25 Gb/s transmission over harsh environment multimode fiber

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Introduction

- This contribution shows experimental results of 25 Gb/s transmission using InGaAs 25G VCSEL, between −40 ºC and +125 ºC, for different optical channels
- 25 Gb/s transmission is demonstrated with 15 m, 40 m, and 205 meters of optical fiber Corning MM50BI-XMT-H (GI glass fiber OM3)
- This contribution does NOT pursue including 200 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 characterized for the different length configurations
- VCSEL devices with different oxide aperture diameters are tested
  - See “perezaranda_OMEGA_02c_1119_InGaAs_25G_VCSEL.pdf”

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

Corning MM50BI-XMT characteristics

- Multimode bend insensitive optical fiber with mid-temperature acrylate-based coatings
- Applications: fiber sensing and data transmission with tight bend requirements and/or high bandwidth requirements

Key Optical Specifications	MM50BI-XMT and MM50BIH-XMT
Operating Wavelength (nm)	850, 1060, 1300
Maximum Attenuation (dB/km)	2.5 @ 850 nm 0.7 @ 1300 nm
Numerical Aperture	0.20 ± 0.015
Bandwidth (MHz-km)*	700 @ 850 nm 500 @ 1300 nm

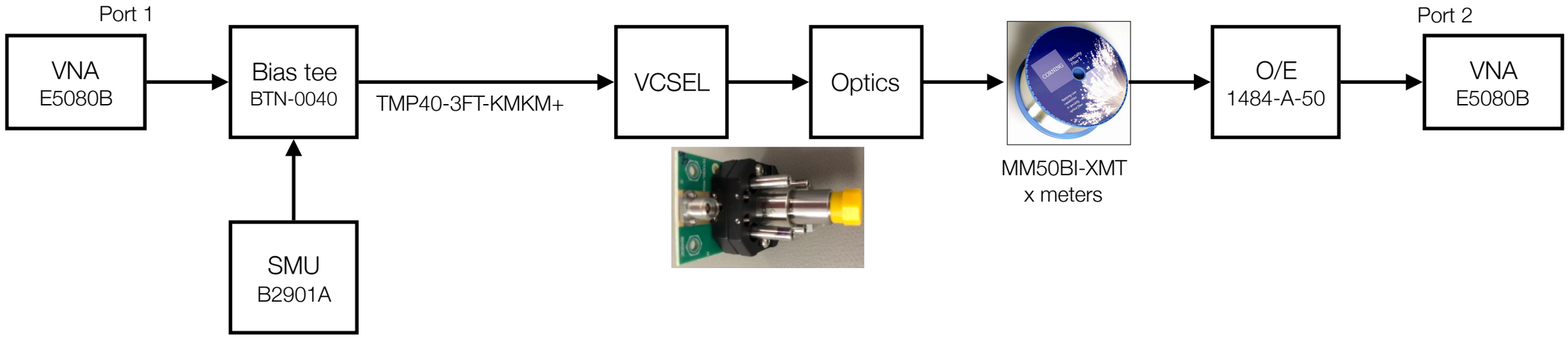
* Higher bandwidths available, contact Corning representative

Key Geometric, Mechanical, and Environmental Specifications

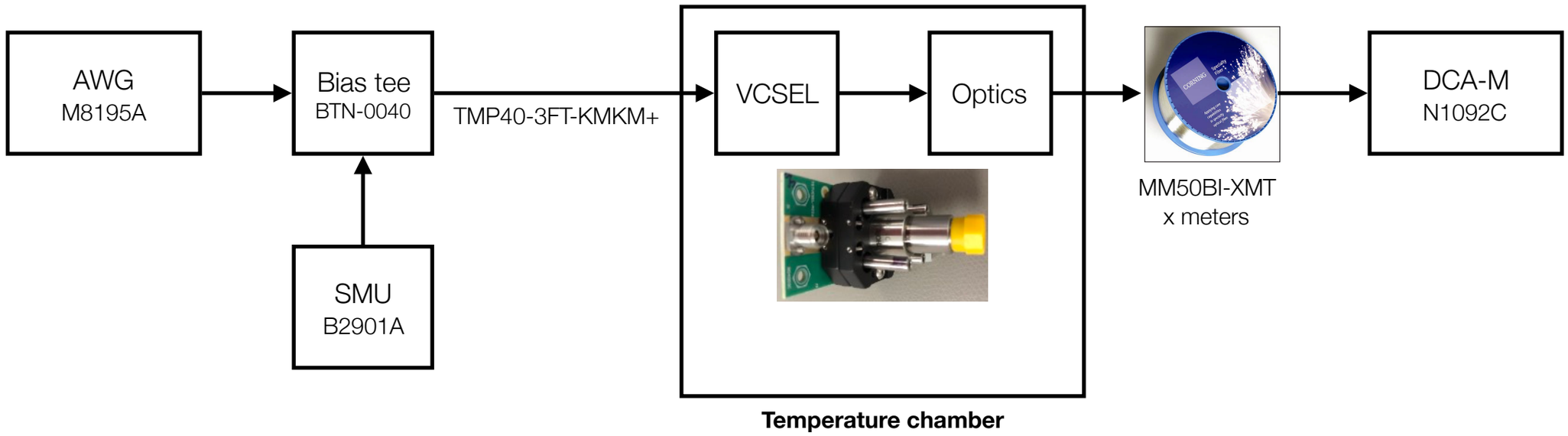
Core Diameter (µm)	50 ± 2.5
Cladding Outside Diameter (µm)	125 ± 2.0
Coating Outside Diameter (µm)	245 ± 10
Core-to-Cladding Concentricity (µm)	≤ 1.5
Proof Test (kpsi)	100 or 200
Operating Temperature (°C)	-60 to +180
Coating	Mid-Temperature Acrylate Optional Hermetic Layer

