

# 25 Gb/s transmission over harsh environment multimode fiber

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# Introduction

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- This contribution shows experimental results of 25 Gb/s transmission using InGaAs 25G VCSEL, between  $-40\text{ }^{\circ}\text{C}$  and  $+125\text{ }^{\circ}\text{C}$  substrate temperature, in 100 m OFS 50  $\mu\text{m}$  OM3 optical cable designed for commercial aircraft/harsh environments, as proxy for MMF optical cable for automotive/harsh environment applications
- This contribution does NOT pursue including 100 m within the OMEGA project objectives
  - Objectives of the project have to be aligned with the market requirements
  - Transmission tests in longer distance gives a measure of the technical feasibility margin
- TRUMPF VCSEL-ULM850-25-TT-V03 is used in the experiments
- AC frequency response of optical channel is also characterized

# Equipment & Software



- Marki Microwave BTN-0040 bias tee (40 kHz to 40 GHz)
  - Used to combine bias current with RF signal from VNA or AWG
- Minicircuits TMP40-3FT-KMKM+, temperature stable 2.92mm cable, 40.0 GHz
  - Used to connect bias tee output to the DUT
- Newport 1484-A-50 fiber-optic multimode receiver, 800-865nm GaAs detector, 22 GHz, FC/PC
  - Used for S21 response measurement with VNA
- Keysight E5080B ENA Vector Network Analyzer
  - S21 magnitude response
  - 2001 points linear sweep from 1 MHz to 20 GHz
  - Power -20 dBm
- Keysight B2901A Precision Source/Measure Unit
  - Bias current to VCSEL

# Equipment & Software



- Keysight M8195A 65 GSa/s, 25 GHz, Arbitrary Waveform Generator
  - Used to generate time-domain RF signal that drives the VCSEL
  - Capability of real-time digital signal processing with 8 bits DAC
  - Used to provide symbol clock to oscilloscope
- Keysight N1092C DCA-M Sampling Oscilloscope (one optical and two electrical channels)
  - Used to make the time-domain characterization with periodic arbitrary signal generated by VCSEL
- Keysight N1010A FlexDCA Sampling Oscilloscope Software, R&D package
- Matlab 2018a:
  - Test automation
  - Signal processing
  - User operator extensions for N1010A

# OFS harsh environment 50 $\mu\text{m}$ MMF characteristics

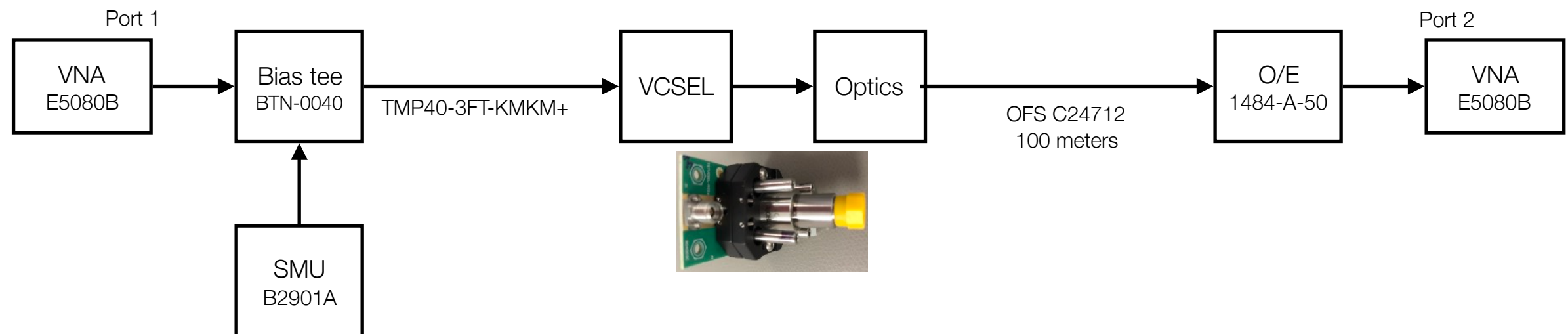


- Bend-optimized multimode optical cable designed for use in commercial aircraft
- This cable meets or exceeds requirements of ARINC 802 for tight buffered cables used in commercial aircraft.

