Characterization report of Vendor E VCSELs

Rubén Pérez-Aranda
Plinio Jesús Pinzón

IEEE 802.3 OMEGA Task Force - August 2020 Interim

Introduction

- KDPOF has characterized 2 different Vendor E VCSEL designs
  - 25Gbps (designed for NRZ, 25GBd) multimode VCSEL for 850 nm based on QD (quantum dots)
  - 25Gbps (designed for NRZ, 25GBd) multimode VCSEL for 850 nm based on QW (quantum wells)
- L-I-V, AC and RIN have been measured according to test methodologies explained in perezaranda_OMEGA_01_0720_VCSEL_test_methods.pdf
- All the test parameters have been measured at -40, 0, 25, 85, 105 and 125 ºC backside temperature
- Eye diagrams for 26.5625 GBd NRZ are shown
  - These eye diagrams are not intended to assess suitability of an specific VCSEL for OMEGA application.
  - These eye diagrams are intended to illustrate the effect of temperature and current in the VCSELs response
- Next step will be to carry out link budget analysis

25Gbps multimode 850nm VCSEL based on QD

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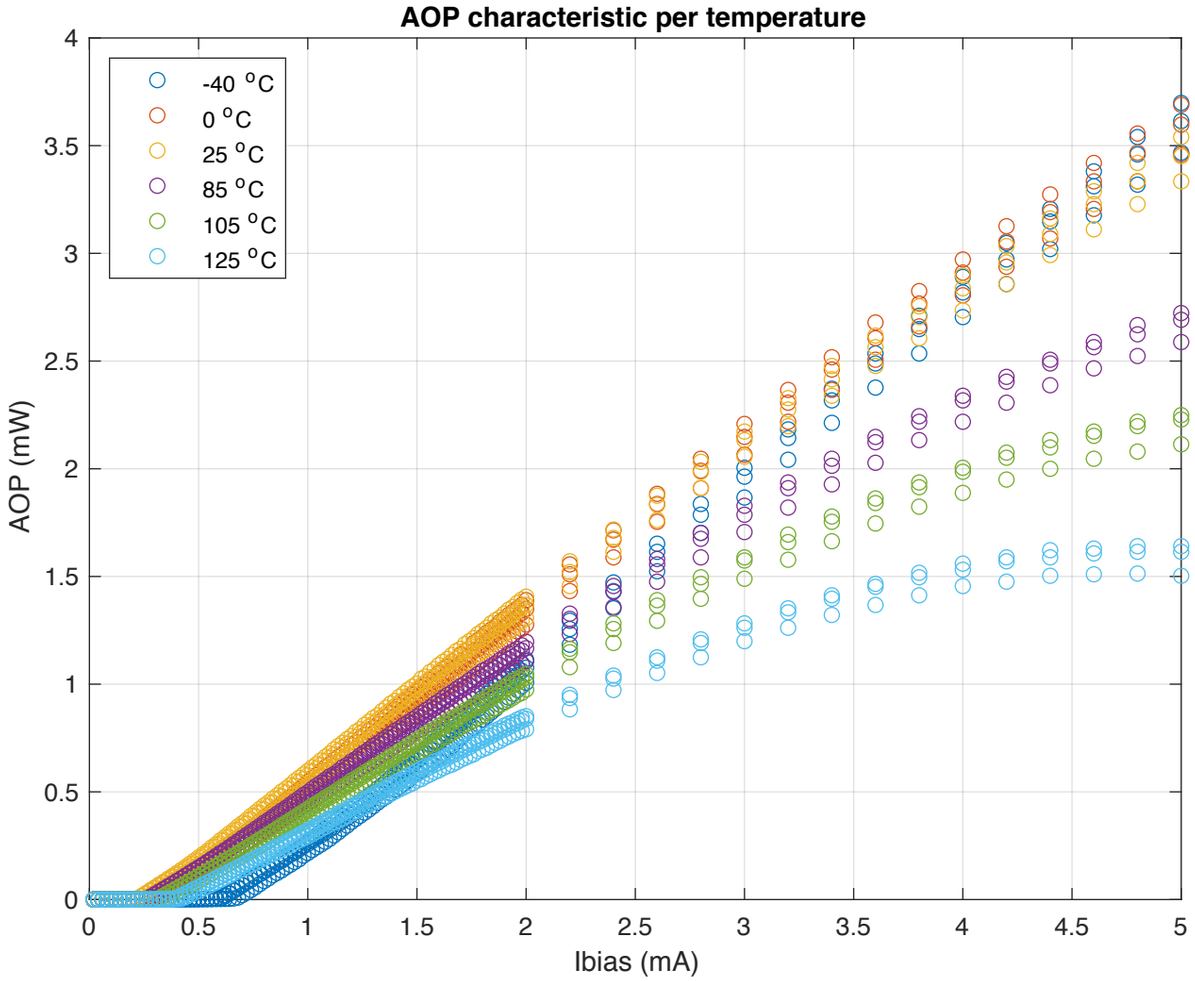
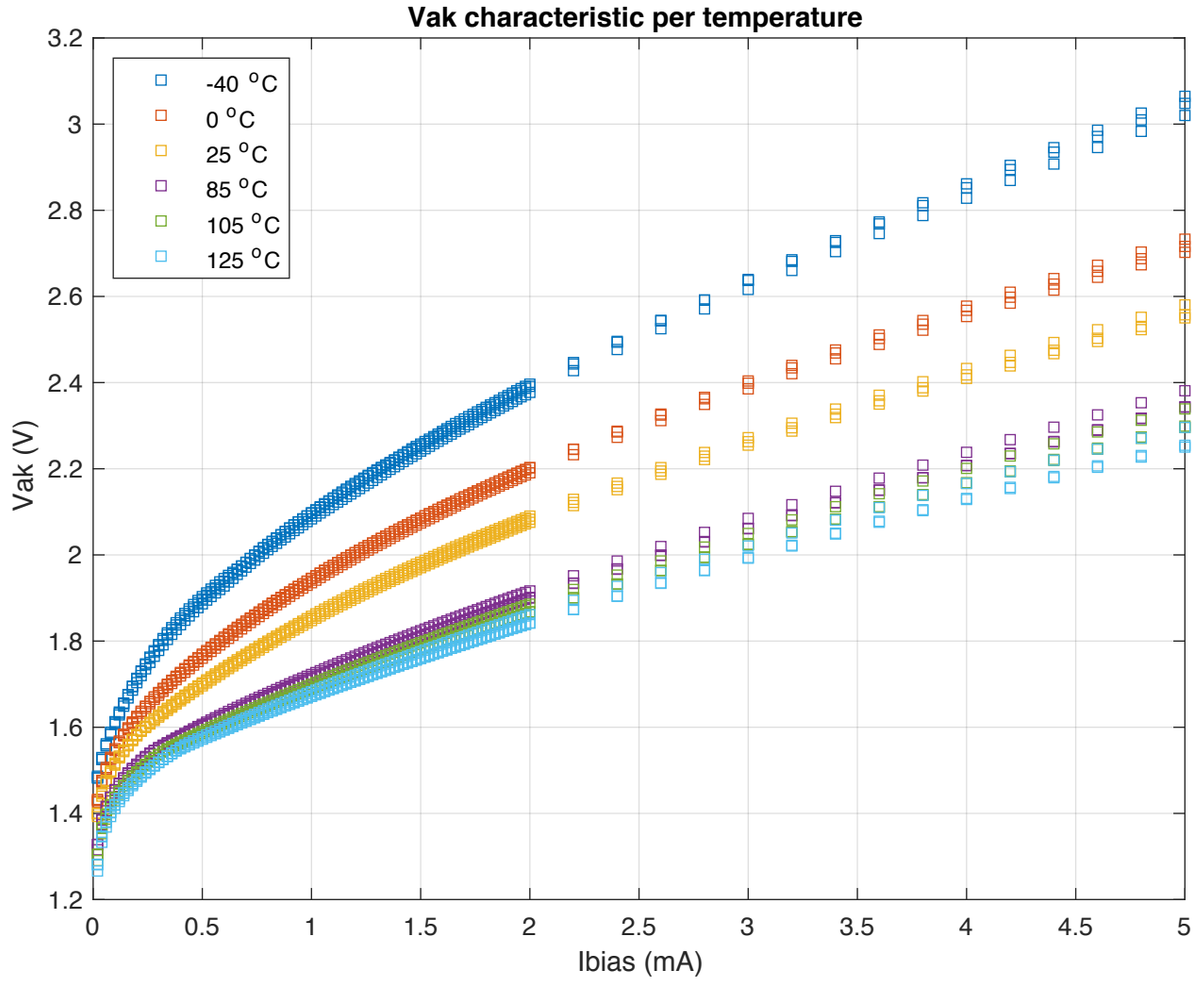
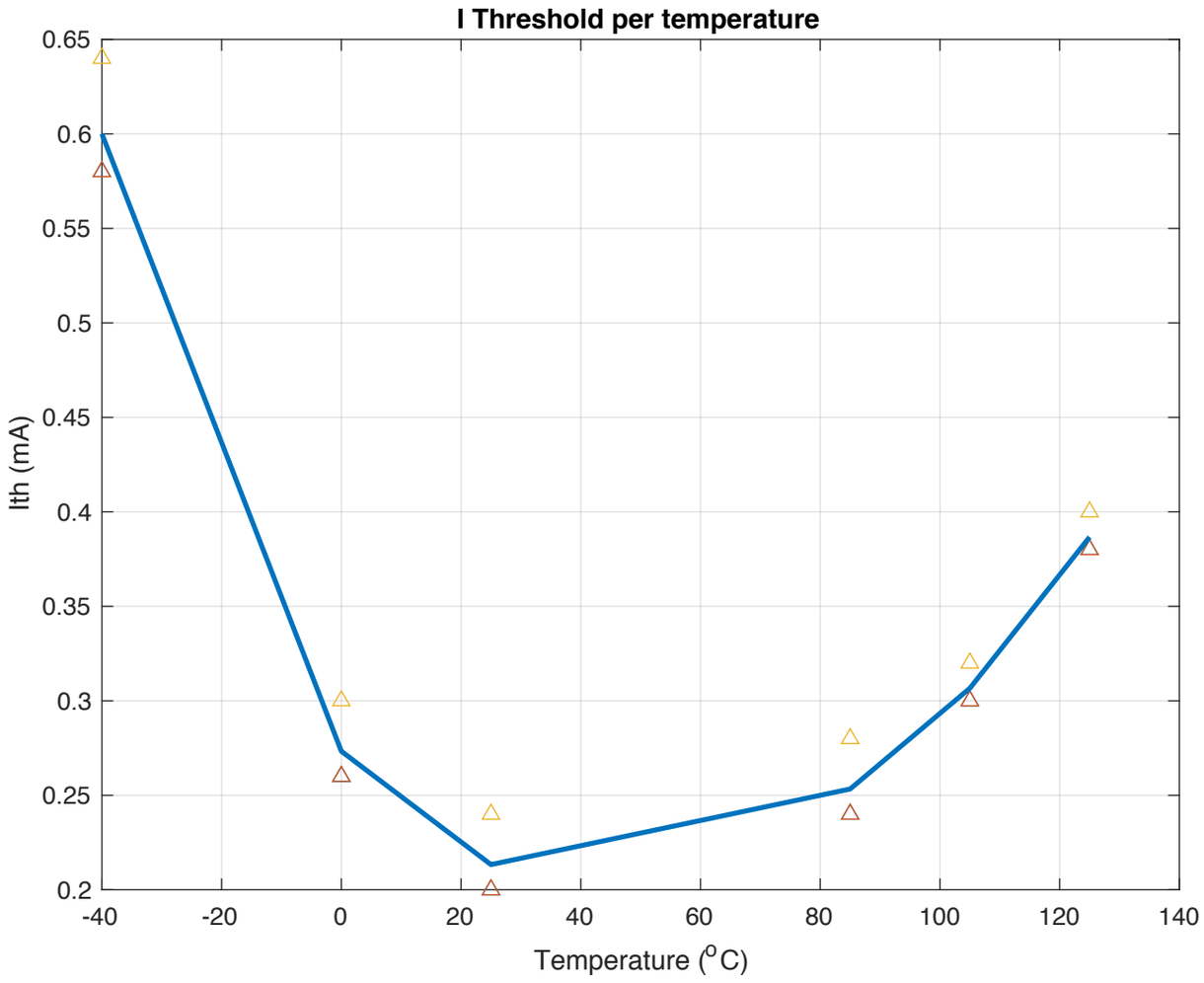
L-I-V characteristic

