GaAs 14G VCSEL characterization for automotive applications

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Introduction

- GaAs 14G VCSEL (TRUMPF VCSEL-ULM850-14G-Gen3-V0) has been characterized in wide range of temperatures, between —40 ºC and +125 ºC, to assess the suitability for automotive applications
- Different oxide aperture diameters have been tested to analyze the parametric deviation due to production process variations
  - Corners: 8.7 um (high I_{TH}, slower) and 6.5 um (low I_{TH}, faster)
  - Devices with different oxide aperture diameters will experience different current density, therefore different aging acceleration, under the same current driving condition
- Characterization of 3 samples per corner is reported
- Temperature is measured in the bottom side of the PCB where the VCSEL is connected, with low thermal resistance vias connected to the top GND plane where VCSEL is attached
  - Temperature reported is substrate temperature: -40, 0, +25, +85, +105, +125 ºC
  - Junction temperature is expected to be higher due to (I·V - Po) and high thermal resistance of GaAs
- CPWG (co-planar waveguide with lower ground plane) high speed topology is used to connect coax cable 2.92 mm connector to VCSEL under test with good signal integrity

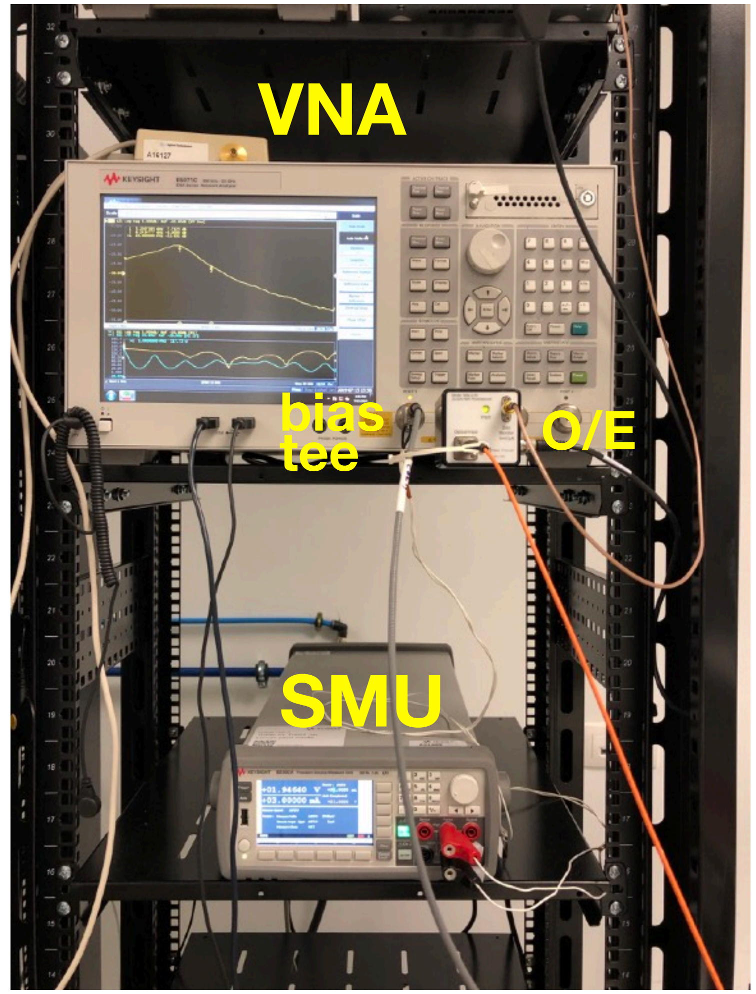
Equipment & Software

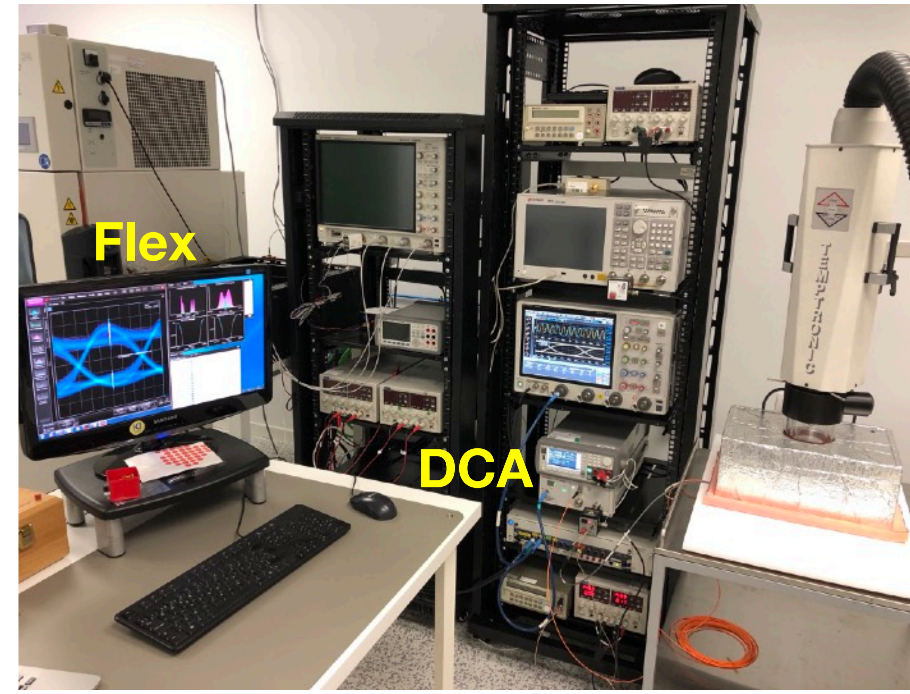
- Marki Microwave BTN-0040 bias tee (40 kHz to 40 GHz)
  - Used to combine bias current with RF signal from VNA or AWG
- Minicircuits TMP40-3FT-KMKM+, temperature stable 2.92mm cable, 40.0 GHz
  - Used to connect bias tee output to the DUT
- Newport 1484-A-50 fiber-optic multimode receiver, 800-865nm GaAs detector, 22 GHz, FC/PC
  - Used for S21 response measurement with VNA
  - Calibration provided for response de-embedding
- Keysight E5071C ENA Vector Network Analyzer
  - S21 magnitude response
  - Z11 real/imag reflect response
  - 2001 points linear sweep from 1 MHz to 20 GHz
  - Power -20 dBm
- Keysight B2901A Precision Source/Measure Unit
  - Bias current to VCSEL
  - Voltage drop measurement (V-I curve)
- Optokon OFT-820
  - Absolute optical power, calibrated for 850 nm

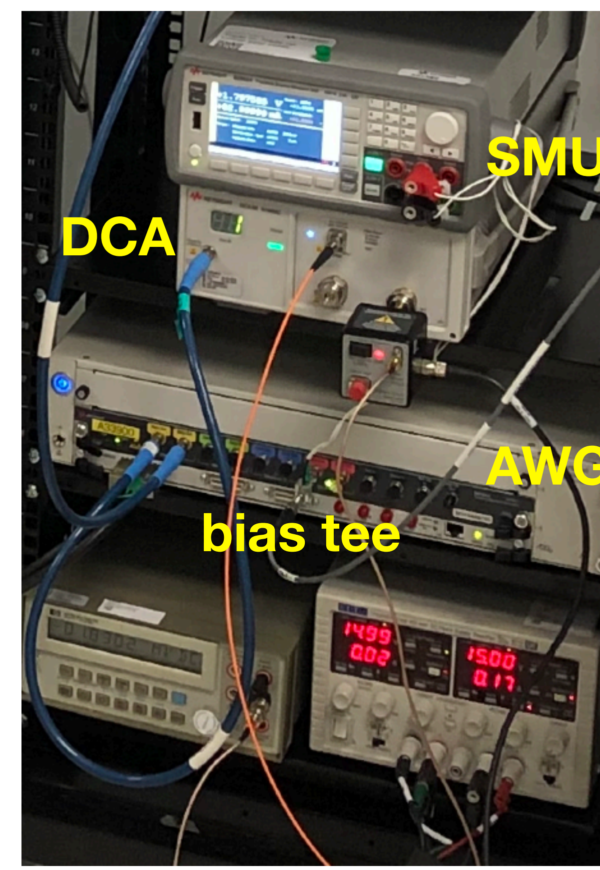
Equipment & Software

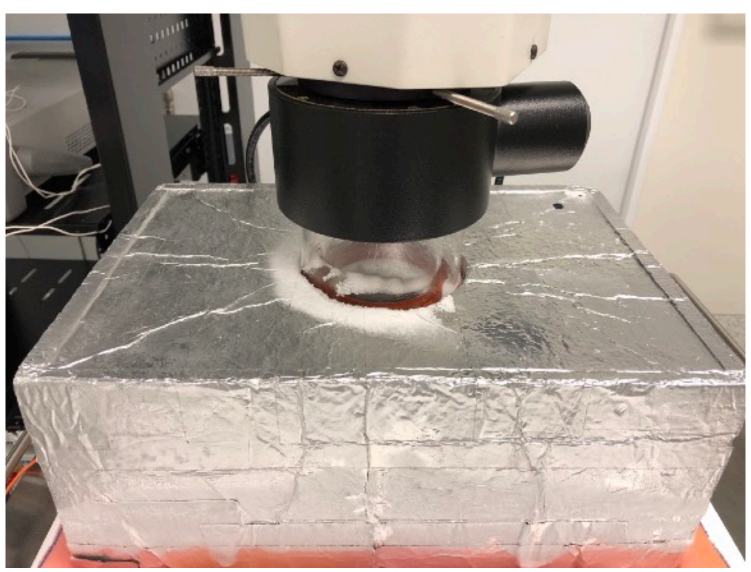
- Thorlabs FP1000URT 1 mm core multi-mode SI 0.50 NA glass fiber with Ø5.0 mm stainless steel tubing FT05SS
  - Used to collect full optical radiation from VCSEL (L-I curve)
- OFS C26133 2.2 mm simplex 62.5/200/230 GiHCS Cable, 3 meters
  - Used for AC and time-domain characterization
- Keysight M8195A 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
  - Model extraction
  - User operator extensions for N1010A