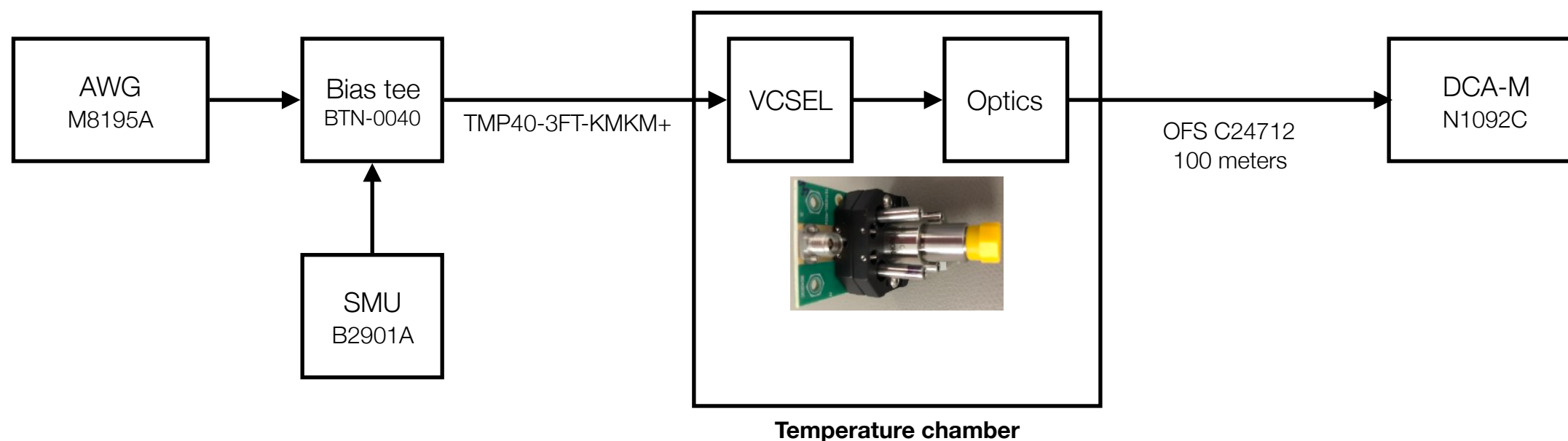
Cable Optical Properties		Cable Design	
Attenuation	@ 850 / 1300 nm, $\leq 5.0 / 3.0$ dB/km	Cable Construction	Tight-buffered Simplex with braided strength member
Bandwidth	@ 1300 nm, $\geq 500$ MHz-km EMB @ 850 nm, $\geq 2000$ MHz-km EMB	Cable Weight	$\leq 4.0$ kg/km
		Outer Jacket Material	PFA
		Outer Cable Diameter	$1.8 \pm 0.1$ mm
		Outer Jacket Color	Light Purple
Buffered Fiber Properties		Installation and Usage Specifications	
Buffer Diameter	$900 \pm 50$ $\mu\text{m}$	Installation Load Maximum	19.3 lb 86 N
Buffer Material	Black PFA	Minimum Bend Installation	25 mm
Cladding Diameter	$125 \pm 1$ $\mu\text{m}$	Minimum Bend Operating	8 mm
Coating Diameter	$400 \pm 25$ $\mu\text{m}$	Operating Load Maximum	9.7 lb 43 N
Coating Material	Silicone	Operating Temperature	-55 to +200 $^{\circ}\text{C}$
Core Diameter	$50 \pm 3$ $\mu\text{m}$	Storage Temperature	-55 to 85 $^{\circ}\text{C}$
Numerical Aperture	$0.200 \pm 0.015$		