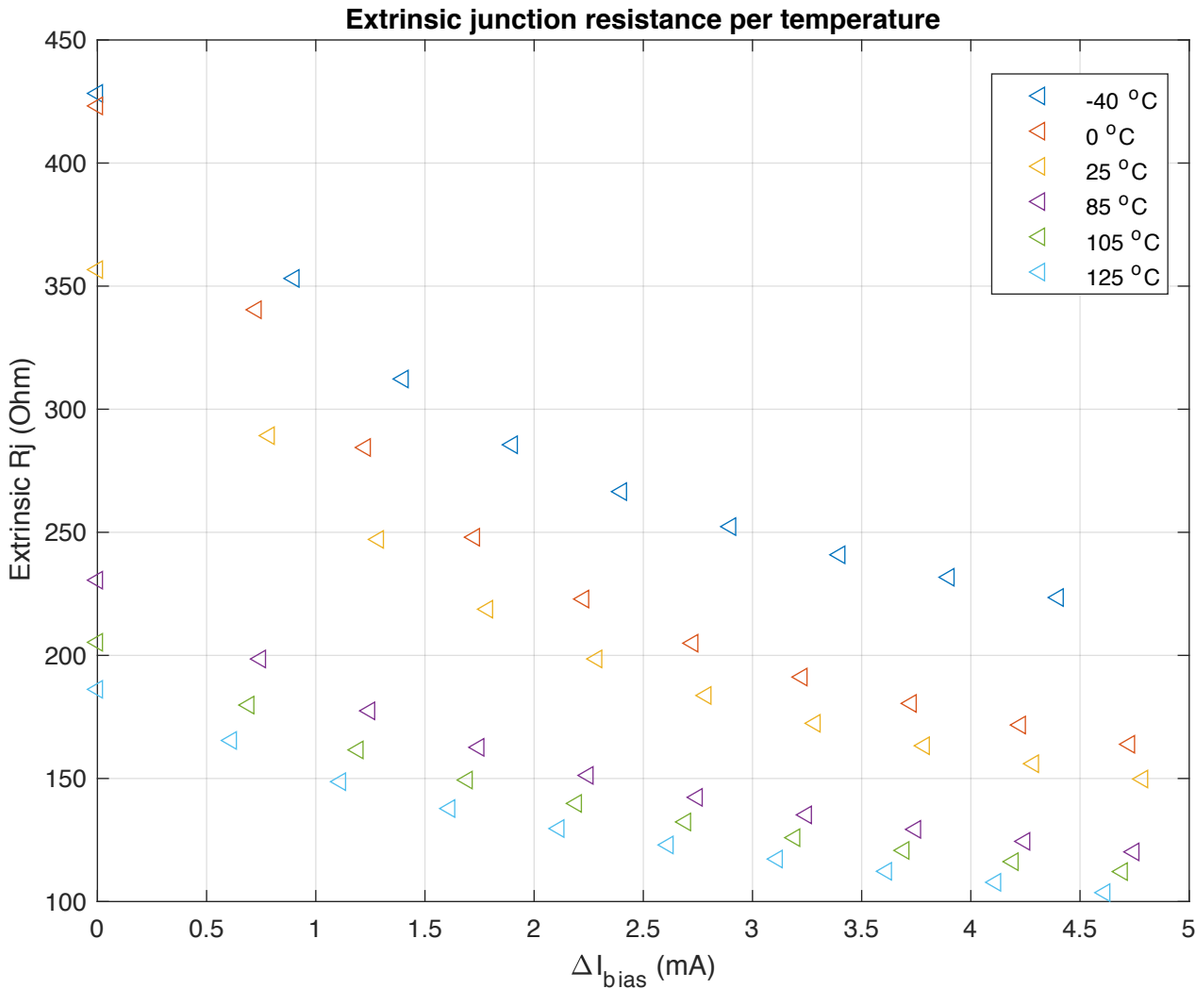


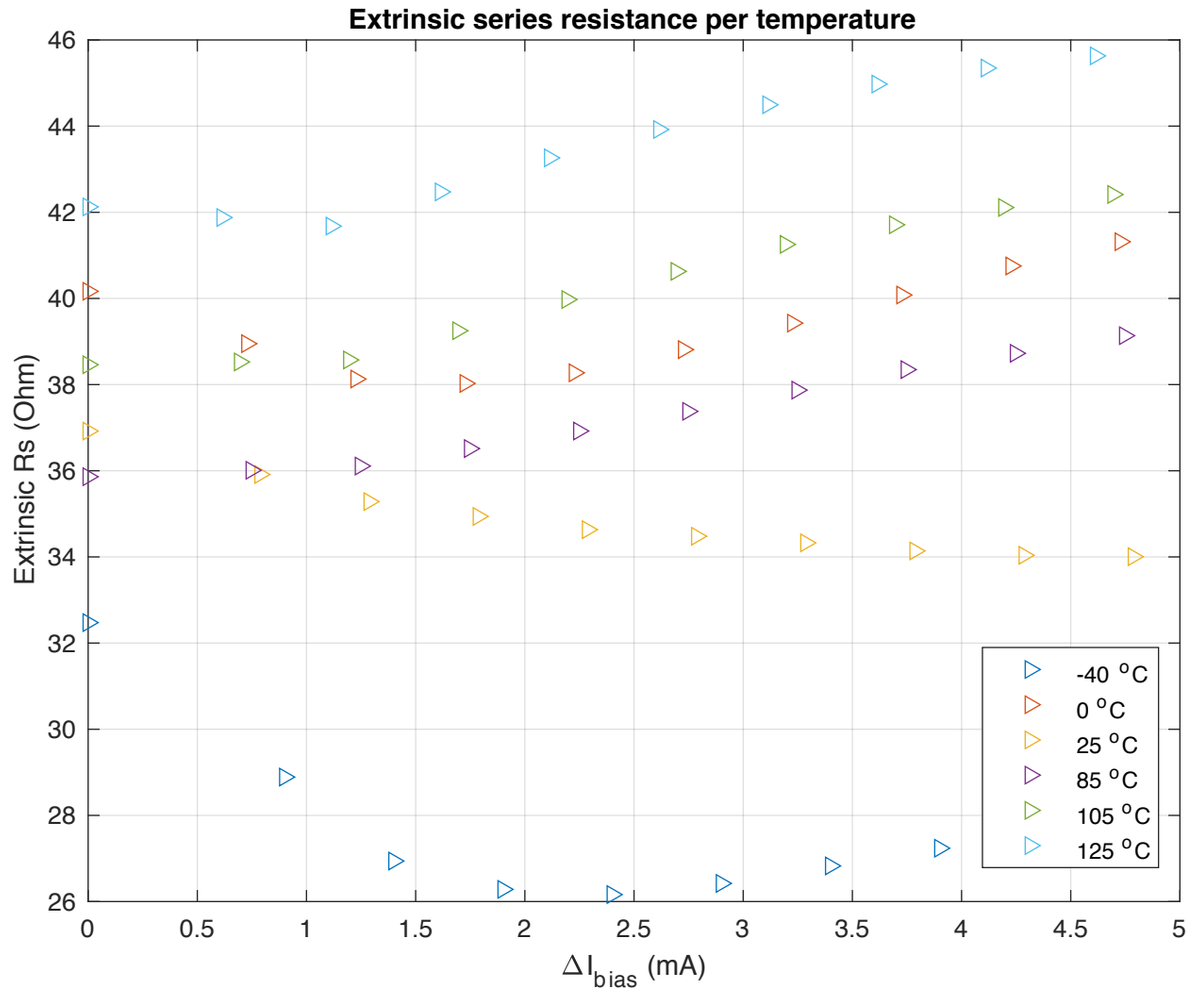


Threshold current characteristic

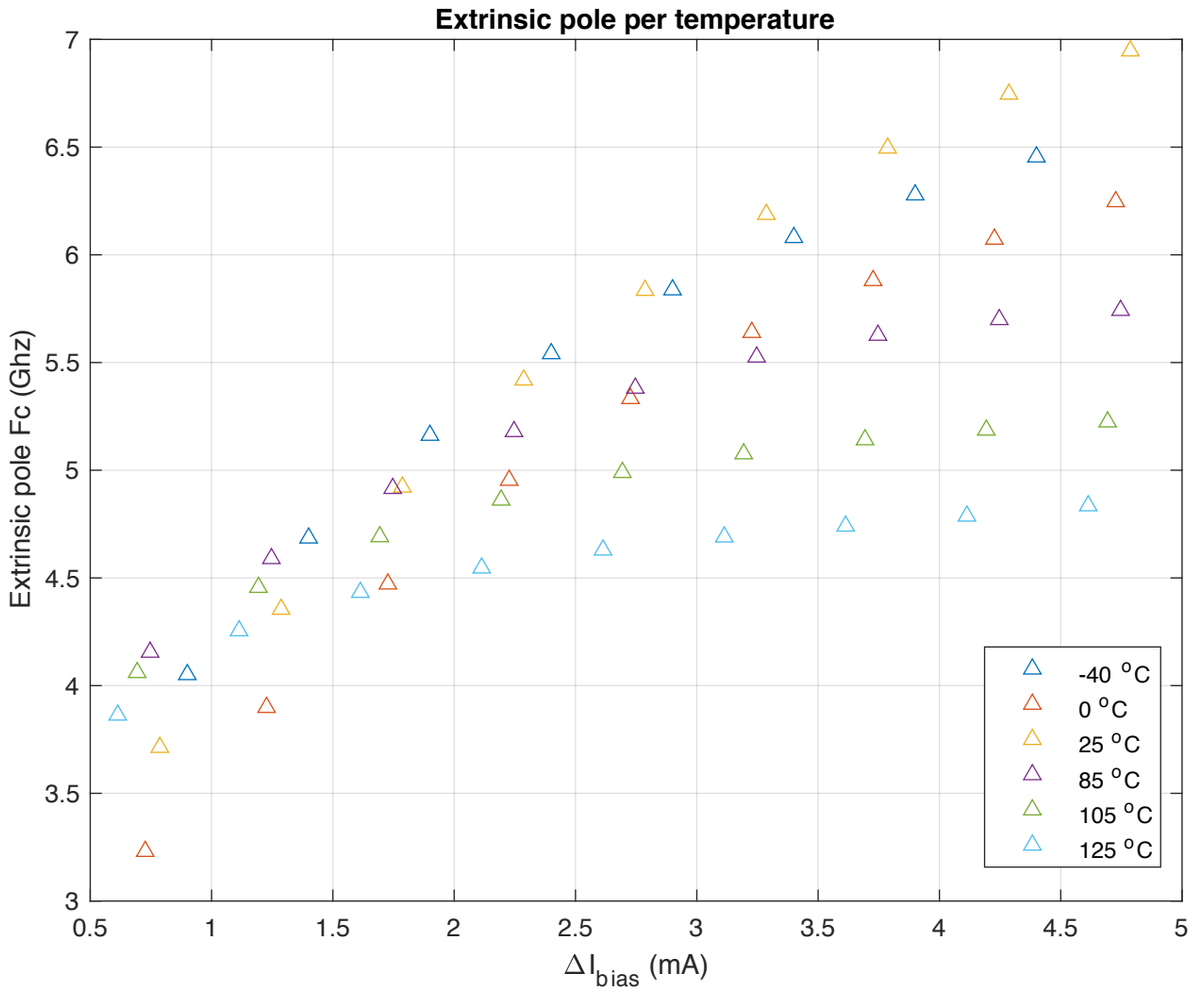


Small signal frequency response



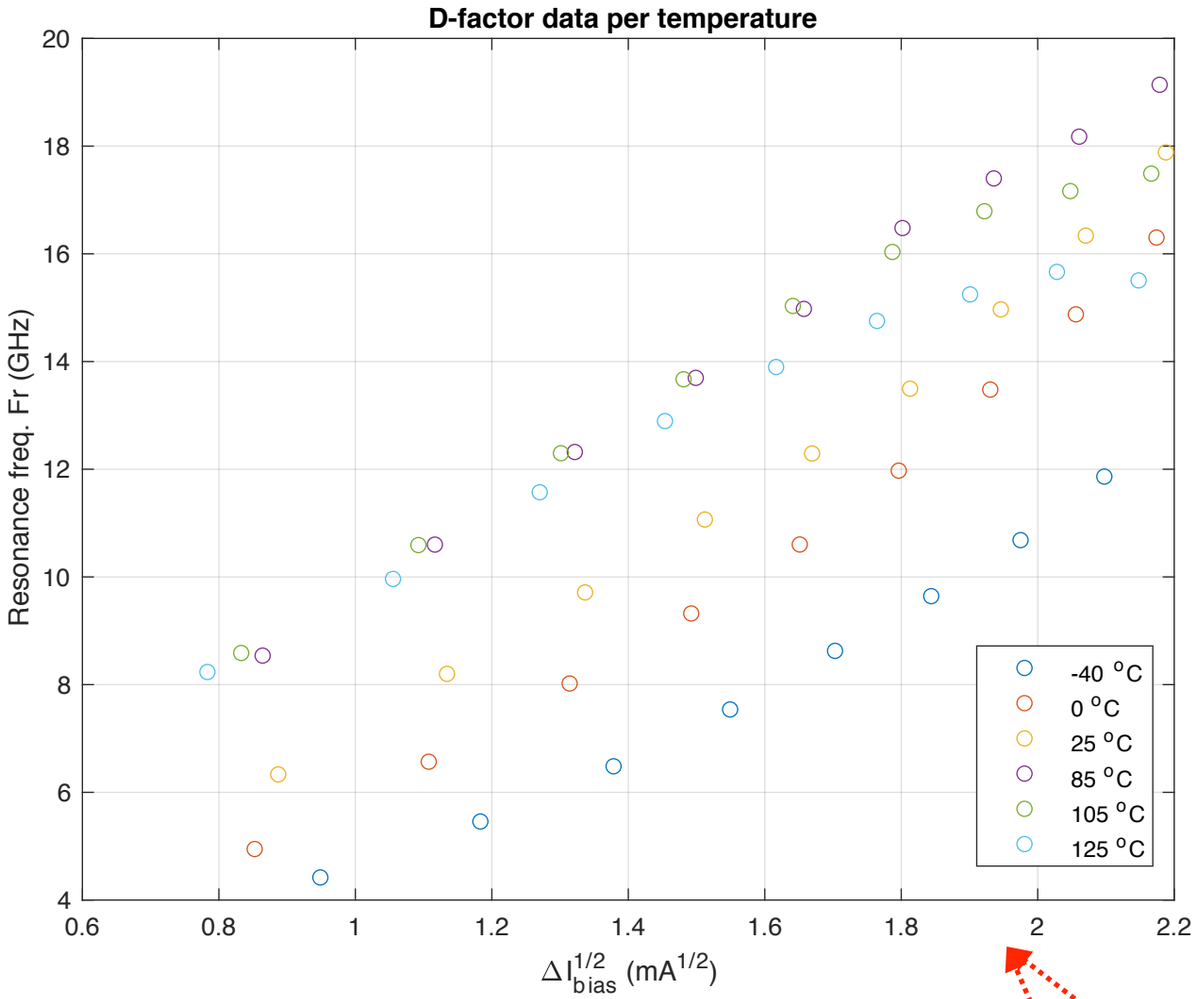


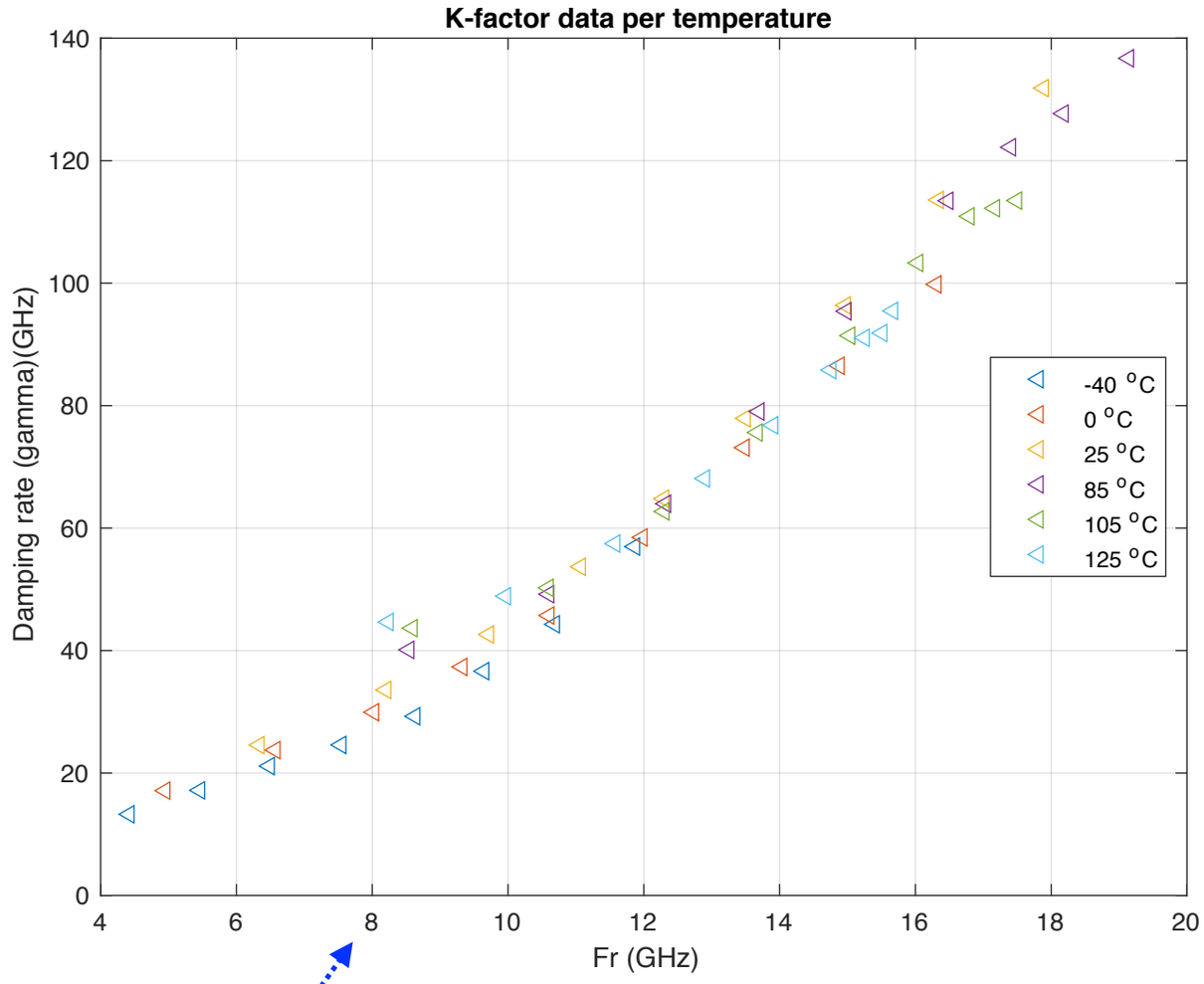
Small signal frequency response



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

Small signal frequency response





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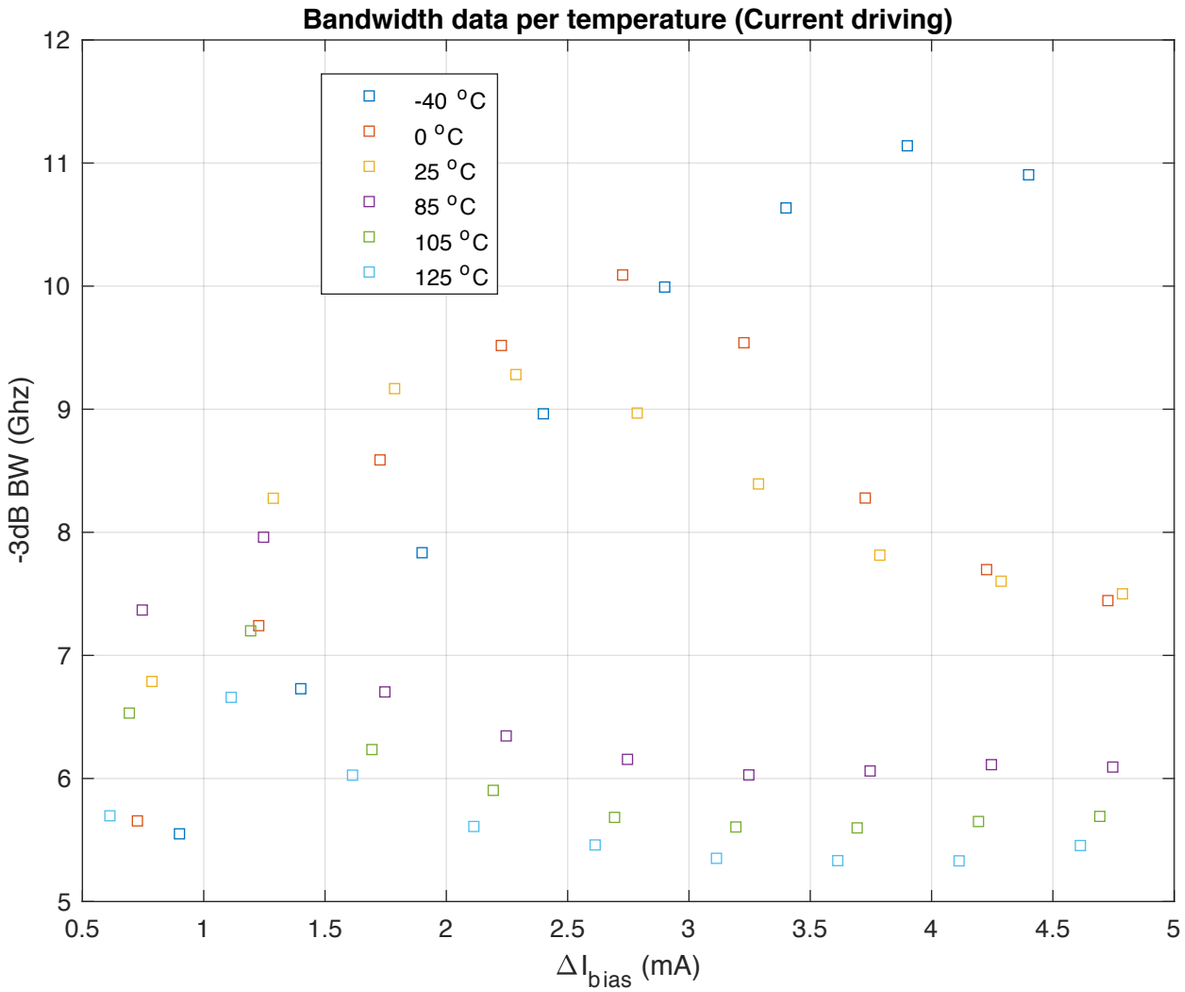
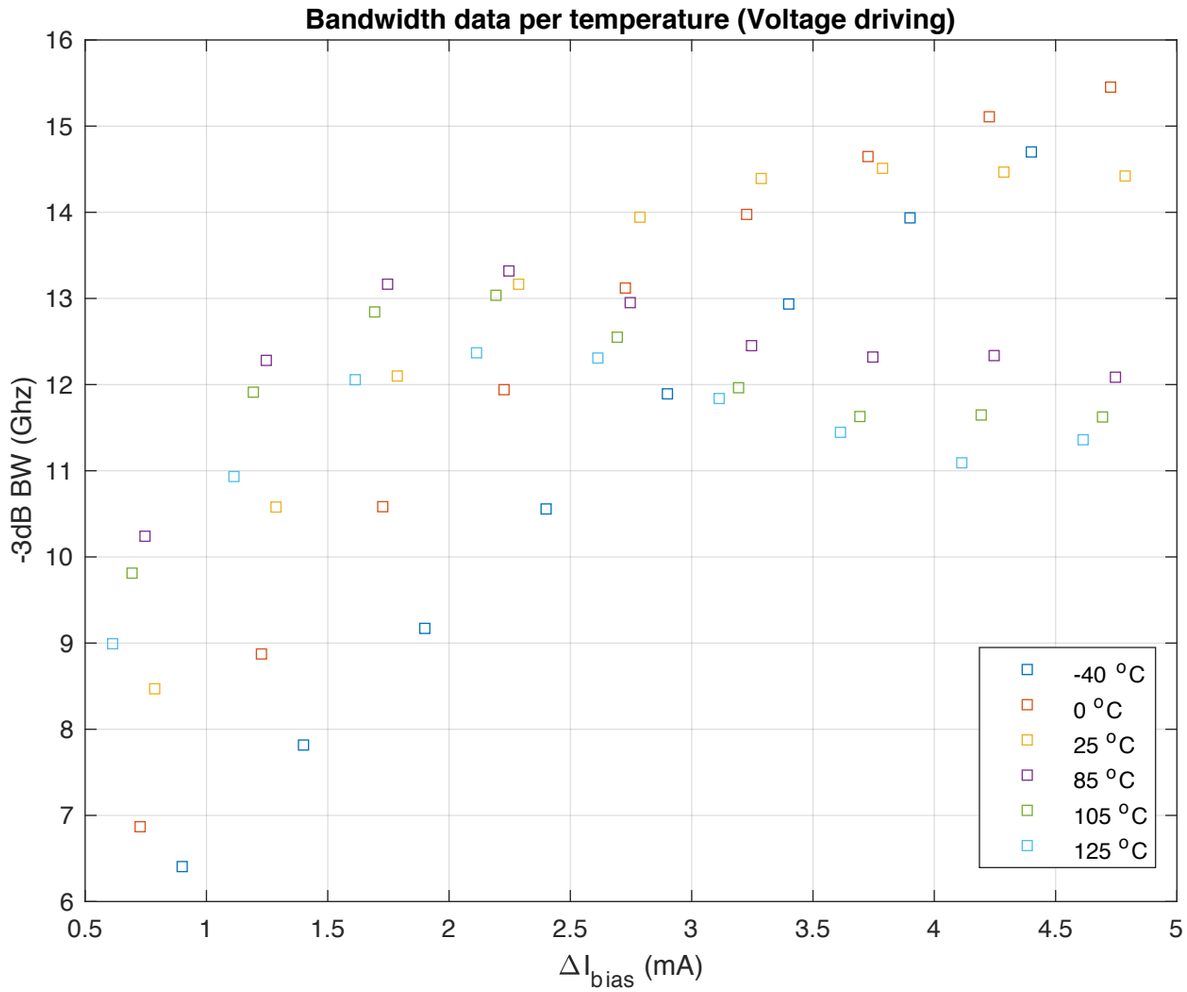
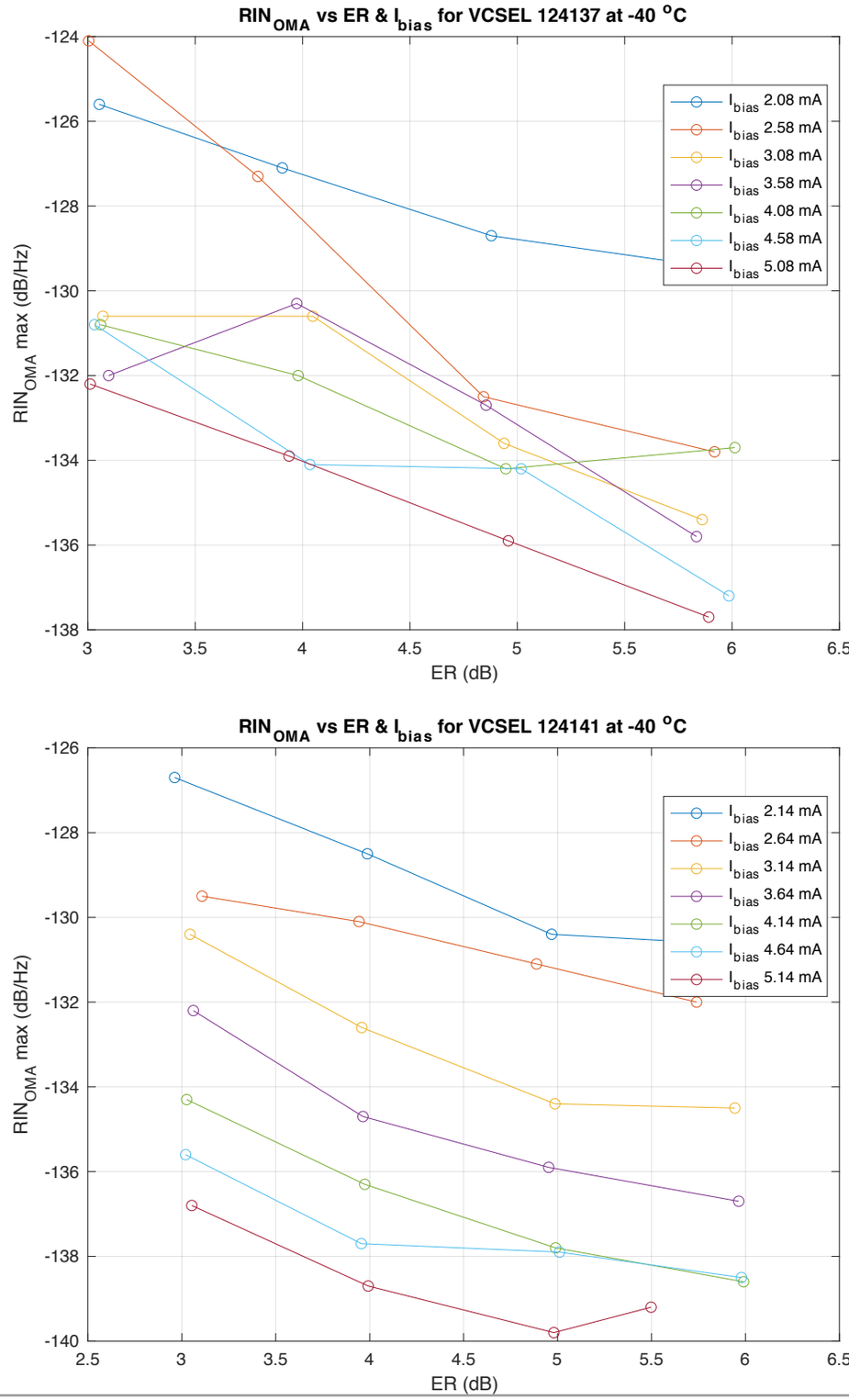
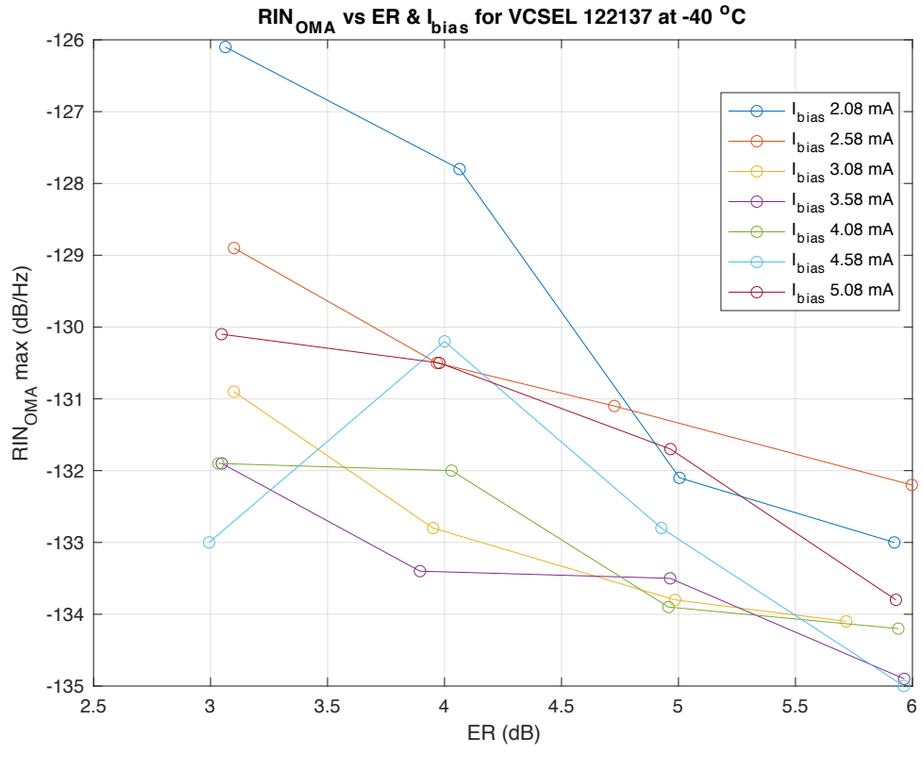




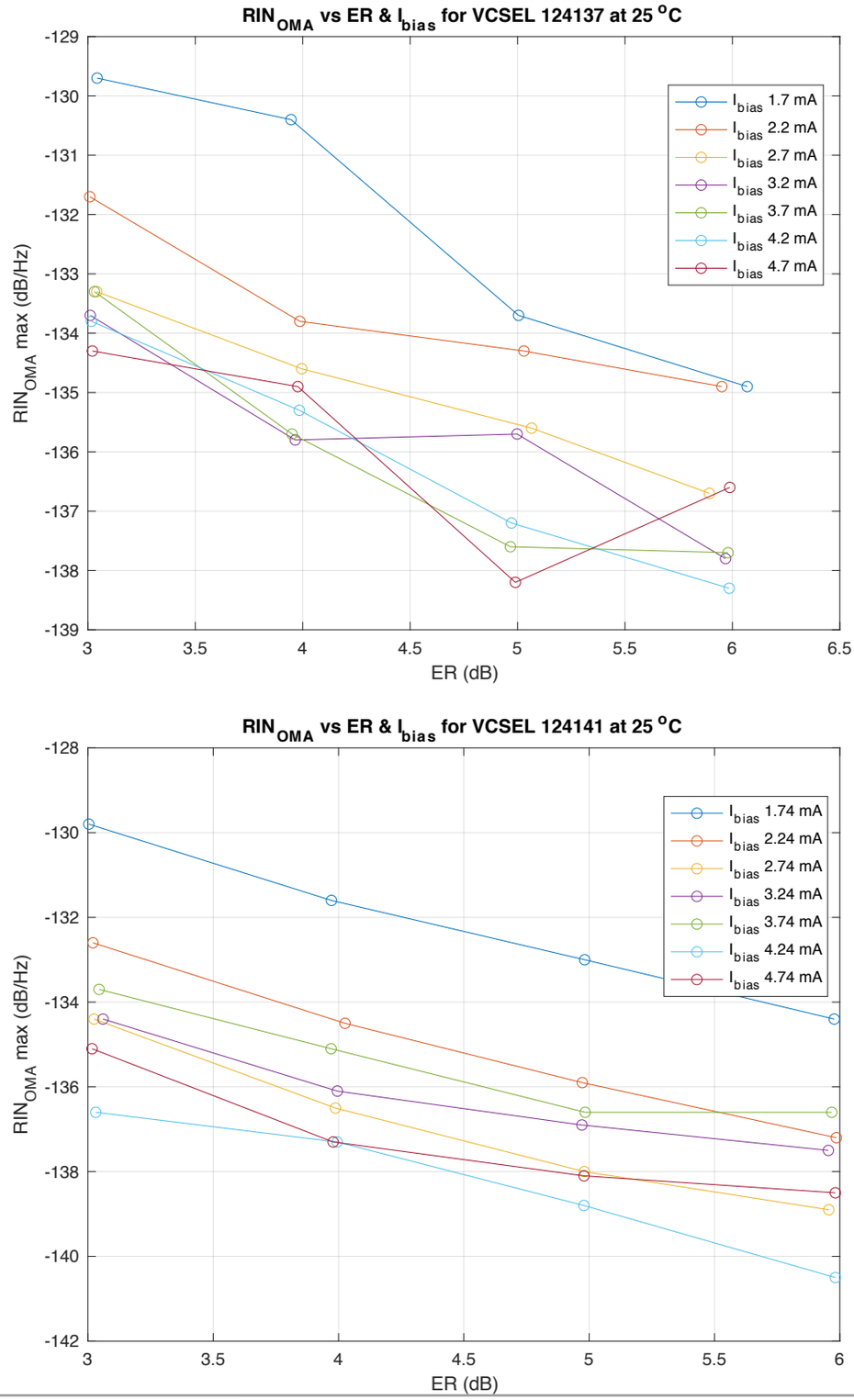
Considered source impedance 100 Ω

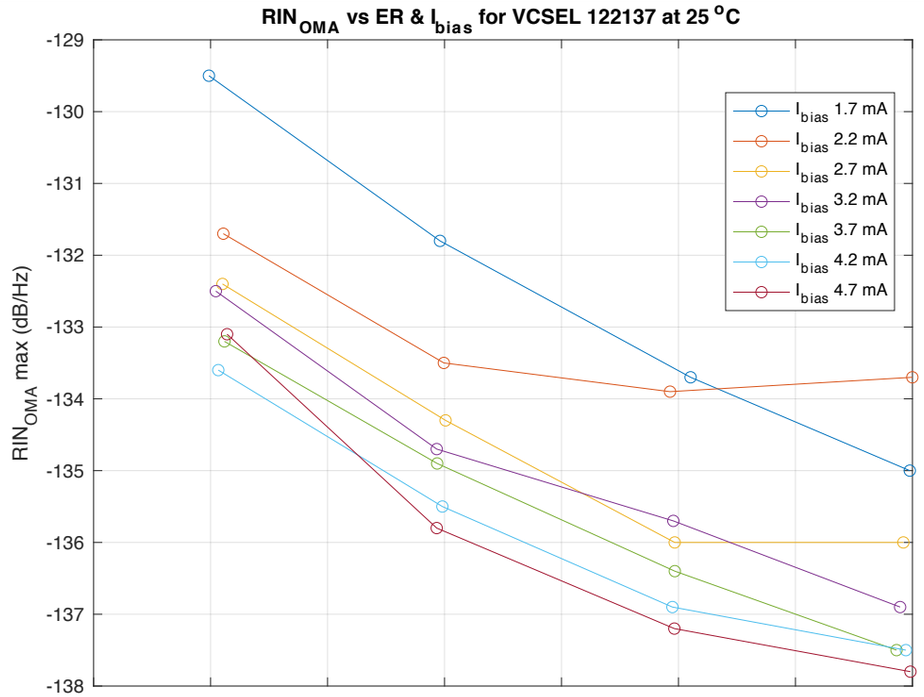
Relative intensity noise (RIN_{OMA}) at -40ºC