Tests setups

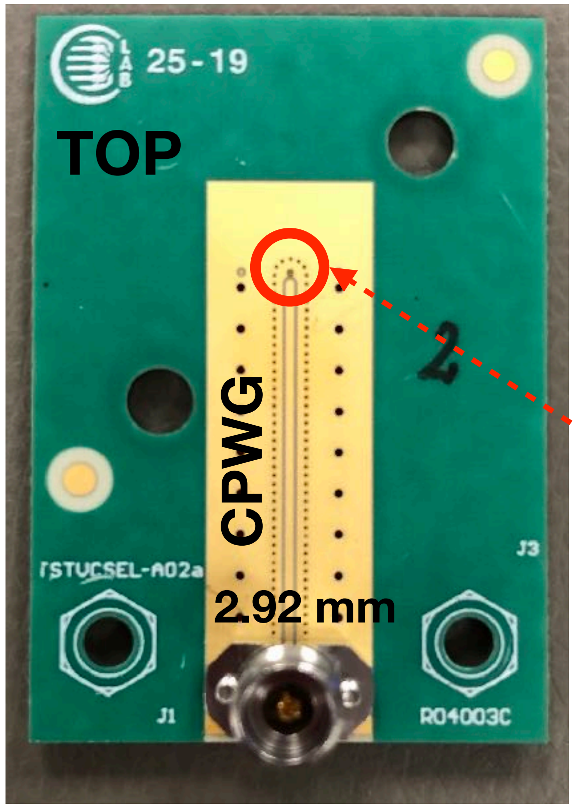




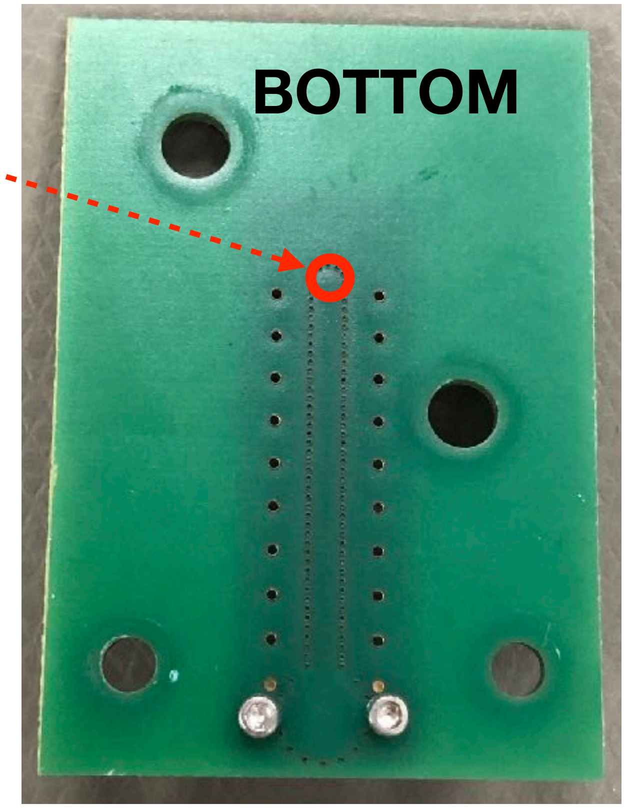




DUT

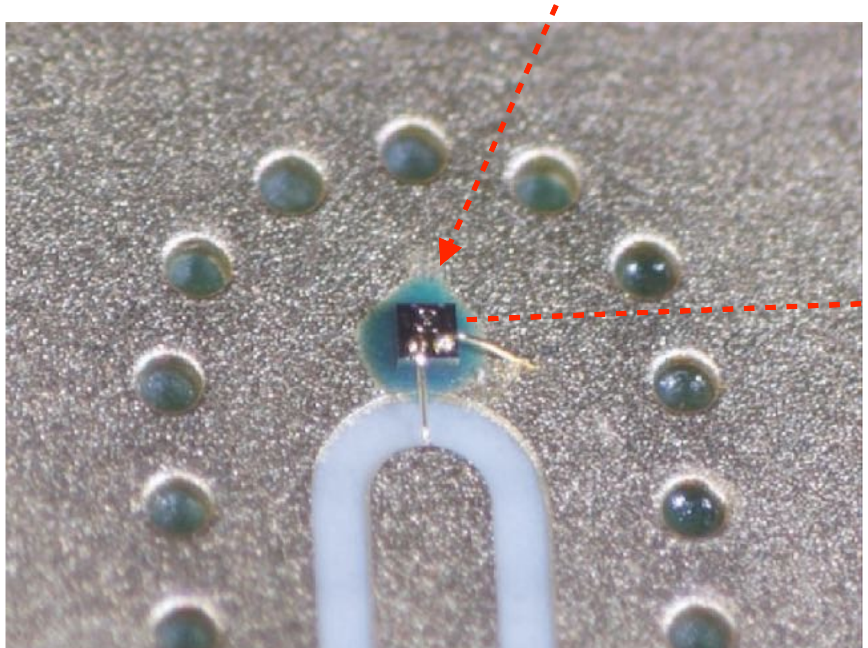


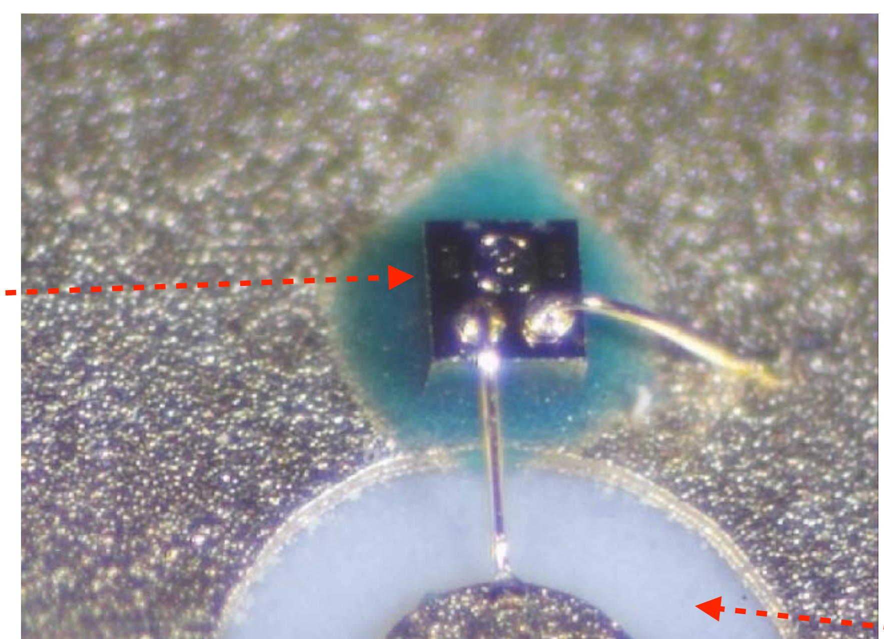
Thermo-couple attachment point

