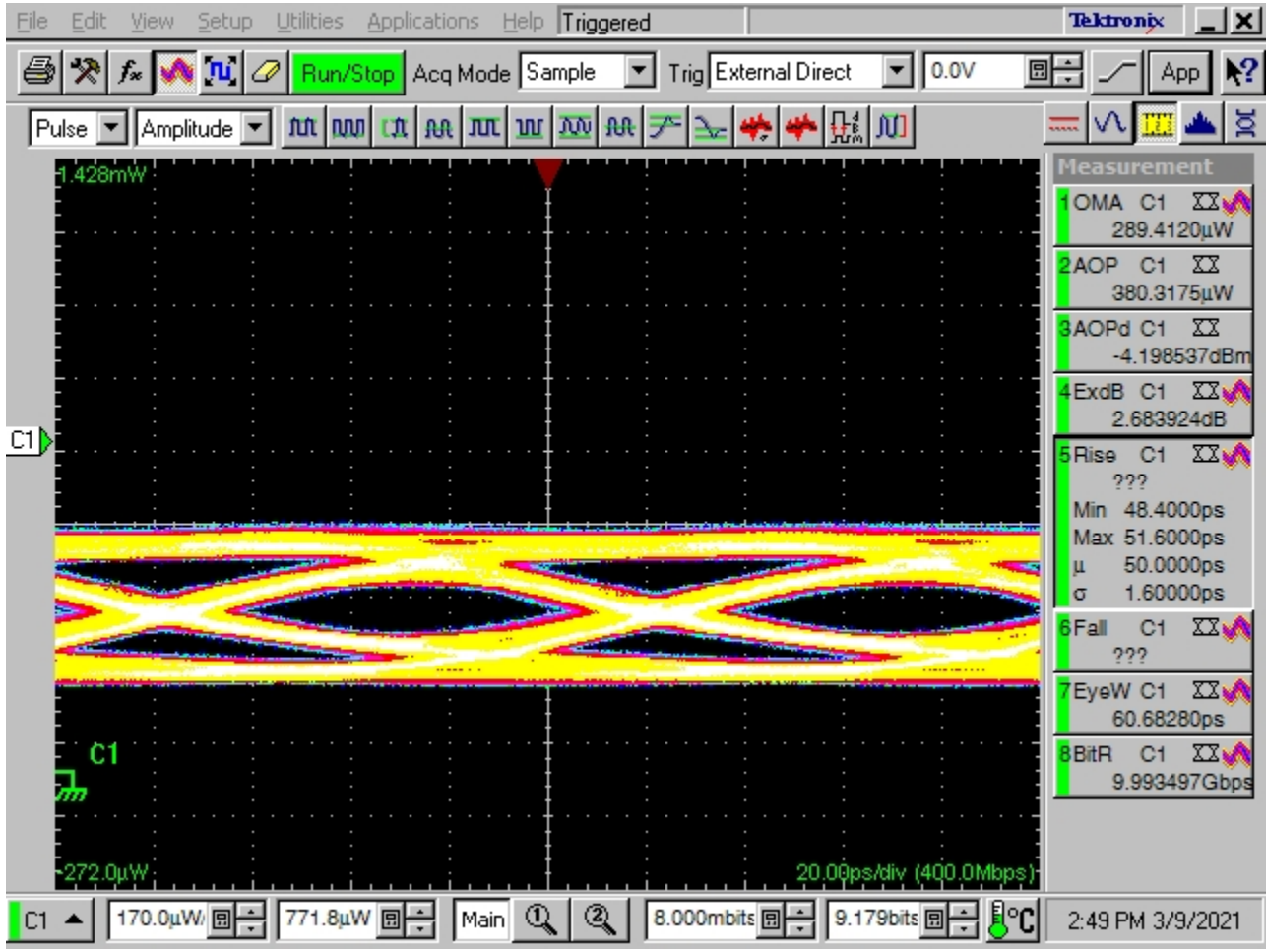


Sample: DFB3

Pattern: PRBS7
Bit Rate: 10 Gbps
Room Temperature



Pattern: PRBS7
Bit Rate: 10 Gbps
LN2

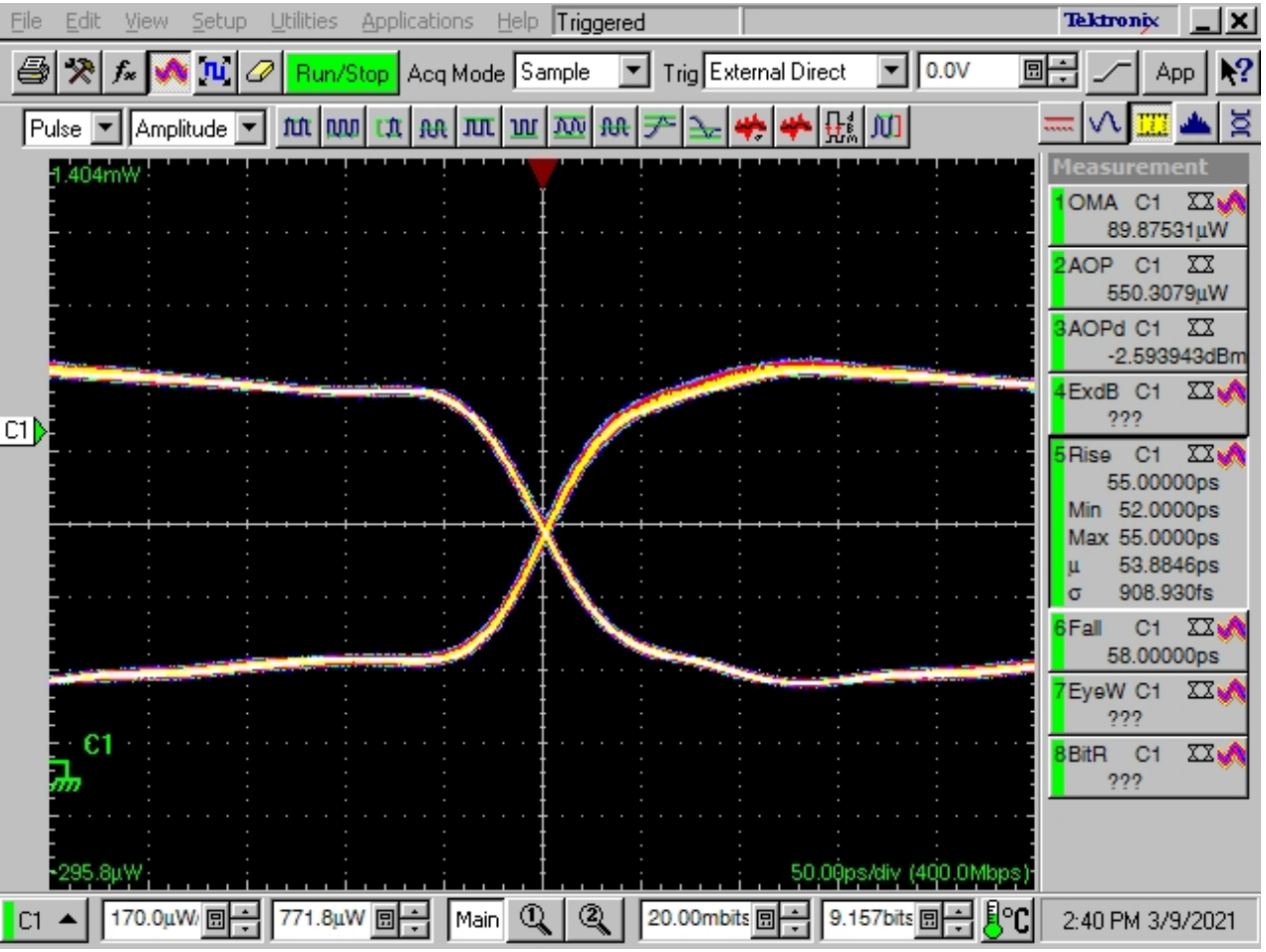