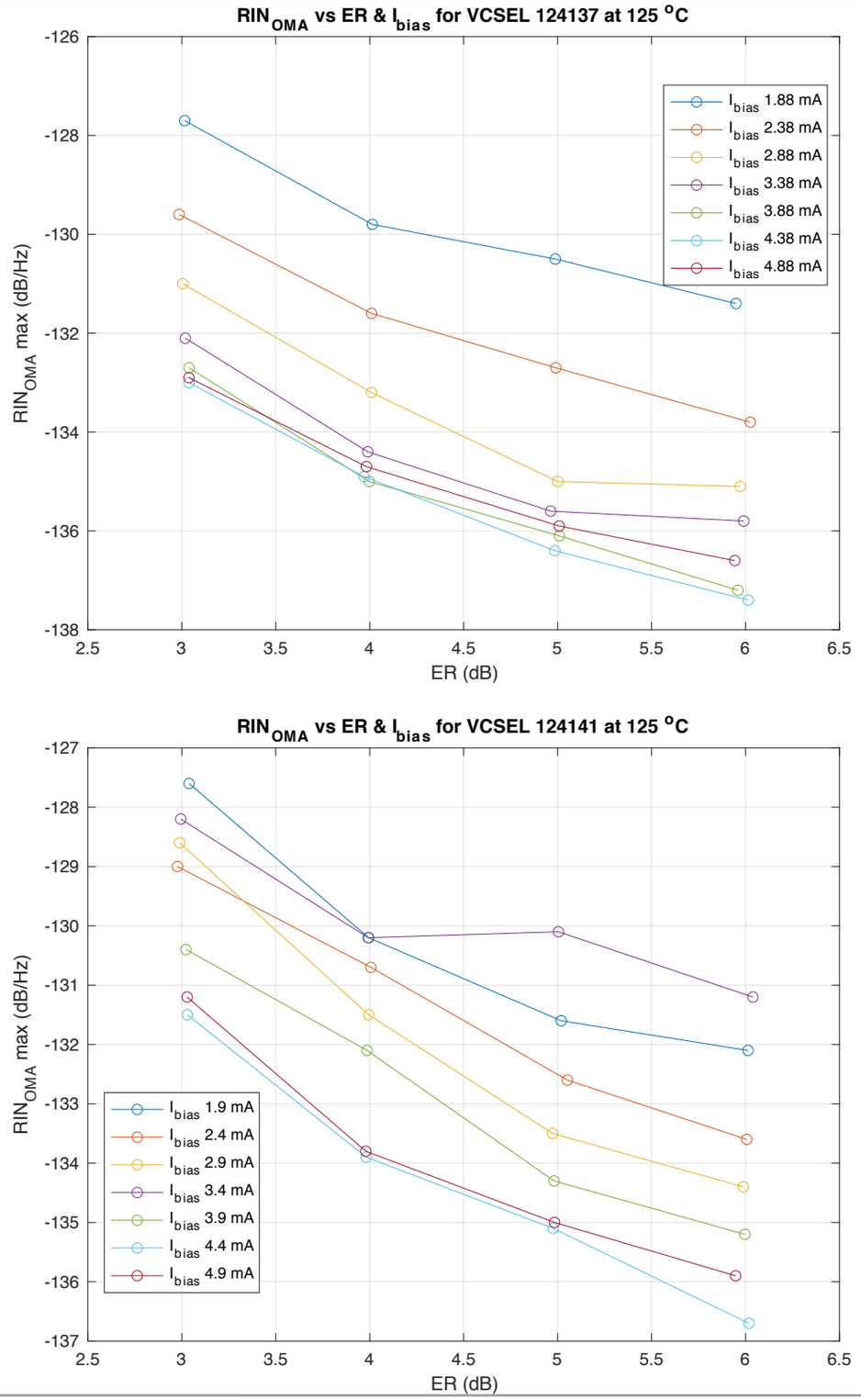


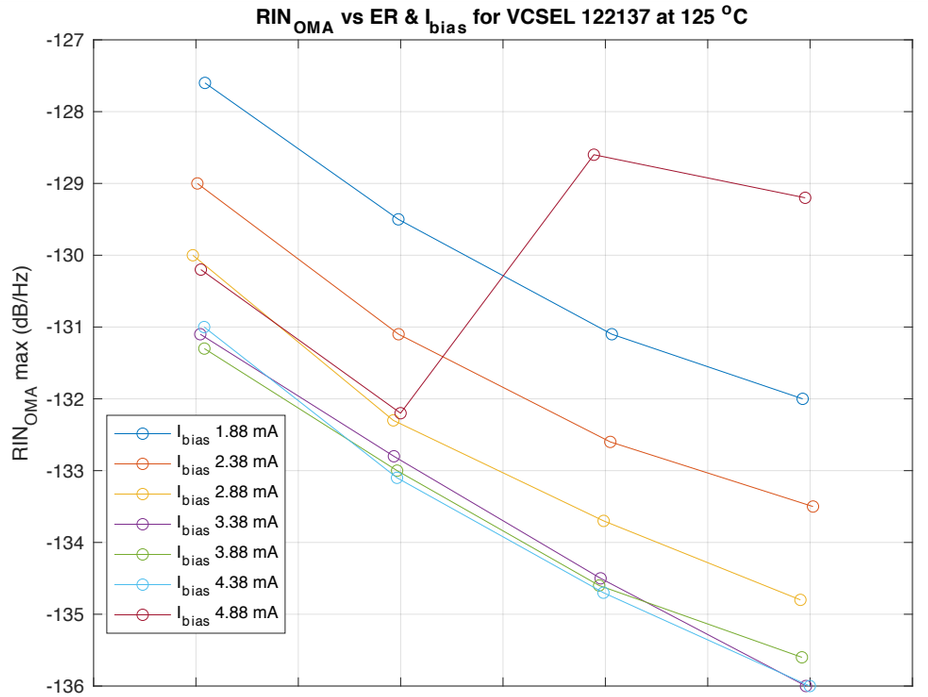
Relative intensity noise (RIN_{OMA}) at 25ºC



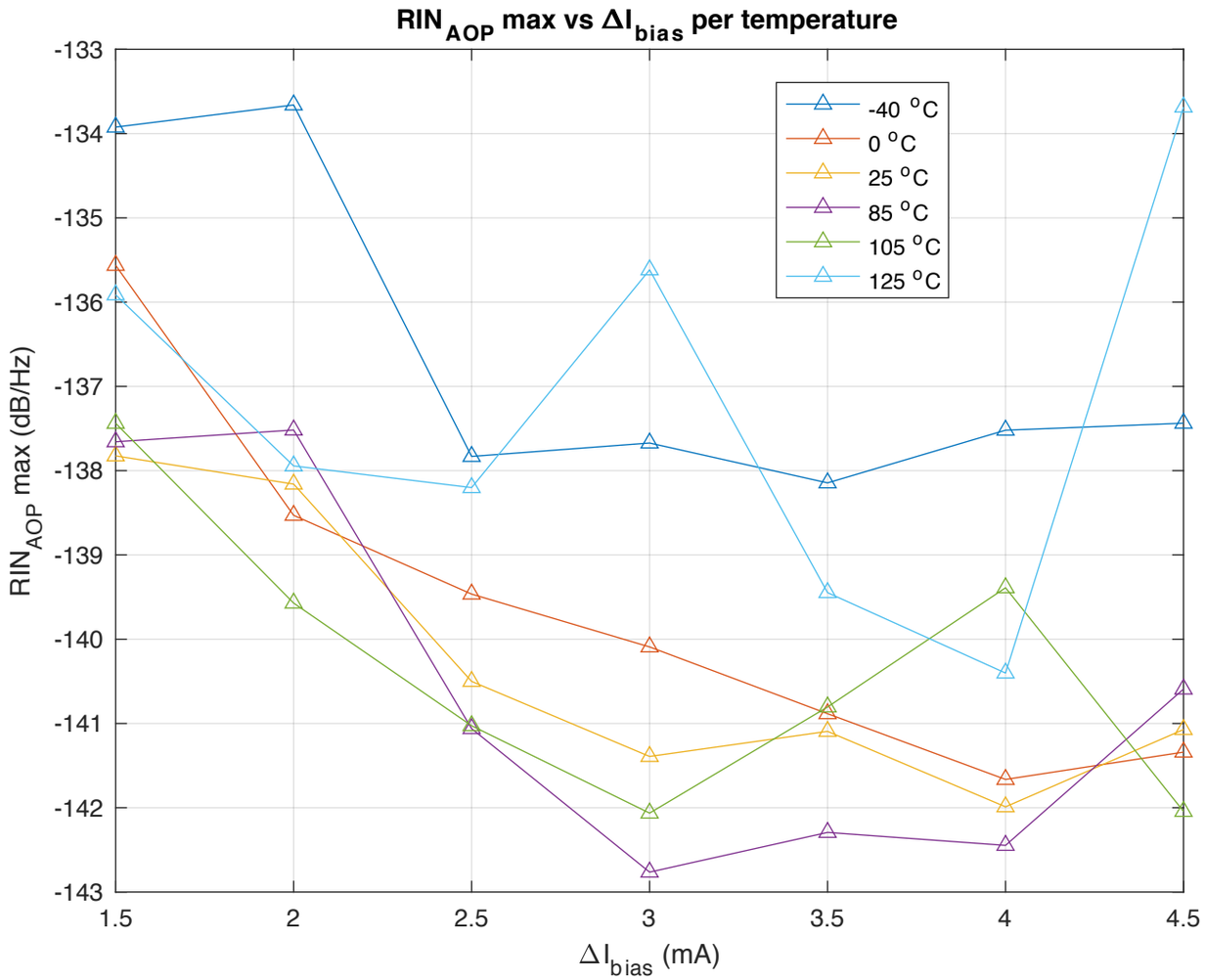


Relative intensity noise (RIN_{OMA}) at 125ºC





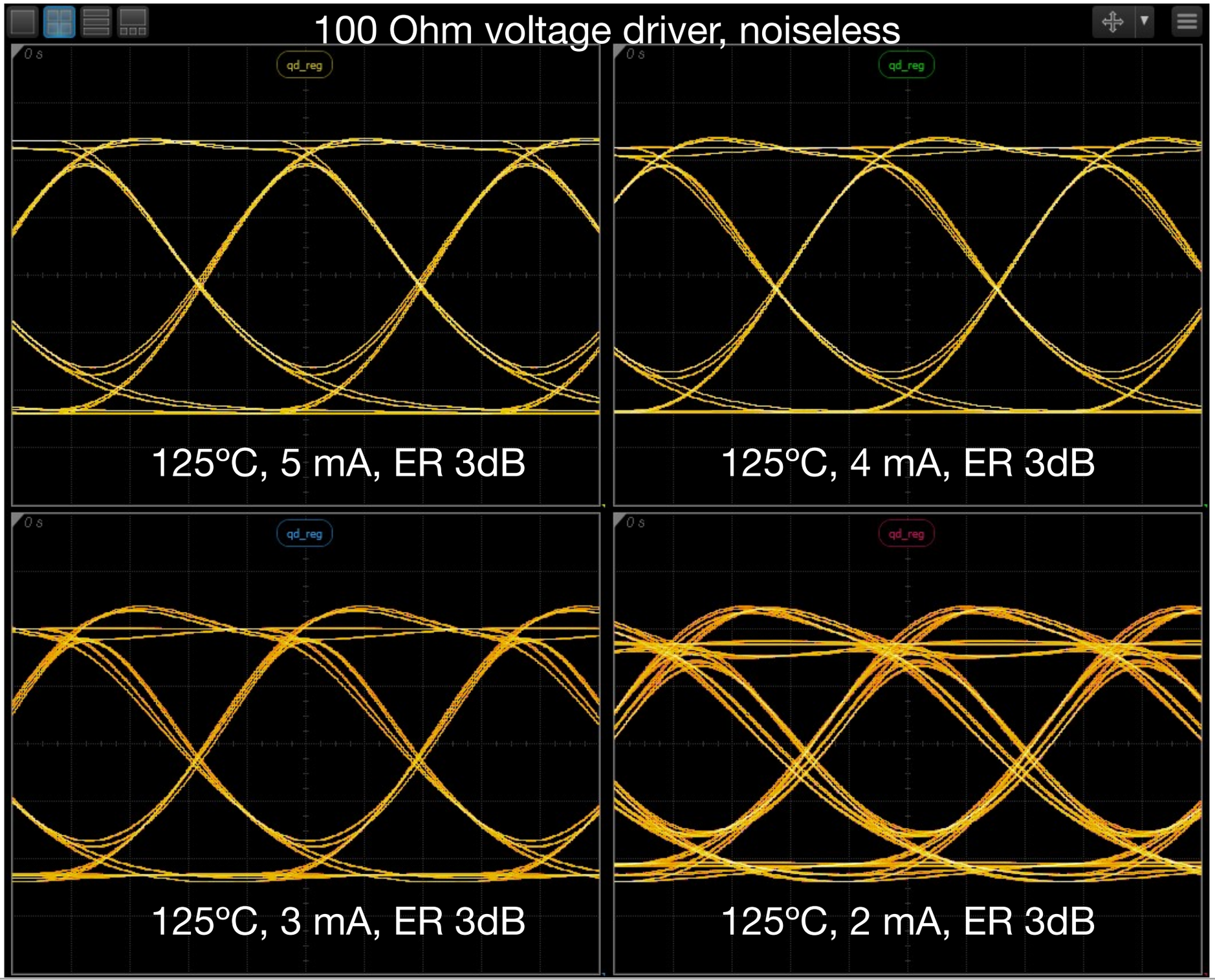
Normalized max RIN (RIN_{AOP})



$$RIN_{AOP}\left(dB/Hz\right) = RIN_{OMA}\left(dB/Hz\right) - 20\cdot\log_{10}\left(\frac{ER_L+1}{ER_L-1}\right)$$

$$ER_L = 10^{ER(dB)/10}$$

Eye diagram for 26.5625 GBd NRZ



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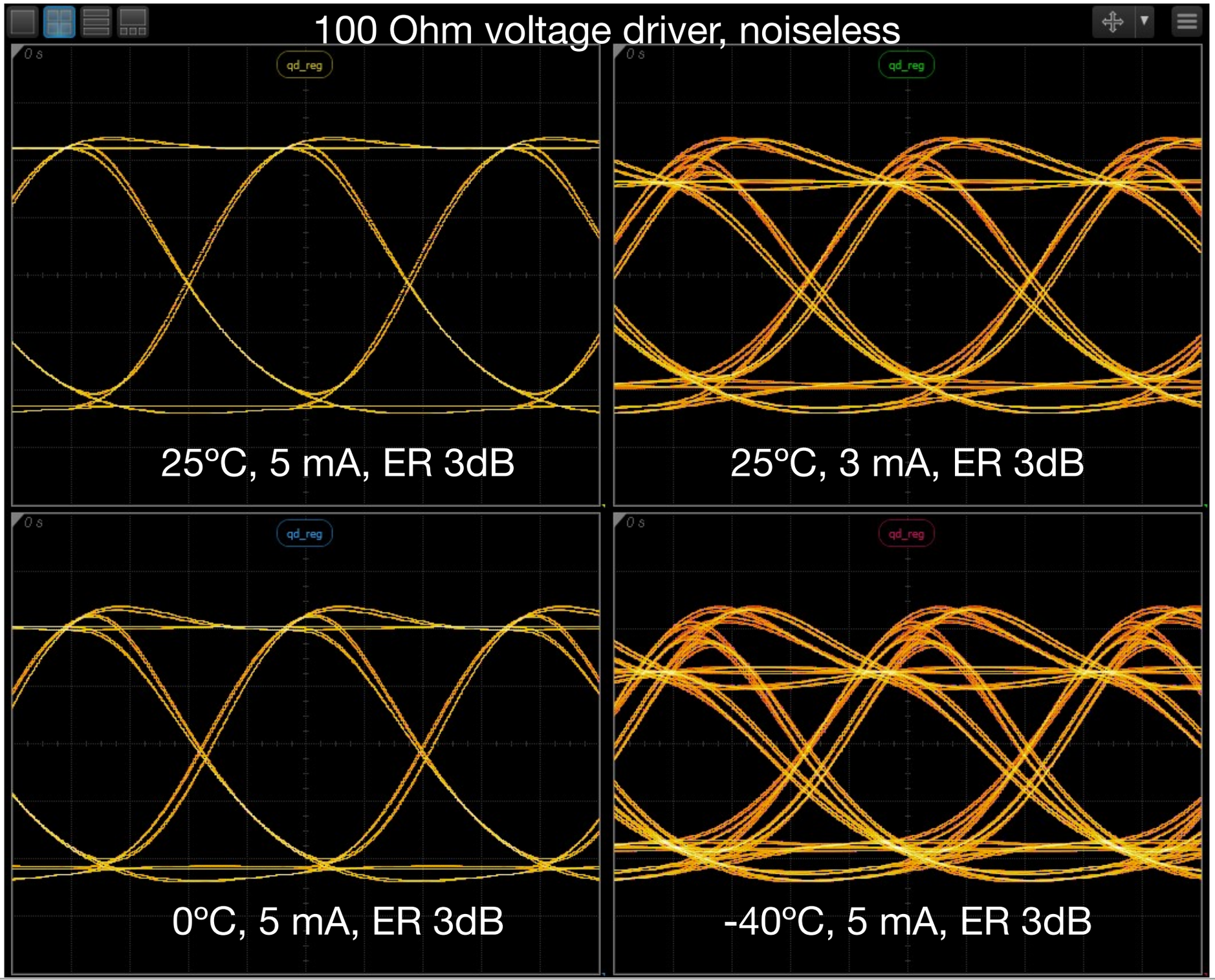

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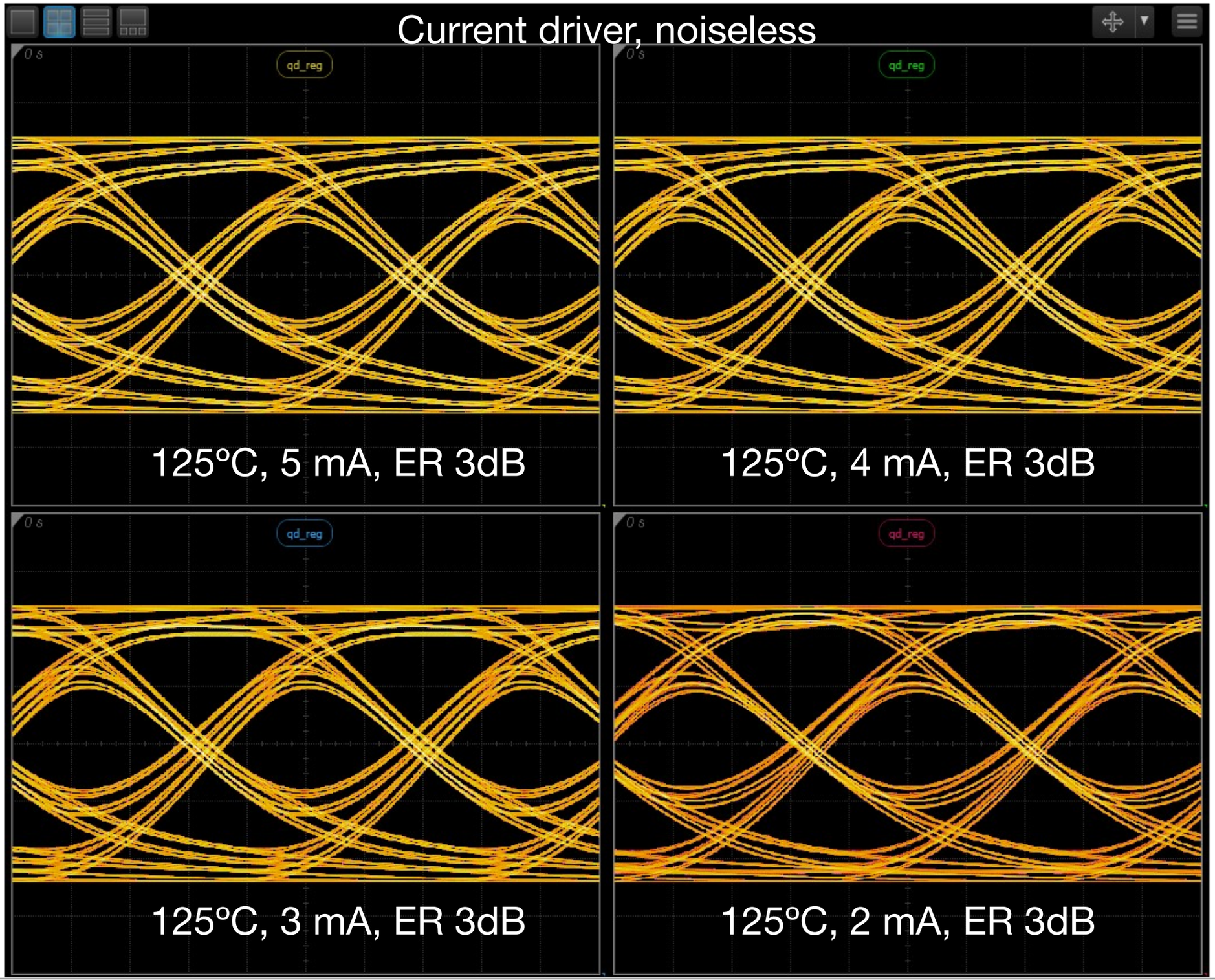

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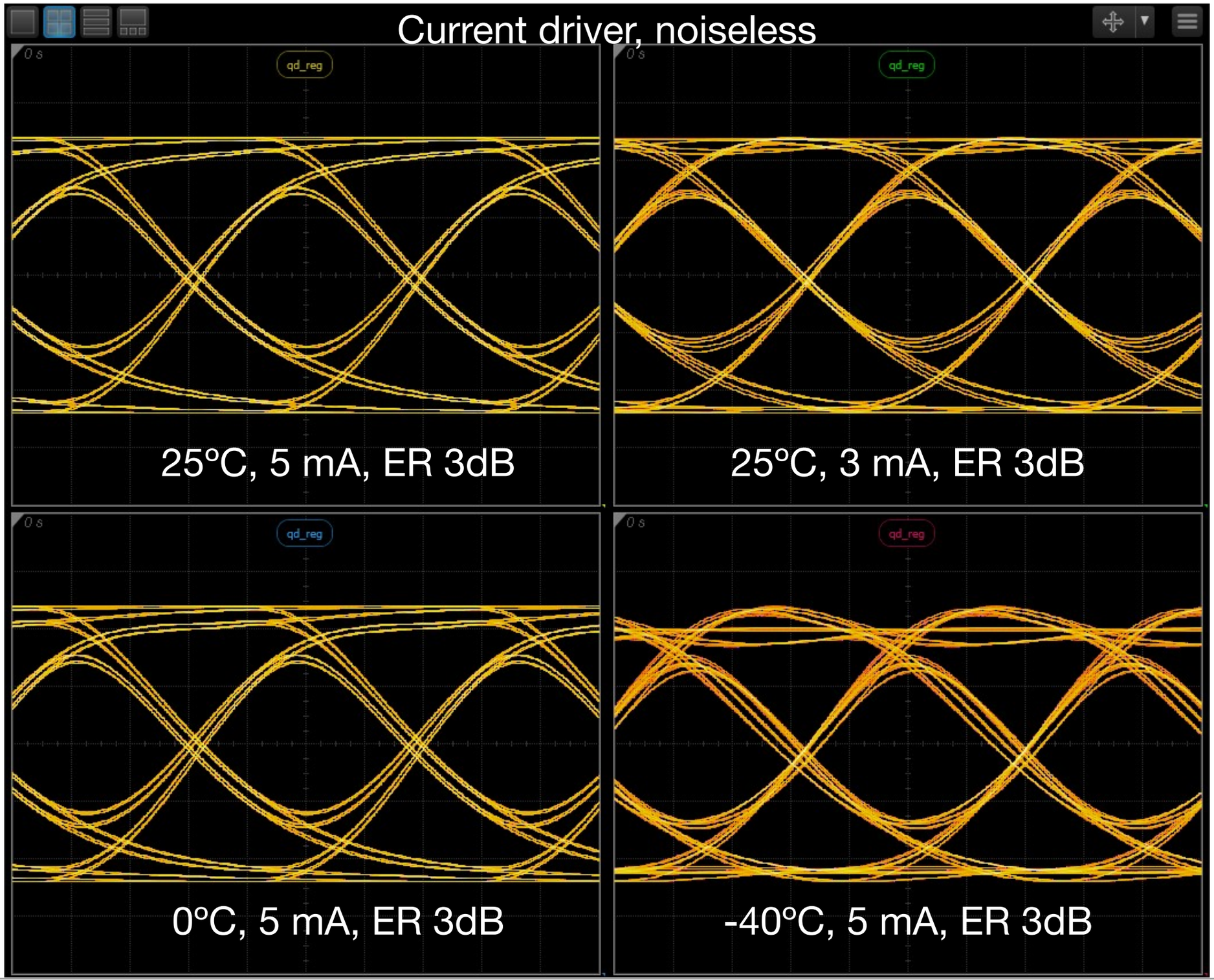

