Optical Link and Component Testing

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Project: To investigate the feasibility of implementing 10 Gbps optical links at LiAr Temperatures

Approach: Perform testing of COTS components at LiN temperatures to start.
Following earlier work by Southern Methodist University, we are beginning with edge-emitting lasers (EELs) (which showed more promise in the tests carried out about 10 years ago)

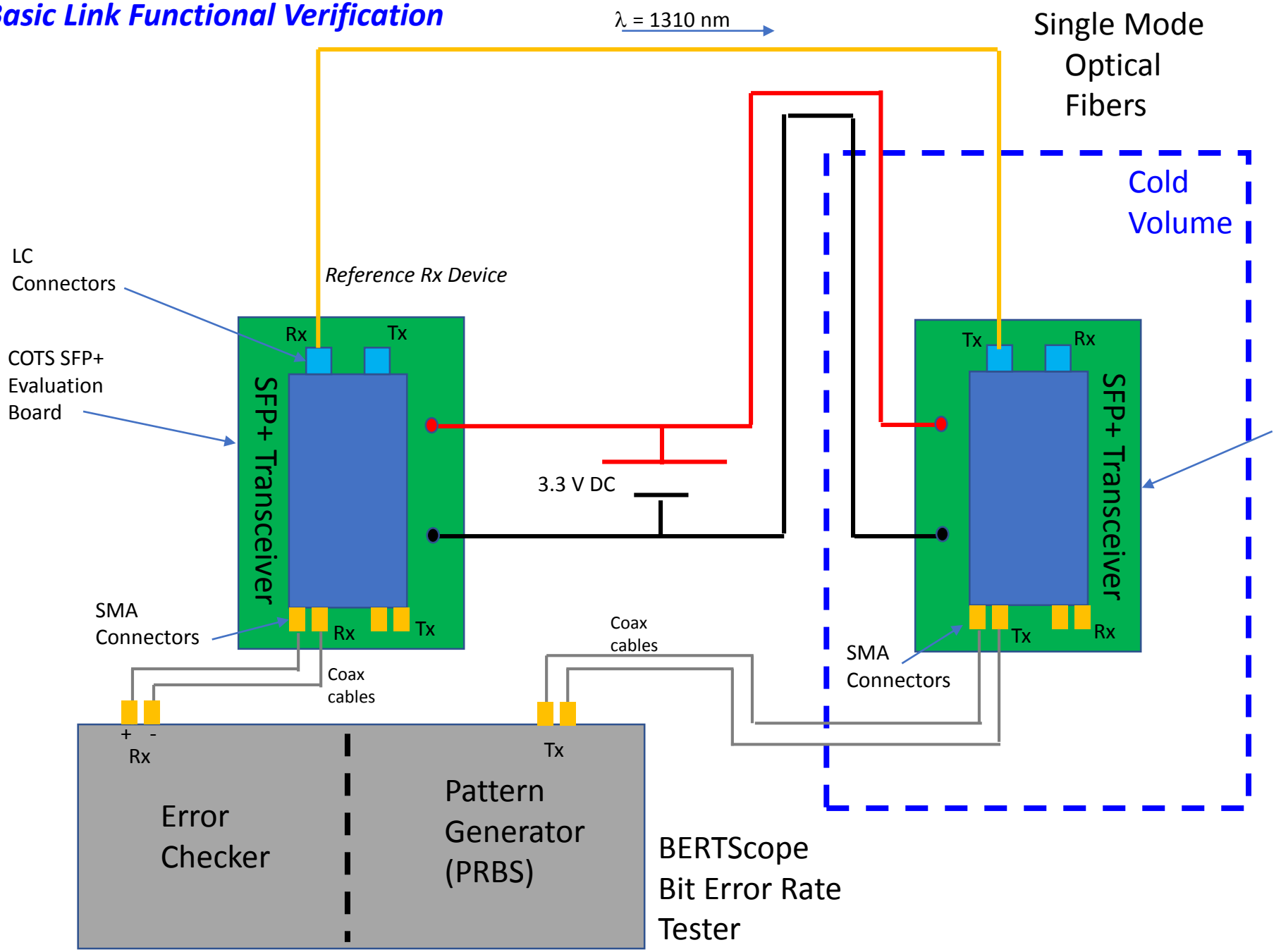
SMU is performing tests of VCSELs to see if recent devices perform better than did those tested 10 years ago.

Agenda:

1. Give an overview of the testing setup to be utilized
2. Give some brief information on the kinds of information to be obtained from these tests
3. Illustrate some of the technology that has been developed/evaluated over the years
4. Outline some emerging technology that may be of interest (optical modulators)

Safety Approvals for Testing at Feynman Computing Center are being pursued (D. Christian, A. Prosser)