Bit Error Rate tests at
10 Gbps resulted in no errors
in 10e12 transmitted bits

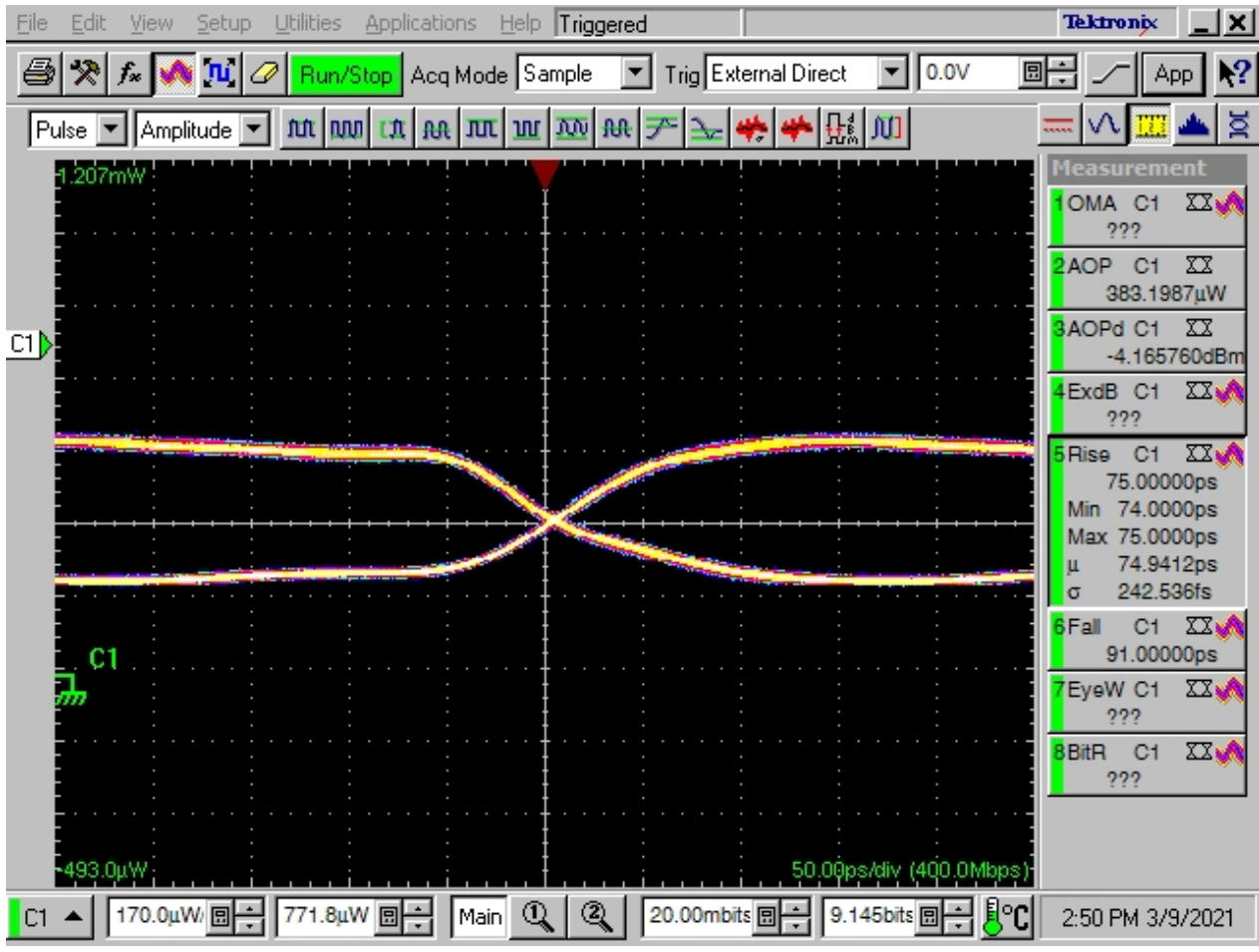
Power cycle test while cold failed