Tests setups

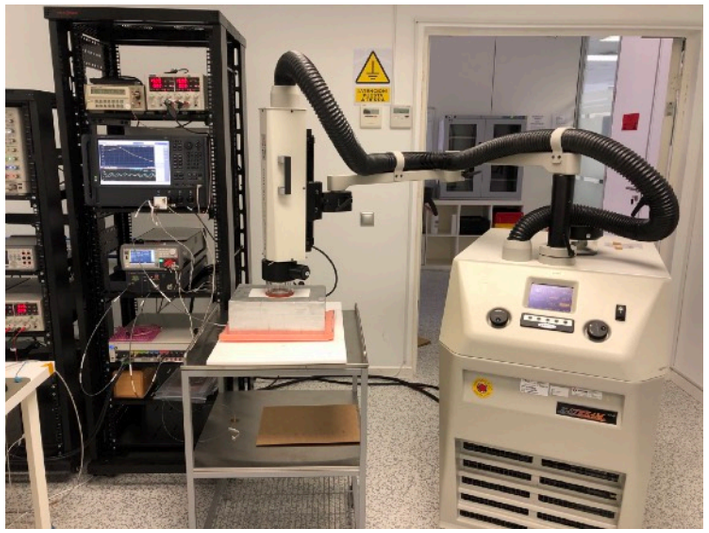
Setup for AC frequency response measurement