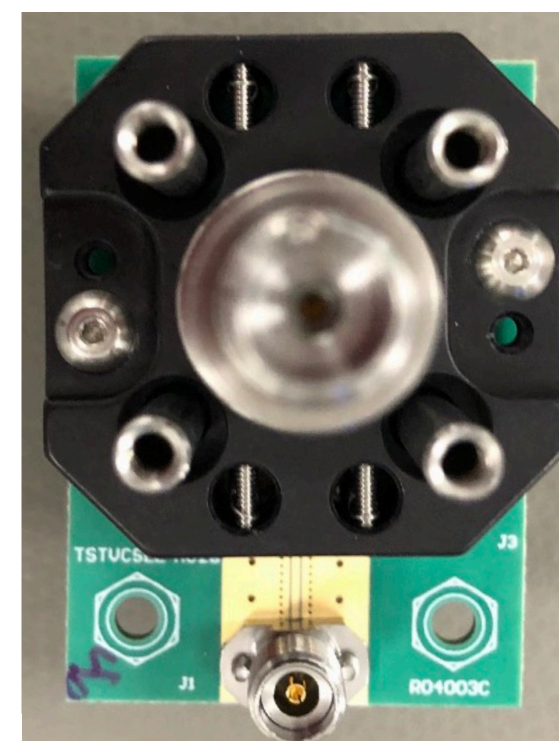


X-Y adjustable collimator with FC connector

VCSEL

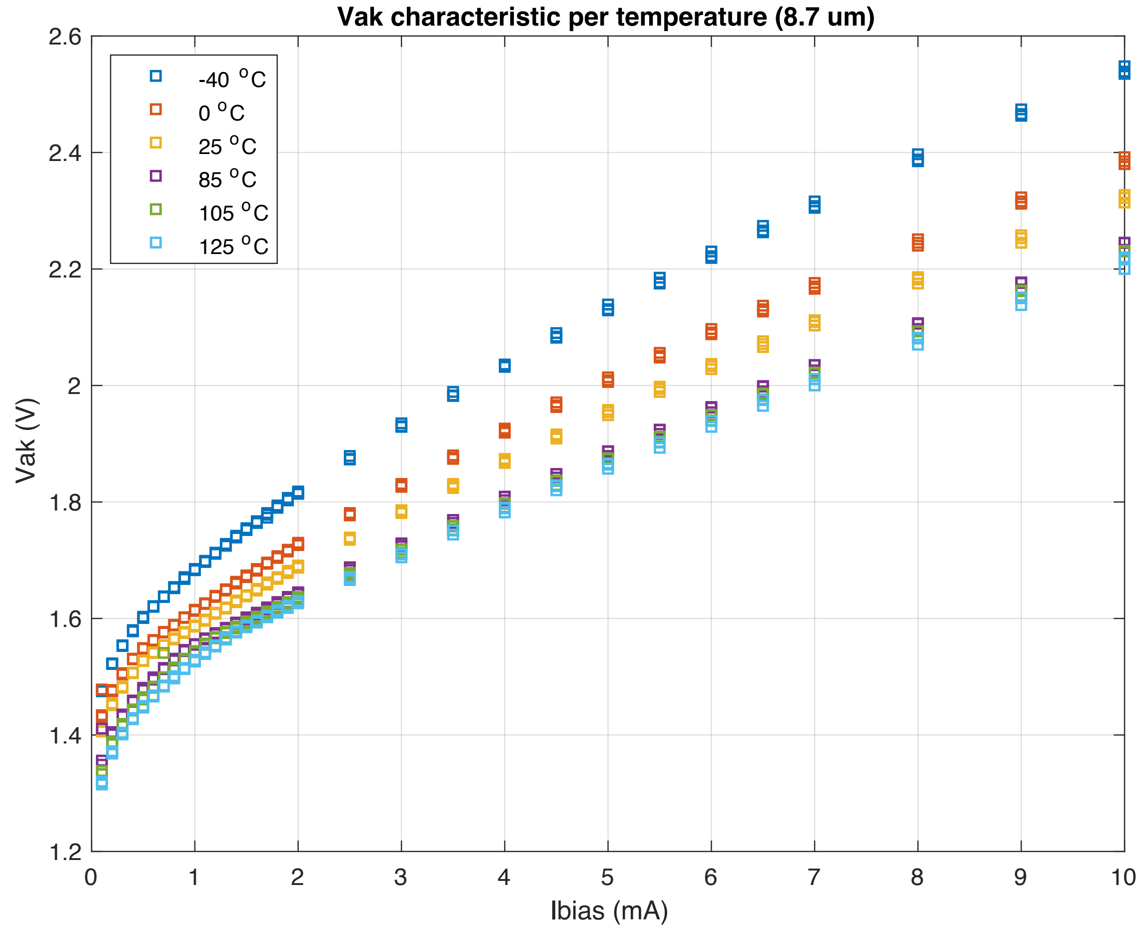


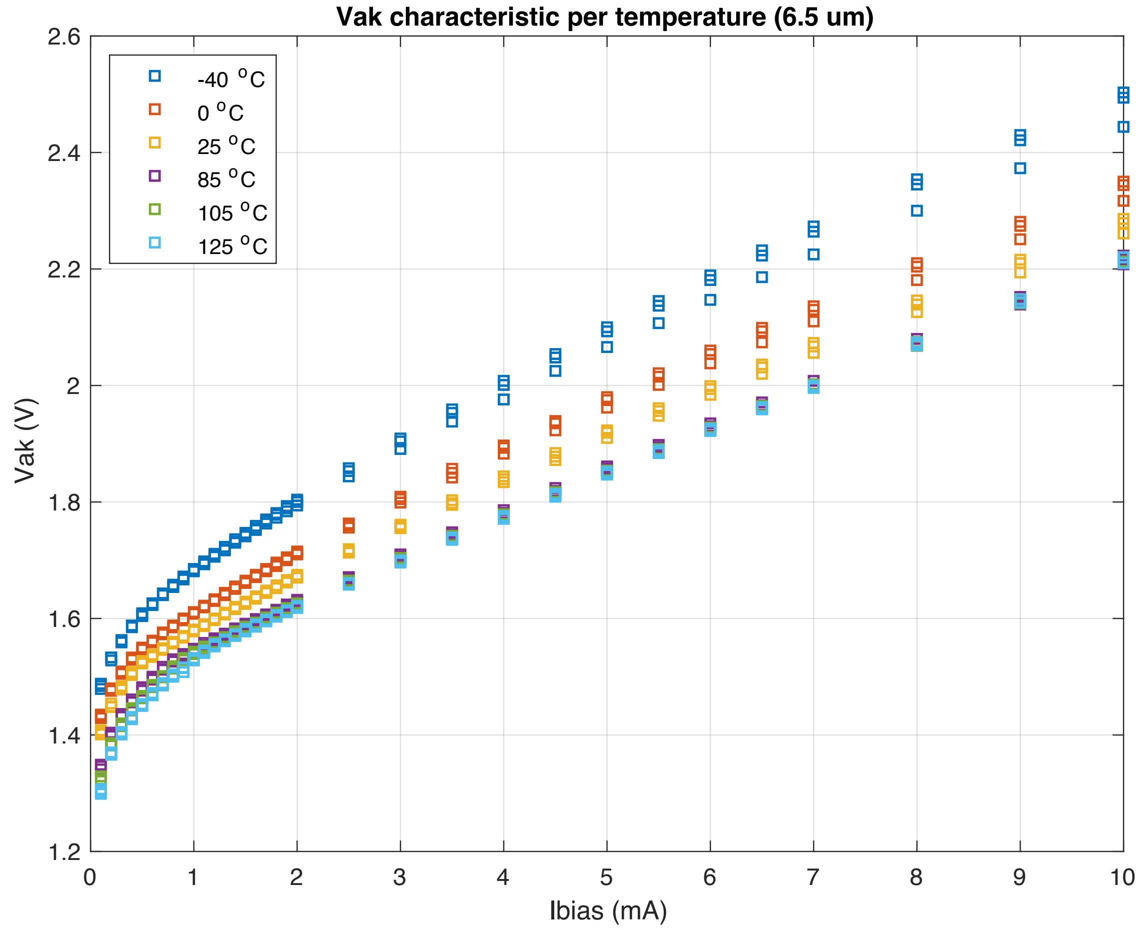




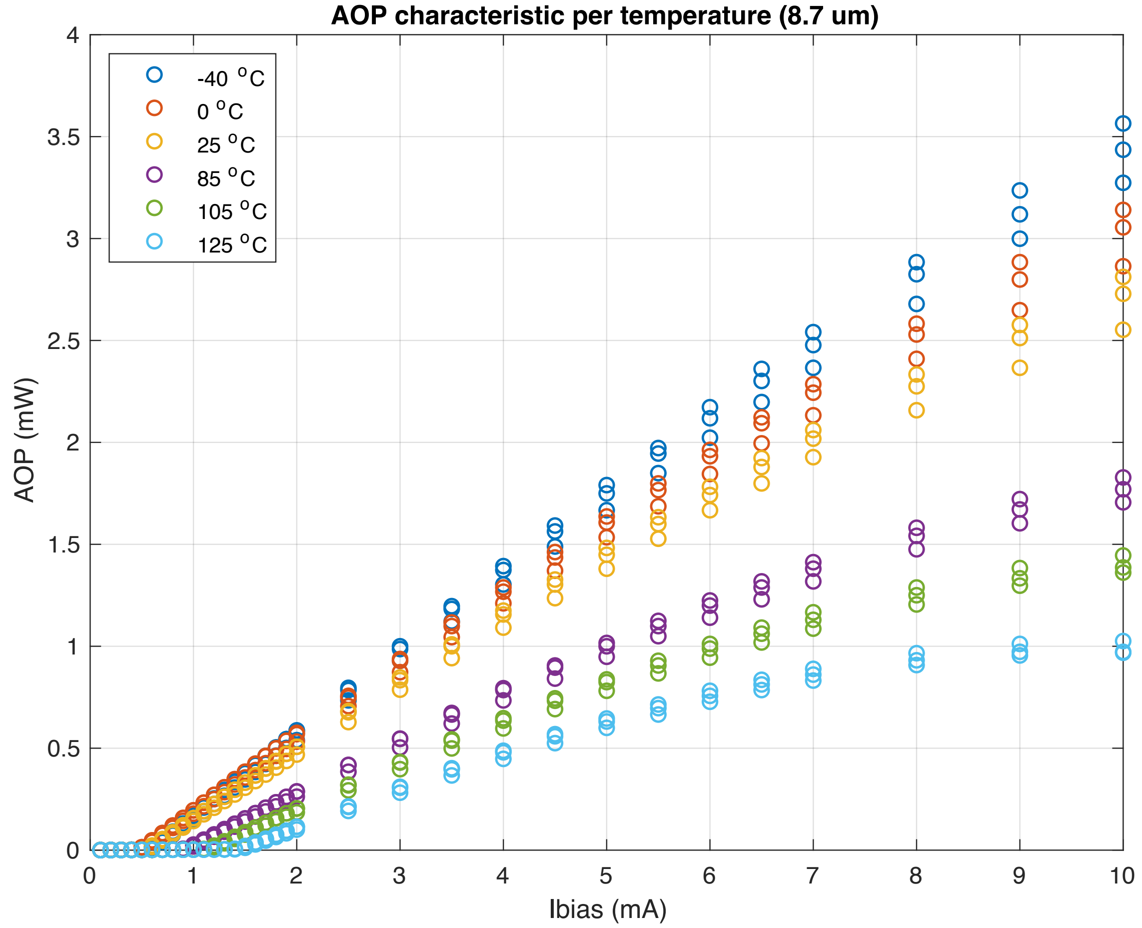
Rogers dielectric

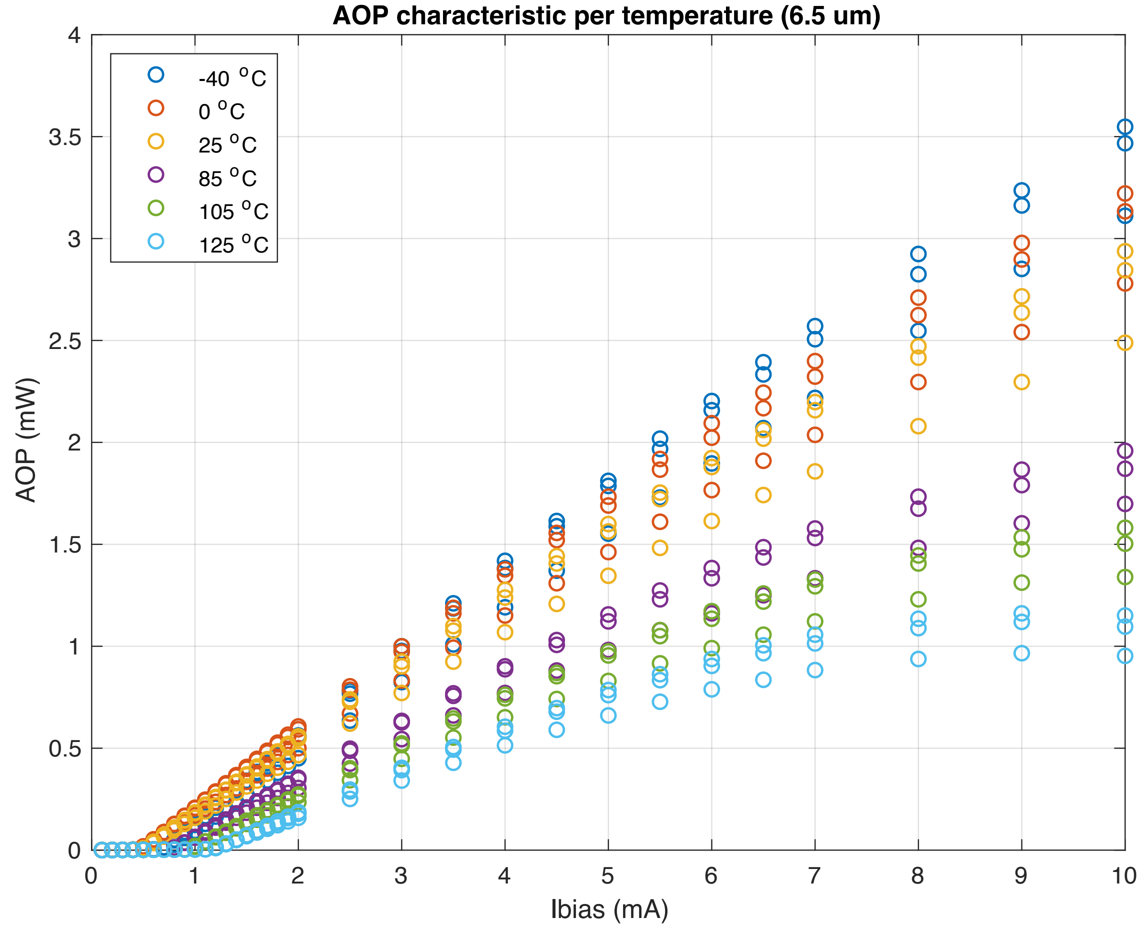