25Gbps multimode 850nm VCSEL based on QW

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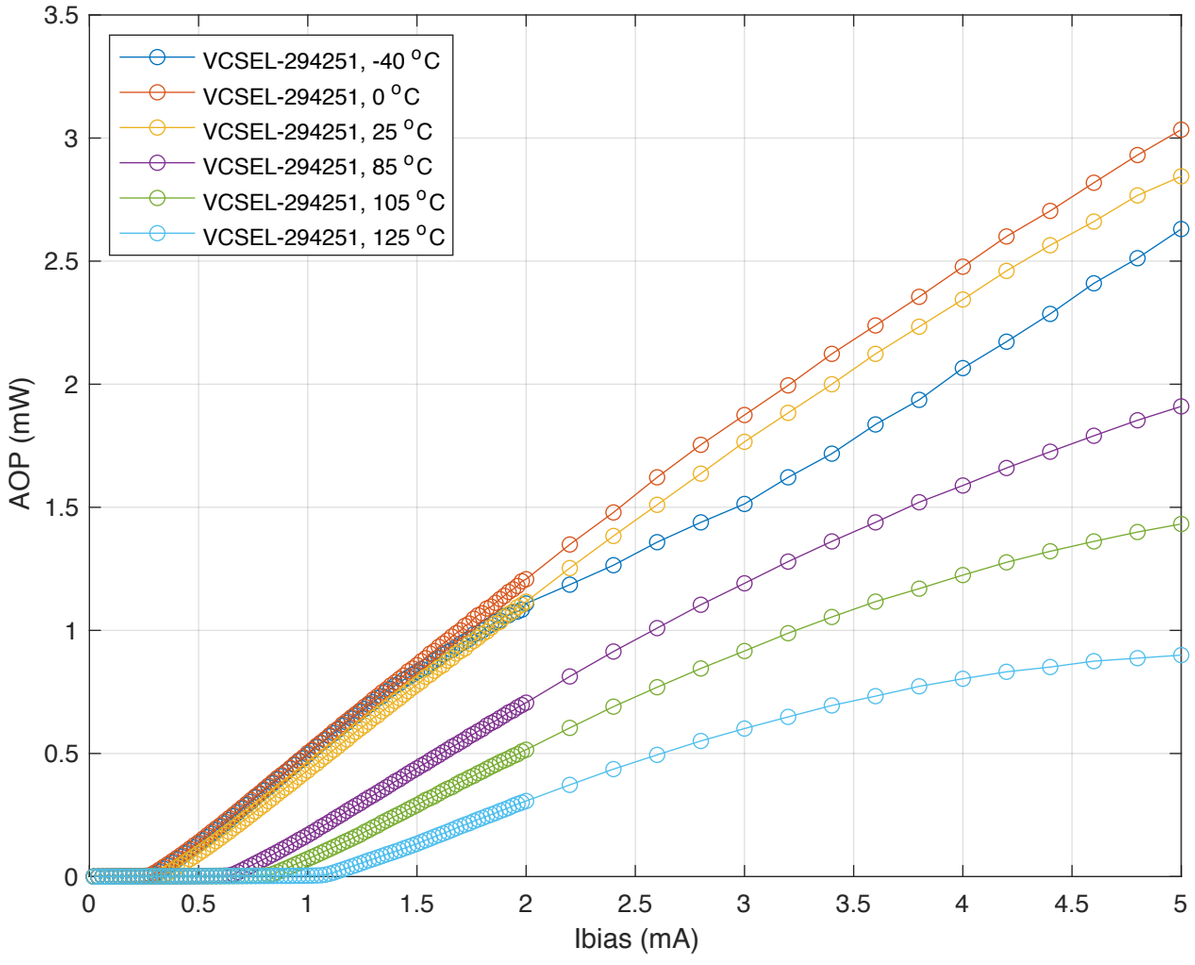
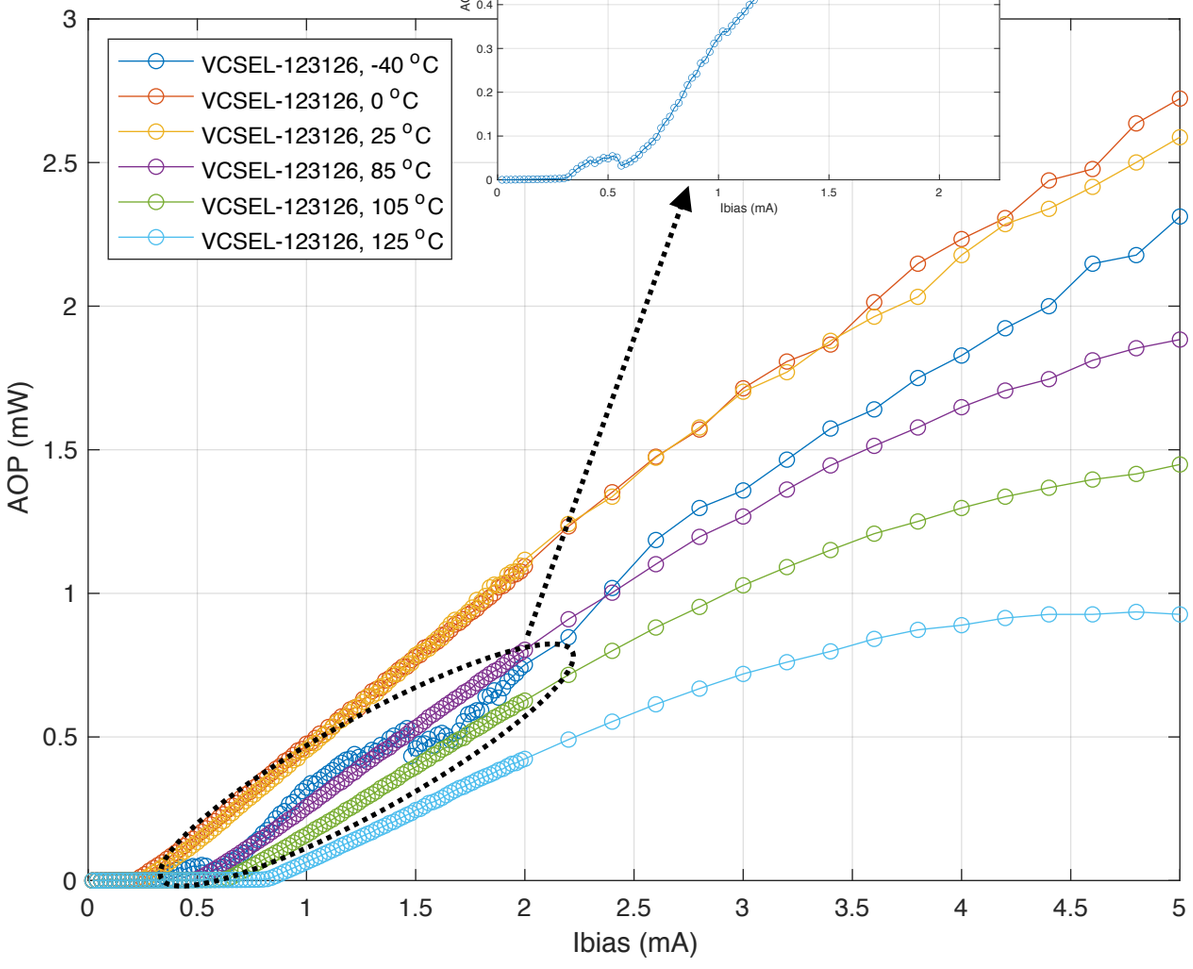
Special considerations

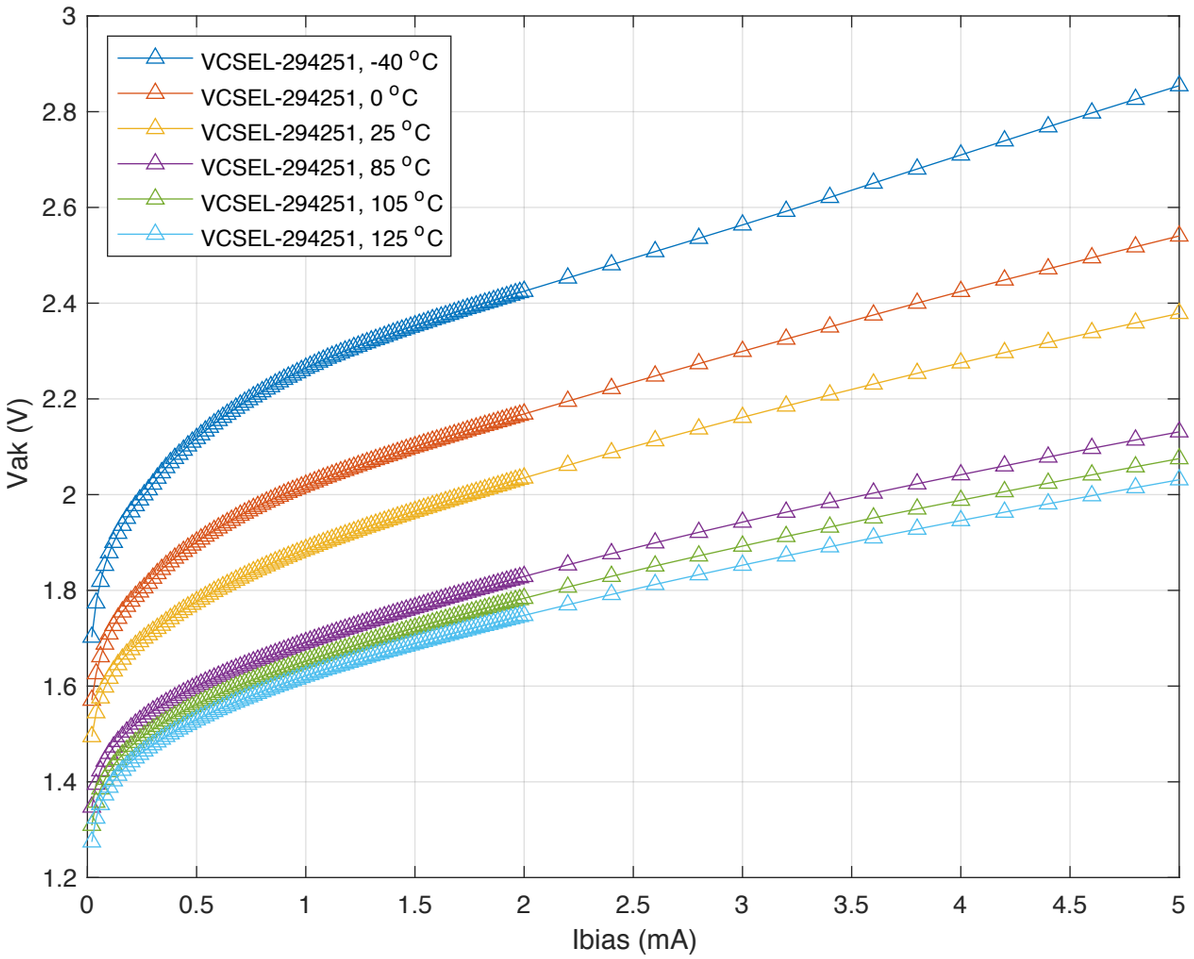
- Devices from different wafers and different quarters of each wafers have been tested, obtaining different characteristics for the same QW VCSEL design
- Based on the found results, the devices have been split in two bins:
  - Bin 1: devices that behave with low threshold current in low temperature
  - Bin 2: devices that show two laser regions with two separated threshold currents in low temperature