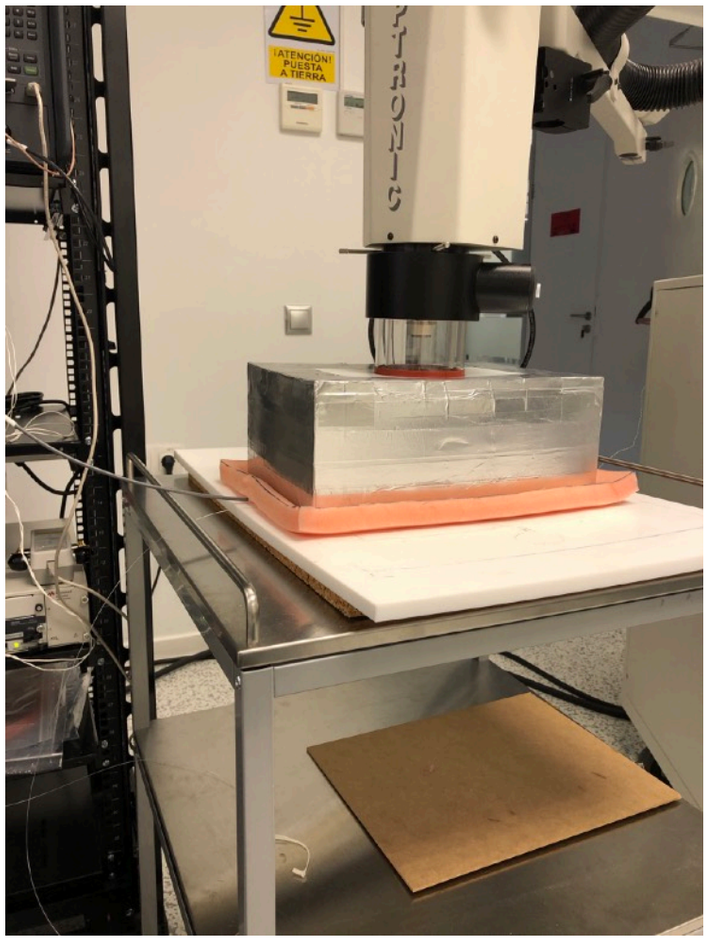


Setup for time-domain data transmission

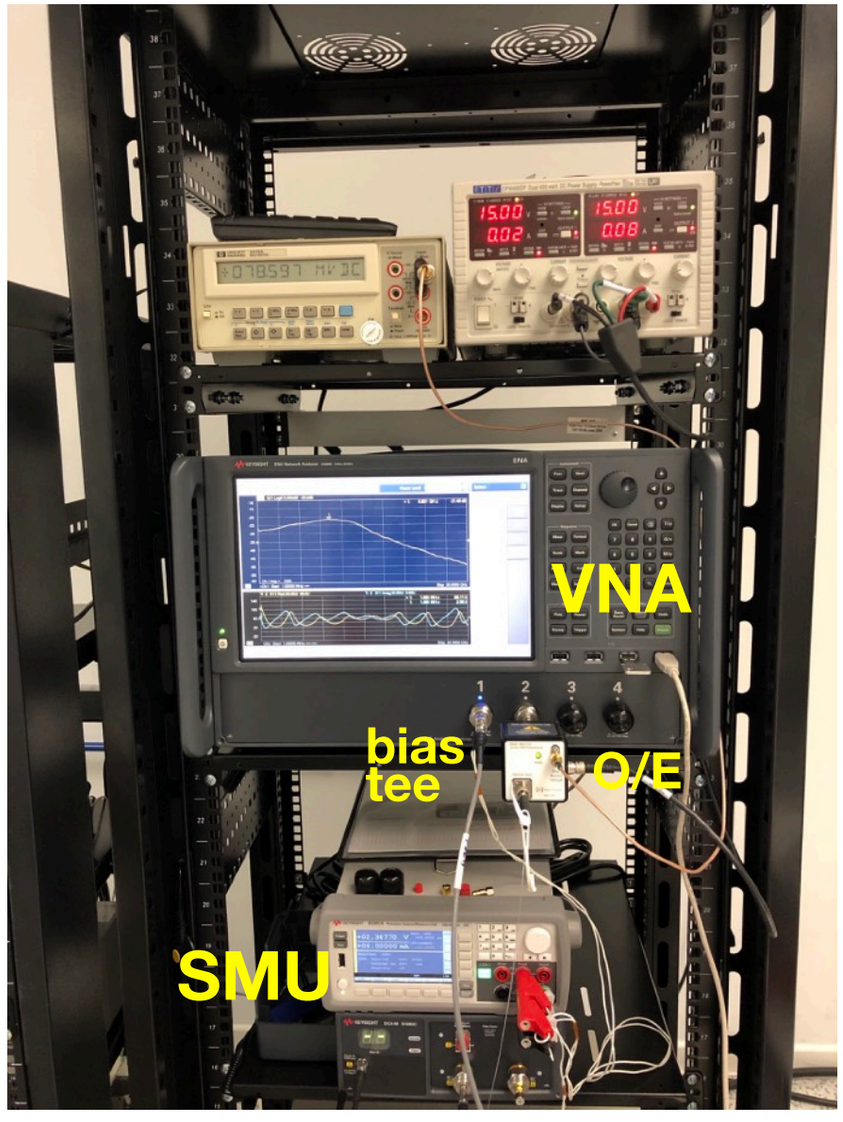