I-V characteristic



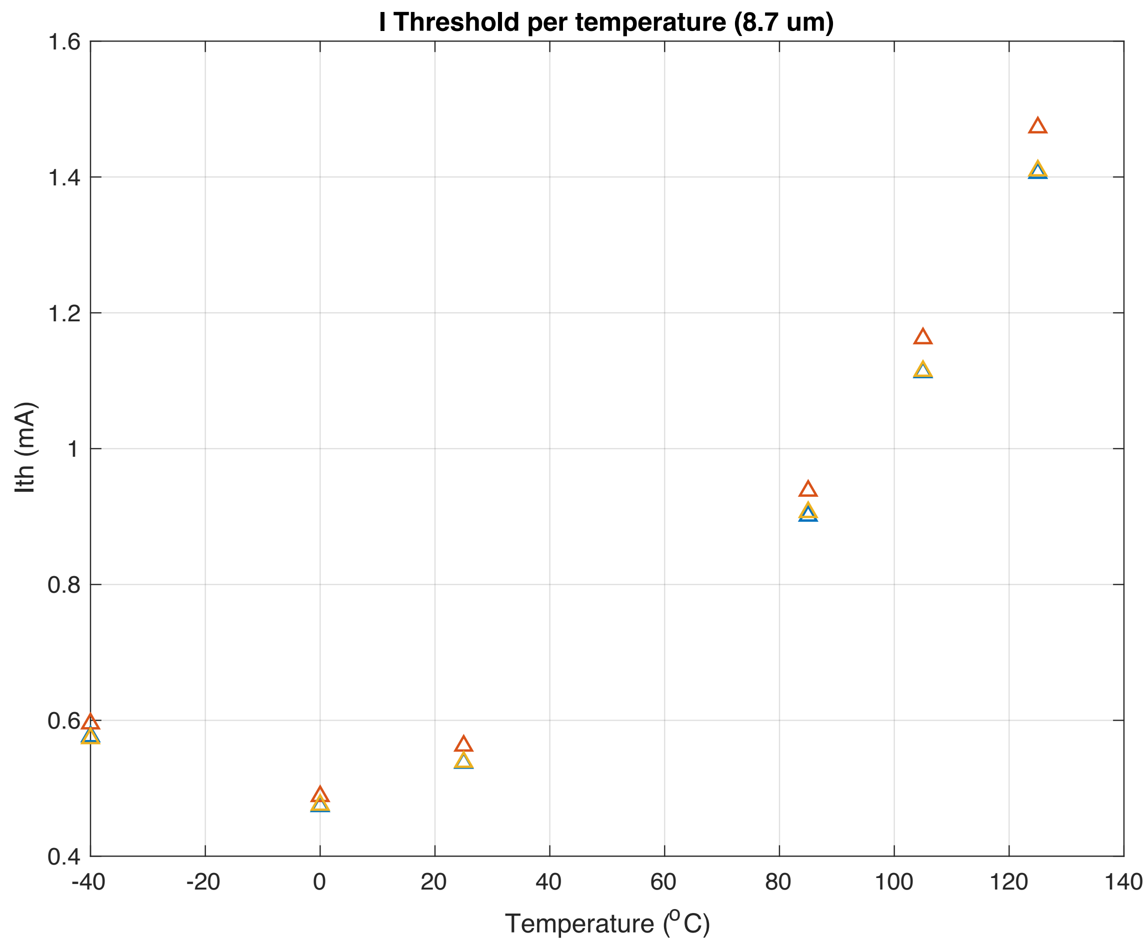


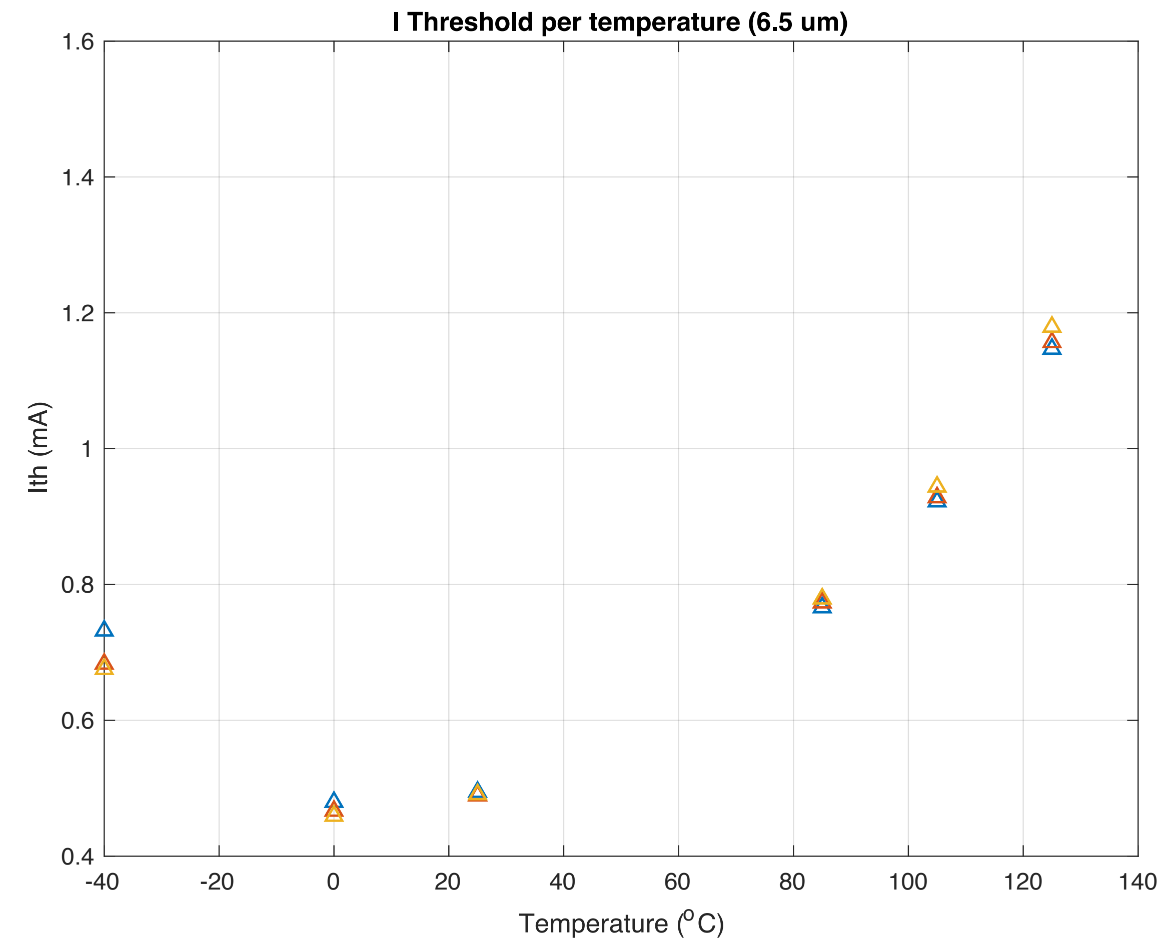
L-I characteristic



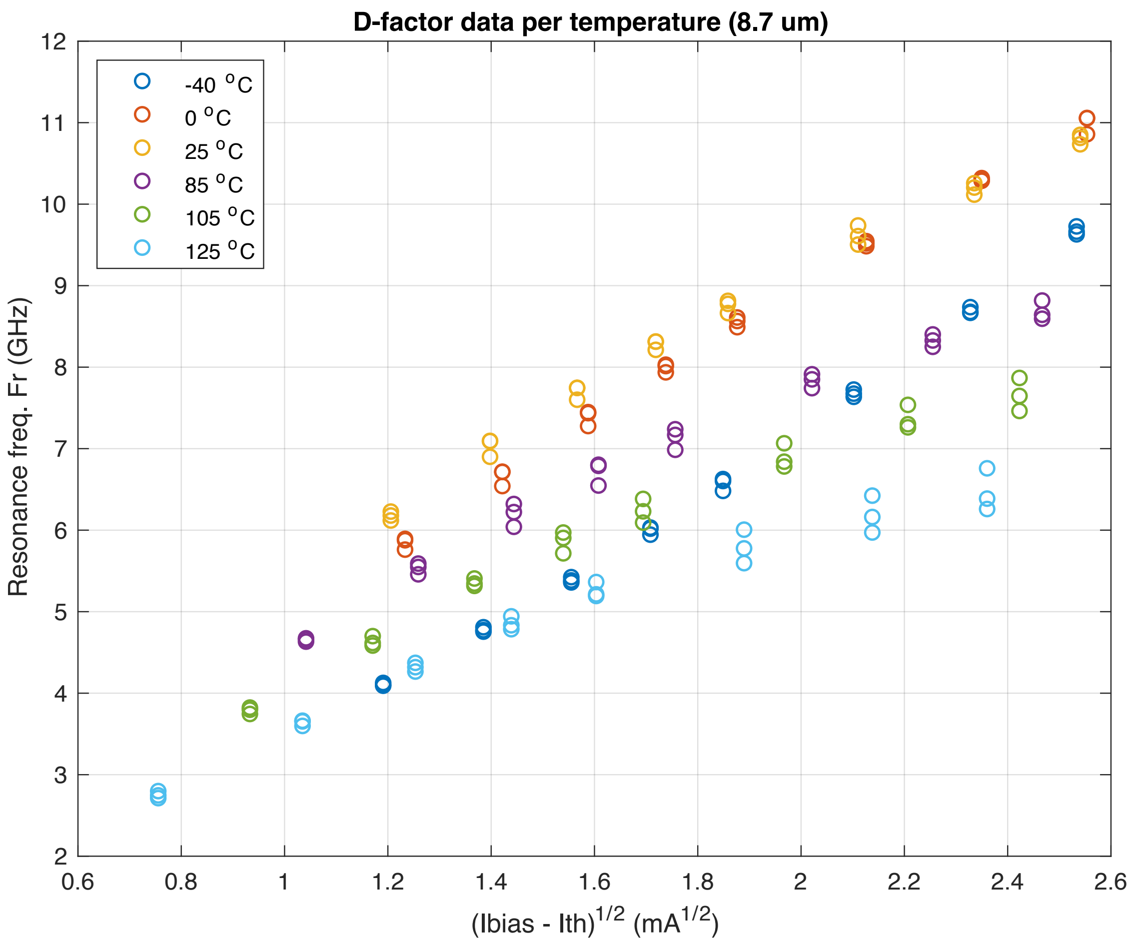


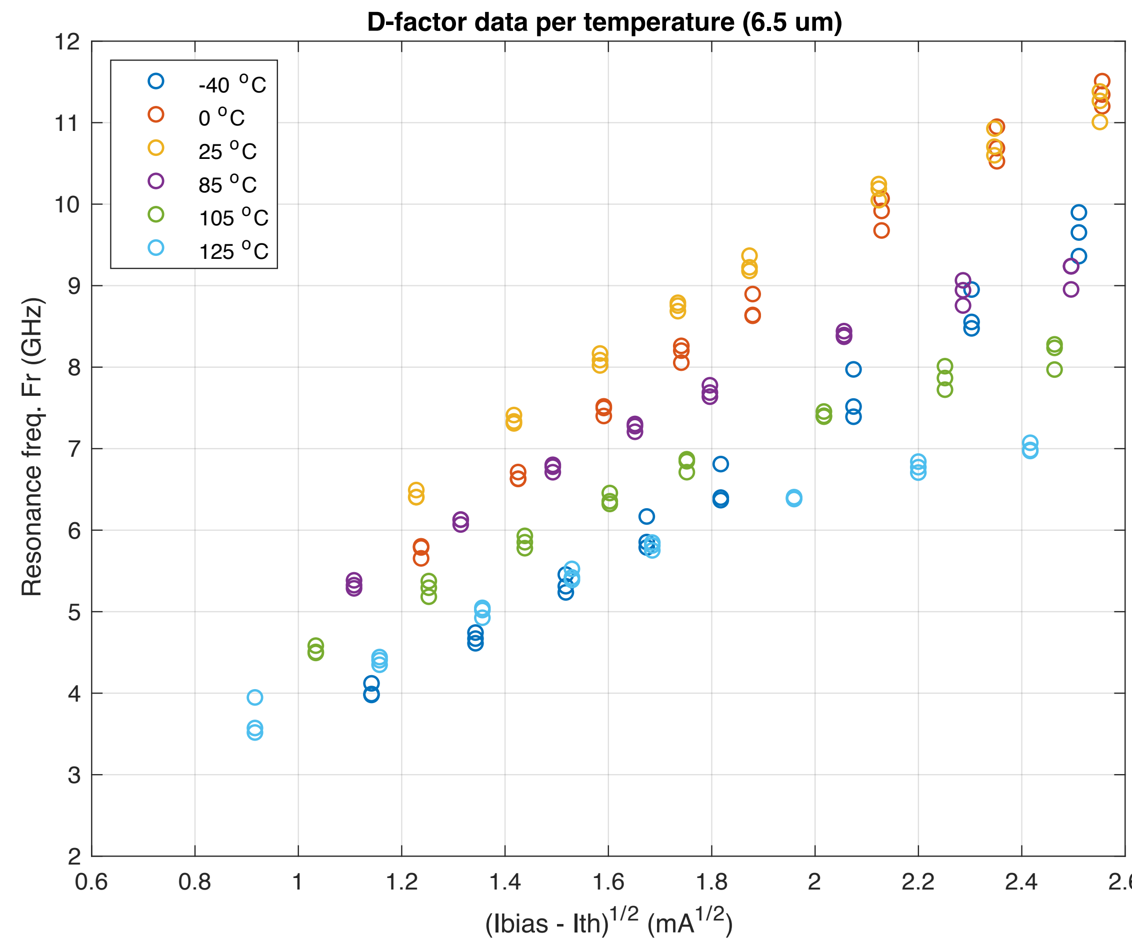