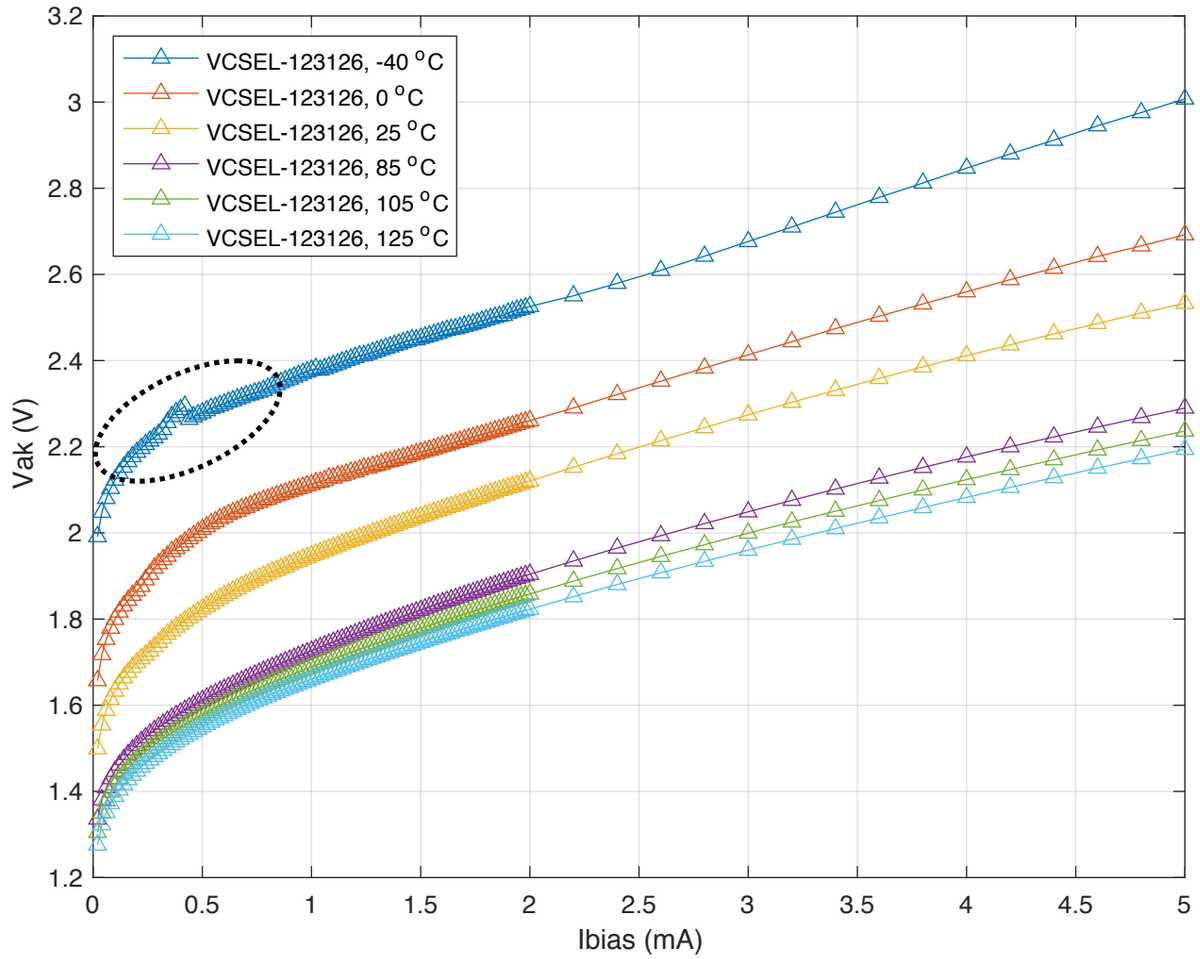
L-I-V characteristic — Bin 1



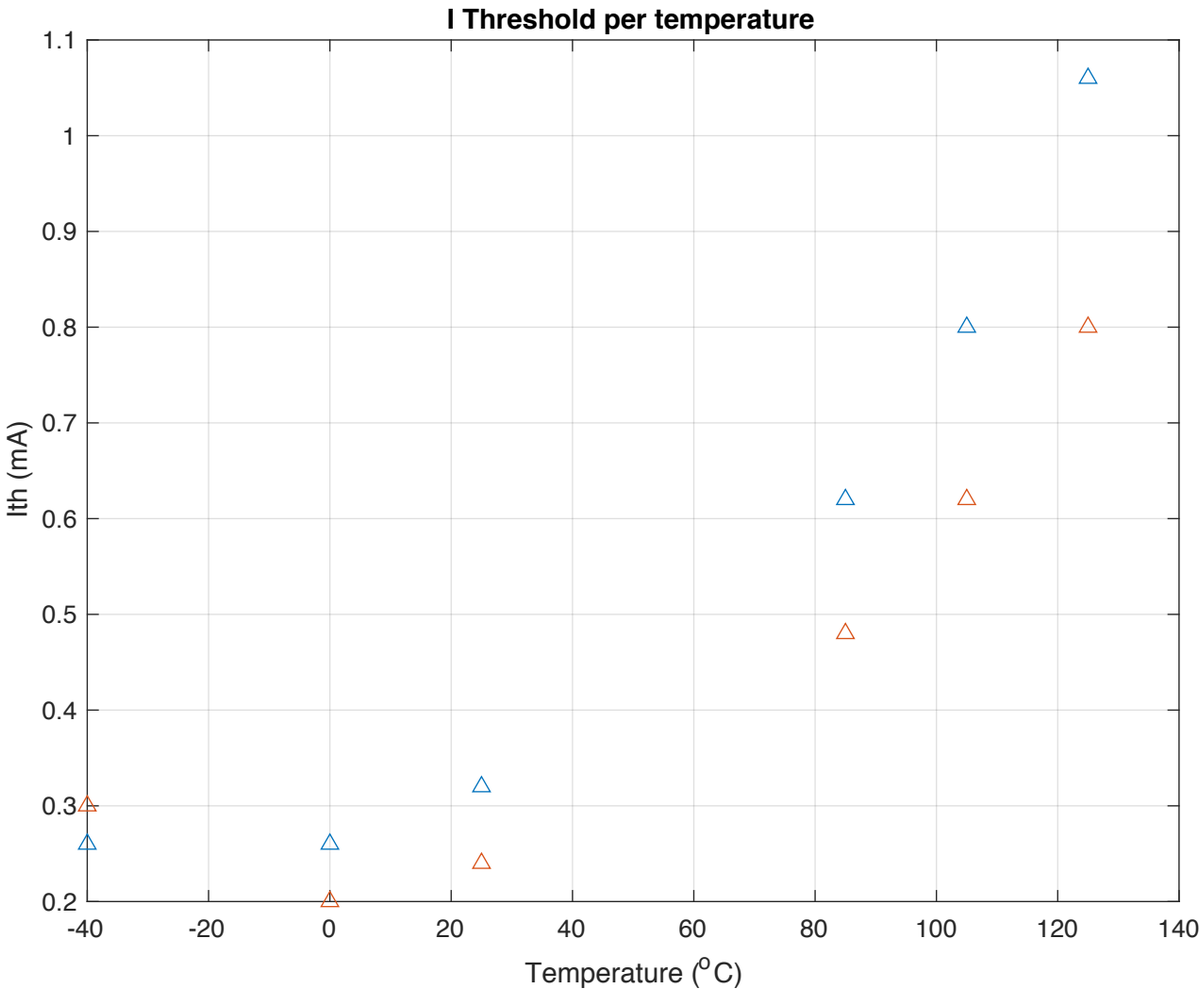


L-I-V characteristic — Bin 1

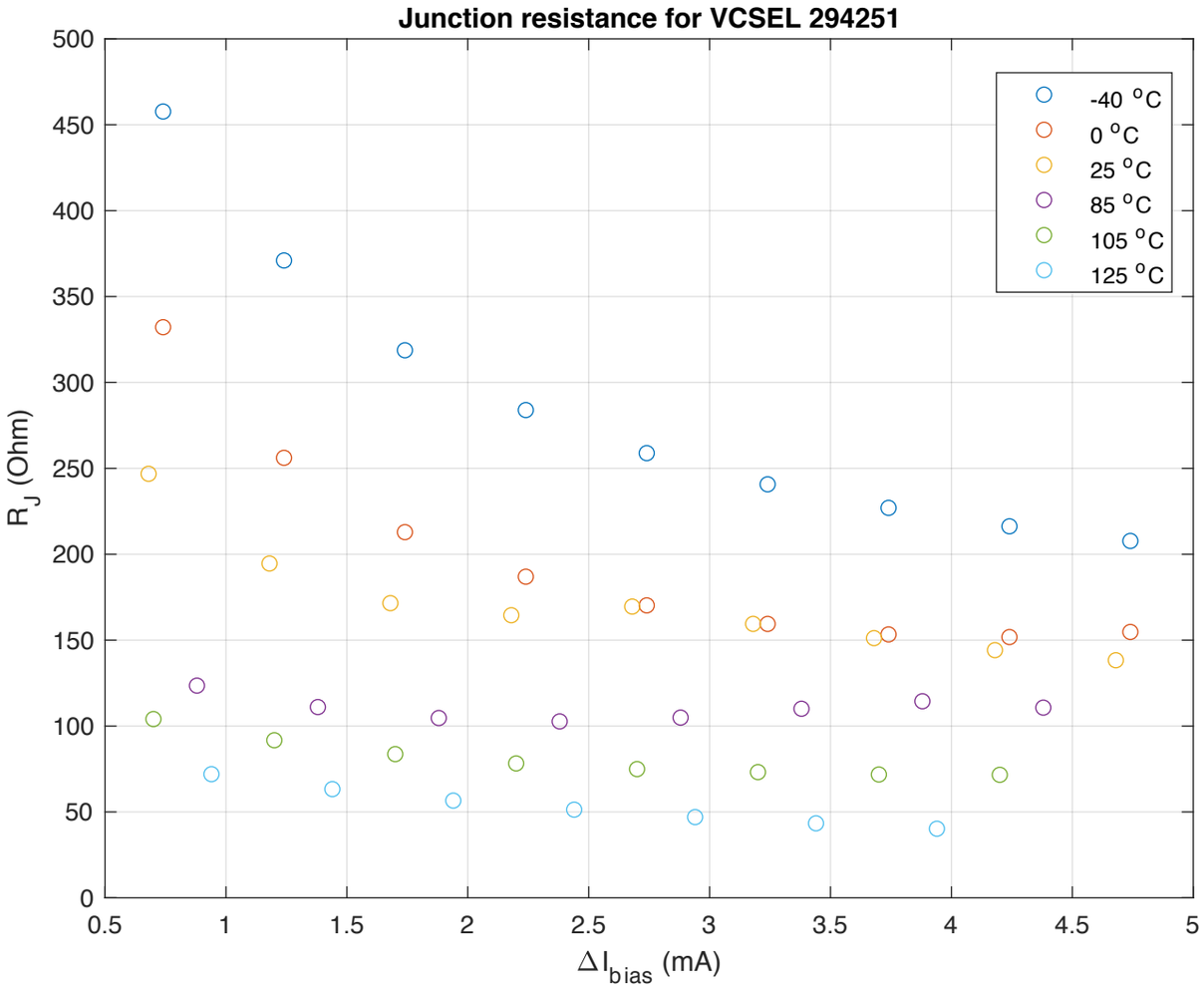


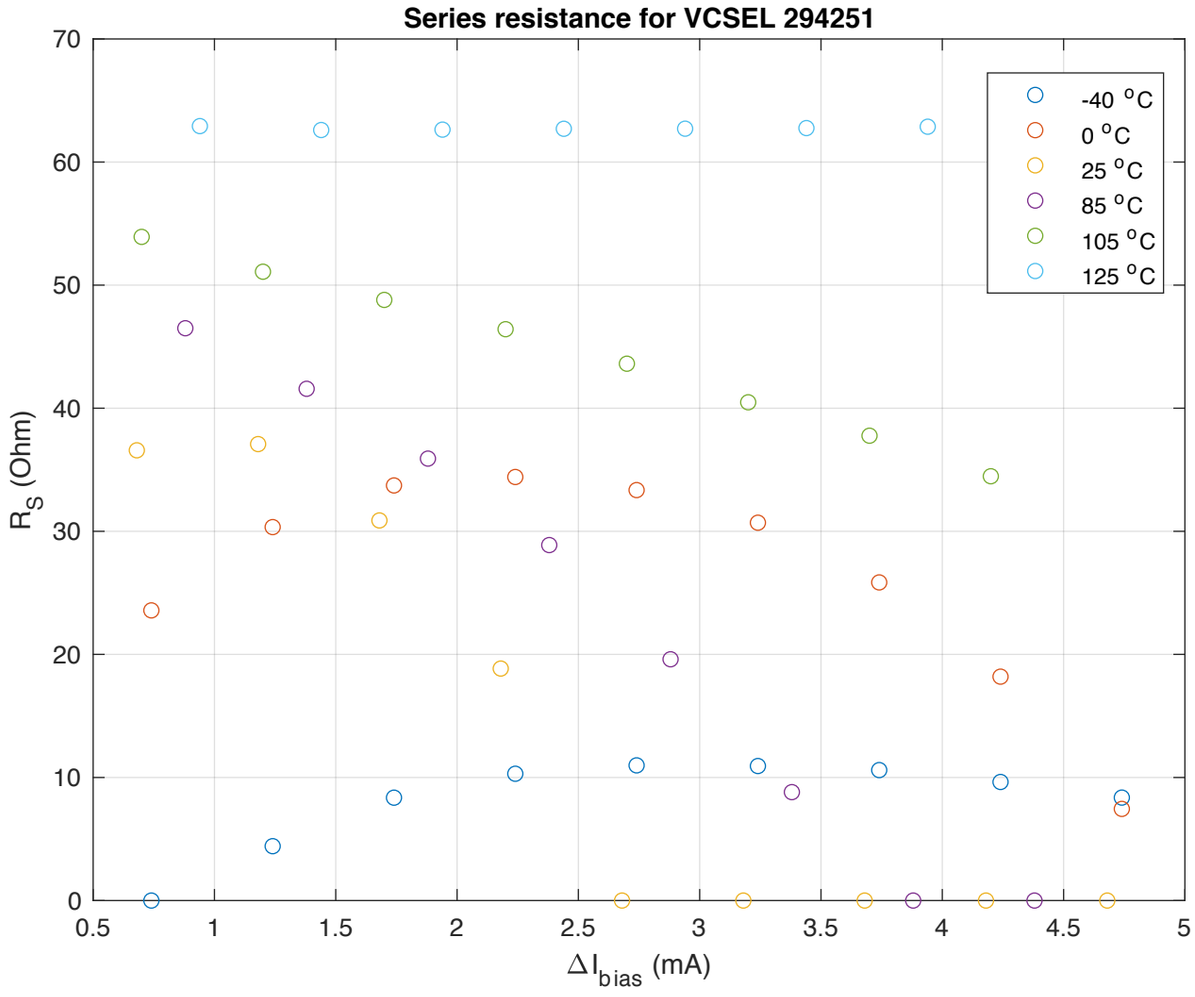


Threshold current characteristic — Bin 1



Small signal frequency response — Bin 1





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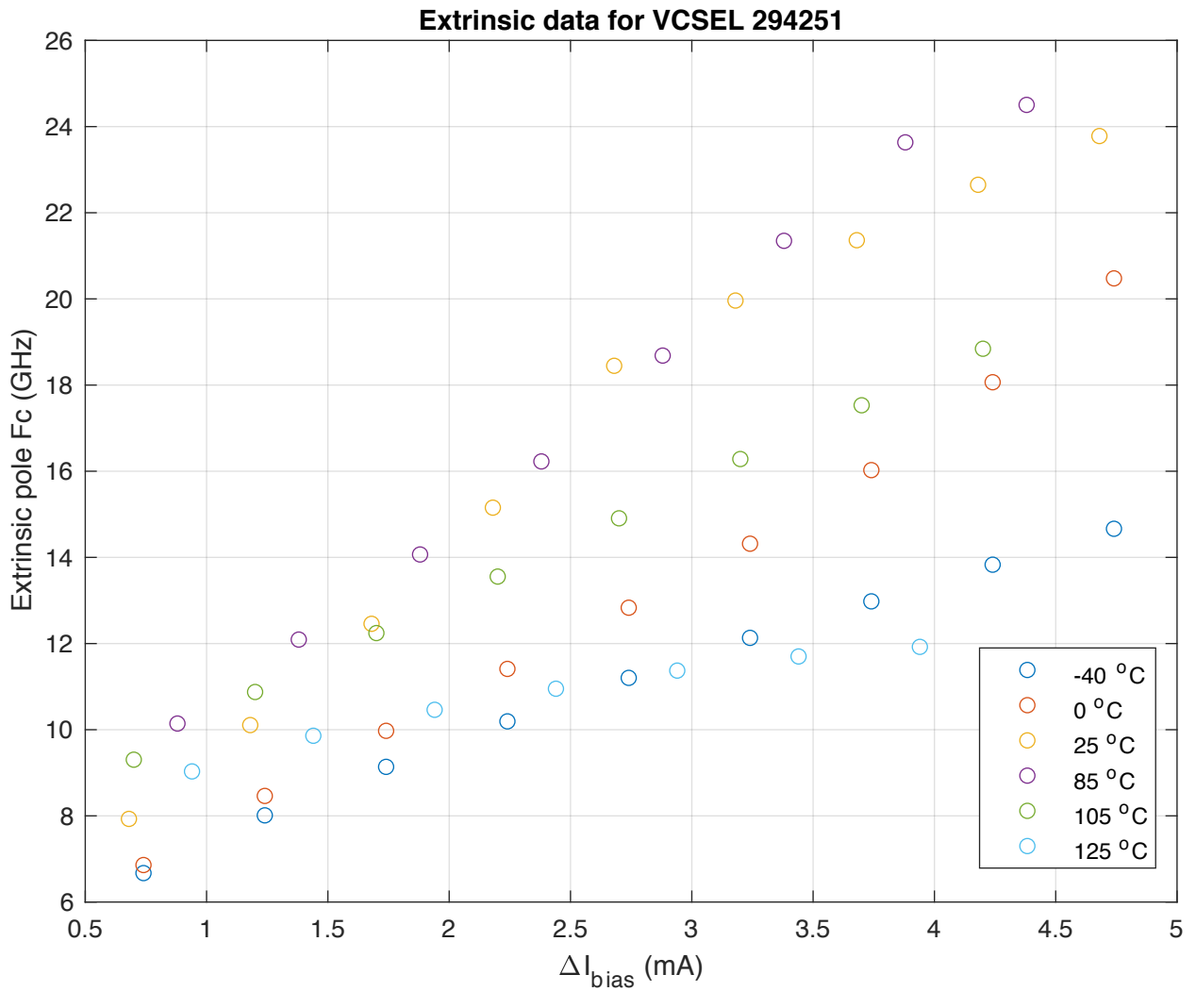

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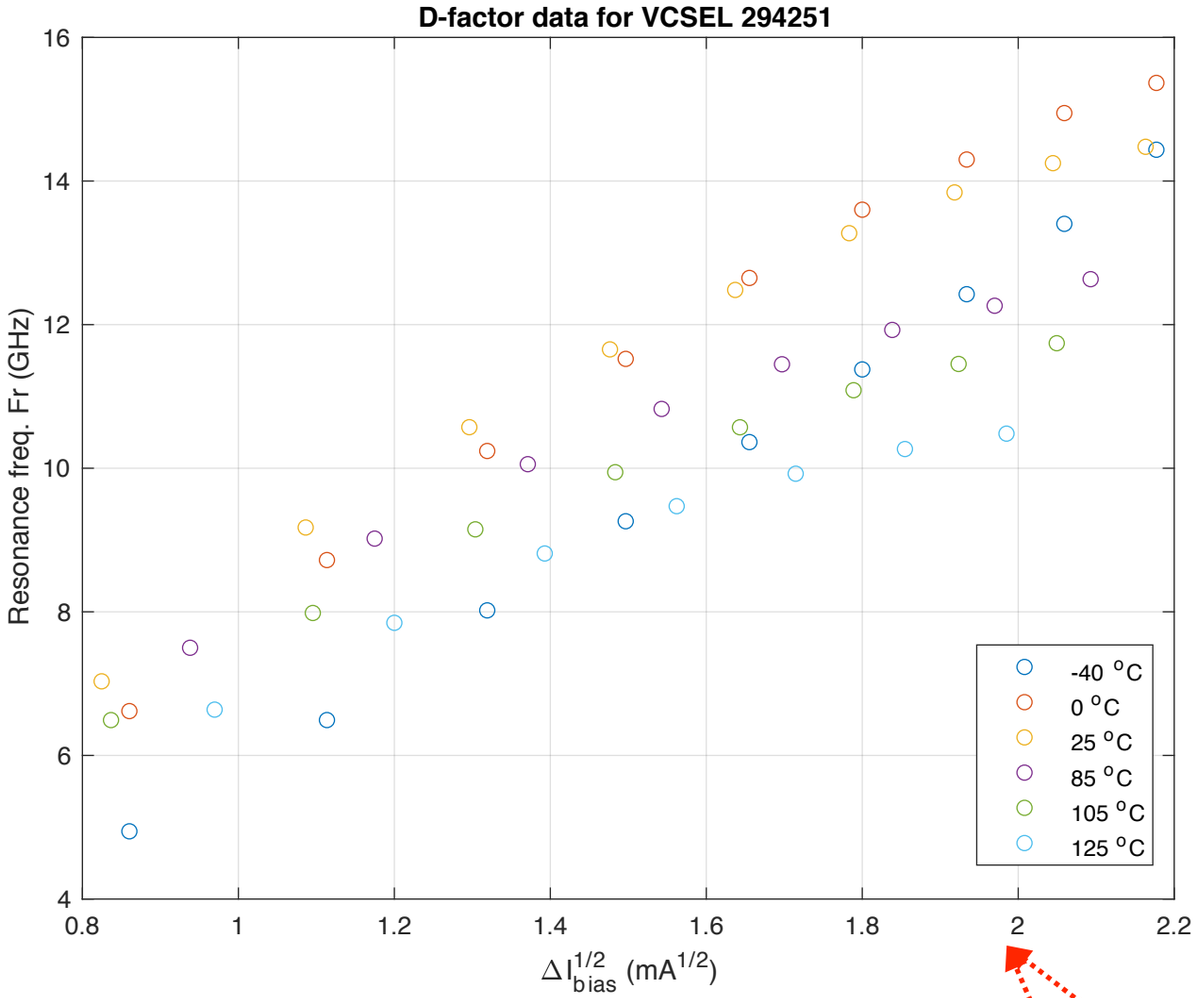
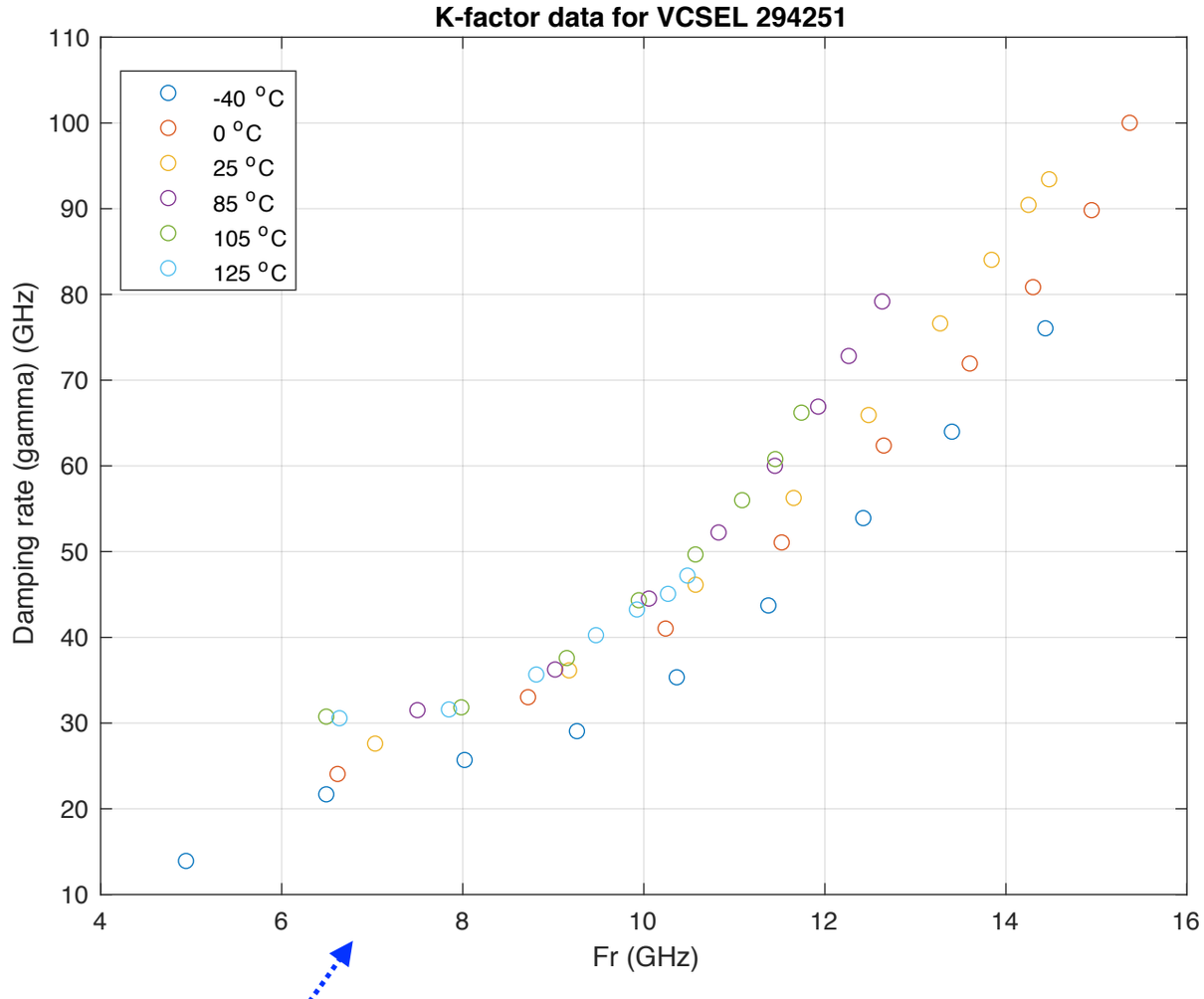
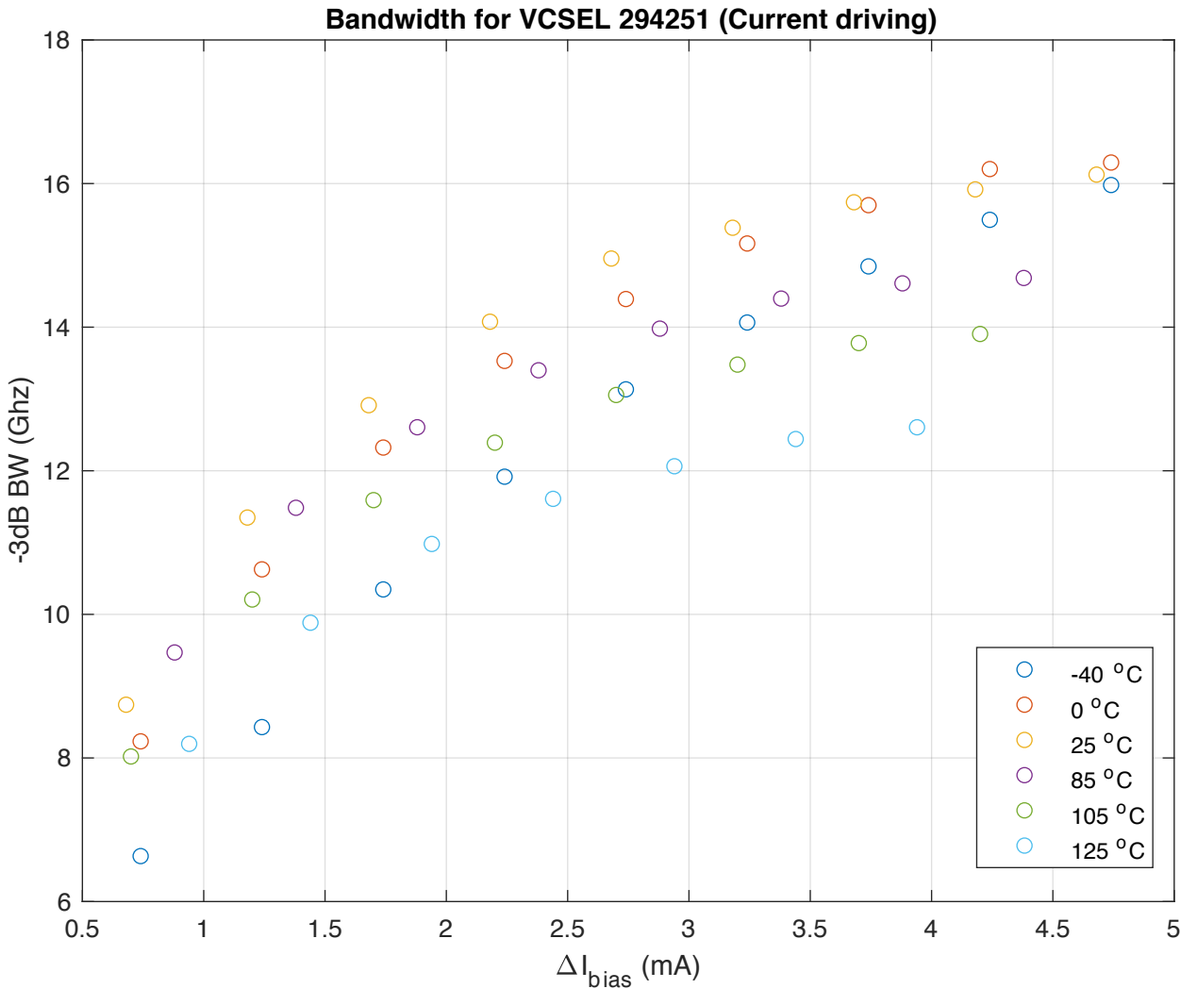
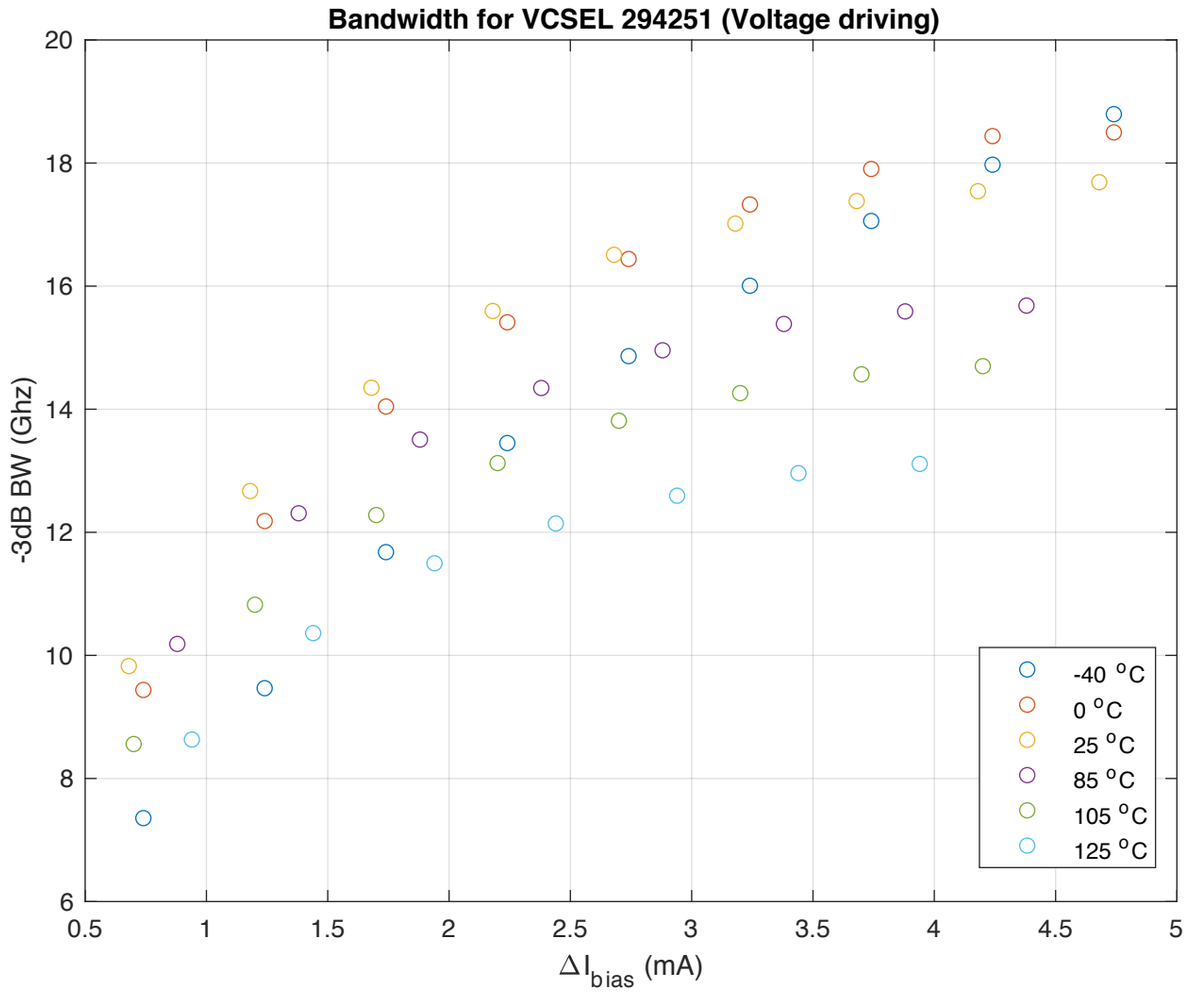




$$H(f) = C \cdot \frac{f_r^2}{f_r^2 - f^2 + j\frac{f}{2\pi}\gamma} \cdot \frac{1}{1 + j\frac{f}{f_p}}.$$ (see [1])