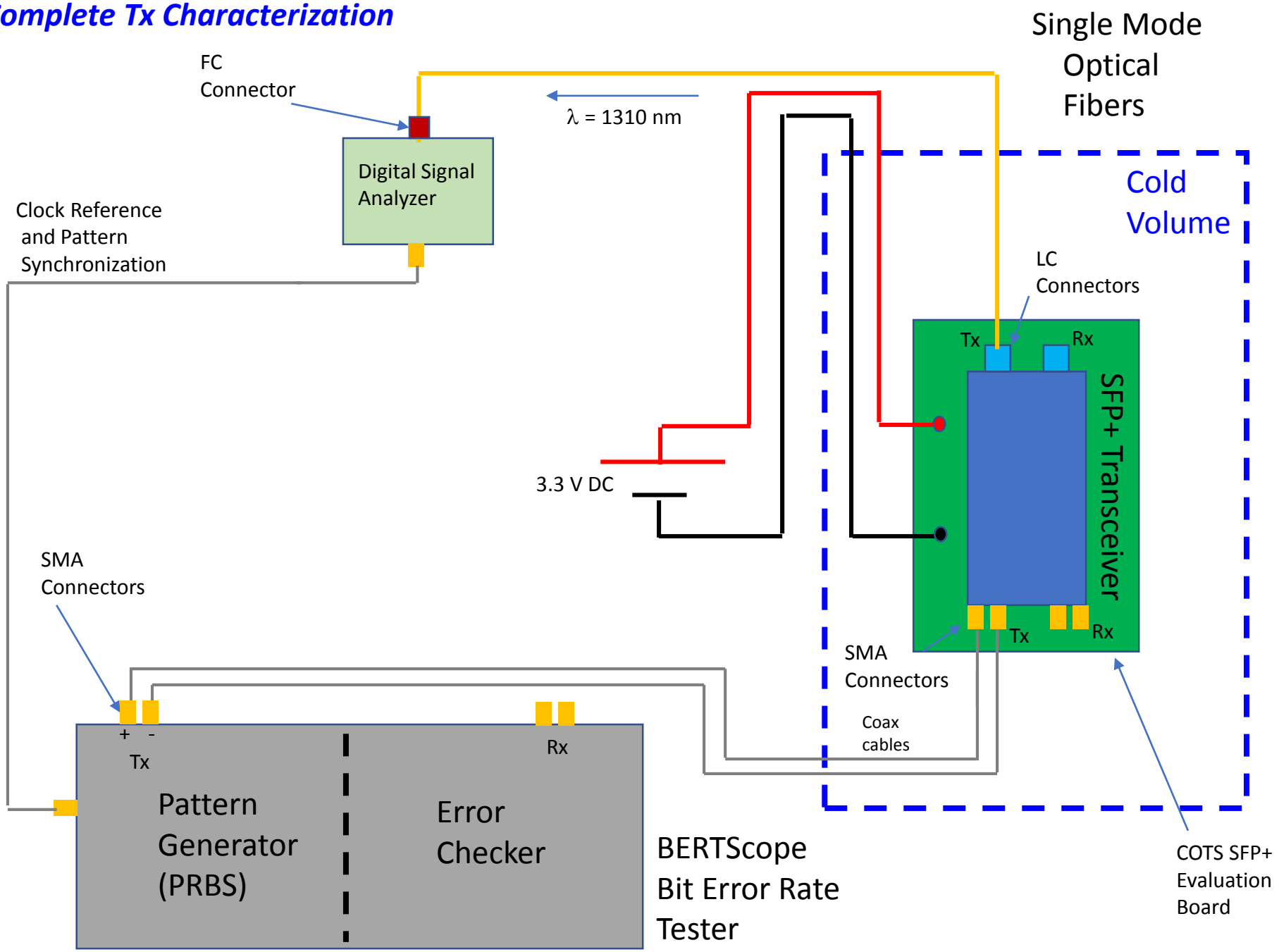
Basic Link Functional Verification



In this configuration, the bit error rate performance of the uplink including the Device Under Test (DUT) within the cold volume can be measured.

This approach more faithfully represents an upstream link

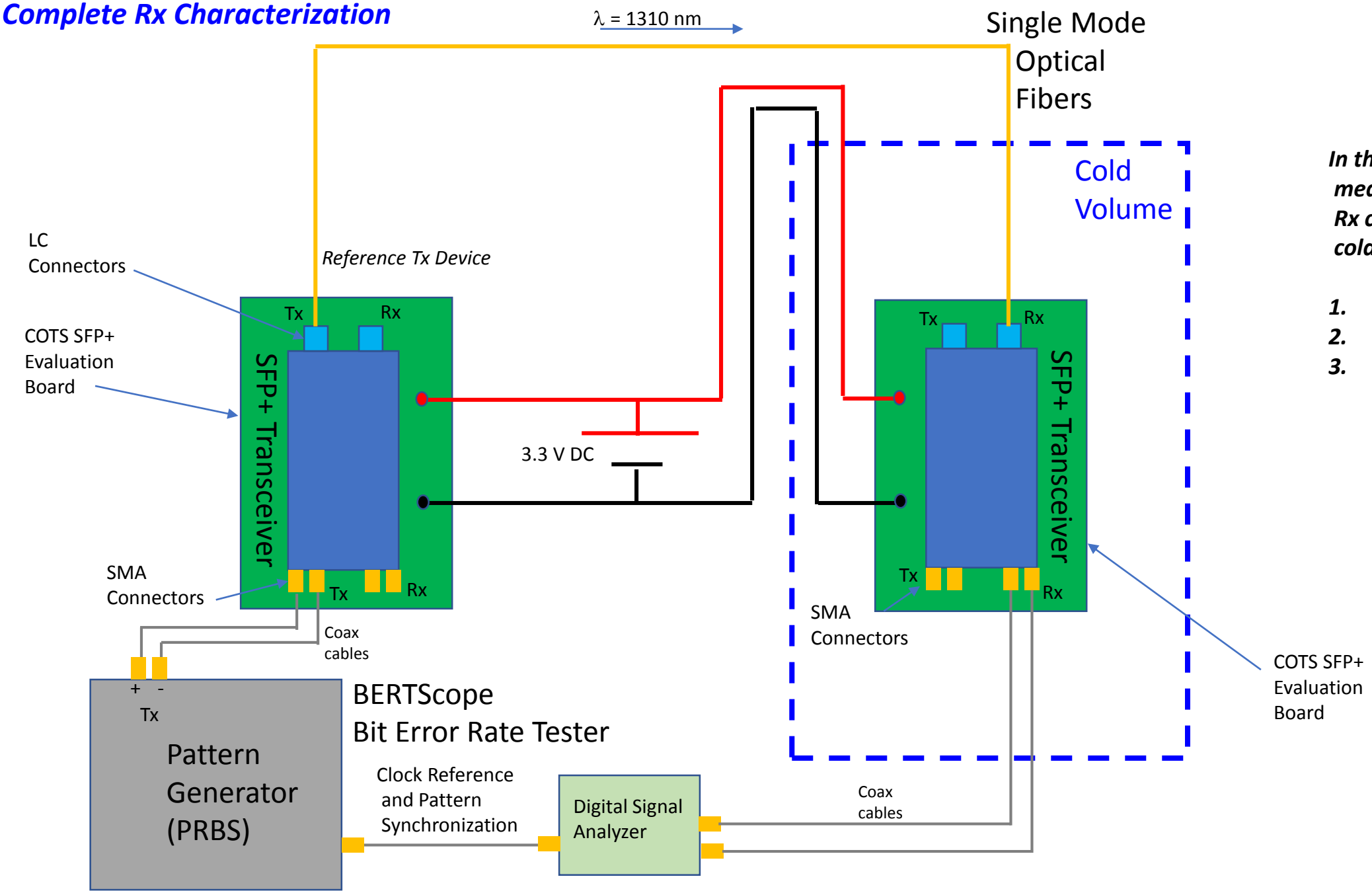
Complete Tx Characterization



In this configuration, measurements of the DUT Tx optical signal can be obtained including:

1. ***OMA***
2. ***Extinction Ratio***
3. ***Eye Height***
4. ***Rise and Fall Times***
5. ***Deterministic Jitter***
6. ***Total Jitter***