I threshold characteristic





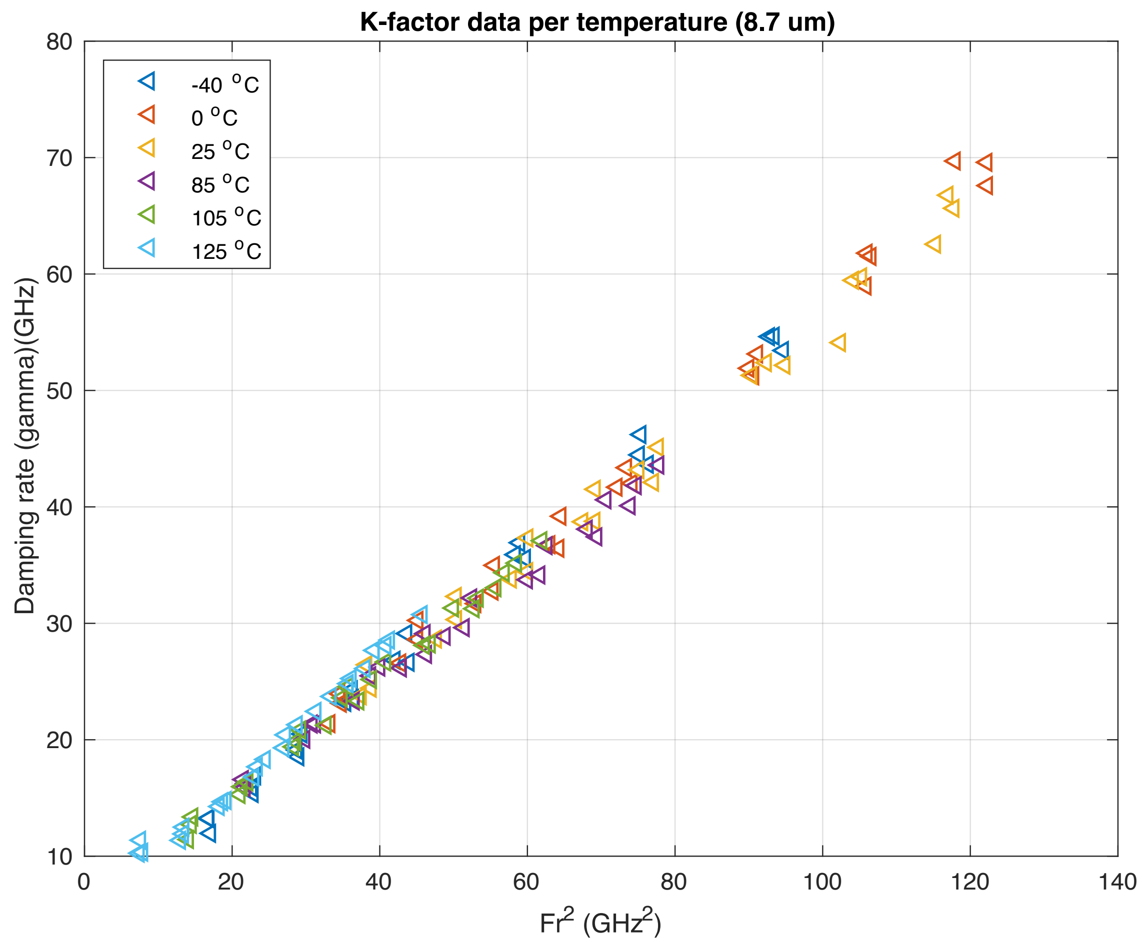
Resonance frequency characteristic

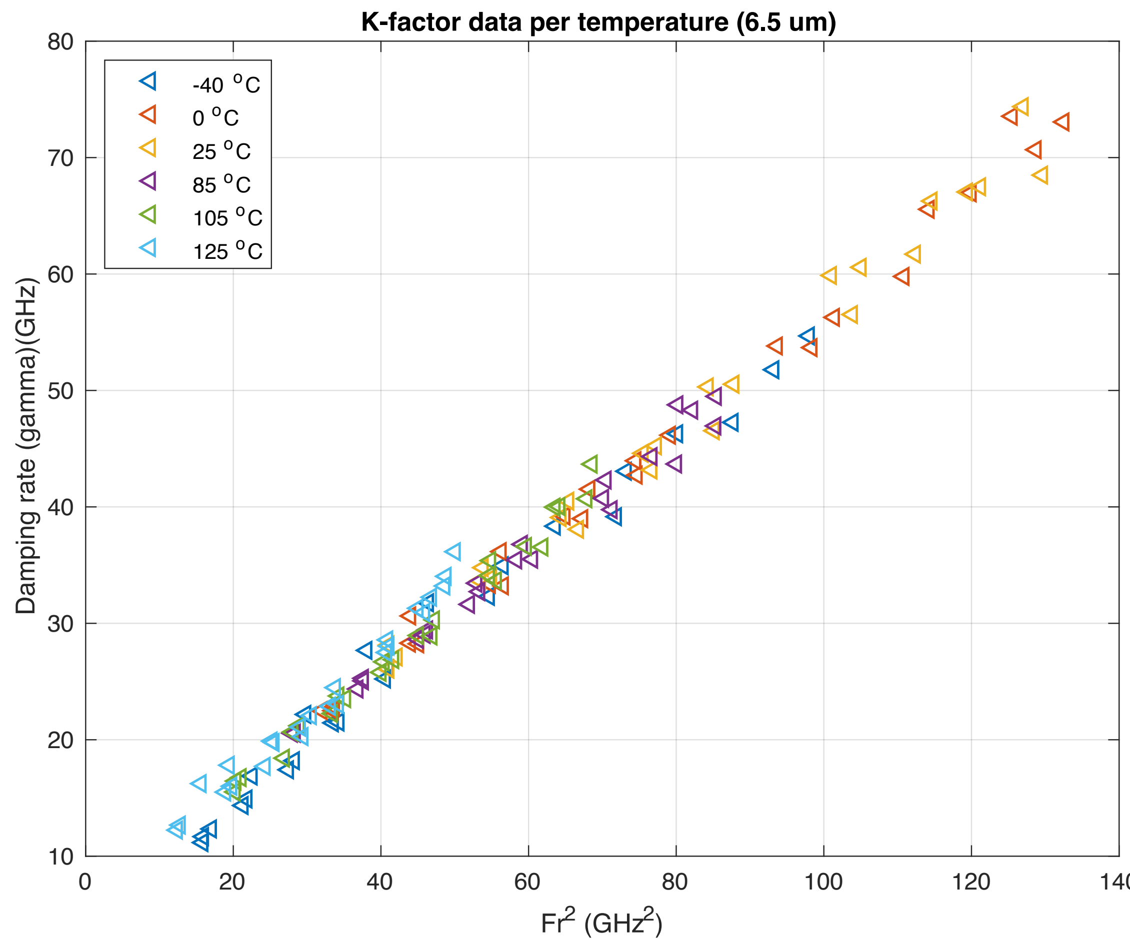




$$H(f) = C \cdot \frac{f_r^2}{f_r^2 - f^2 + j\frac{f}{2\pi}\gamma} \cdot \frac{1}{1 + j\frac{f}{f_p}}.$$