Sample: DFB3

Pattern: OMA Pattern
Bit Rate: 10 Gbps
Room Temperature



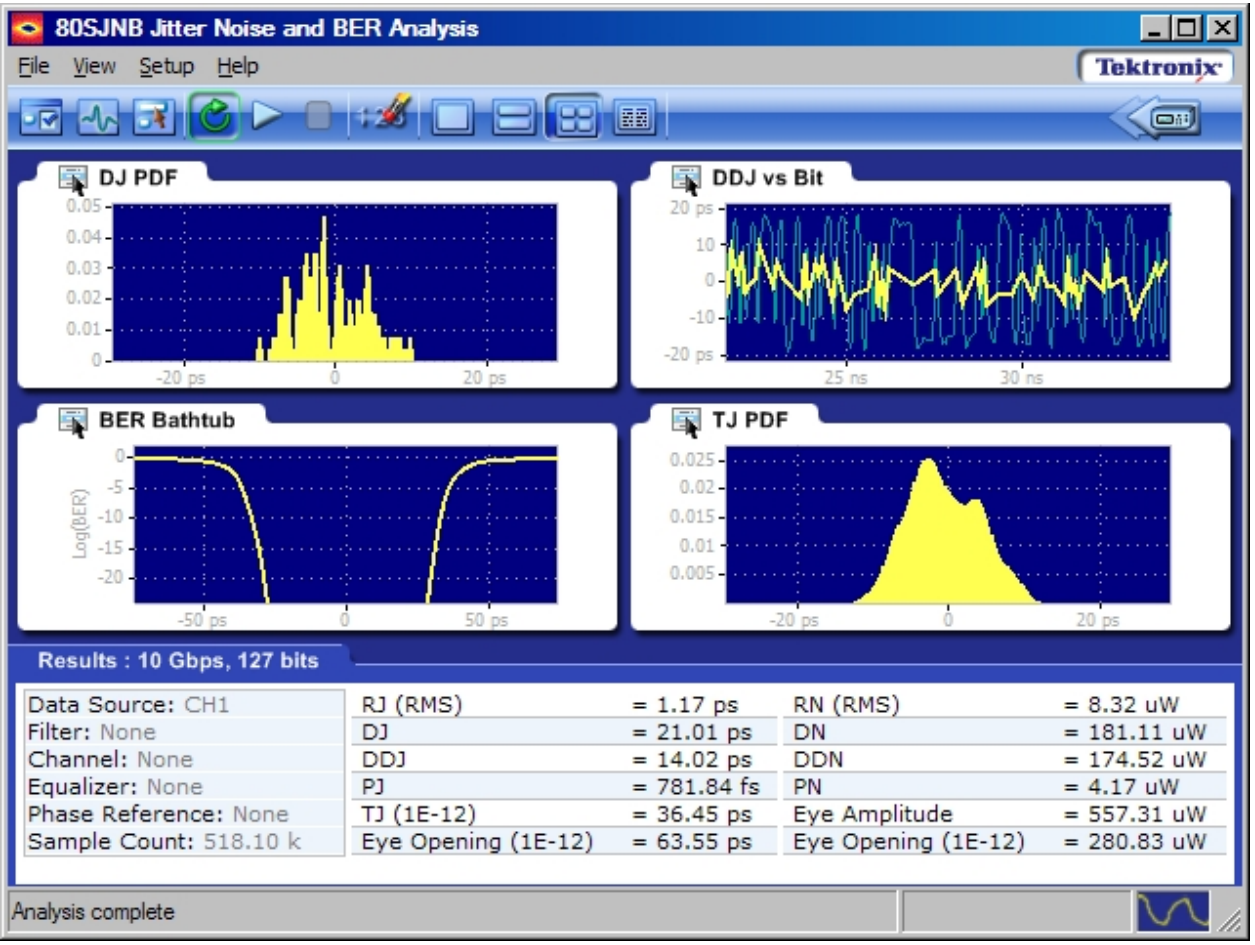
Pattern: OMA Pattern
Bit Rate: 10 Gbps
LN2