Tests setups





AC characterization

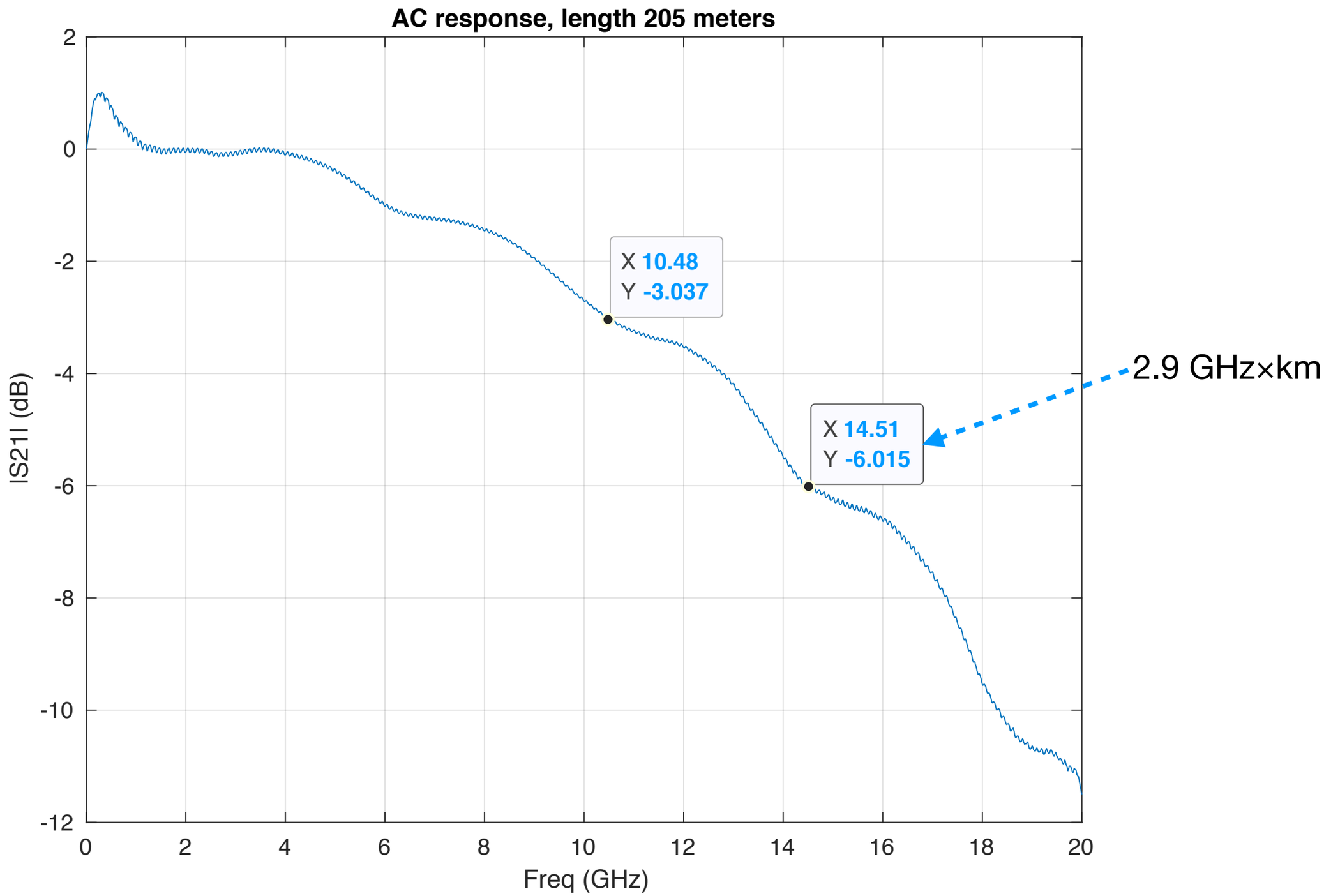


Time-domain