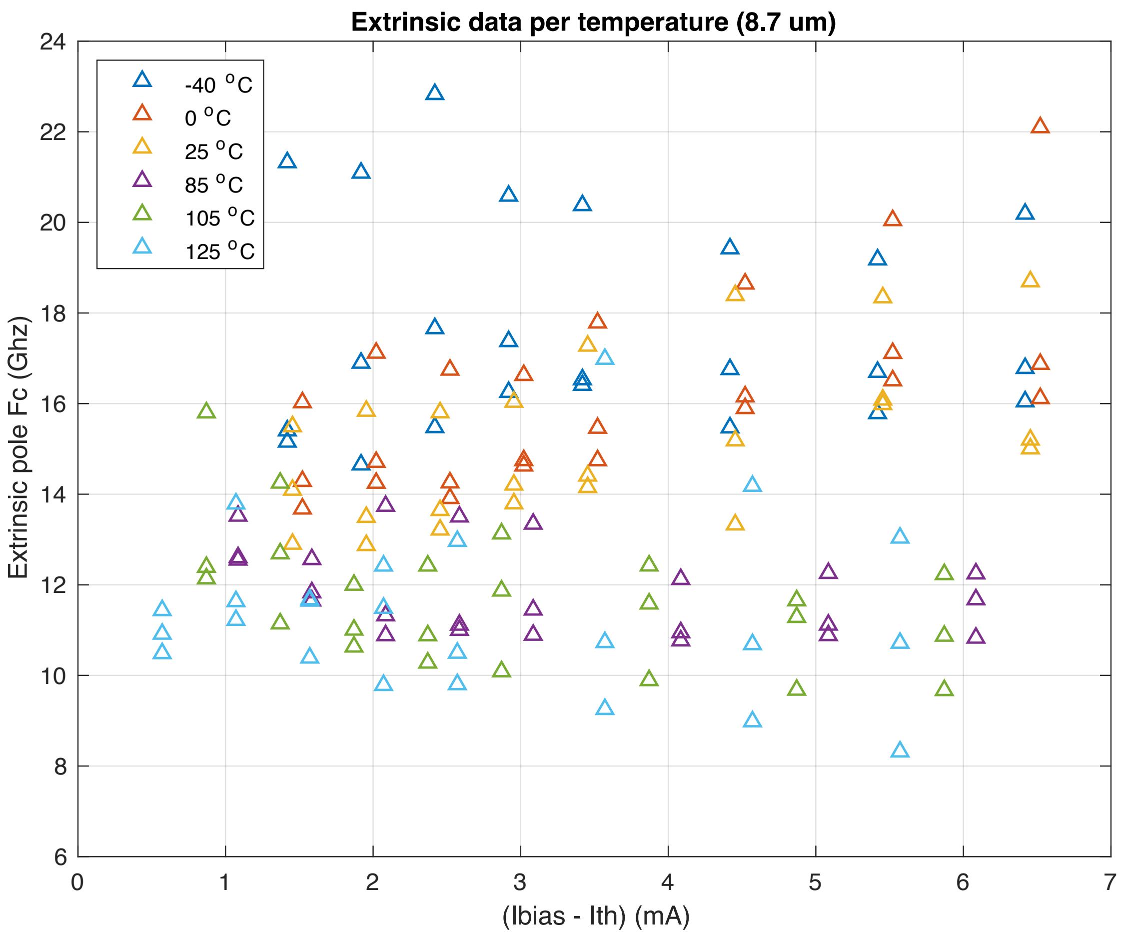
Damping rate characteristic

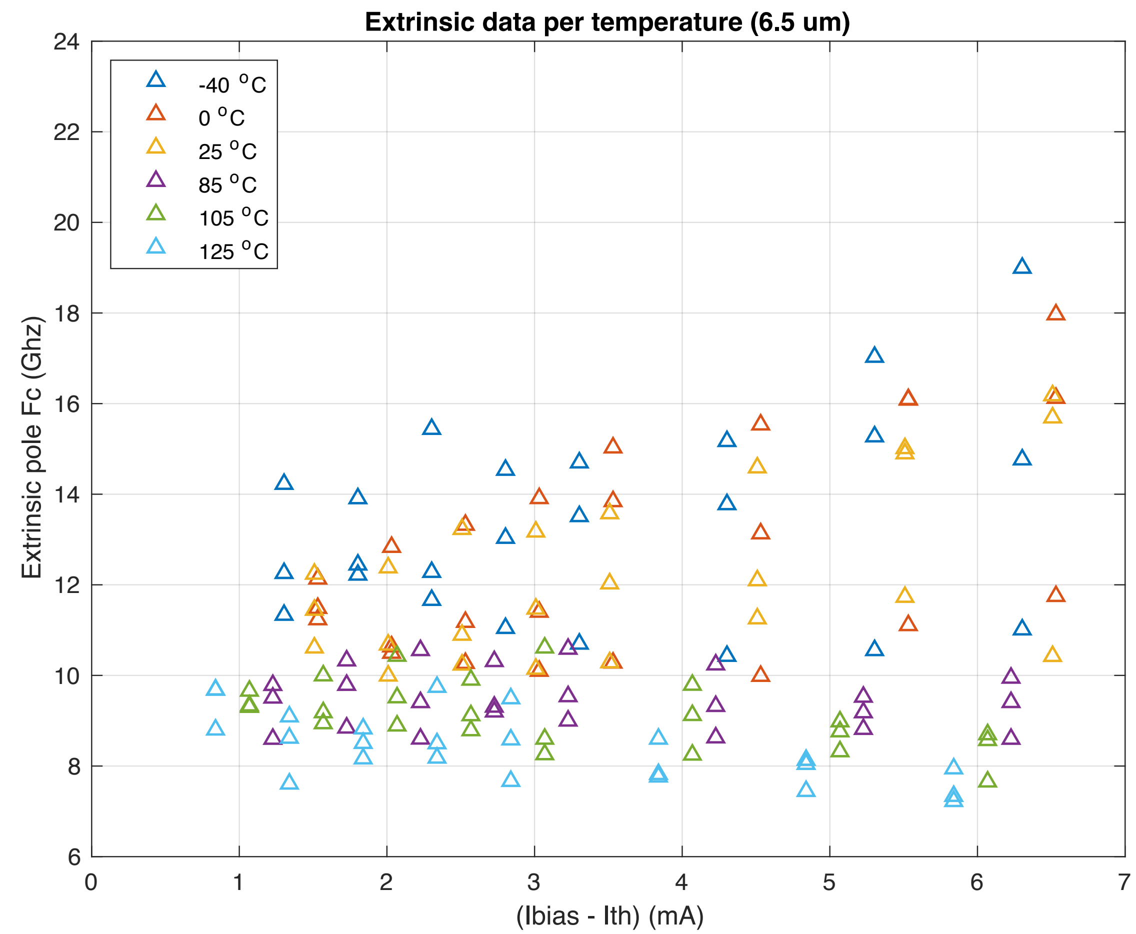




$$H(f) = C \cdot \frac{f_r^2}{f_r^2 - f^2 + j\frac{f}{2\pi}\gamma} \cdot \frac{1}{1 + j\frac{f}{f_p}}.$$

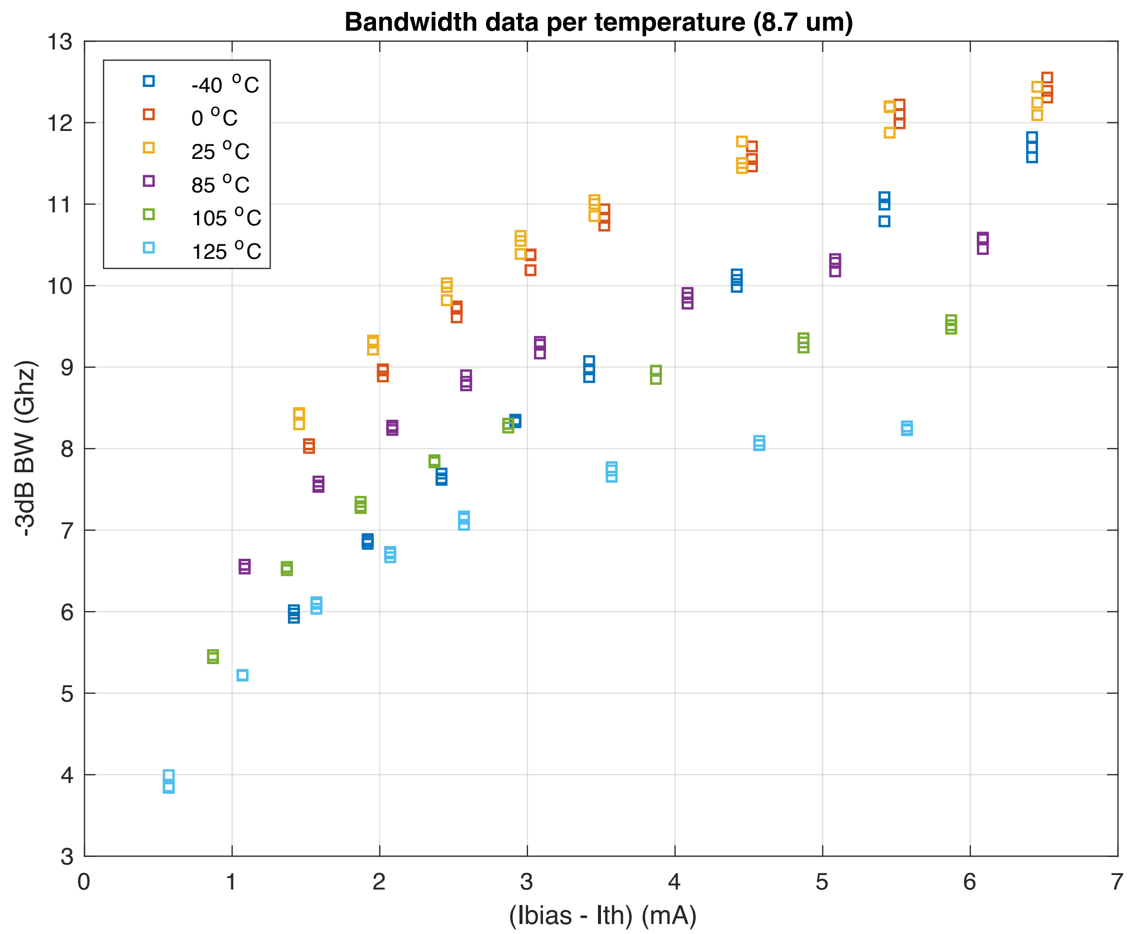
Extrinsic pole characteristic

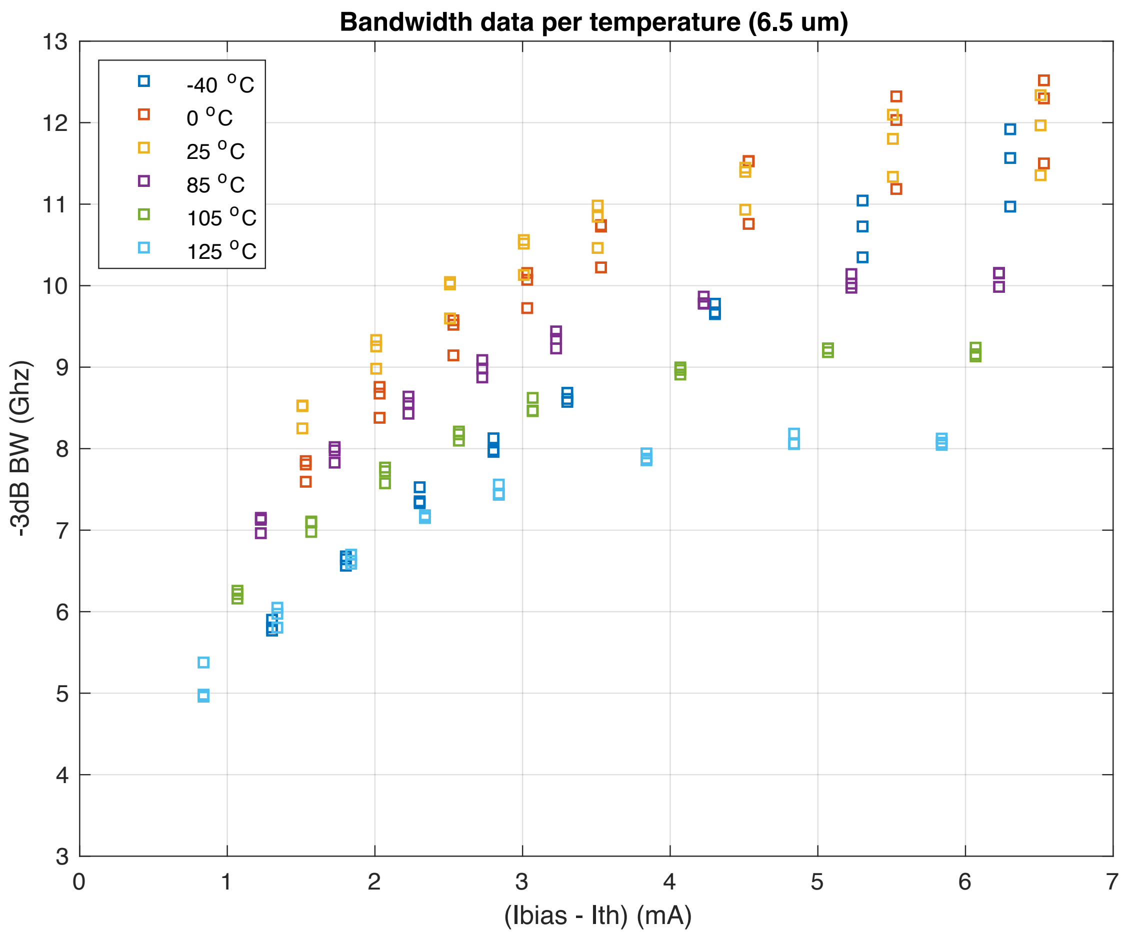




$$H(f) = C \cdot \frac{f_r^2}{f_r^2 - f^2 + j\frac{f}{2\pi}\gamma} \cdot \frac{1}{1 + j\frac{f}{f_p}}.$$