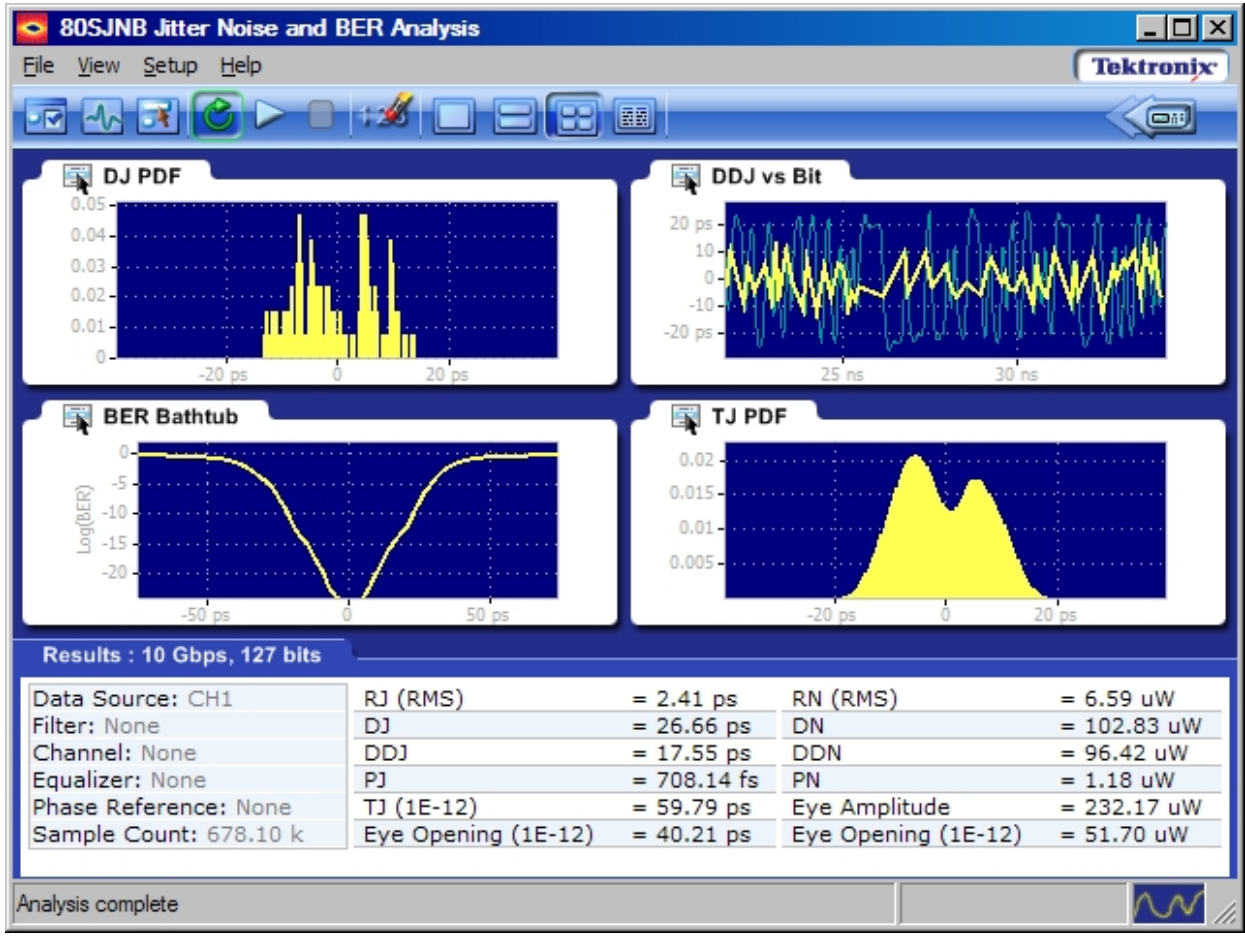
Reduced amplitude obtained
in cold. Even so, BER tests succeeded.