# Tests setups

## Setup for AC frequency response measurement

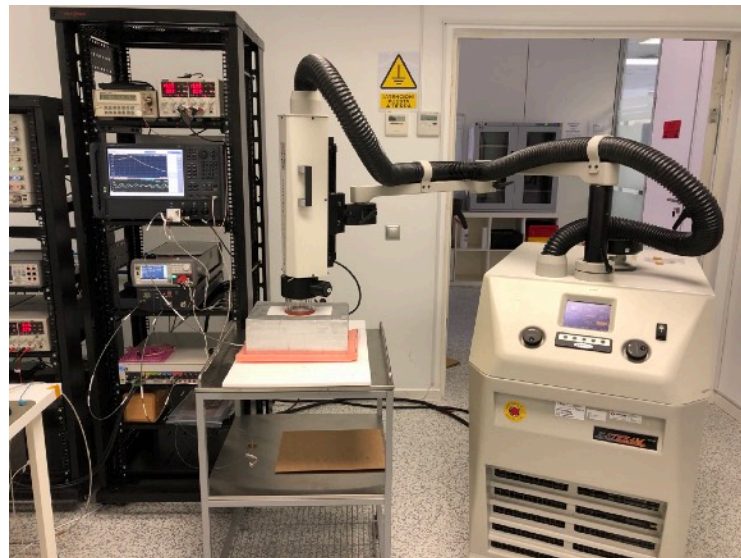


## Setup for time-domain data transmission

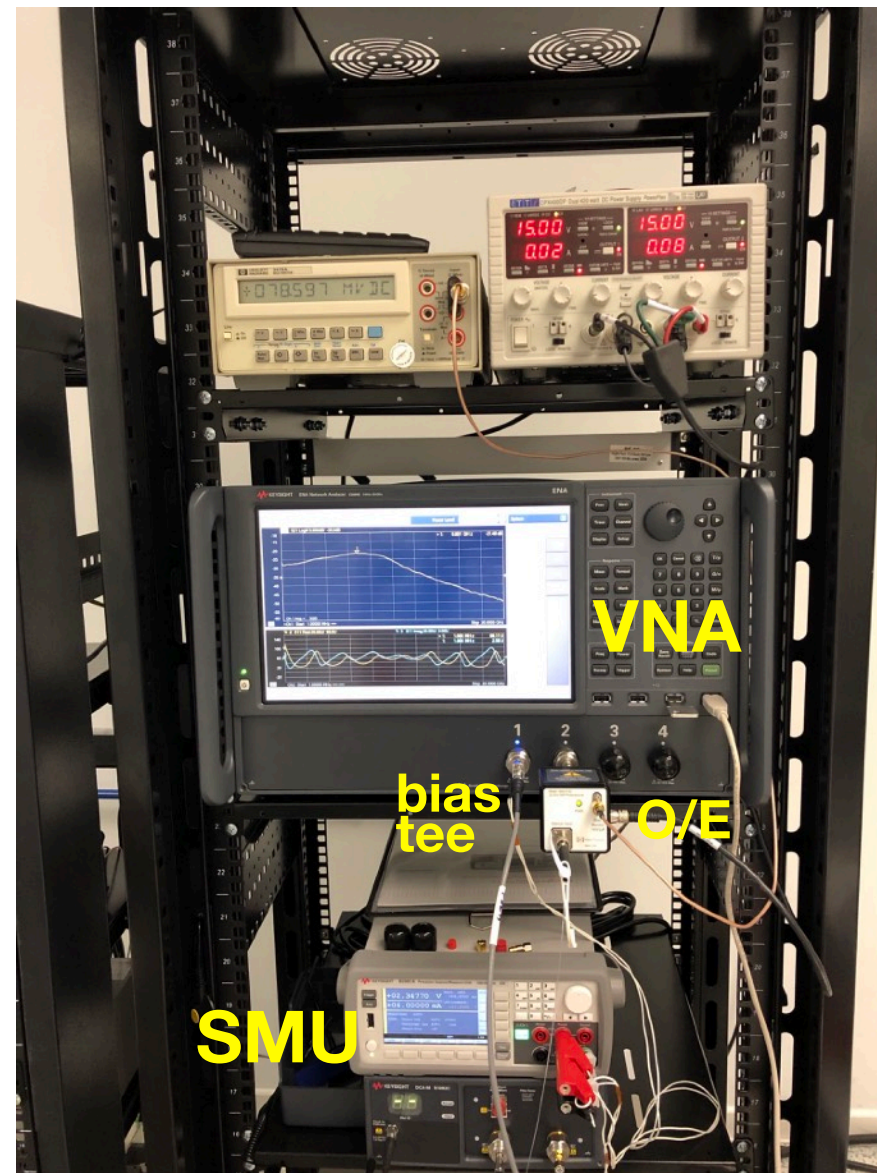
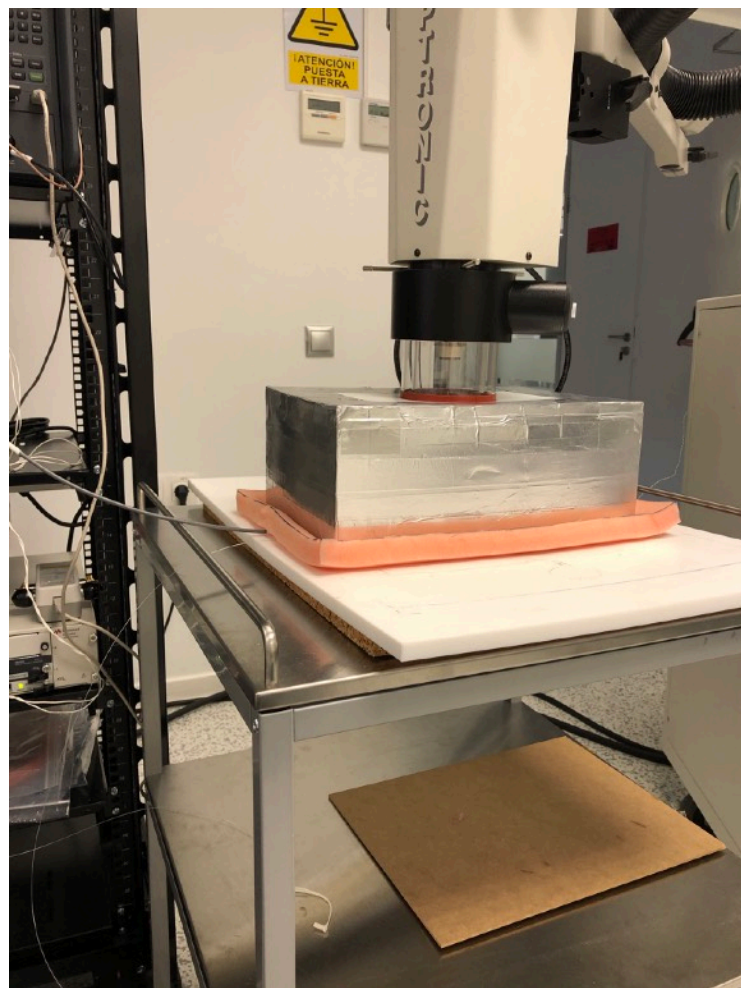