-3 dB bandwidth characteristic



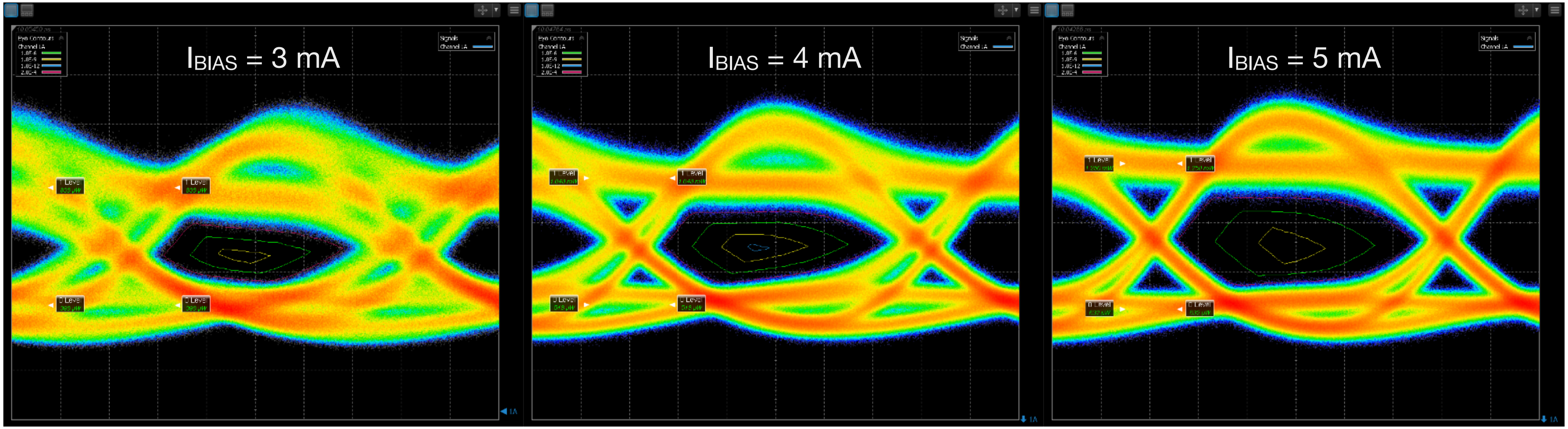


Eye diagram, 10 Gbps

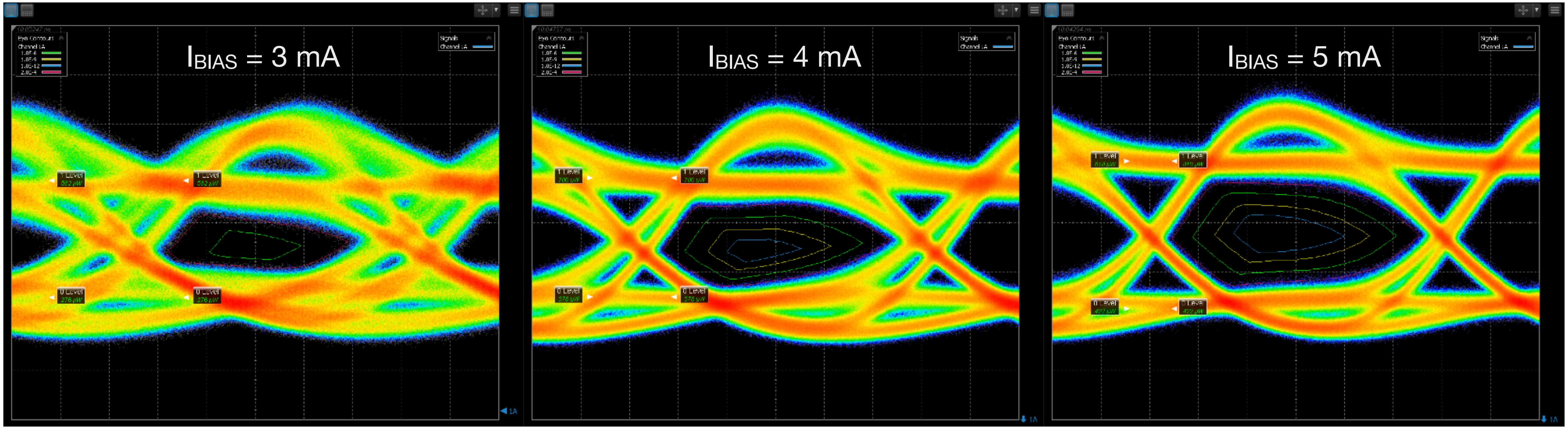
- Signal type: NRZ
- Baud-rate: 10.625 GBd
- ER (current): 3 dB (expected worst case)
- AWG is configured with response correction calibrated from factory to avoid additional driving bandwidth limitations
- DCA receiver input filter: Bessel-Thomson 4th order BW_{-3dB} = 21 GHz
  - Configured to observe VCSEL response entirely w/o bandwidth limitation and make possible time-domain simulation correlation
- It is observed that as higher is the current density, better is the performance
  - Increasing current will not be a reliability problem in low temperatures
  - In high temperature we need to demonstrate feasibility with low current densities