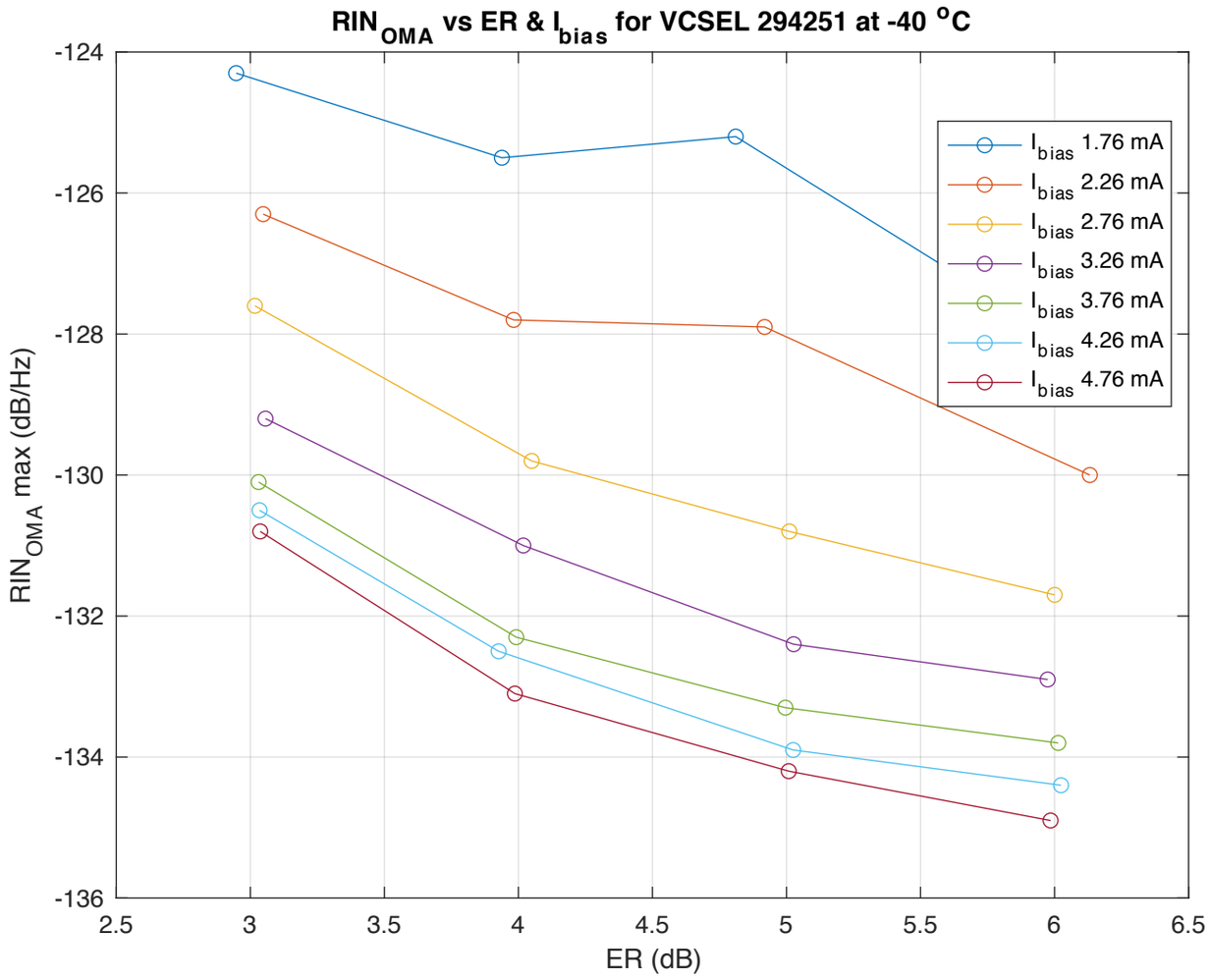
Small signal frequency response — Bin 1

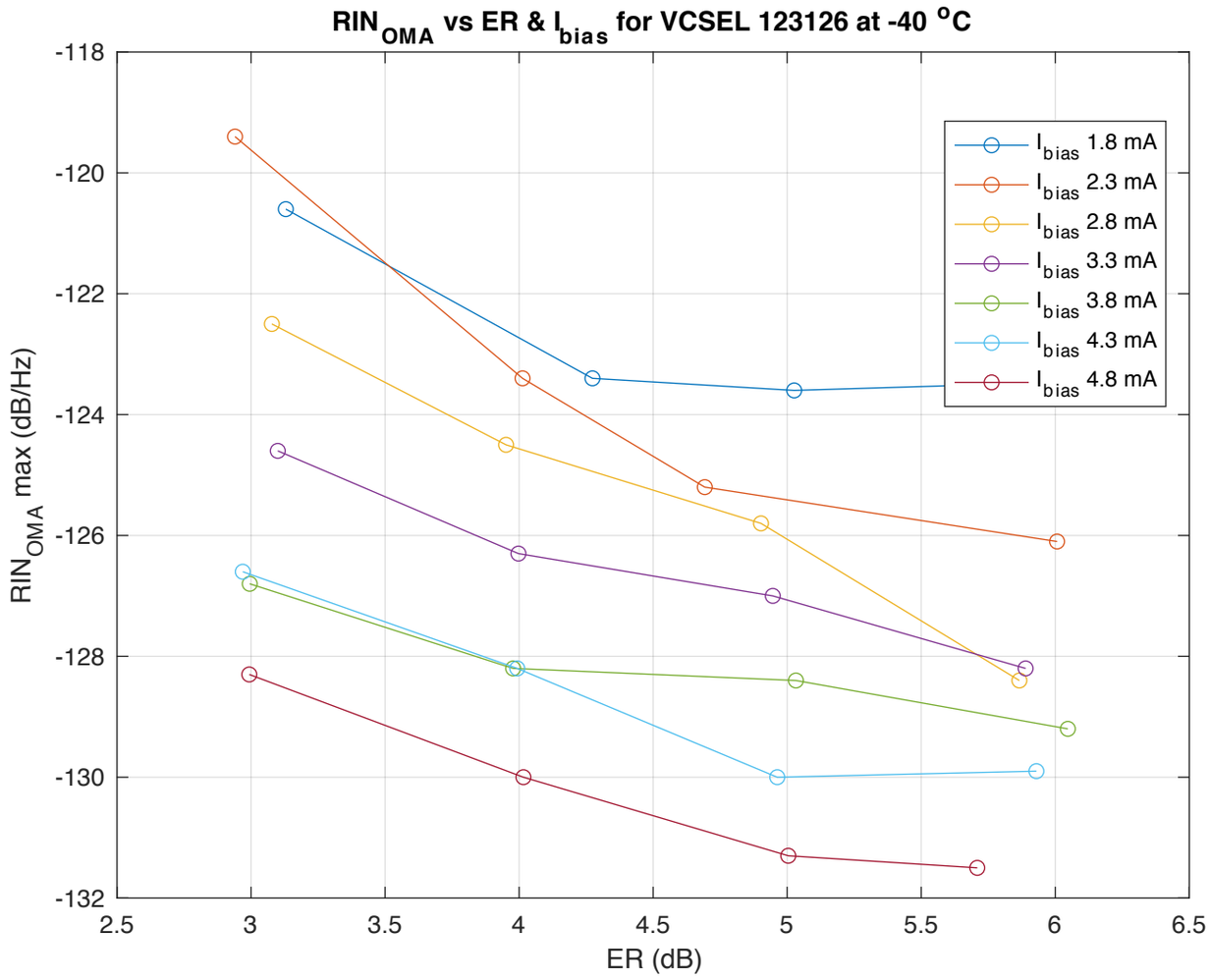




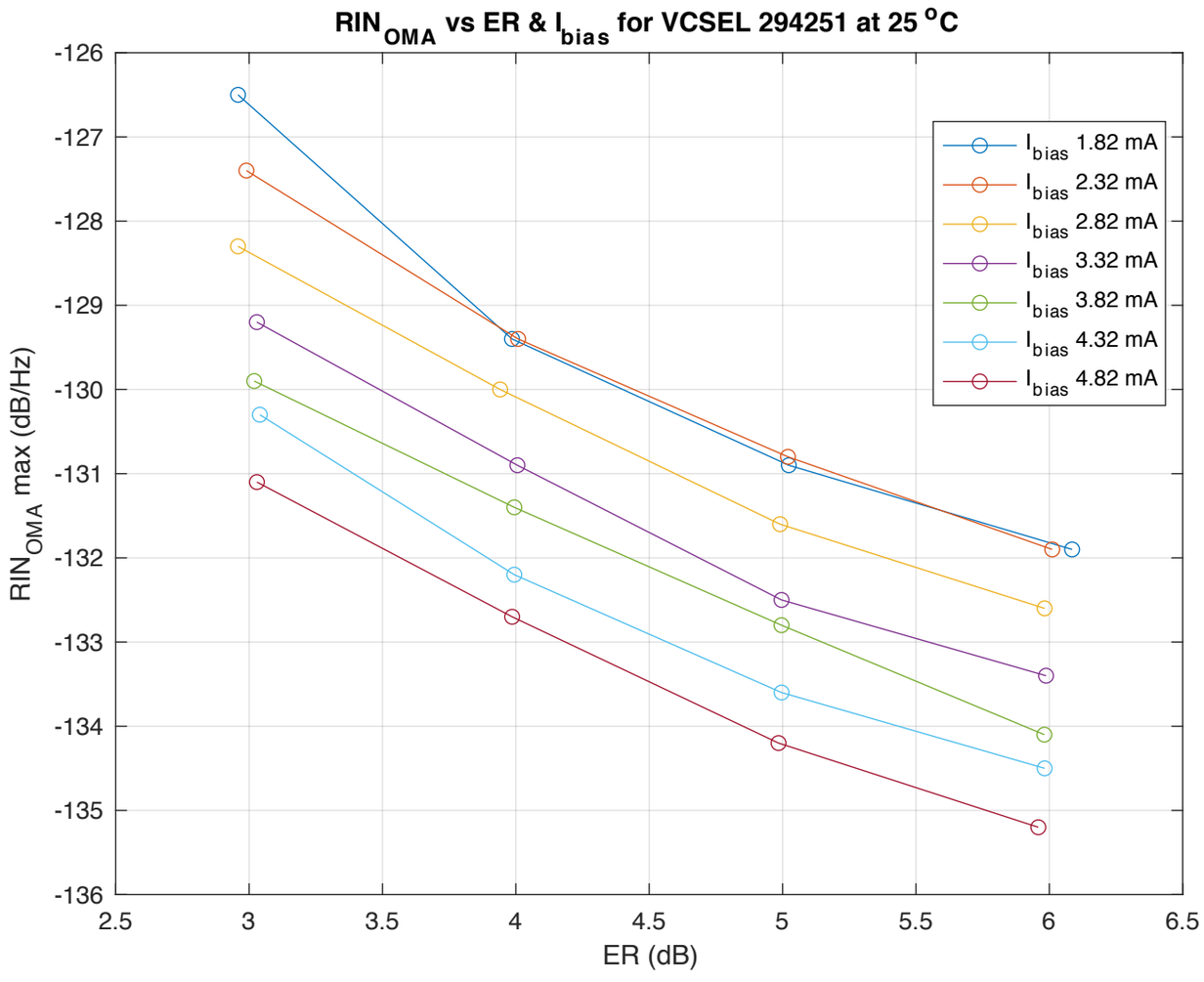
Considered source impedance 100 Ω

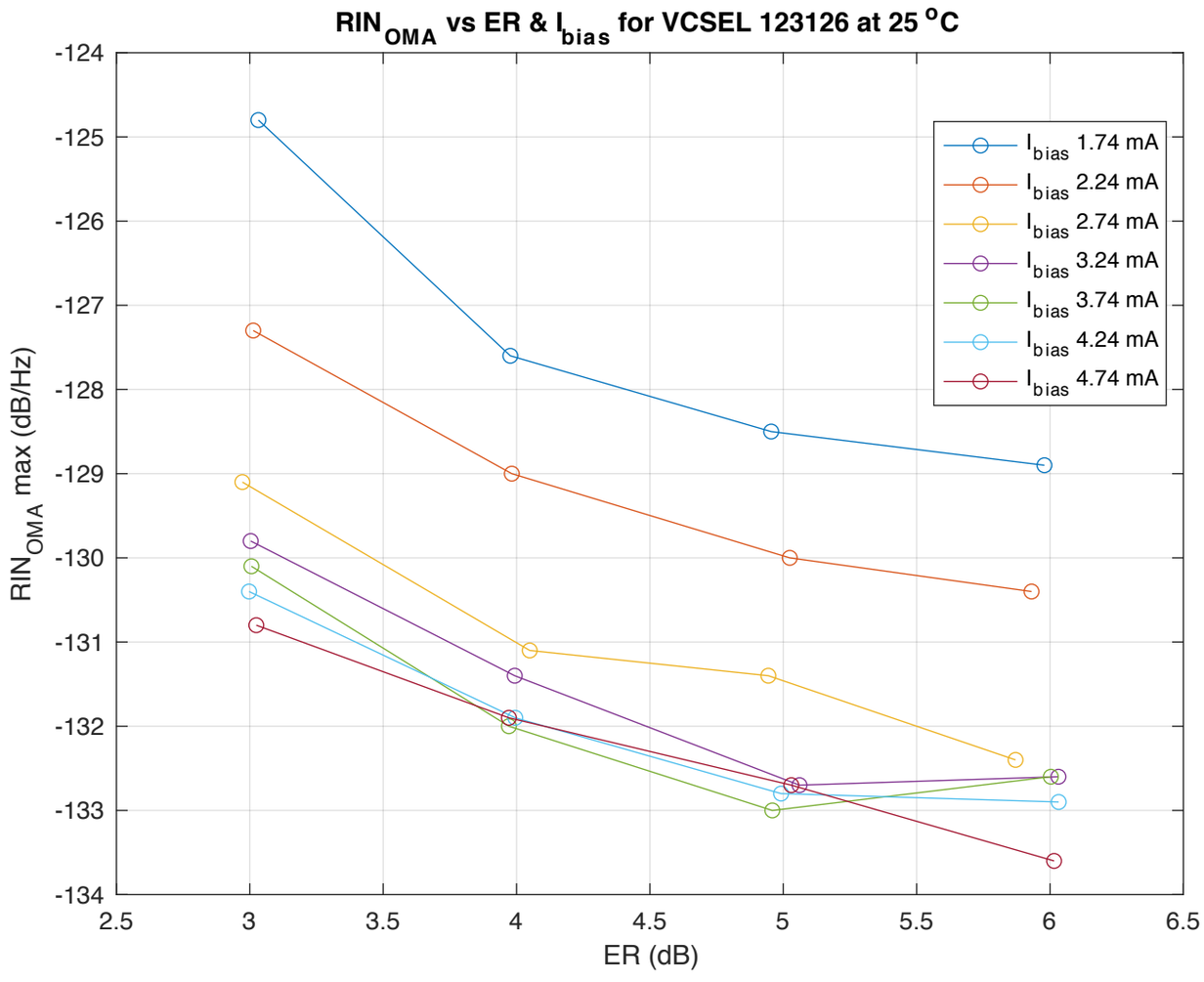
Relative intensity noise (RIN_{OMA}) at -40ºC — Bin 1



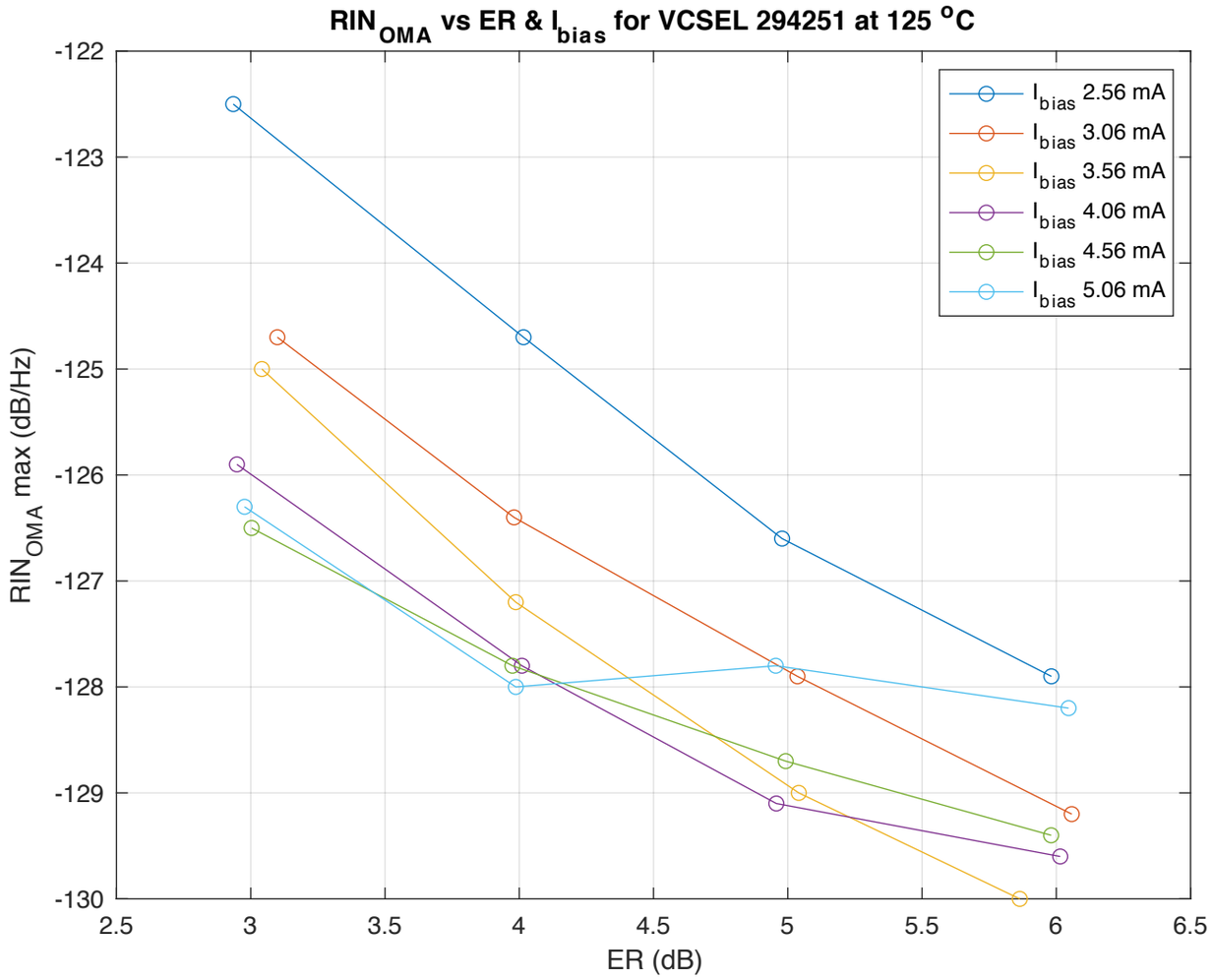


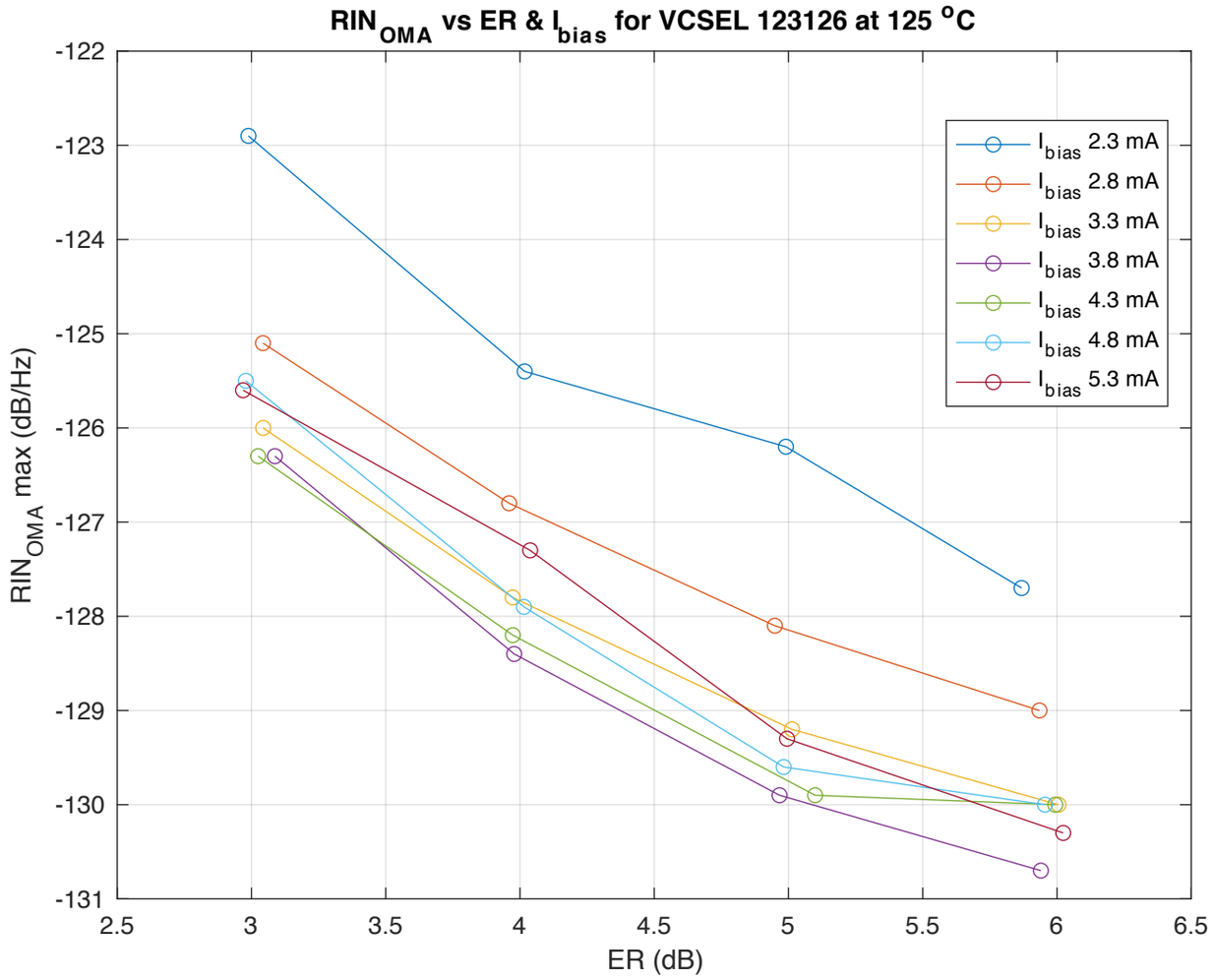
Relative intensity noise (RIN_{OMA}) at 25ºC — Bin 1



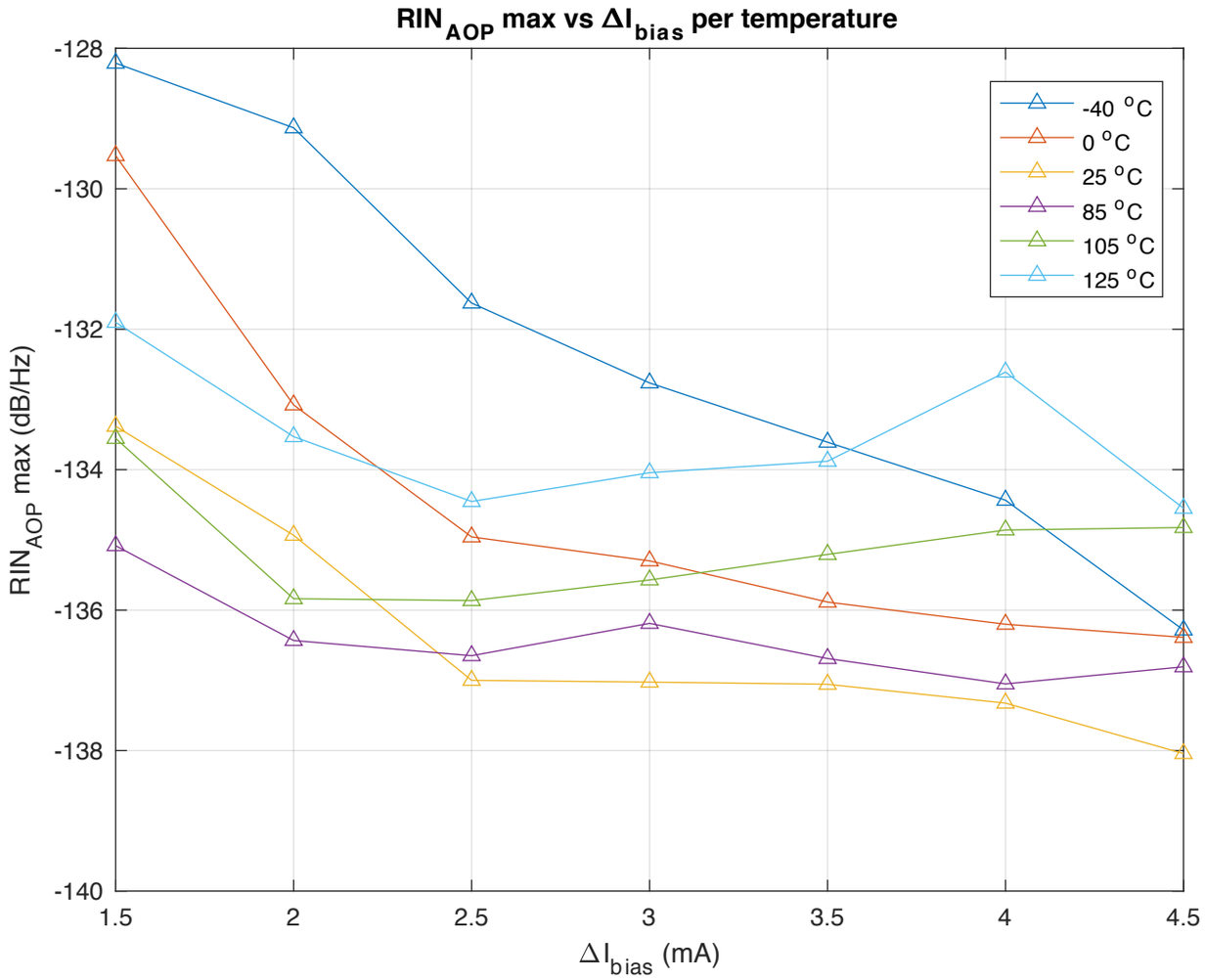


Relative intensity noise (RIN_{OMA}) at 125ºC — Bin 1





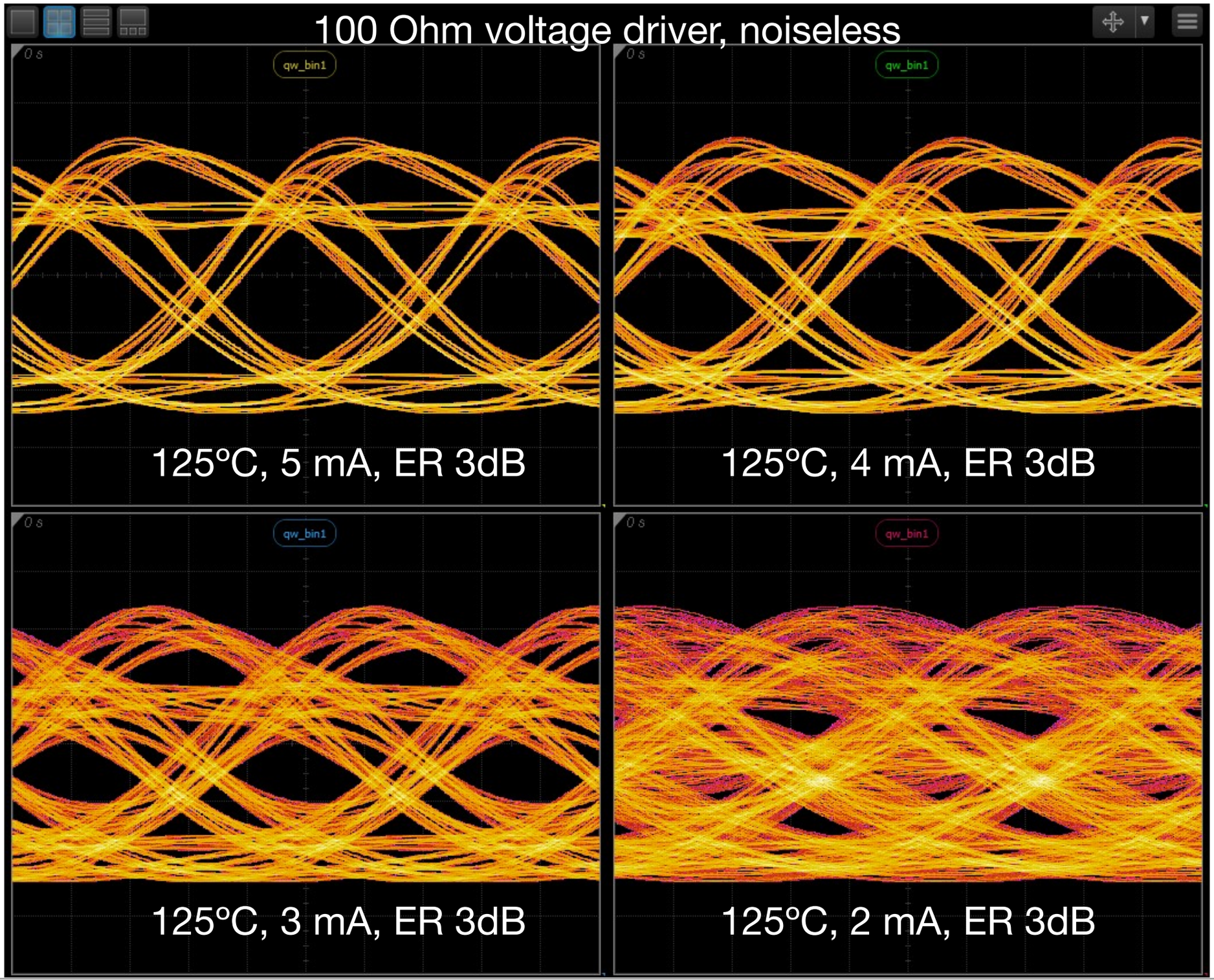
Normalized max RIN (RIN_{AOP}) — Bin 1



$$RIN_{AOP}\left(dB/Hz\right) = RIN_{OMA}\left(dB/Hz\right) - 20\cdot\log_{10}\left(\frac{ER_L+1}{ER_L-1}\right)$$