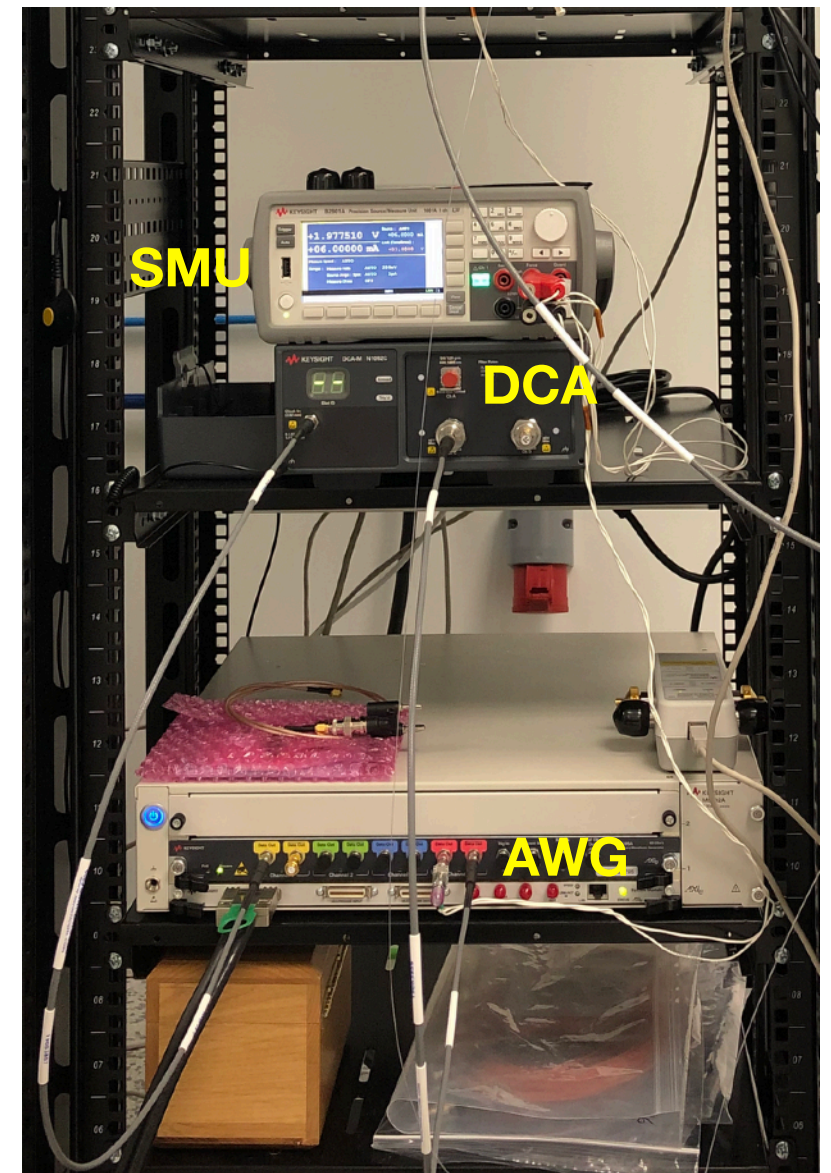
# Tests setups



AC characterization



Time-domain  
eye characterization



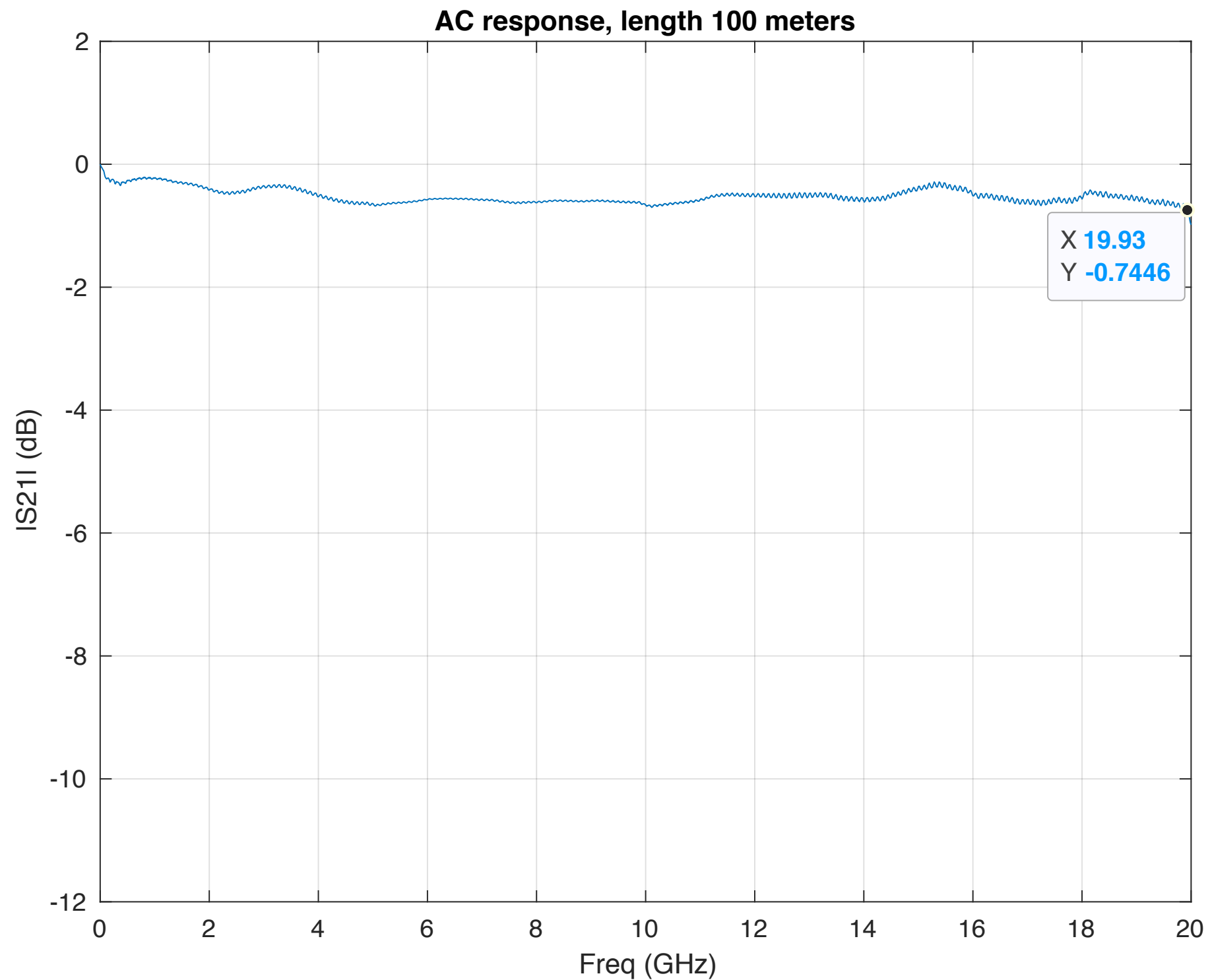


# AC frequency response of optical channels

## Room temperature measurements



# AC frequency response — 100 meters





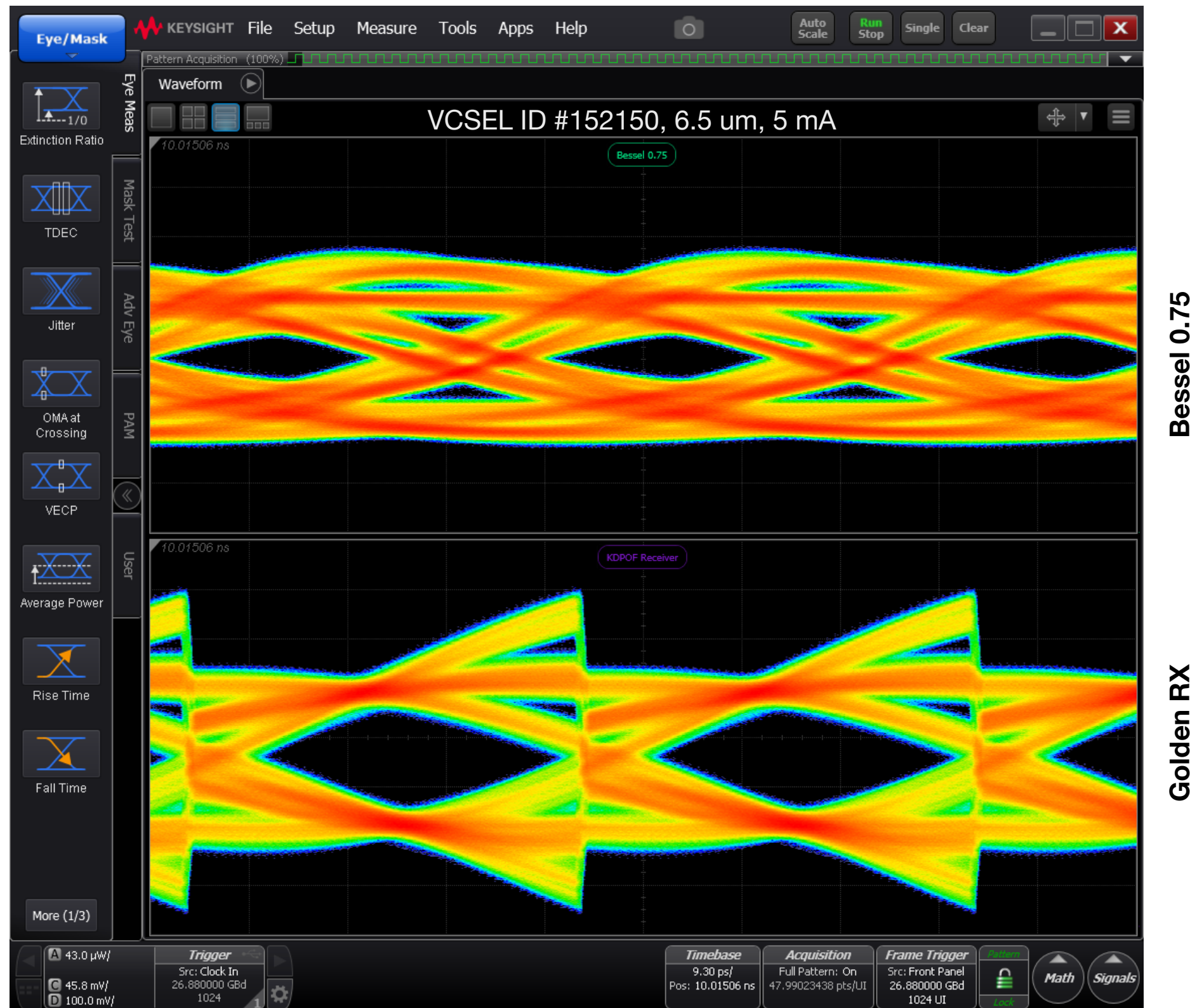
# 25 Gb/s experiments

# Eye diagram, 25 Gbps

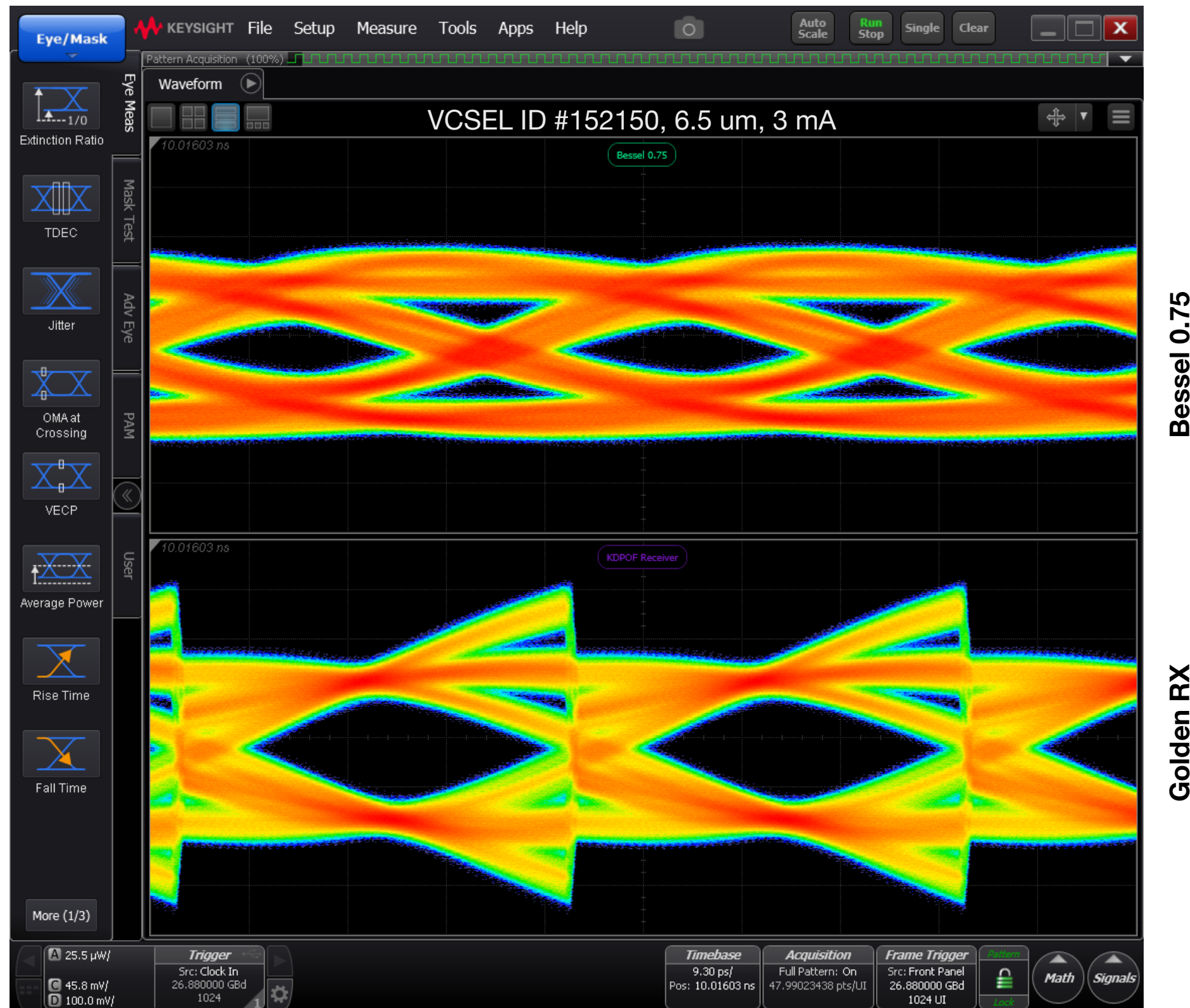


- Signal type: NRZ
- Baud-rate: 26.88 GBd (selected according to the AWG clock configuration capabilities)
- ER (current): 3 dB (expected worst case)
- Current densities at  $T_s = 125^\circ\text{C}$  are limited to  $\sim 9 \text{ kA/cm}^2$ 
  - See “perezaranda\_OMEGA\_05a\_1119\_VCSEL\_Reliability.pdf”
- AWG is configured with response correction calibrated from factory to avoid additional driving bandwidth limitations
- DCA configuration:
  - Receiver input filter is Bessel  $\text{BW}_{-3\text{dB}} = 39.8 \text{ GHz}$  (SIRC)
  - Trace 1: signal is filtered with Bessel 4<sup>th</sup> with  $\text{BW}_{-3\text{dB}} = 0.75 \times \text{BR}$  (20.16 GHz)
    - Used to observe the eye diagram as usual
  - Trace 2: golden (KDPOF) receiver implemented in the DCA, consisting of:
    - Timing recovery for optimum symbol sampling
    - Adaptive equalizer coefficients calculation
    - Signal sampling and equalization processing (discontinuous eye diagrams effect produced by integrated DFE)
    - Implemented to demonstrate technical feasibility and to correlate with system level simulations