Eye diagram, -40 ºC

8.7 um, sample ID #4

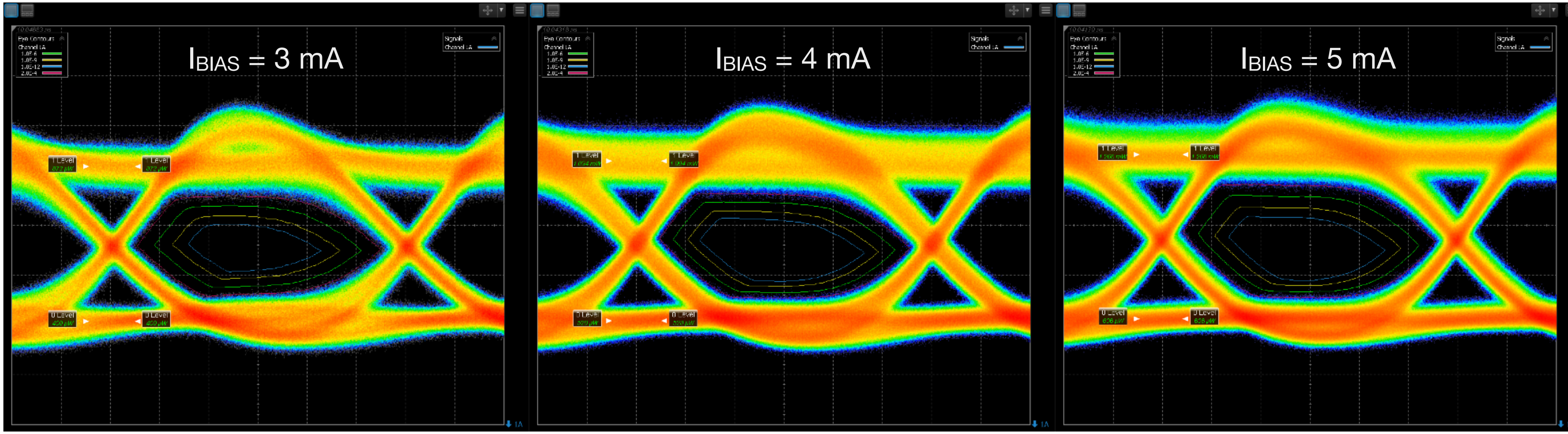


6.5 um, sample ID #12

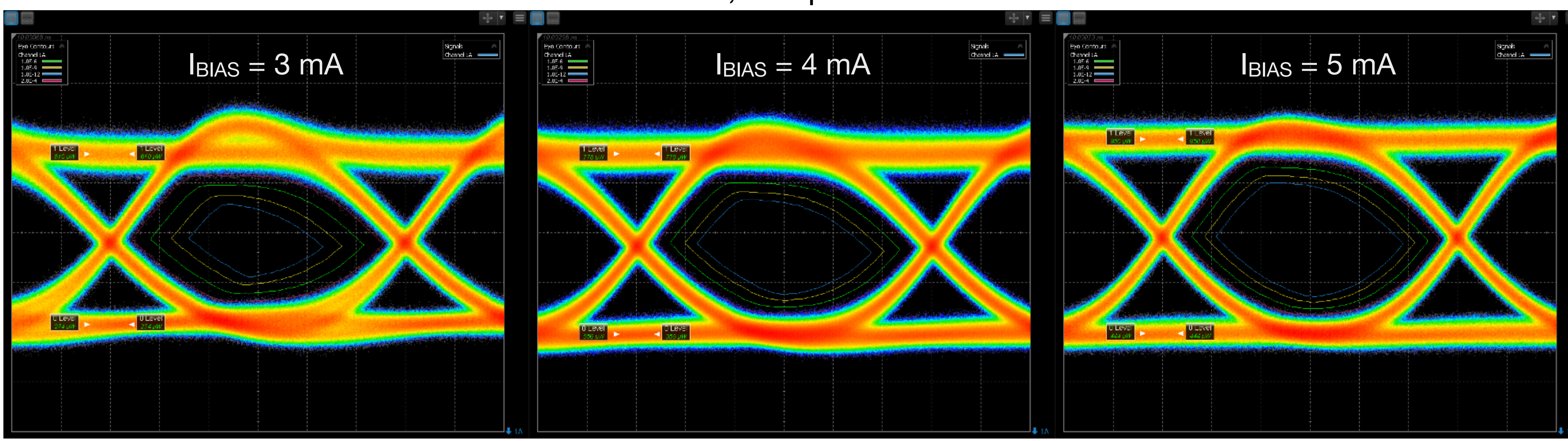


Eye diagram, 25°C

8.7 um, sample ID #4

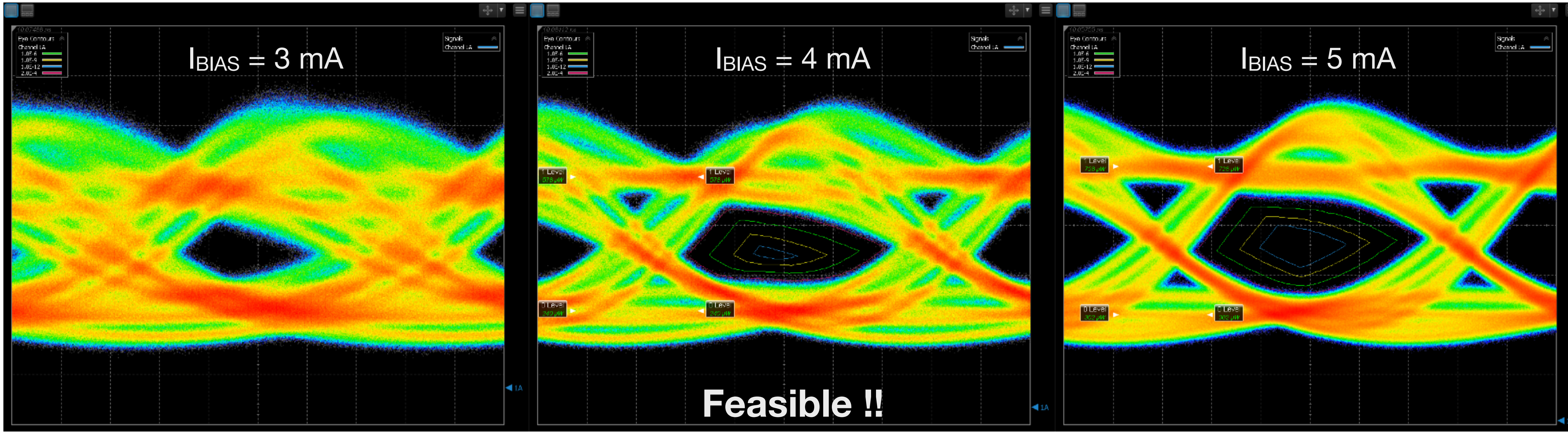


6.5 um, sample ID #12

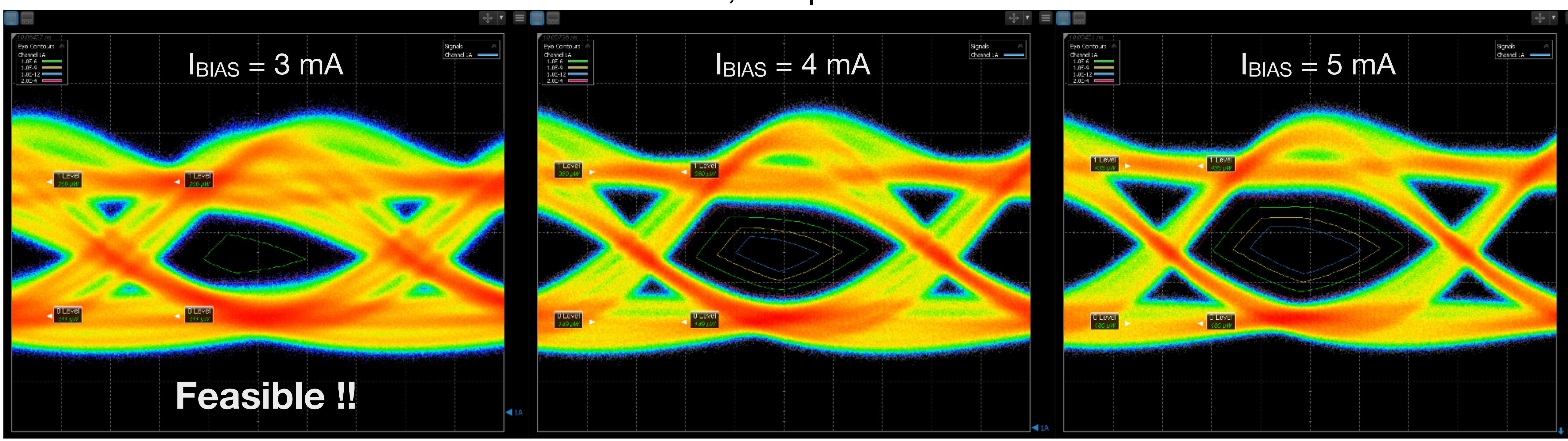


Eye diagram, 125°C

8.7 um, sample ID #4

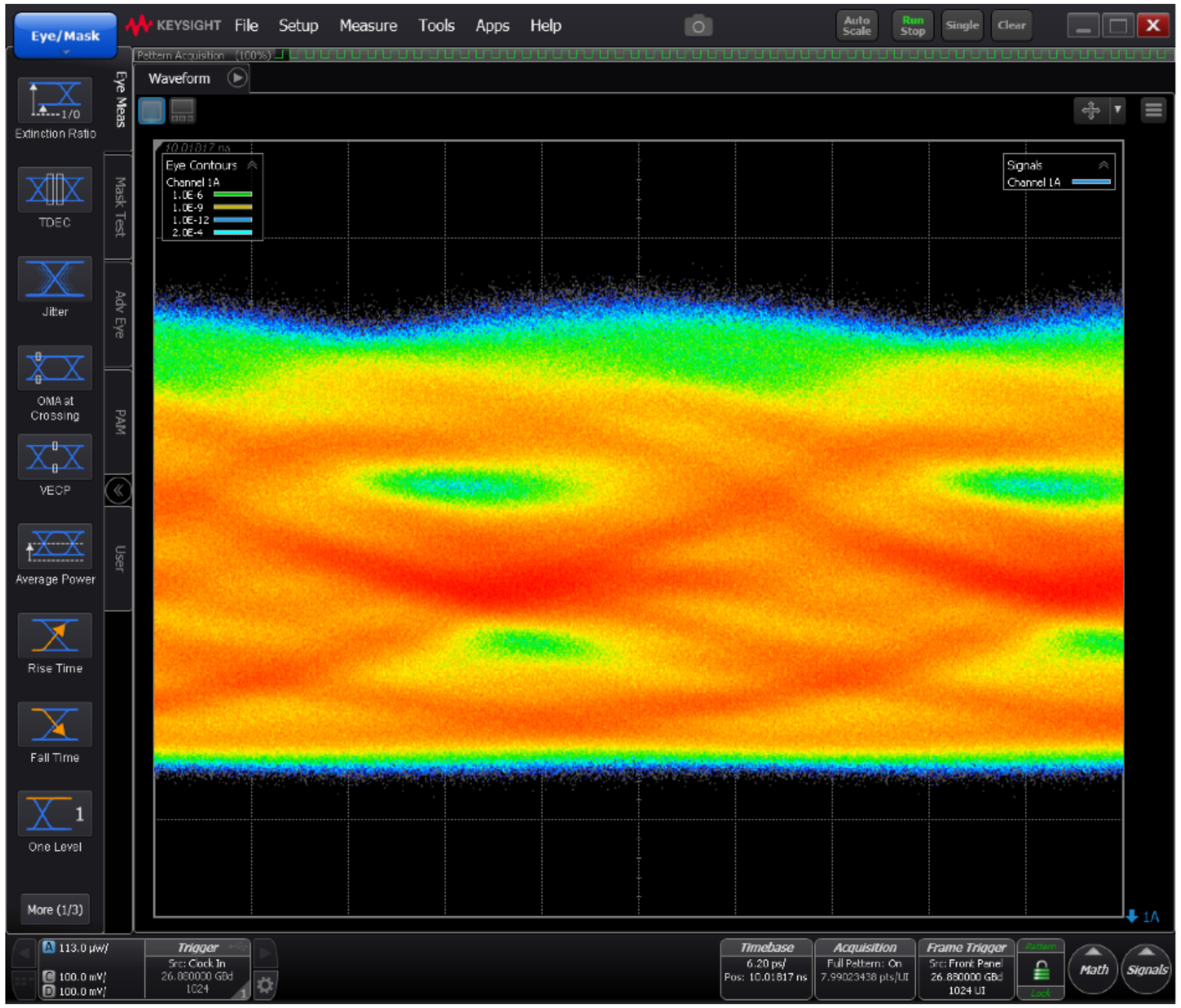


6.5 um, sample ID #12

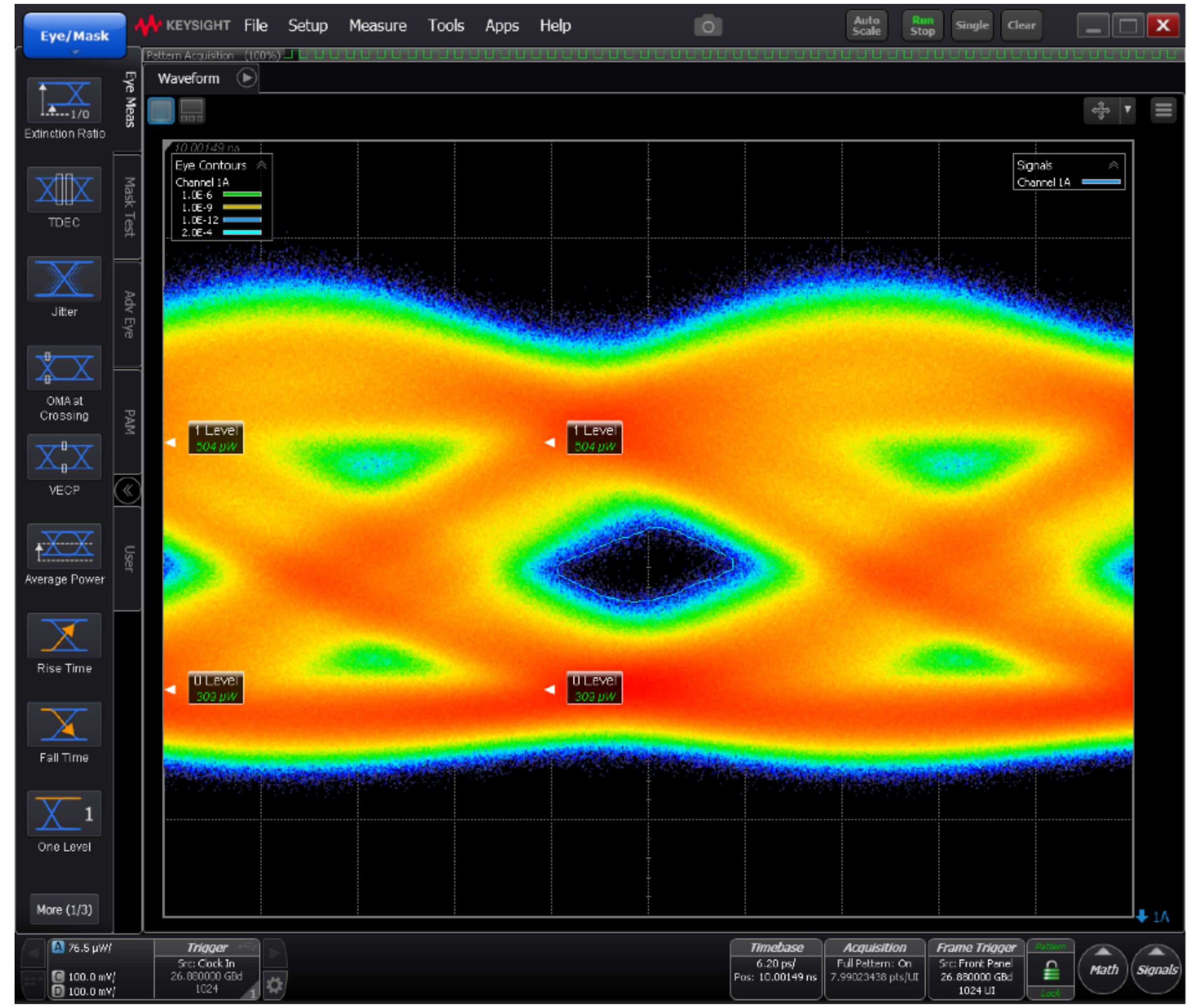


Is it possible to use this VCSEL for 25 Gbps?

8.7 um, sample ID #4



T_{SUB} = 125°C, I_{BIAS} = 6 mA, ER = 3 dB
26.88 GBd NRZ signal



T_{SUB} = 125°C, I_{BIAS} = 6 mA, ER = 3 dB
26.88 GBd NRZ signal
DSP based pre-emphasis

- 25 Gbps can be transmitted by implementation of pre-emphasis in the driver and higher average current density in the VCSEL, at the cost of higher complexity and power consumption
- Lesson learned: pre-emphasis may be implemented in the driver to improve the VCSEL response, therefore the receiver sensitivity for the same I_{BIAS} driving

Thank you