$$ER_L = 10^{ER(dB)/10}$$

Eye diagram for 26.5625 GBd NRZ — Bin 1



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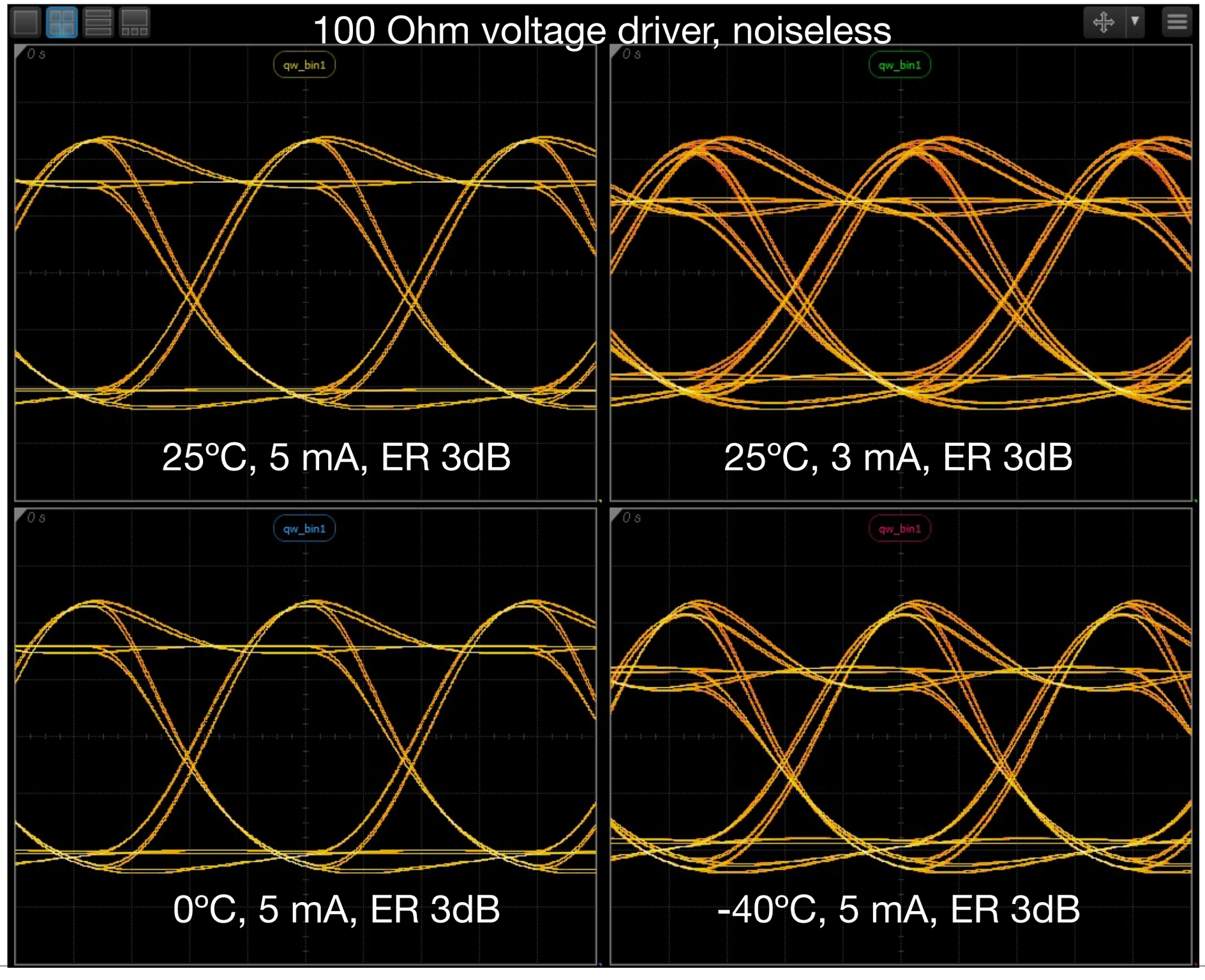

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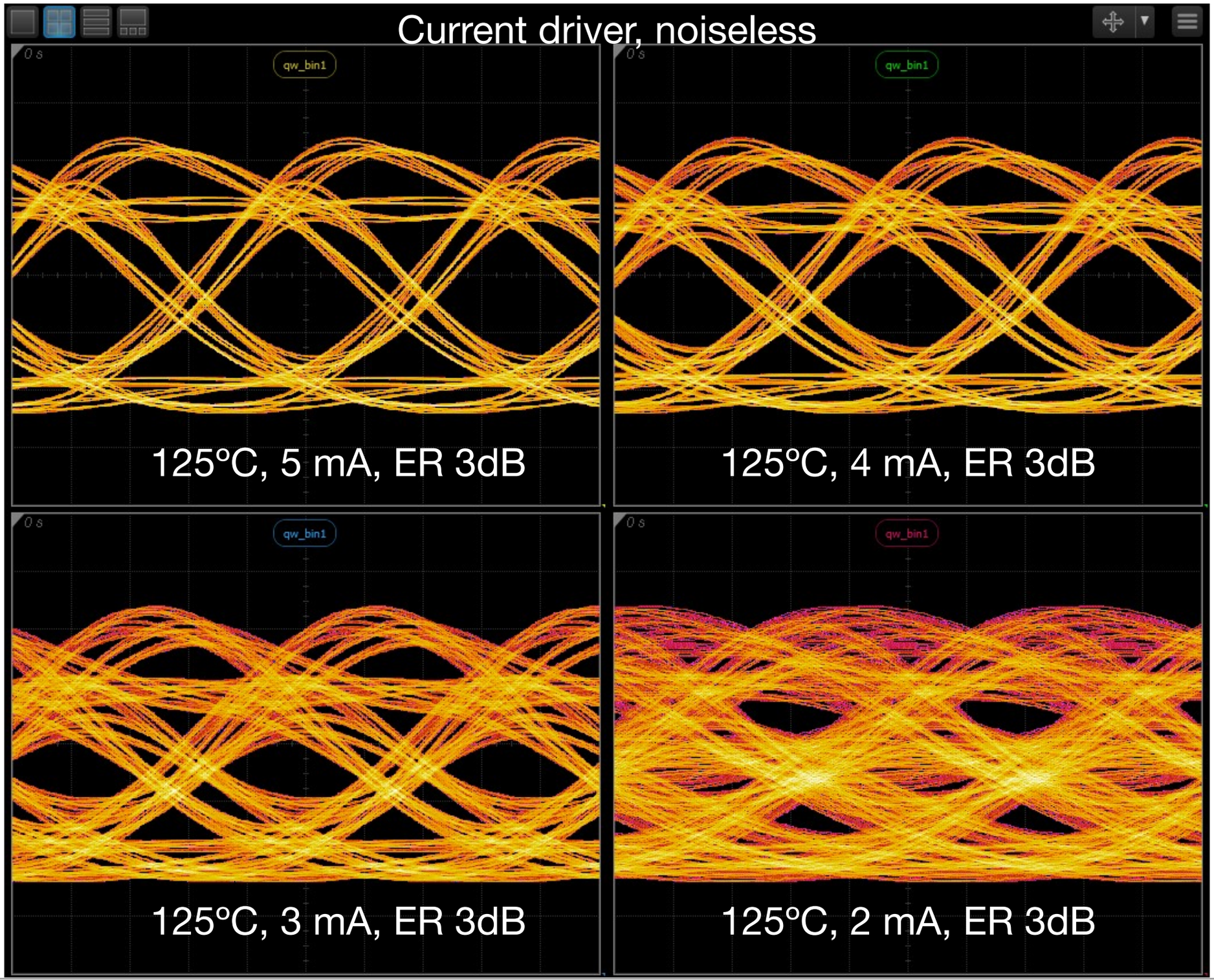
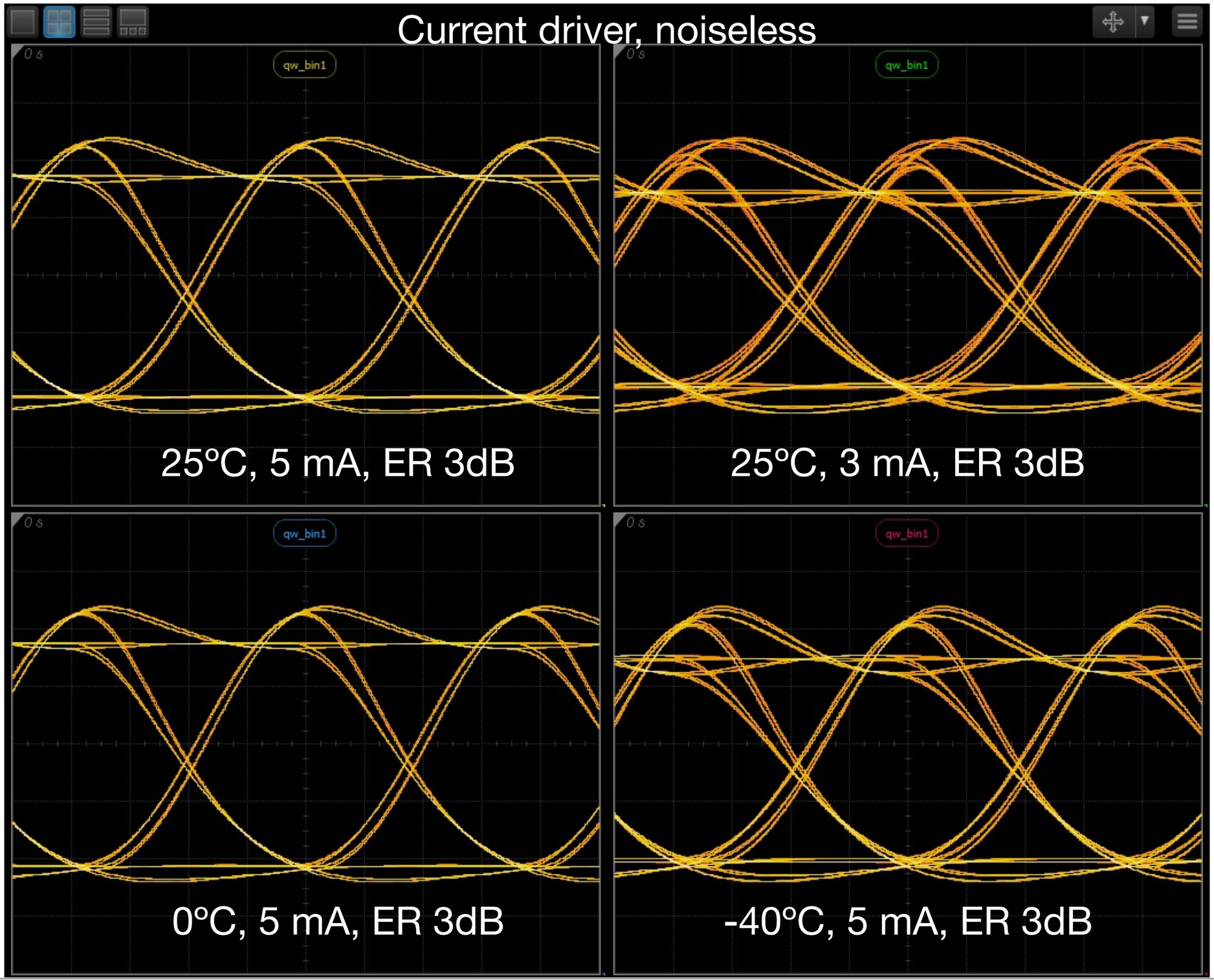
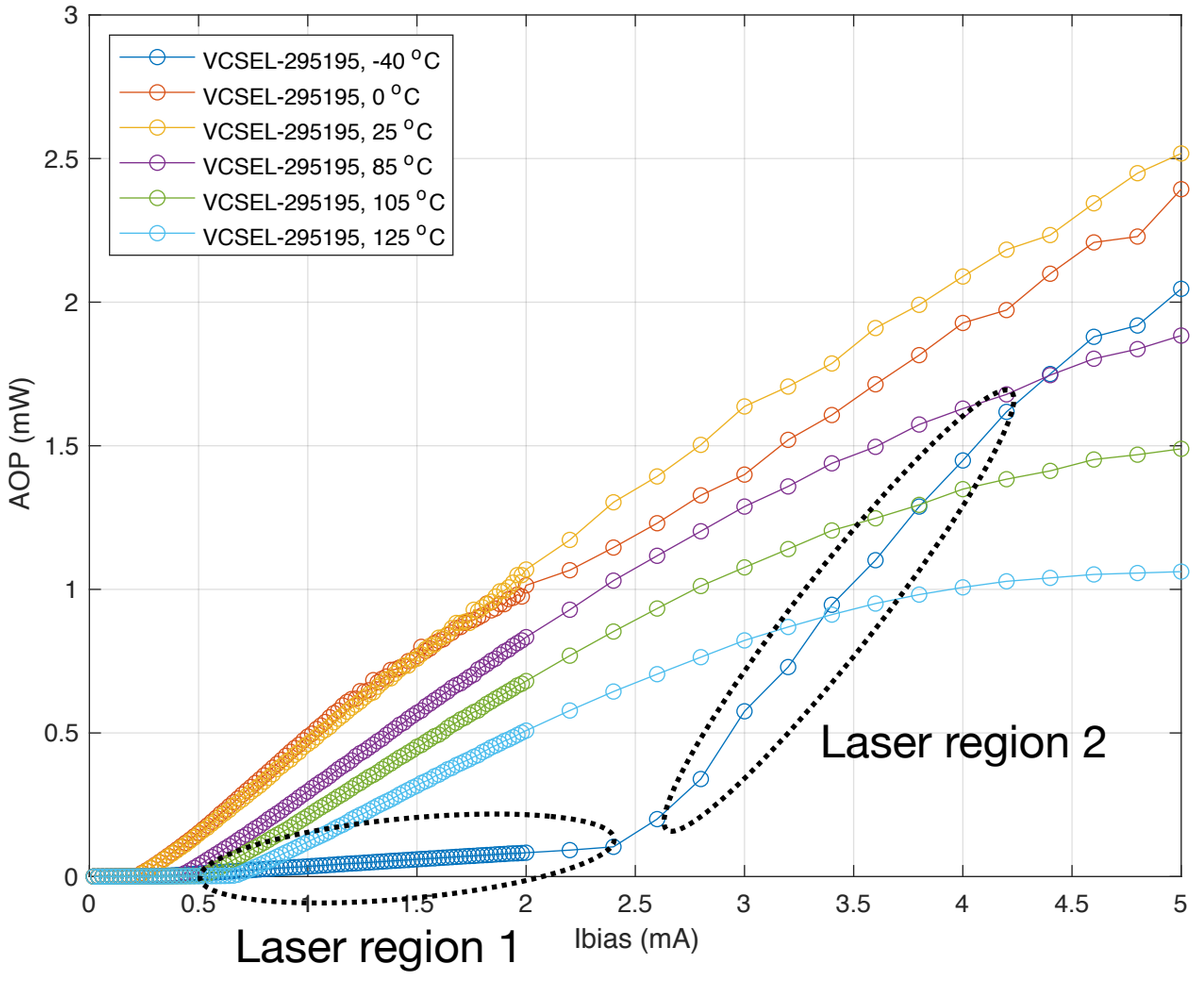
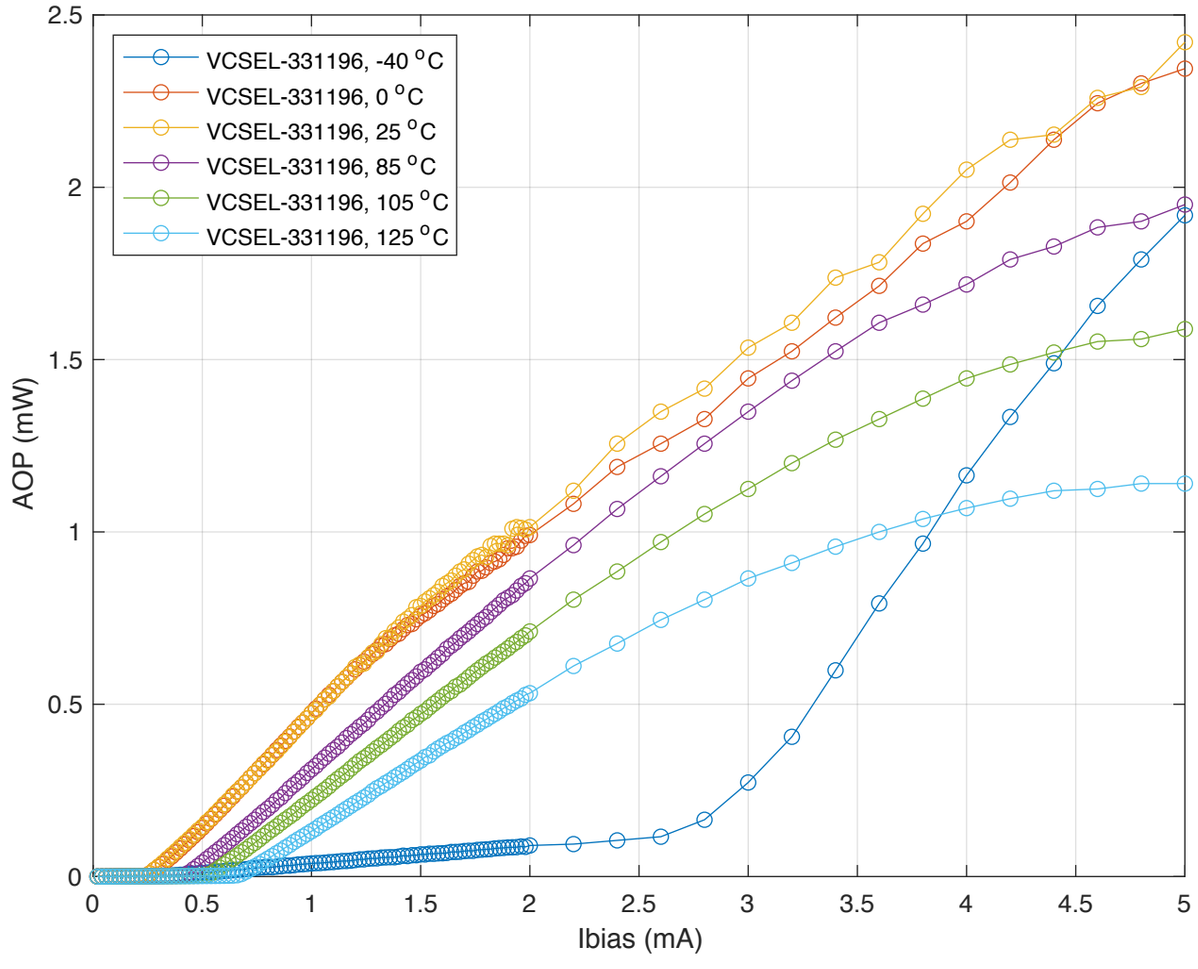