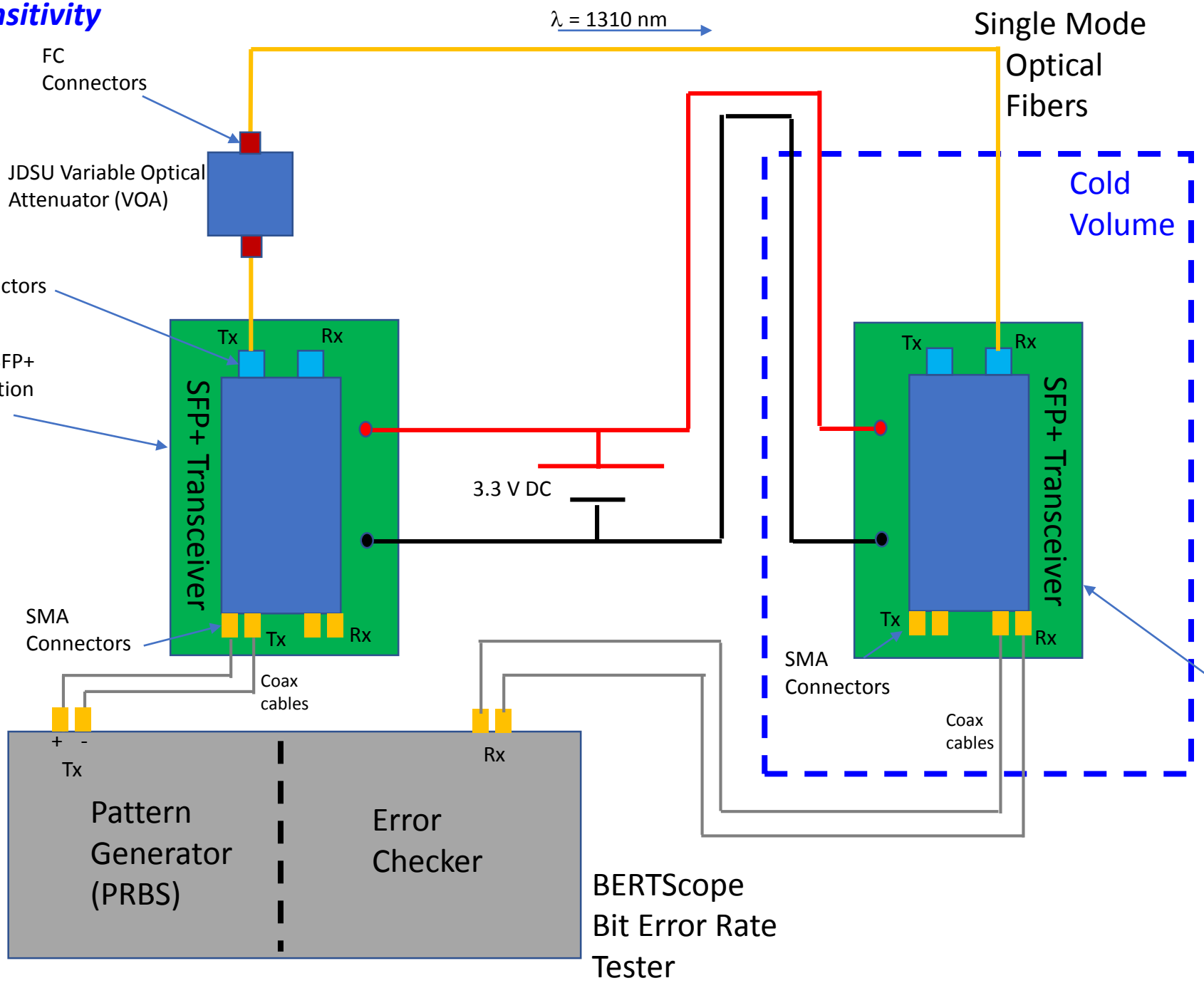
Complete Rx Characterization



In this configuration, measurements of the DUT Rx channel eye in the cold can be made including:

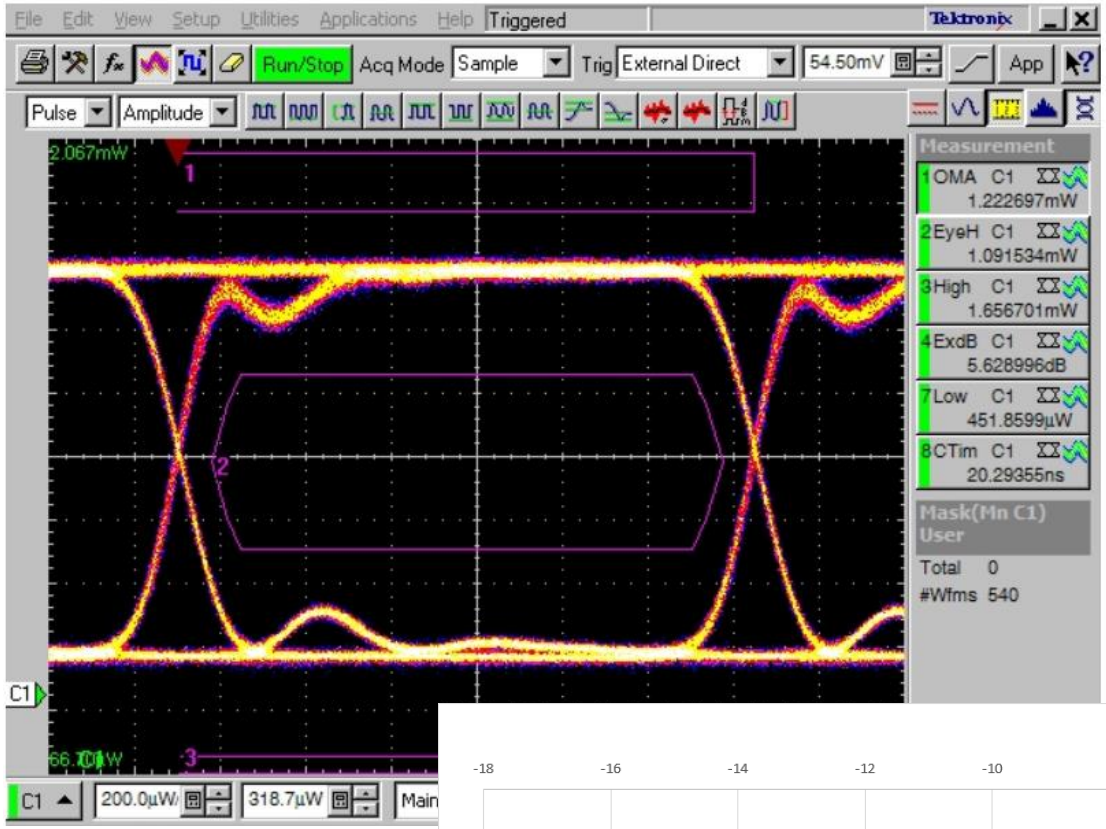
1. ***Rise and fall times***
2. ***Eye amplitude***
3. ***Deterministic and total jitter***