Sample: DFB3

Pattern: PRBS7
Bit Rate: 10 Gbps
Room Temperature

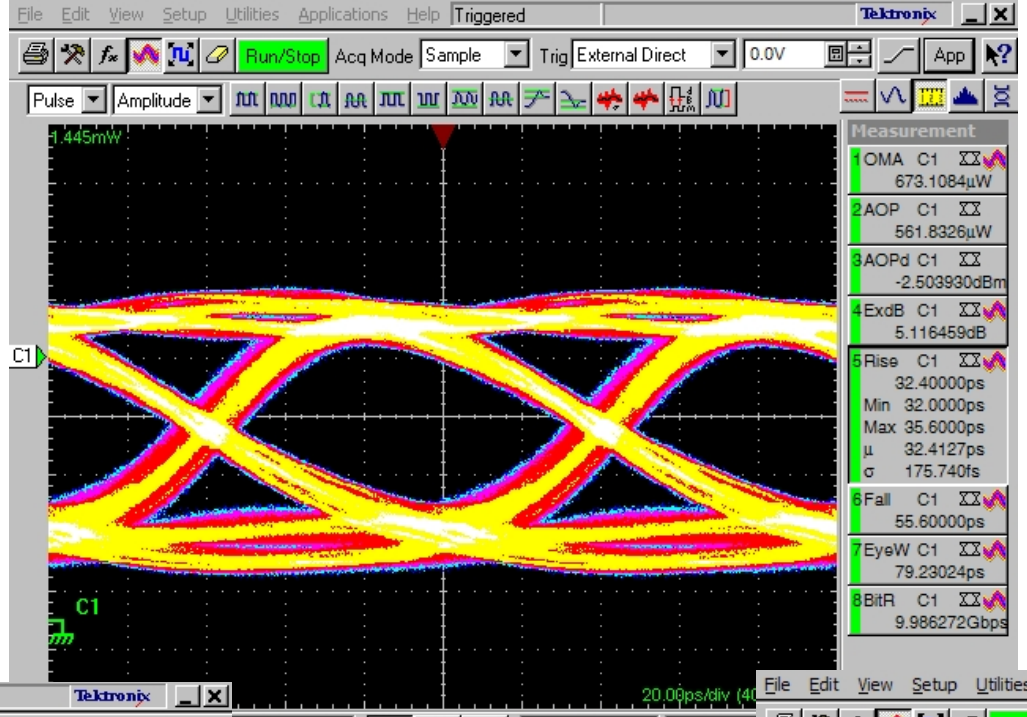


Pattern: PRBS7
Bit Rate: 10 Gbps
LN2

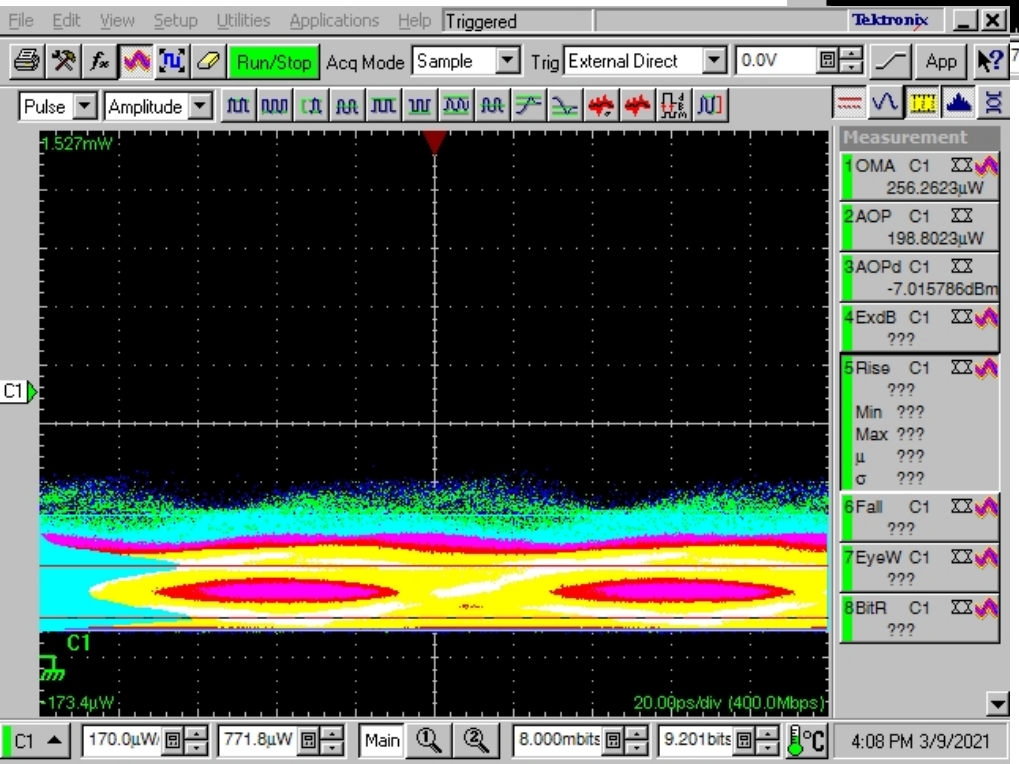


Sample: FP2

Pattern: PRBS7
Bit Rate: 10 Gbps
Room Temperature



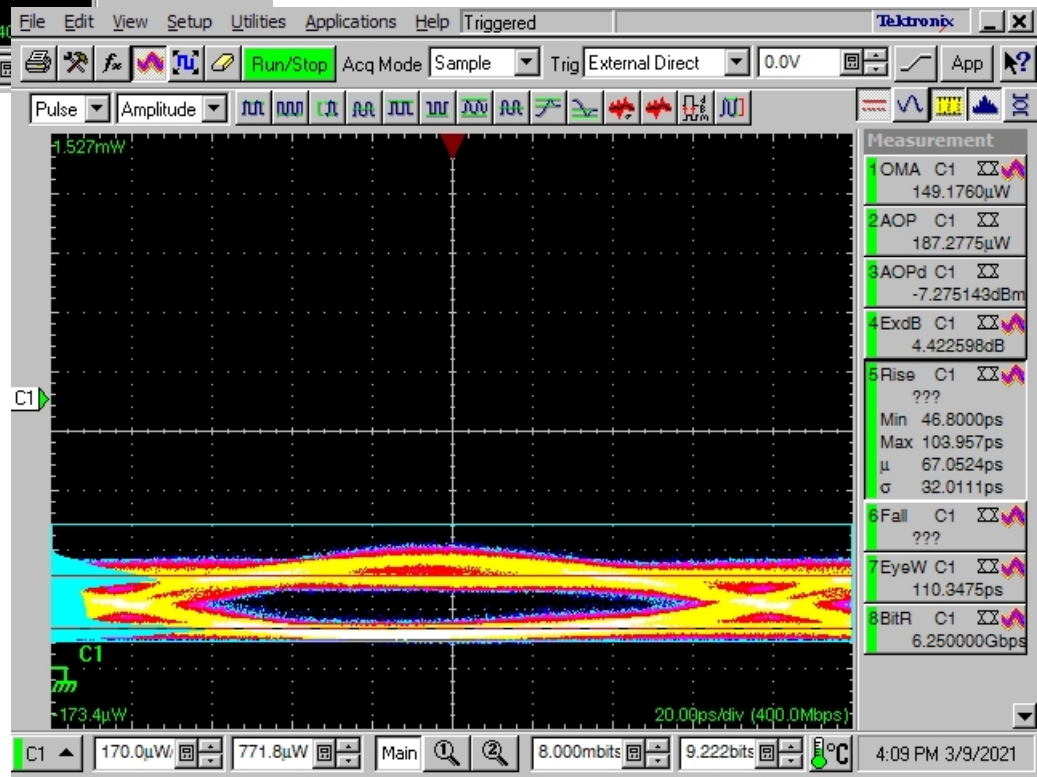
Pattern: PRBS7
Bit Rate: 10 Gbps
LN2



Bit Error Rate tests at 10 Gbps and 6.25 Gbps failed.