eye characterization

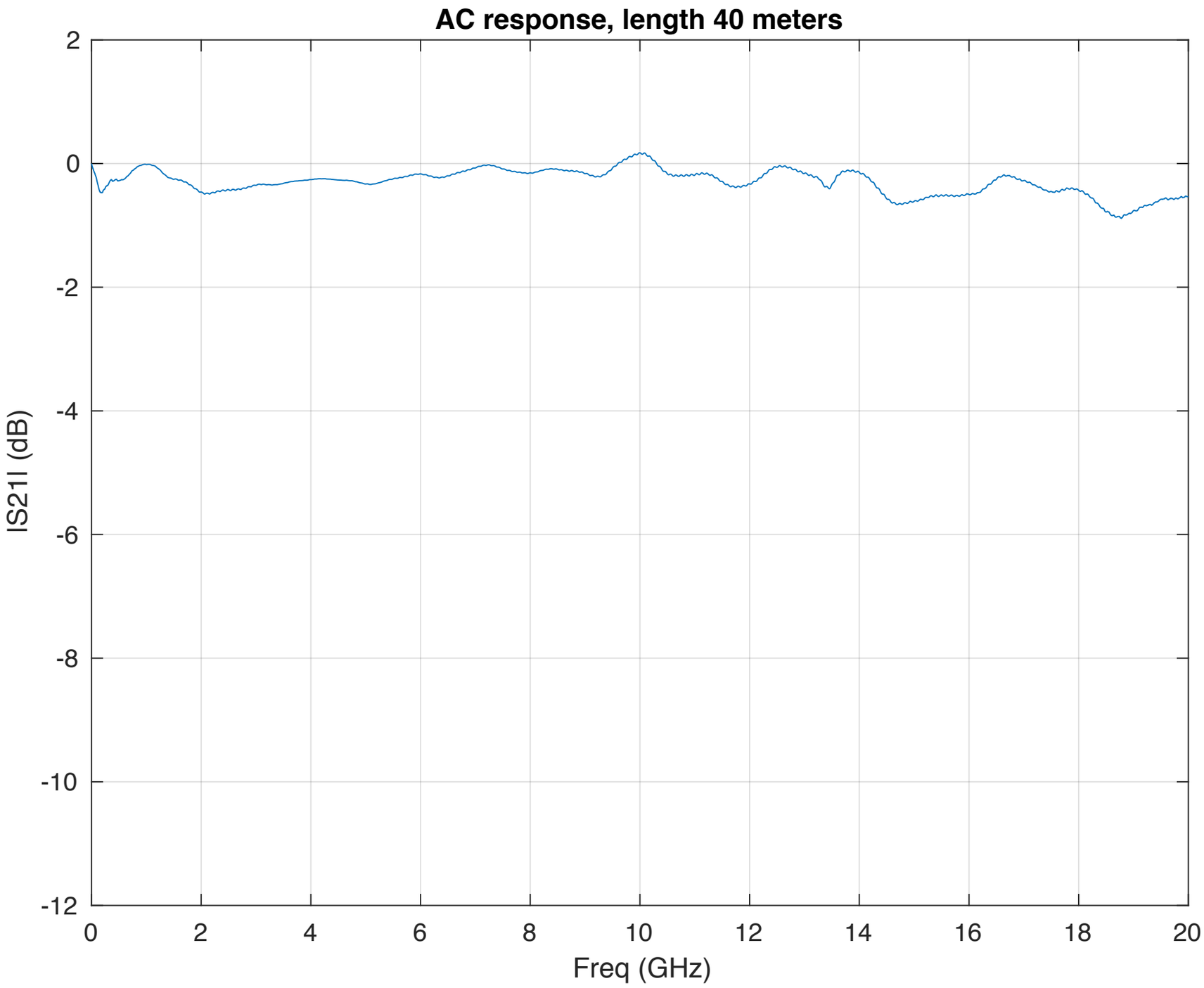
AC frequency response of optical channels