Rx Sensitivity

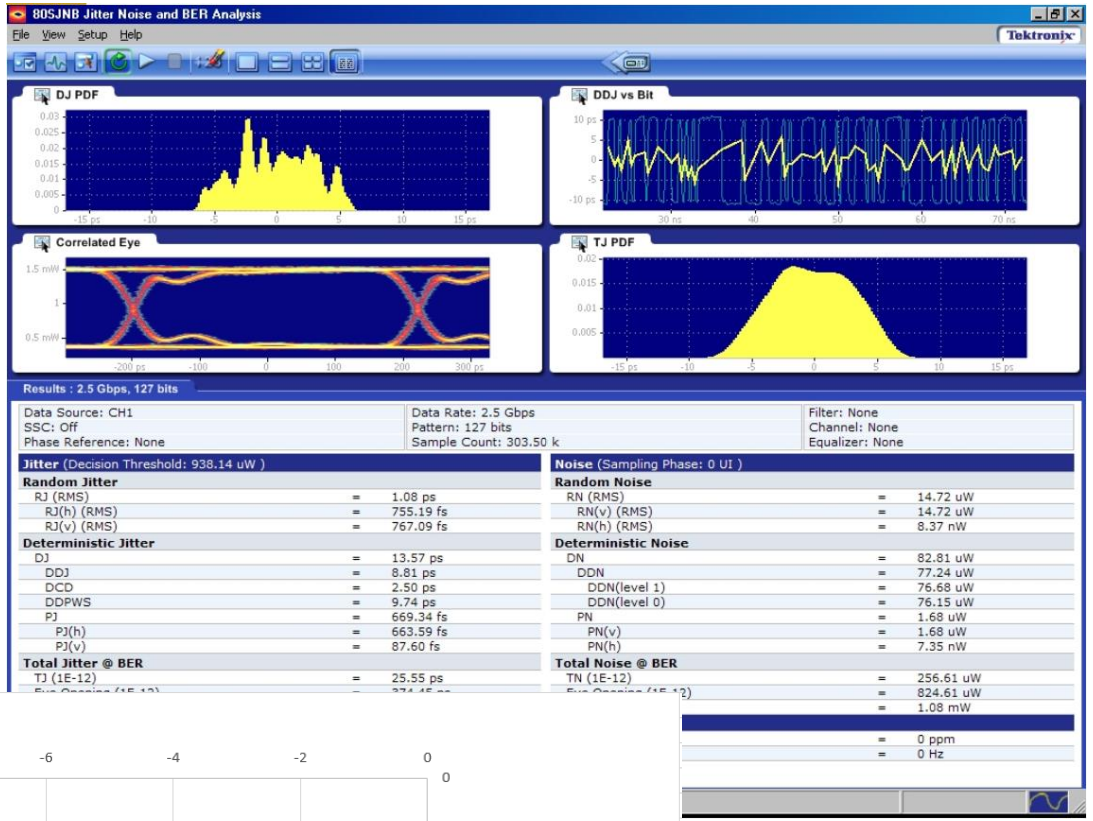


In this configuration, the bit error rate performance as a function of the Optical Modulation Amplitude delivered to the DUT Rx port (varied by introducing optical impairment through the VOA) will permit a measurement of the DUT Receiver Sensitivity in the cold.

Eye Pattern Measurements (Optical and Electrical)

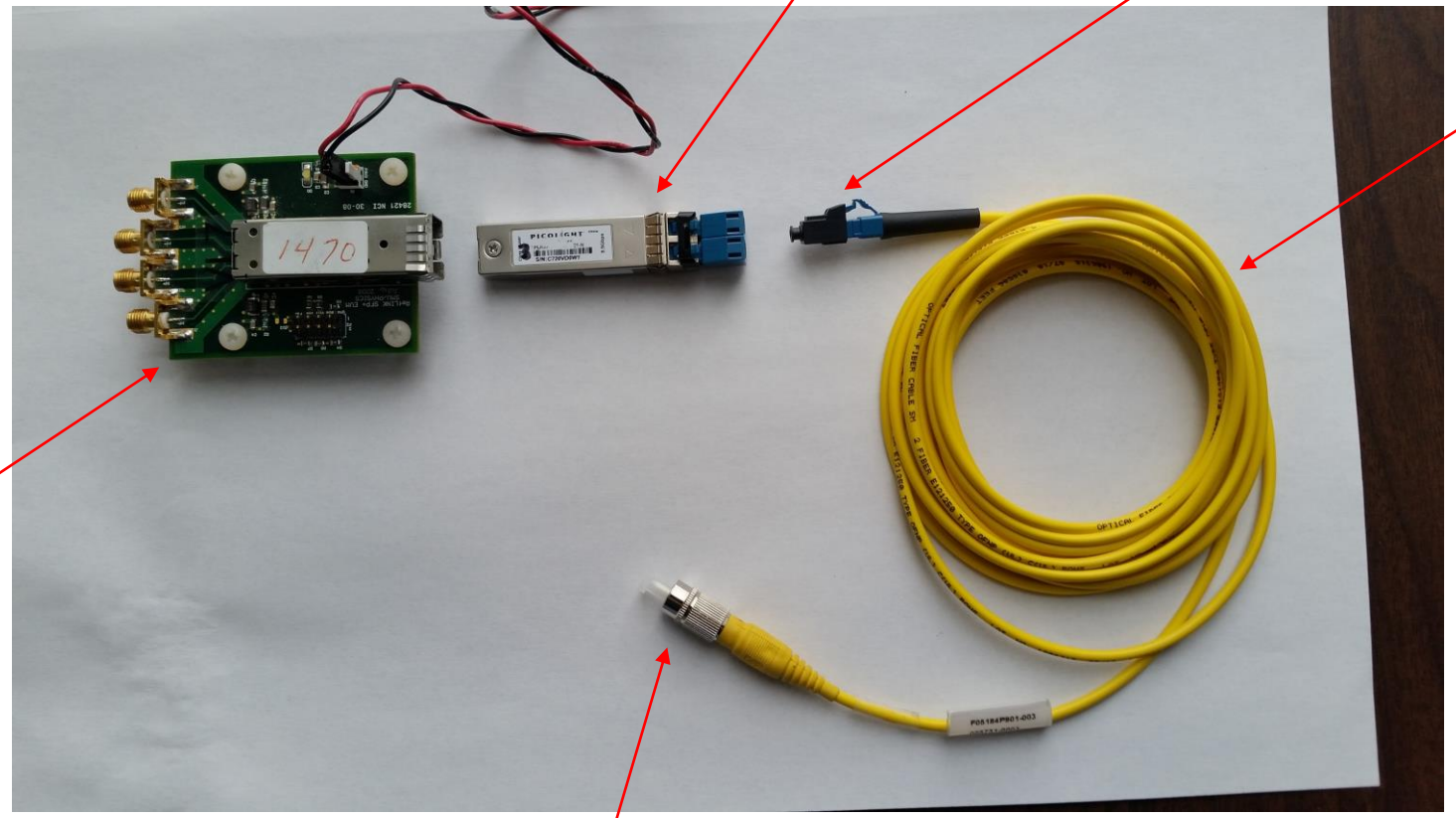


Jitter Composition Measurements (Optical and Electrical)