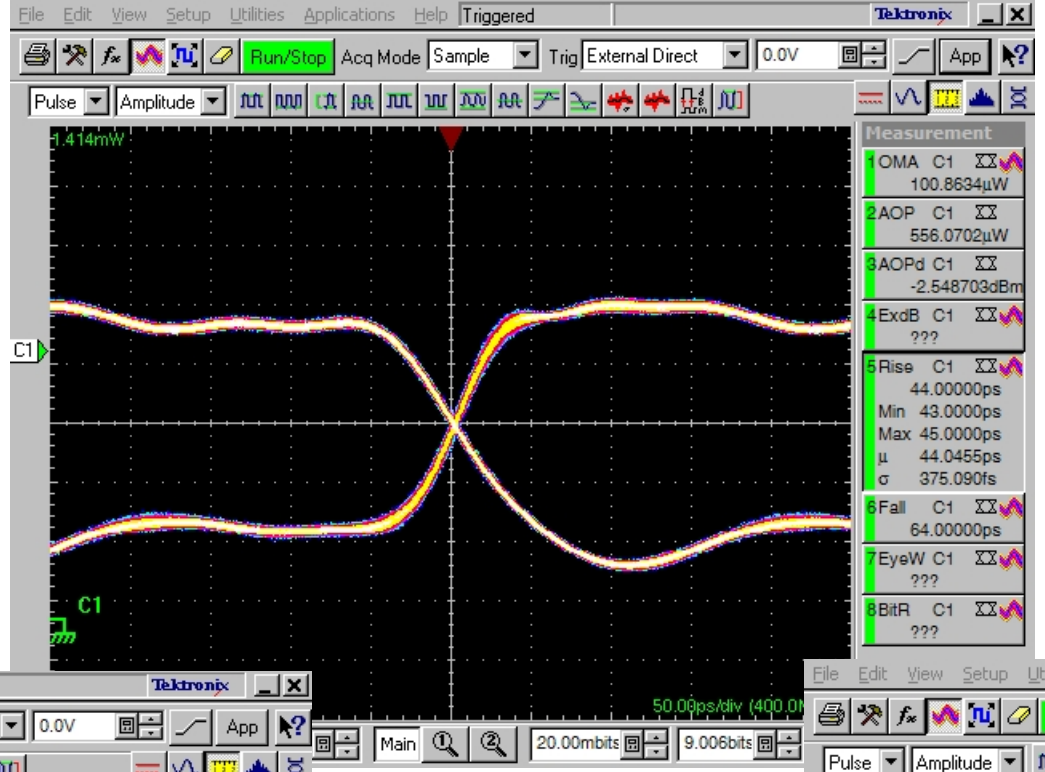
Power cycle test while cold failed

Pattern: PRBS7
Bit Rate: 6.25 Gbps
LN2

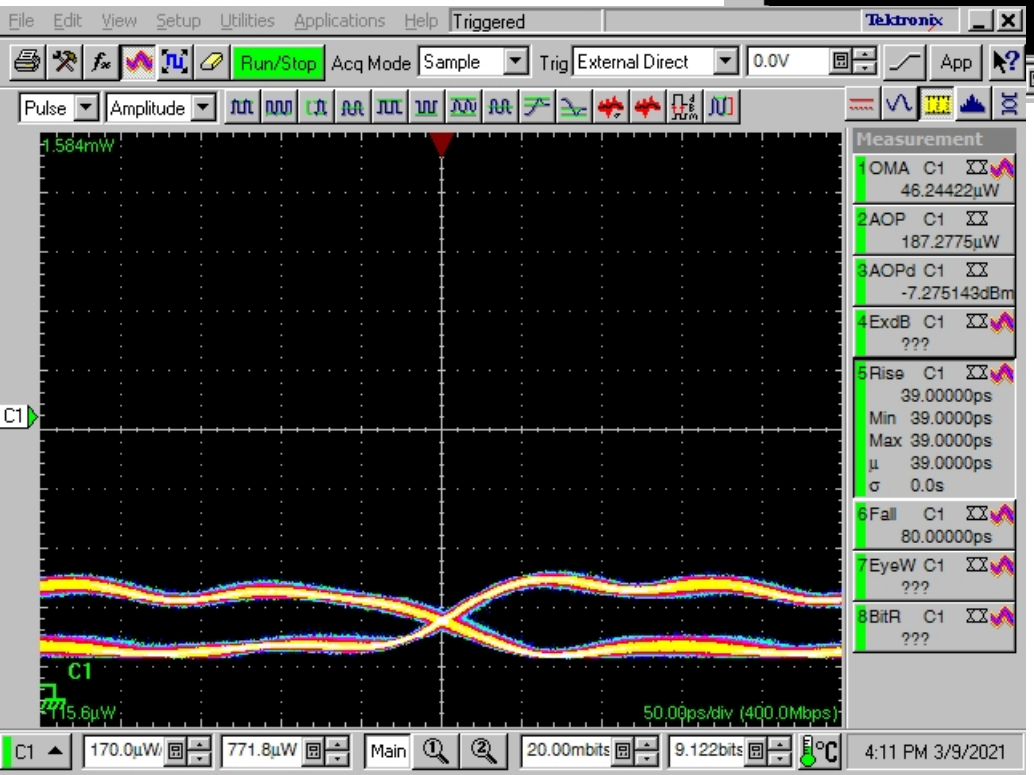


Sample: FP2

Pattern: OMA Pattern
Bit Rate: 10 Gbps