Room temperature measurements

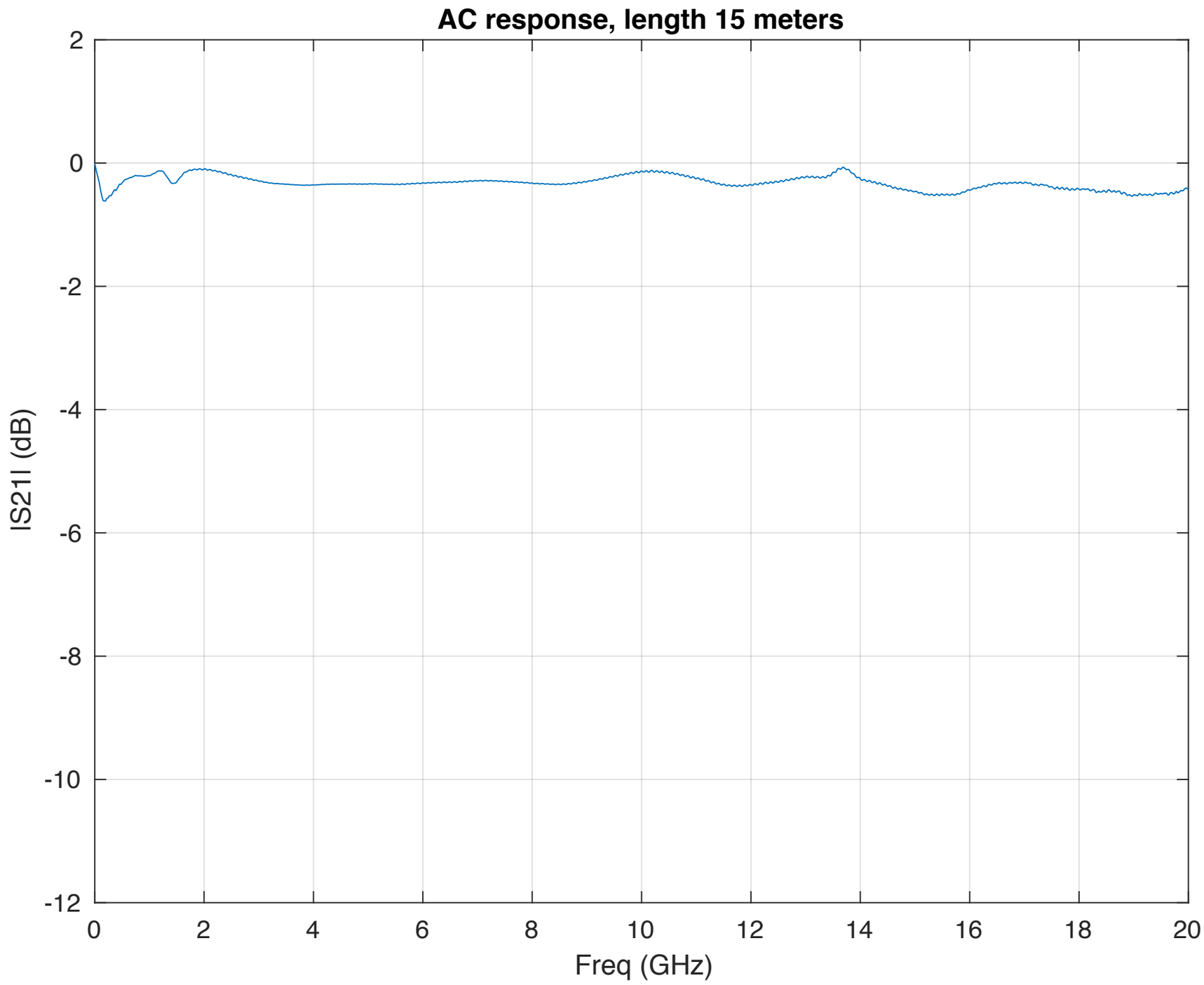
AC frequency response — 205 meters



AC frequency response — 40 meters



AC frequency response — 15 meters



25 Gb/s experiments

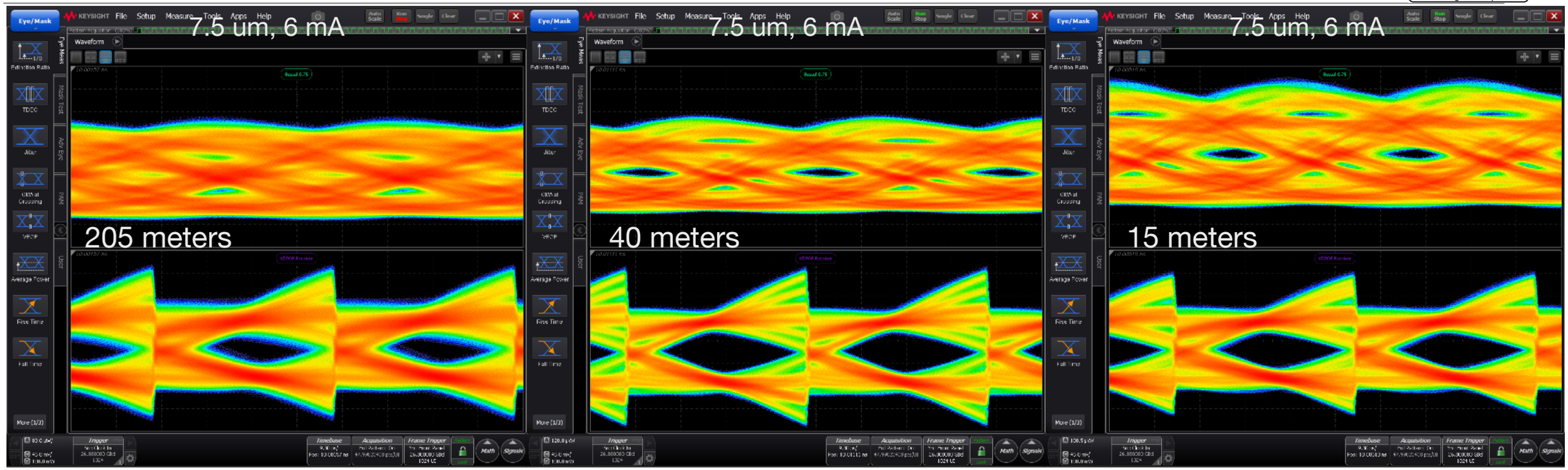
Eye diagram, 25 Gbps

- 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 = 125ºC are limited to ~9 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 BW_{-3dB} = 39.8 GHz (SIRC)
  - Trace 1: signal is filtered with Bessel 4th with BW_{-3dB} = 0.75 x 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