Rx Sensitivity Measurements

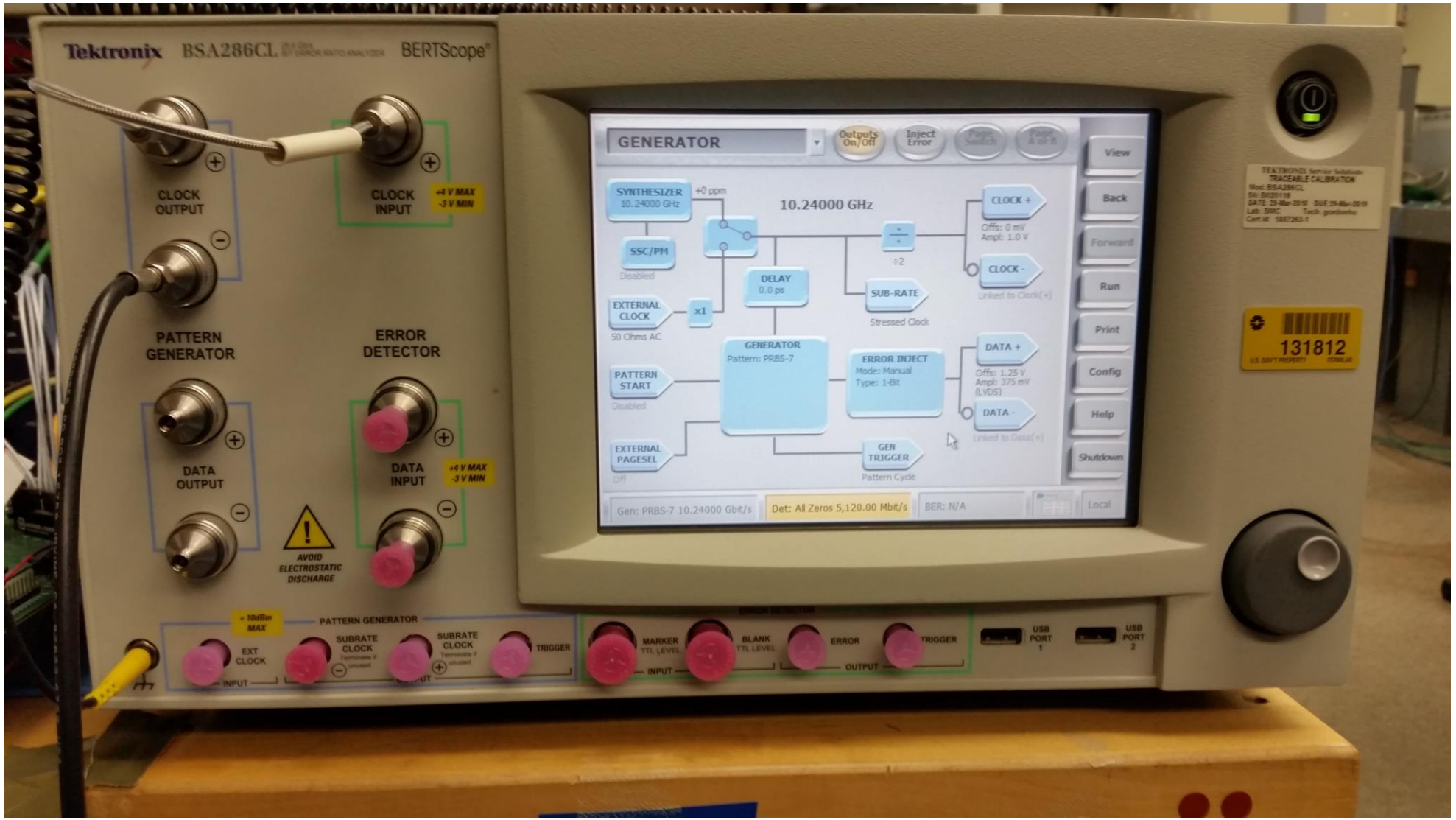
Hardware For First Tests at DUNE



1 Tx (transmitter)
1 Rx (receiver)
2 fibers with LC Connectors
10 Gbps capable
Multimode and Single Mode Variants

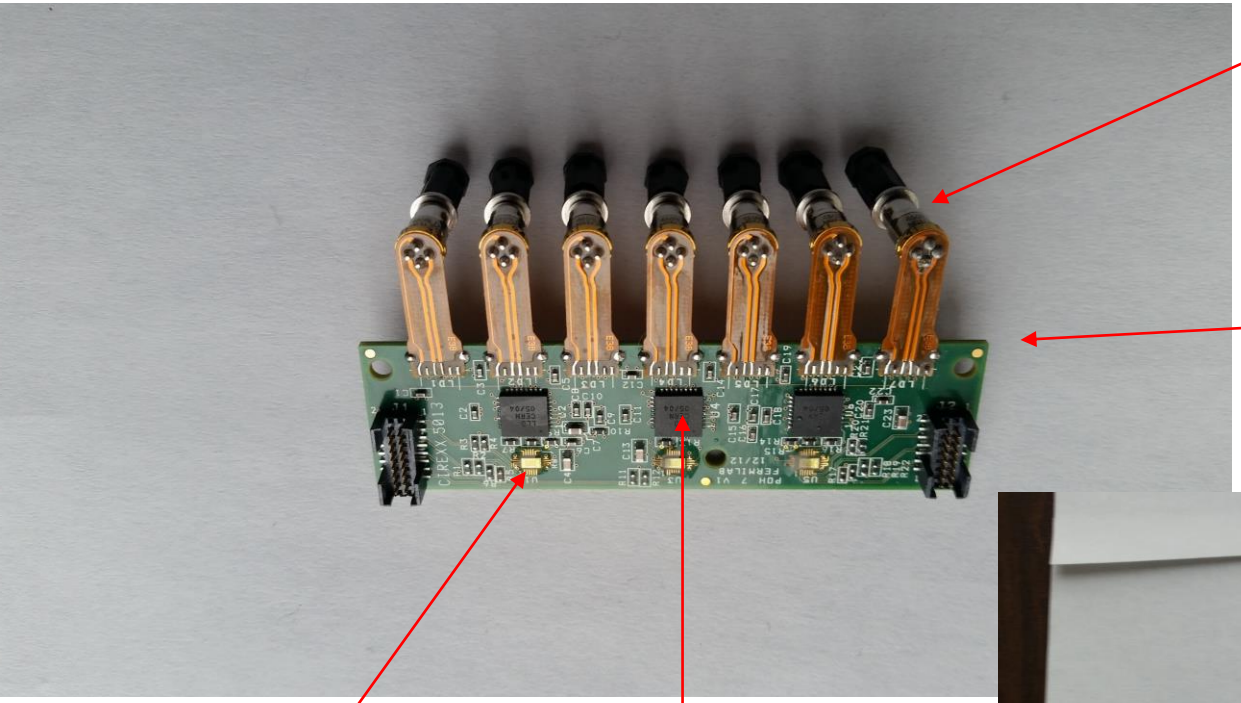
Hardware For First Tests at DUNE

Test Equipment For First Tests at DUNE



Alan will perform checkout of the system and components starting today or tomorrow.