Room Temperature

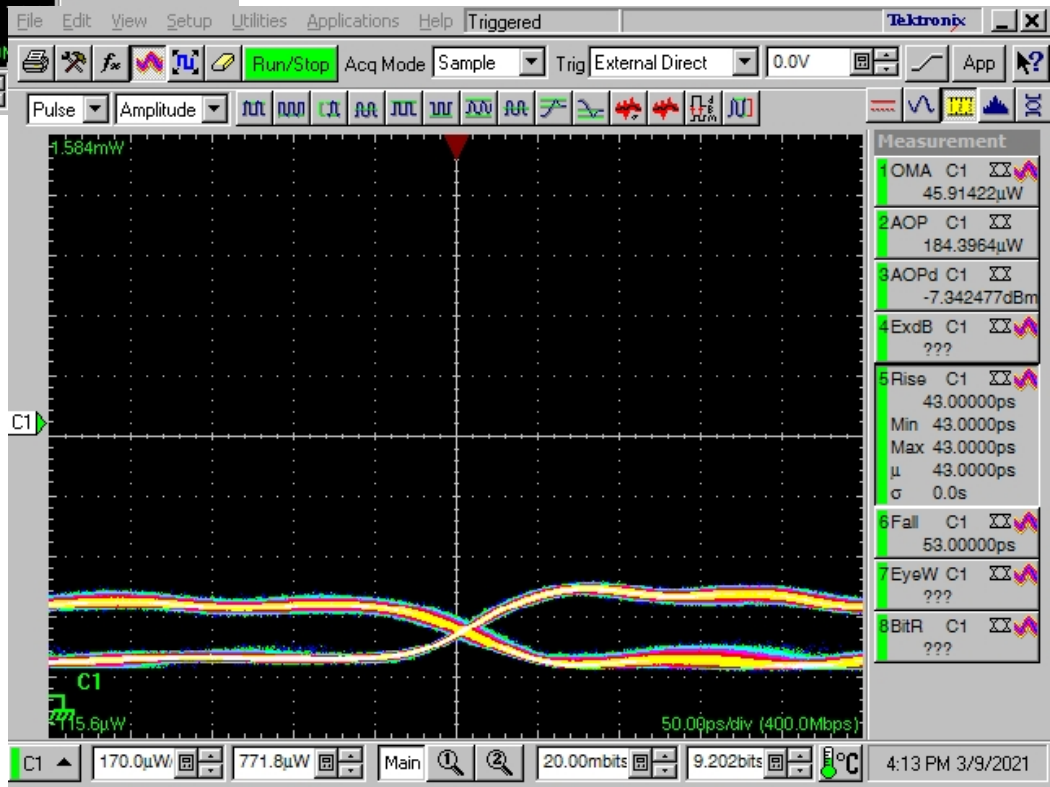


Pattern: OMA Pattern
Bit Rate: 10 Gbps
LN2



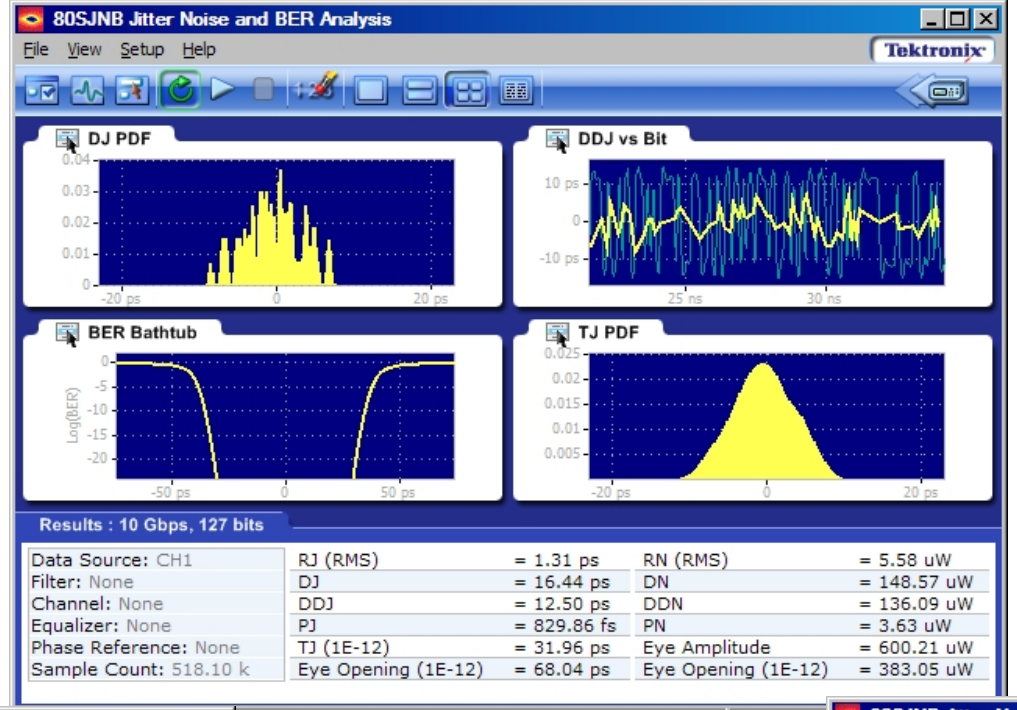
Reduced amplitude obtained in cold. BER tests failed.