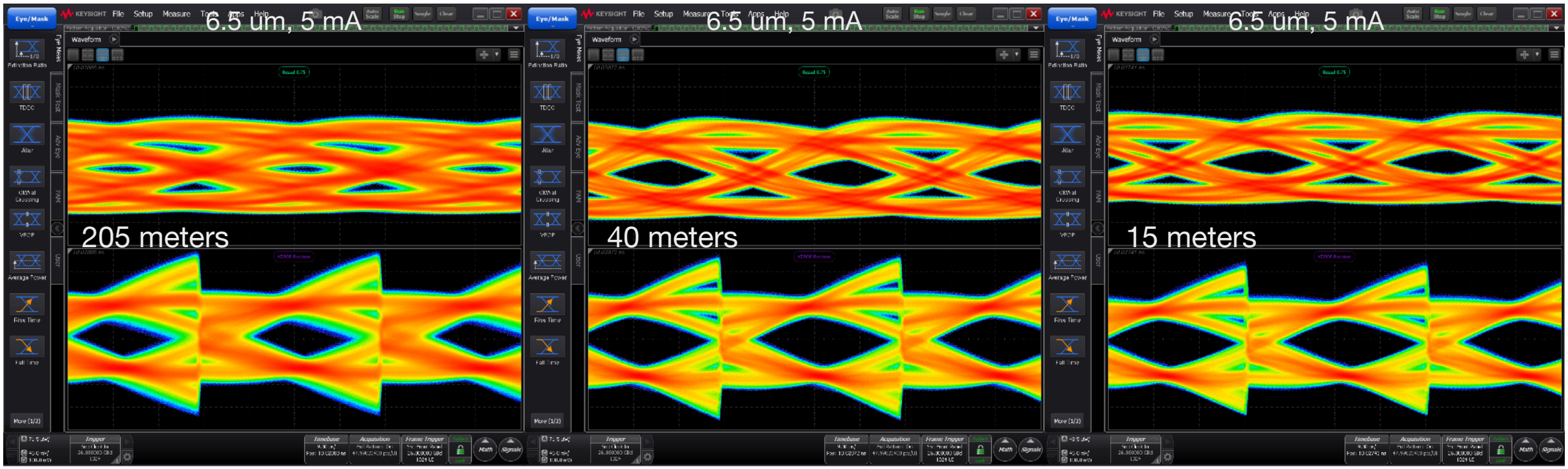
Bessel 0.75

Golden RX



Bessel 0.75

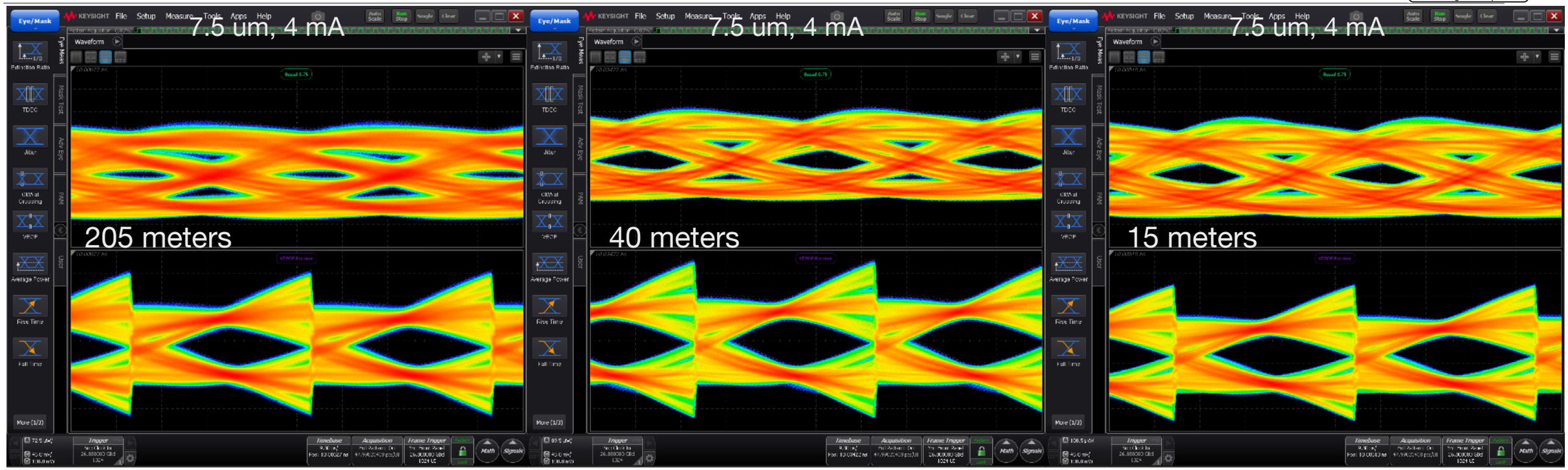
Golden RX



Eye diagram, 25°C

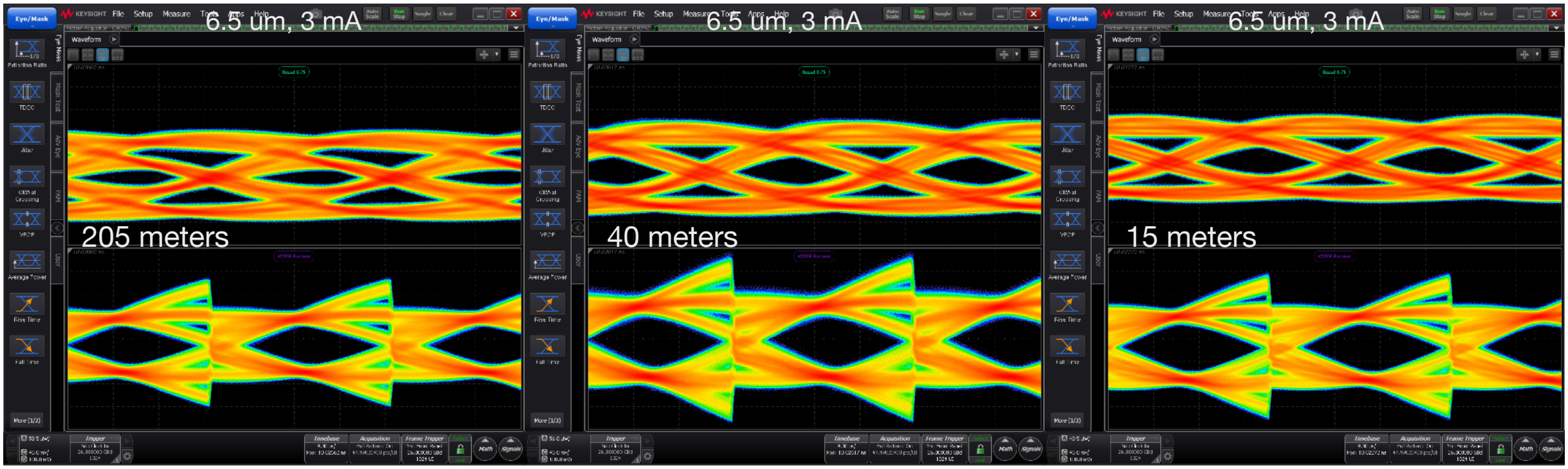
Bessel 0.75

Golden RX



Bessel 0.75

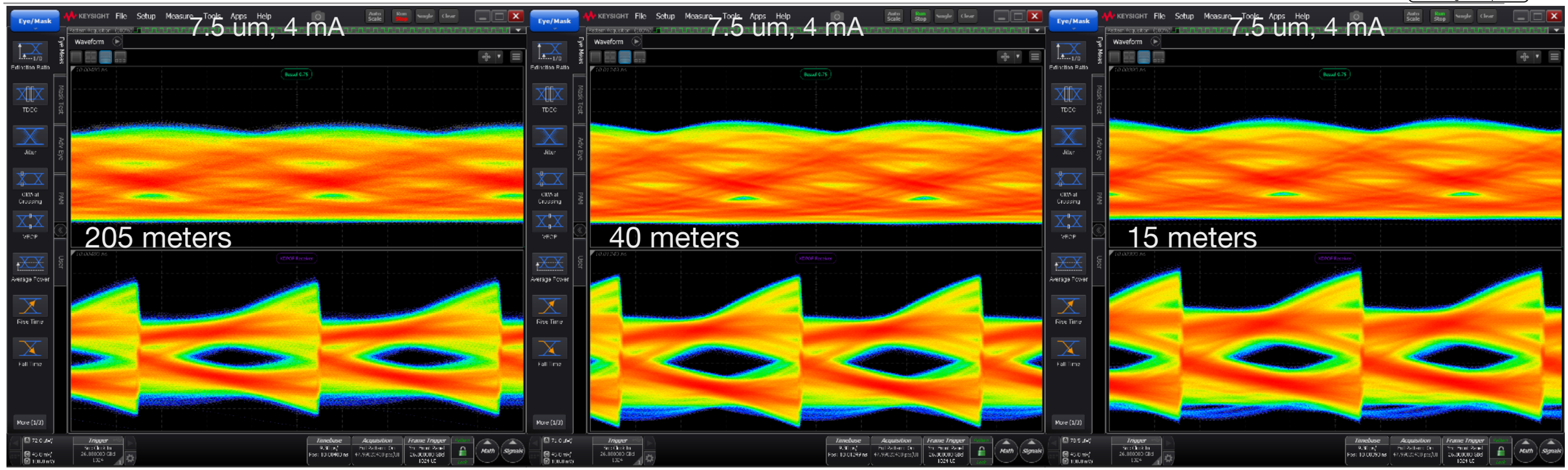
Golden RX



Eye diagram, 125°C

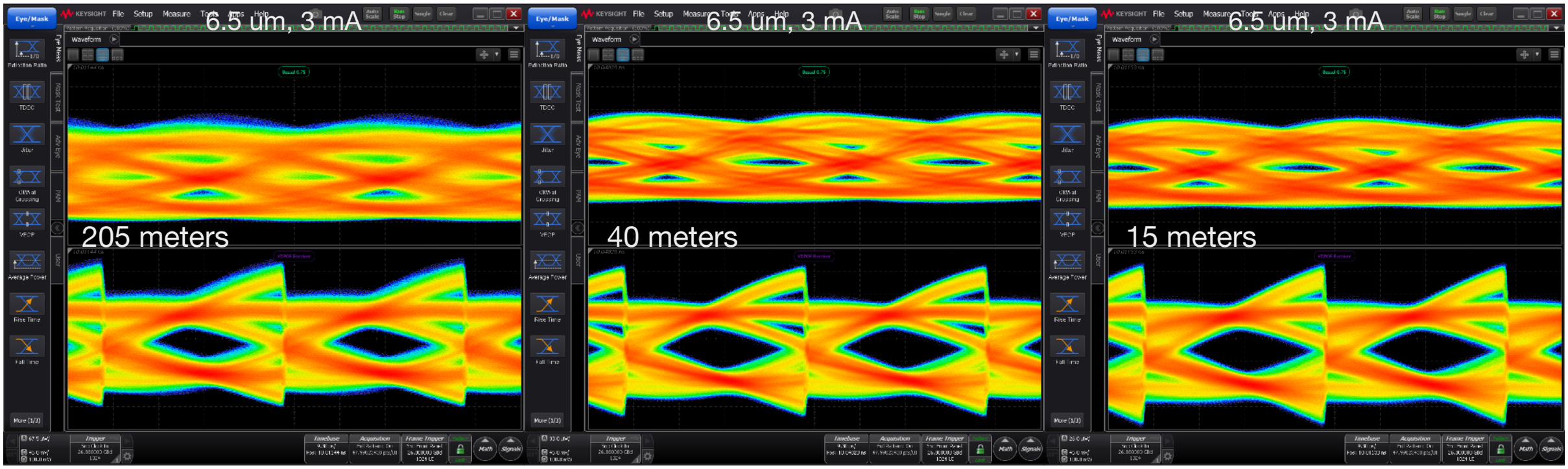
Bessel 0.75

Golden RX



Bessel 0.75

Golden RX



Conclusions

- 25 Gb/s transmission has been demonstrated in automotive temperature range (-40 to 125 ºC), based on 850 nm InGaAs VCSEL and 15 an 40 meters of multimode glass optical fiber for data transmission with tight bend requirements and/or high bandwidth requirements for harsh environment applications
  - Transmission test was also satisfactory in 200 meters length, which demonstrates the technical feasibility margin
- 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