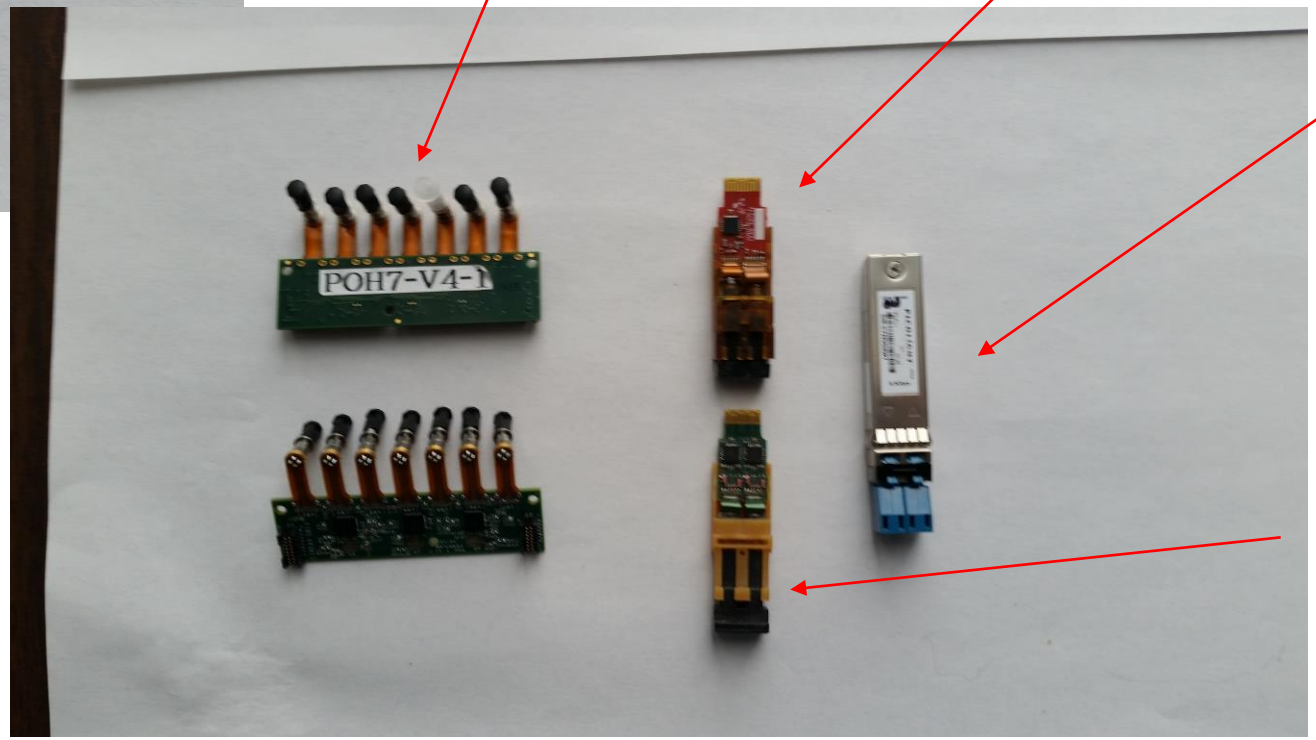
Some Single Channel Technology



Mitsubishi 1310 nm
Transmitter Optical SubAssembly (TOSA)
(COTS)

CERN/PSI/ETH/FNAL
Pixel OptoHybrid (POH 7Ch Tx)
CMS Phase 1 FPix

CERN VTRx
Rad Hard TRx



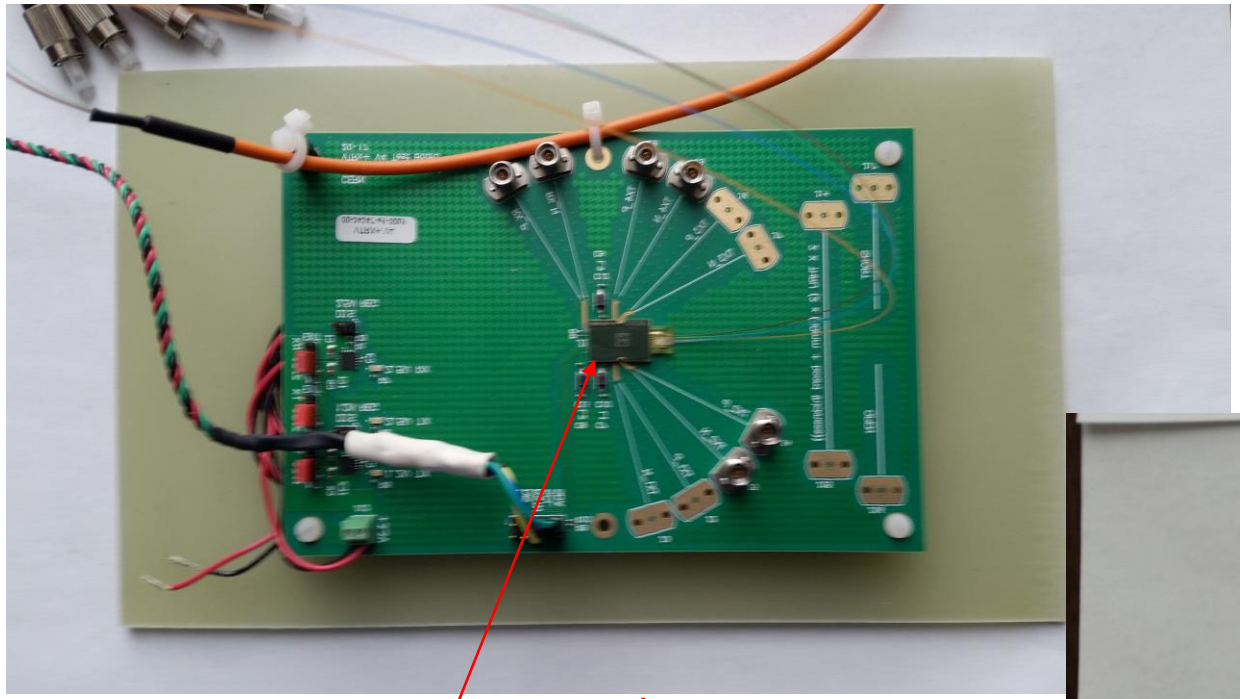
COTS SFP+

CERN VTTx
Rad Hard
Twin
Transmitter

Digital Level Translator (DLT)
(Custom)