Pattern: OMA Pattern
Bit Rate: 6.25 Gbps
LN2



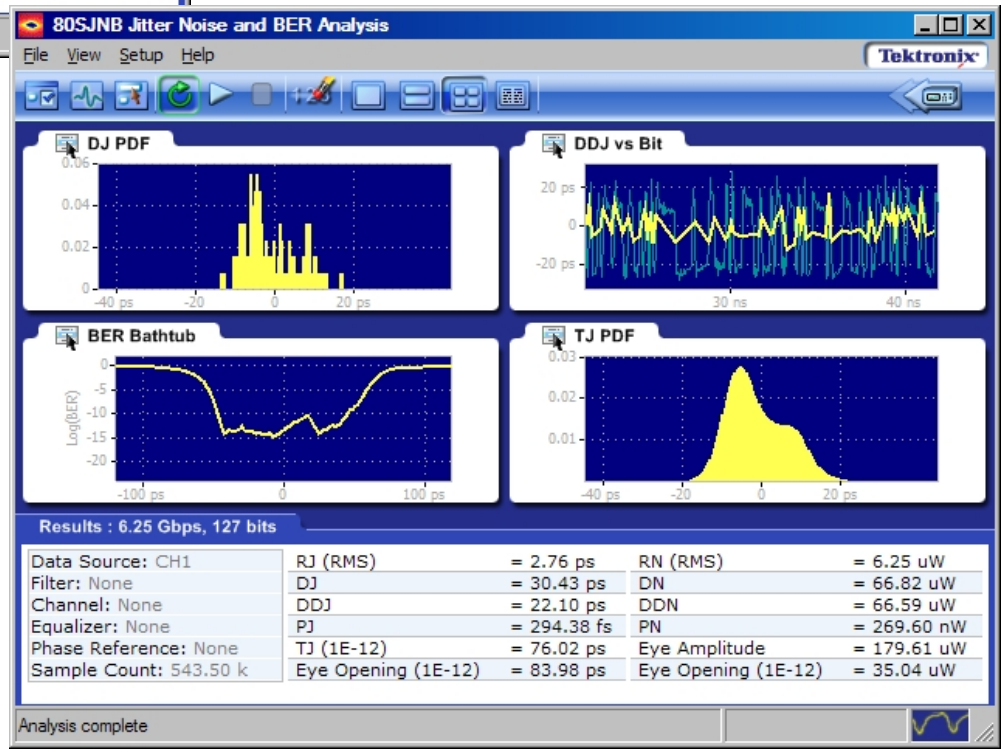
Sample: FP2

Pattern: PRBS7
Bit Rate: 10 Gbps
Room Temperature



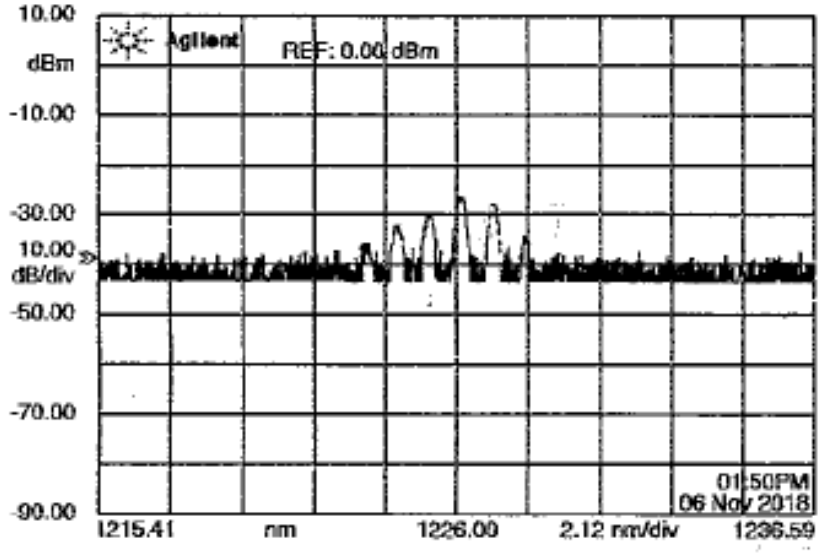
Pattern: PRBS7
Bit Rate: 10 Gbps
LN2

Pattern: PRBS7
Bit Rate: 6.25 Gbps
LN2

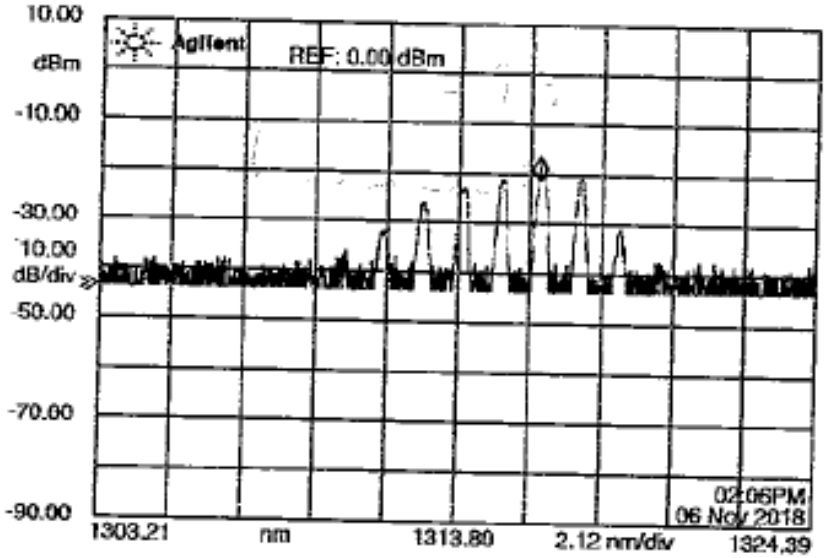


Sample: FP2

Optical Spectra



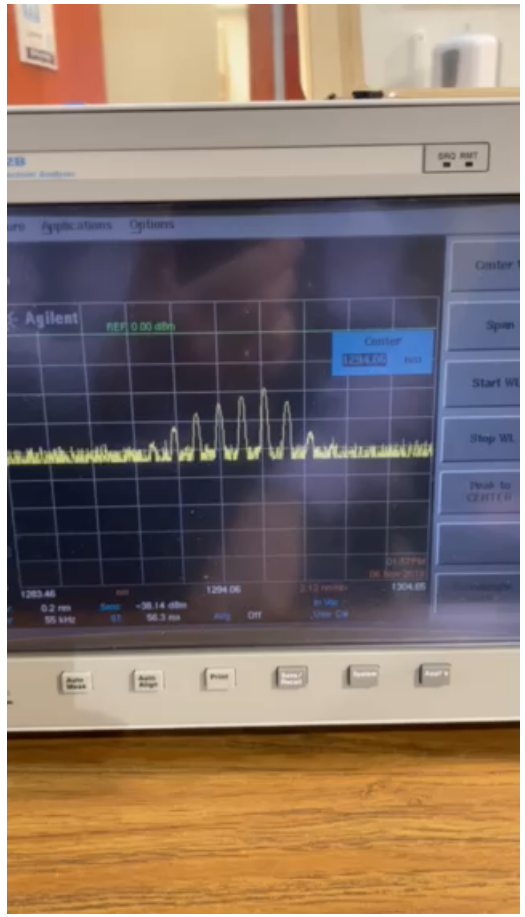
LN2 Temperature (PAB)
Peak Wavelength: 1226 nm
Optical Power at Peak: -26 dBm



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.