# Eye diagram, -40 °C, 100 m

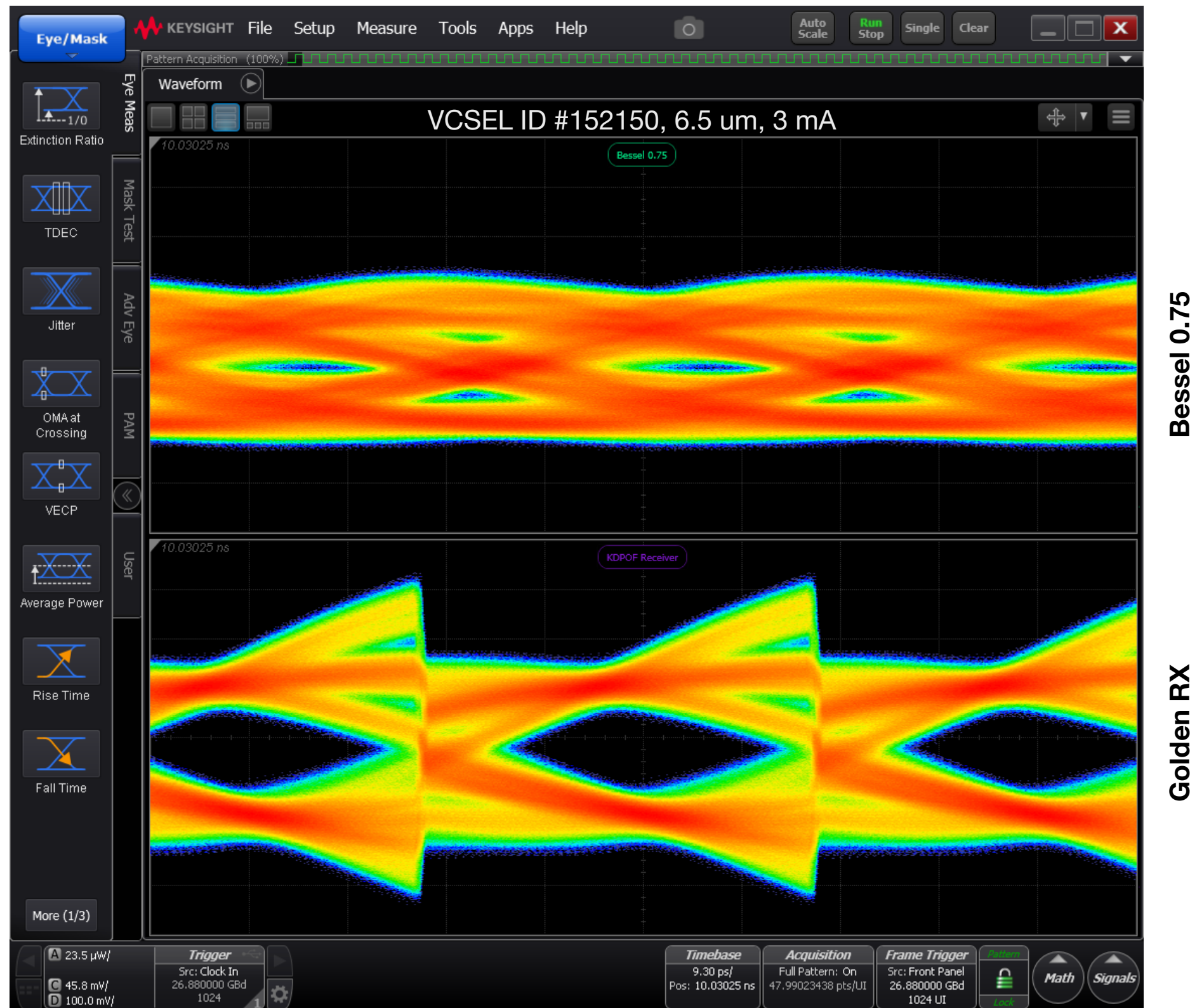


# Eye diagram, 25°C, 100 m





# Eye diagram, 125°C, 100 m



# Conclusions

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- 25 Gb/s transmission has been demonstrated in automotive temperature range (-40 to 125 °C), based on 850 nm InGaAs VCSEL and 100 meters of multimode OM3 glass optical cable designed for harsh environments
  - Transmission tests in 100 m gives a measure of the technical feasibility margin
- This contribution supports an objective of 25 Gb/s operation over glass optical fiber with reaches up to 40 m for automotive environments/applications.
- This contribution reinforces the technical feasibility of the project and supports the leveraging of currently in volume production fibers qualified to be used in harsh environments comparable to automotive requirements



Thank you