Multi-Channel
Laser Driver
(Custom)

HL-LHC Components (Versatile Link Plus Project)



Front End Element
(custom)

10.24 Gbps upstream
2.56 Gbps downstream

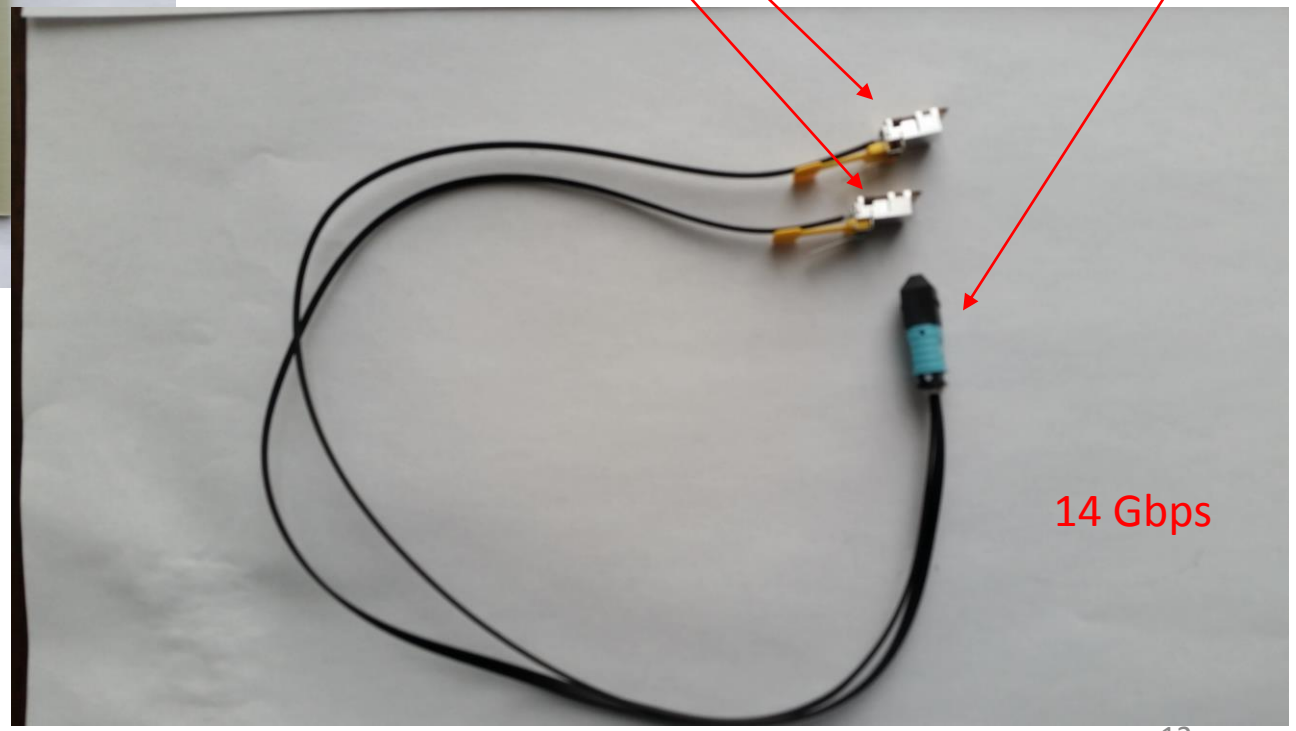
Early VTRx+ Prototype (Front End Element)
(This example has 2 transmitters, 1 receiver)
Devices and evaluation card from CERN

NOTE: This effort even involves the development
of custom optical packaging

Back End Element (COTS*)

SAMTEC FireFly Tx/Rx Pair…

… with Y cable (terminates
in a single 24 fiber MTP connector)



Reminder: An Optical Link is Very Much a System Concept

5. POWER BUDGET

The optical power budget for the VL+ system is shown in table 5.1. All power levels are specified to meet target performance of bit error ratio better than 10^{-12}.

Table 5.1 Versatile Link Plus Power Budget

	Upstream VTx+_Rx (10.24 Gbps)		**Downstream Tx_VRx+ (2.56 Gbps)**	
	Standard Grade	**Extended Grade**	**Standard Grade**	**Extended Grade**
Tx OMA	> -5.2 dBm	> -5.2 dBm [3]	> -5.6 dBm	>-1.6 dBm
Rx sensitivity	< -11.5 dBm	< -12.5 dBm	< -13.1 dBm	< -13.1 dBm [3]
Power budget	**> 6.3 dB**	**> 7.3 dB**	**> 7.5 dB**	**> 11.5 dB**
Fiber attenuation (50m/100m/150m)	<0.125 dB / 0.25 dB / 0.375 dB		< 0.375 dB	
Insertion loss	< 1.75 dB		< 1.75 dB	
Link penalties[1] (50m/100m/150m)	1.7 dB / 1.9 dB / 2.3 dB		< 0.5 dB	
Tx radiation penalty	1.0 dB		NA	
Rx radiation penalty	NA		< 1.4 dB	<5.4 dB
Fiber radiation penalty	< 0.5 dB	<1.5 dB	< 0.5 dB	<1.5 dB
Margin (50m/100m/150m)	**1.225/0.9/0.375 dB**	**1.225/0.9/0.375 dB**	**> 2.975 dB**	**> 1.975 dB**
Coding Gain[2]	**1dB**		**1 dB**	

Note 1: The link lengths documented here represent the actual link length where the first 7 meters consists of radiation hard OM2 fiber. For example, the length of 100 m is an overall link length of 100, which includes 7 m of OM2 fiber followed by 100 − 7 = 93 m of OM3 fiber.

Analog Optical Data Communication

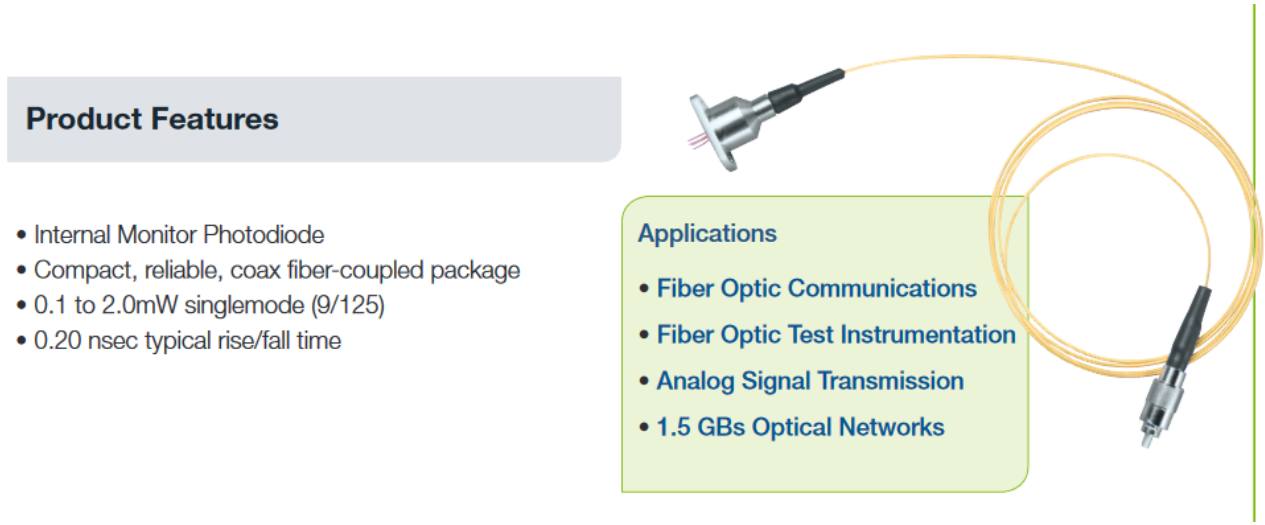
Yesterday, we heard from DarkSide on their plans to pursue an analog solution

The approach is founded on the desire to preserve the signal to noise ratio of the measured signals.

The link uses:

1. 1310 nm LED (wavelength is not a source of noise in LiAr)
2. 200 micron core diameter optical fiber (the numerical aperature in LiAr could be an issue for 9 micron core single mode fibers)
3. Photodiode and Transimpedance Amplifier on the outside

We are looking into components that might be useful for similar testing here at FNAL:



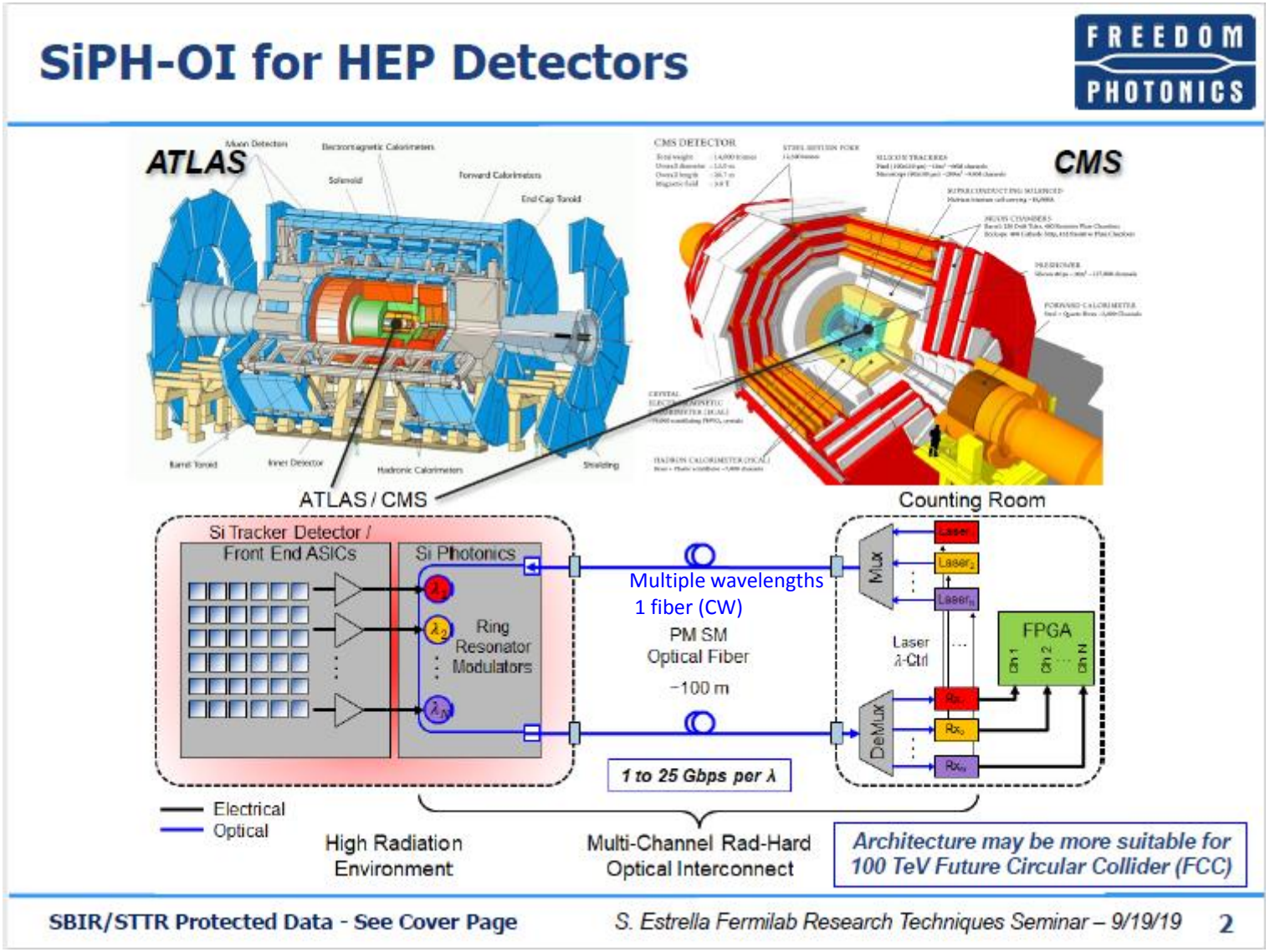
Some Evolving Technology

Direct Modulated Laser Diode systems are reaching the limits of performance

Indirect Modulated devices are in use already (Lithium Niobate Mach-Zehnder Modulators)

Newer devices are being investigated to combine the high-speed, low-power promise of indirect modulation with Wavelength Division Multiplexing (WDM) for compact high throughput links with enhanced utilization of fiber resources. These developments are part of the emerging technology known as Silicon Photonics.

Some Evolving Technology – Example
Ring Resonator Modulators



No lasers on the front end (low power)

Not without issues:
1. Thermal dependence
2. Polarization sensitivity

This approach has attracted interest from members of the community operating in cryogenic environments.