Eye diagram for 26.5625 GBd NRZ — Bin 1

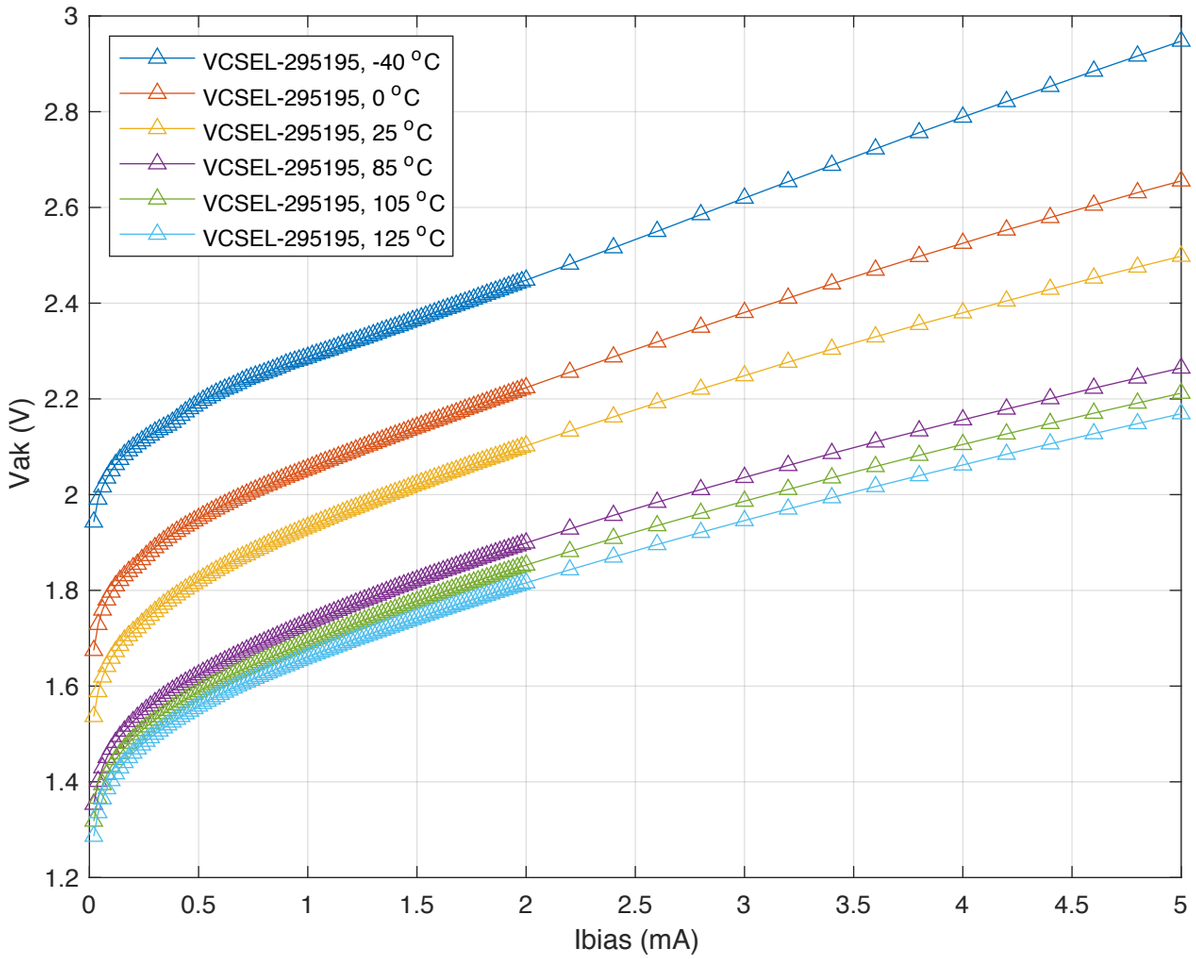


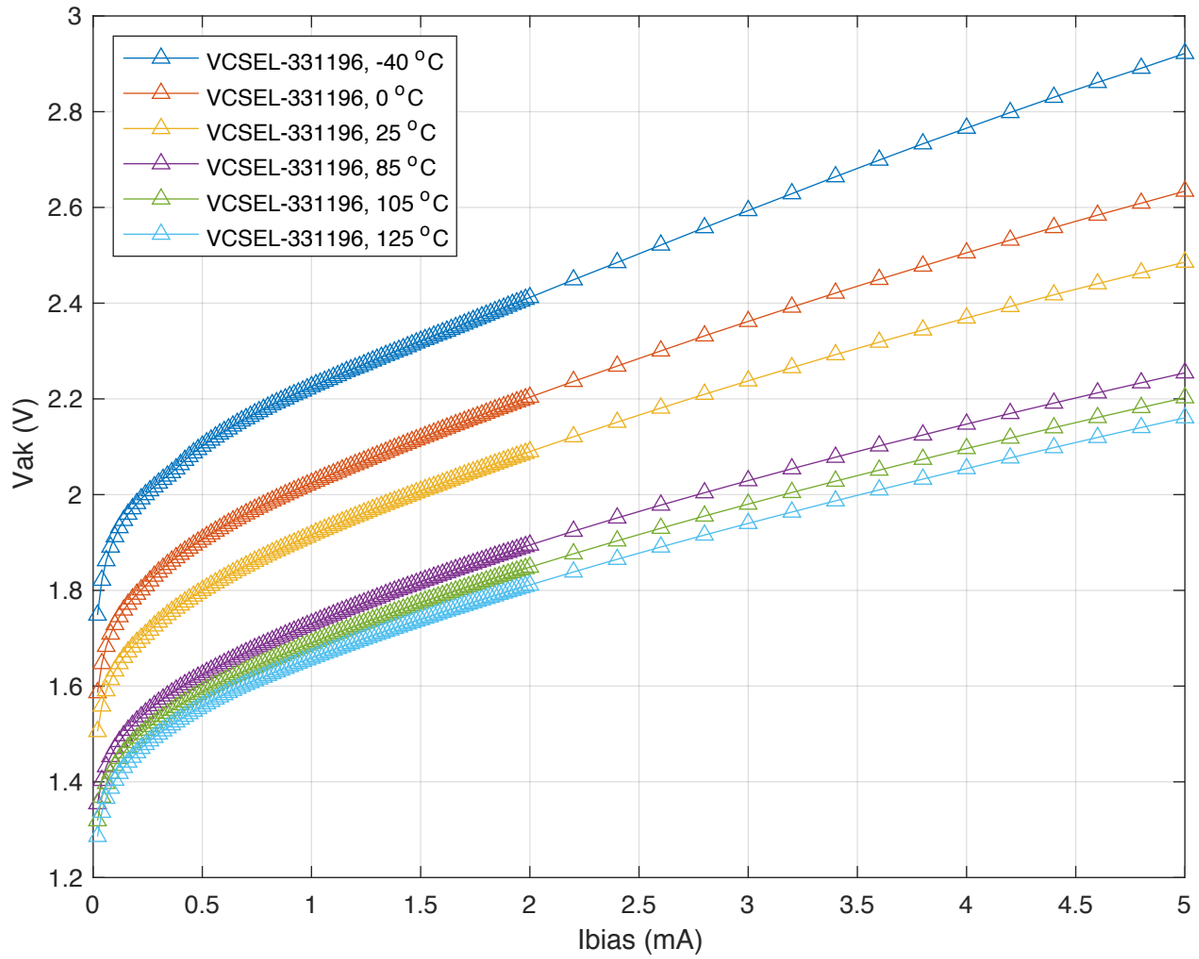
L-I-V characteristic — Bin 2



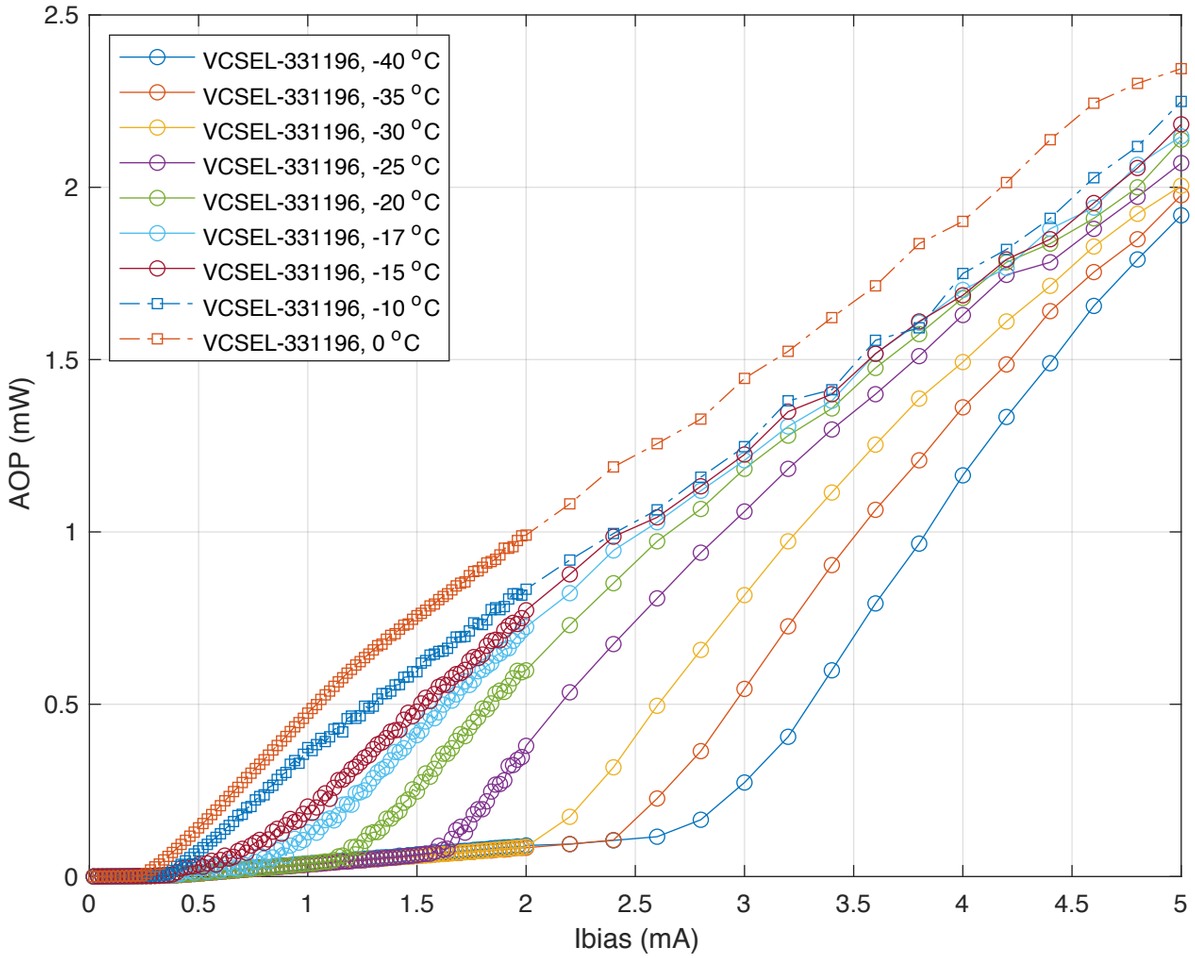


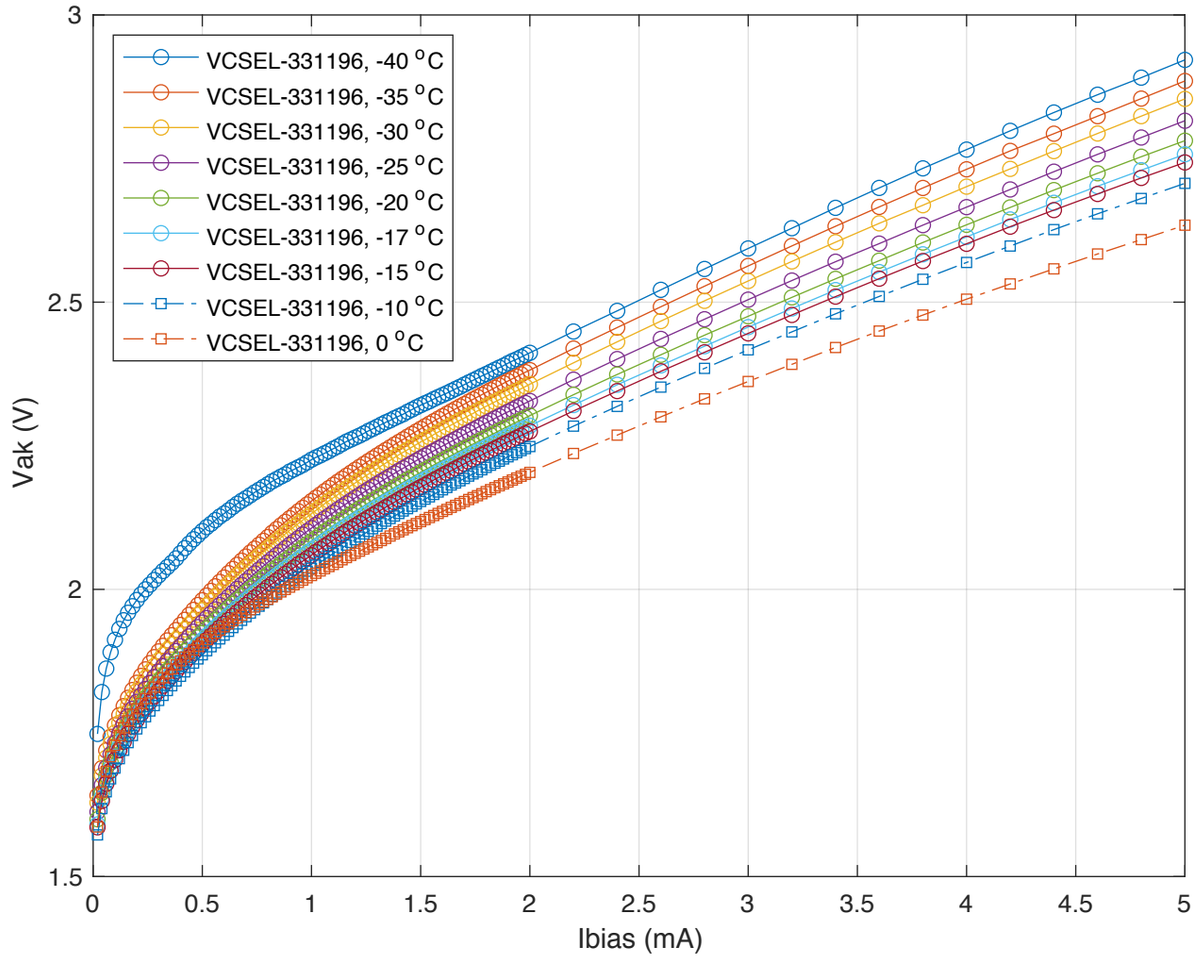
L-I-V characteristic — Bin 2



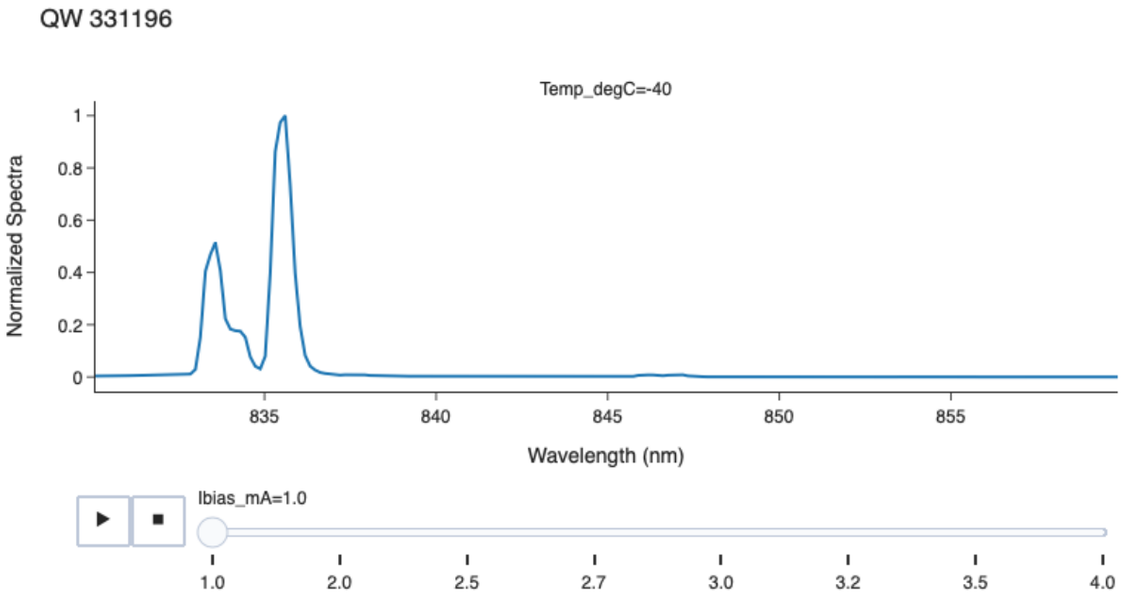


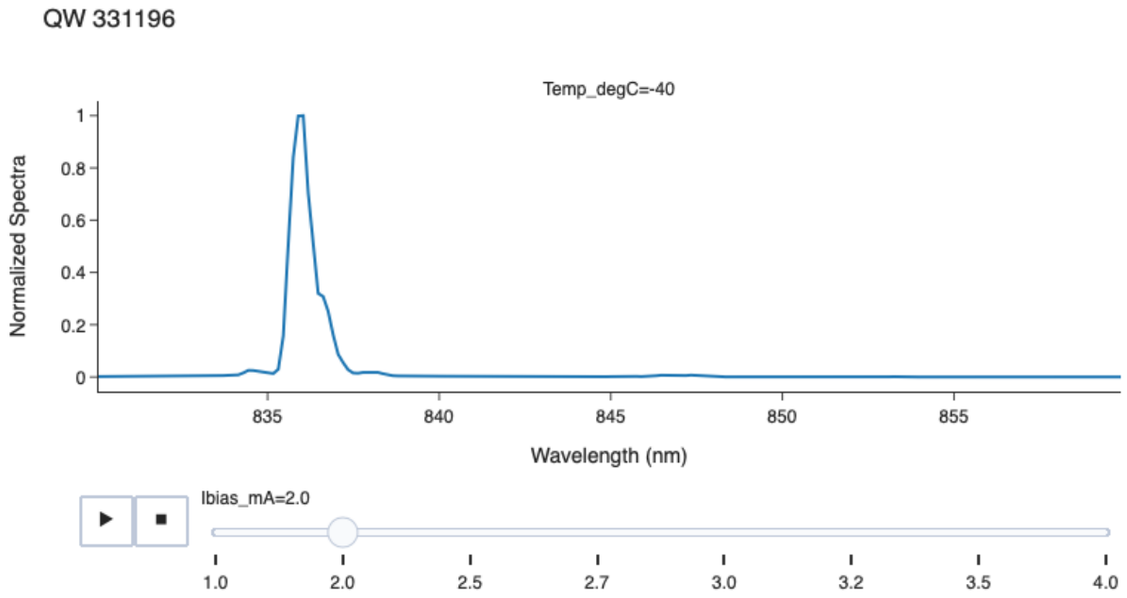
L-I-V characteristic — Bin 2

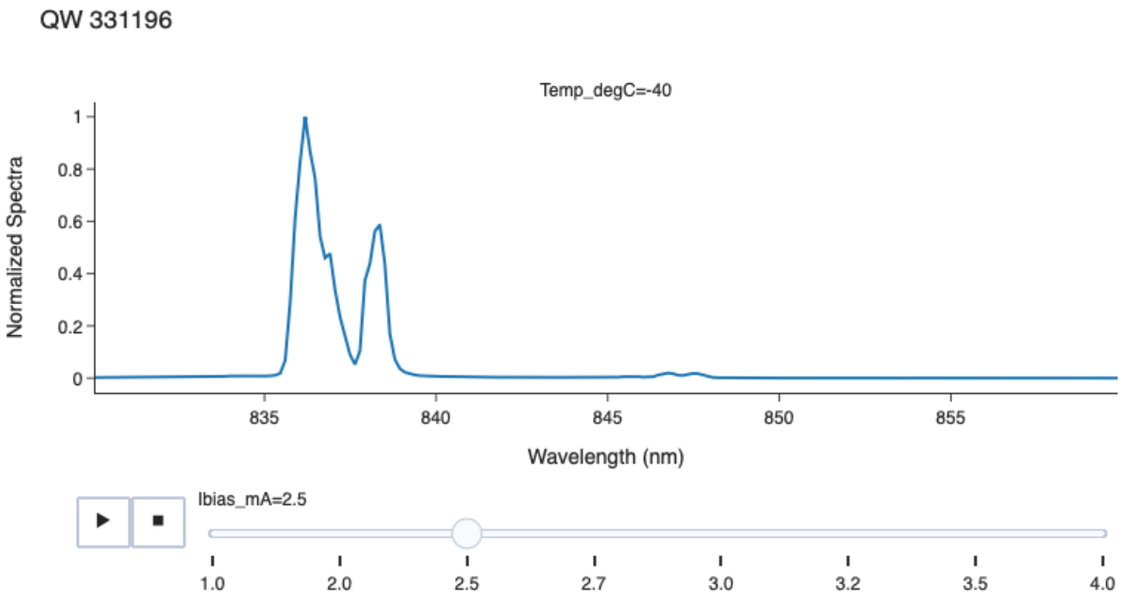


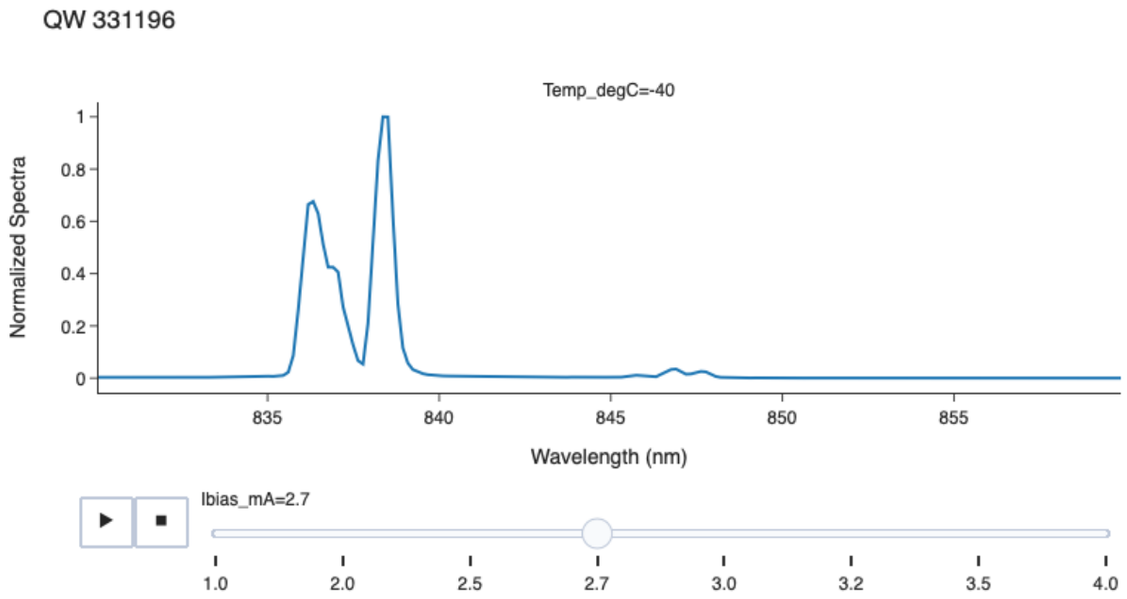


Spectrum characteristic @ -40ºC — Bin 2

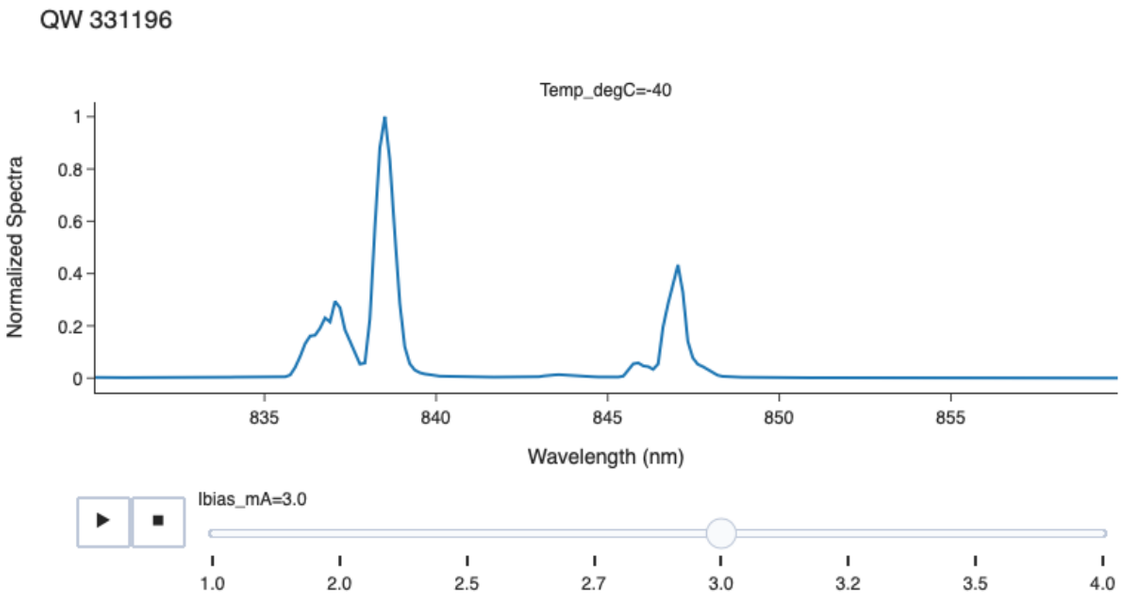


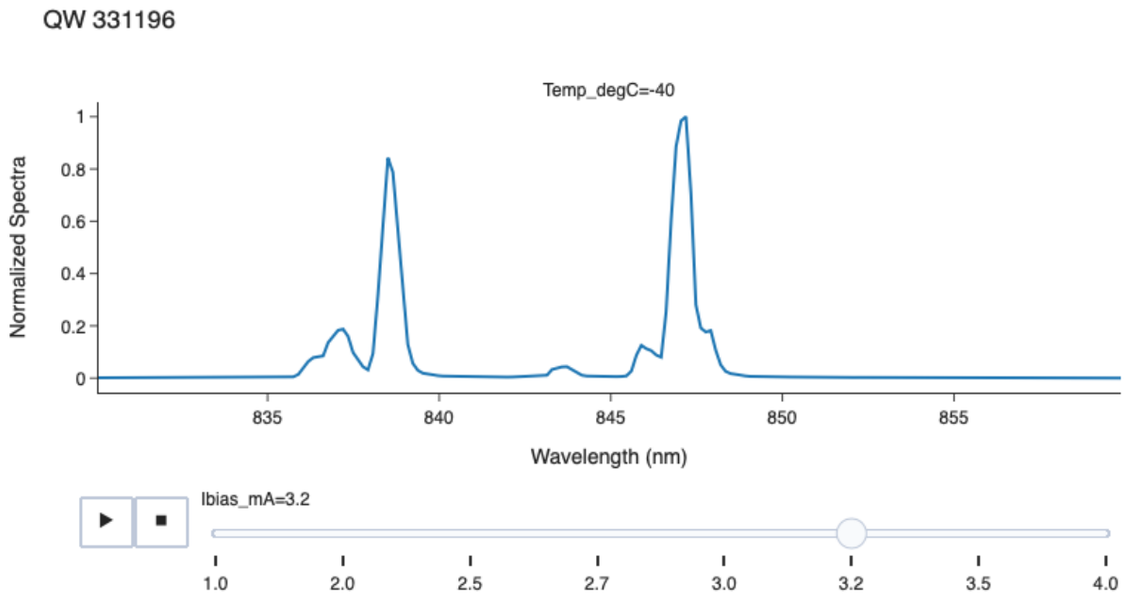


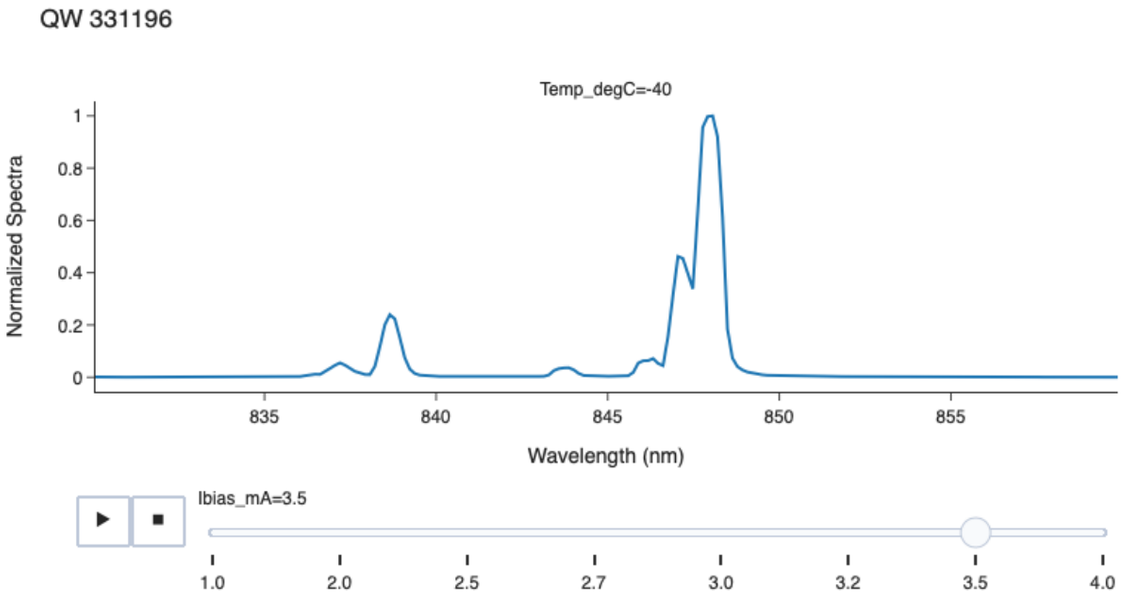


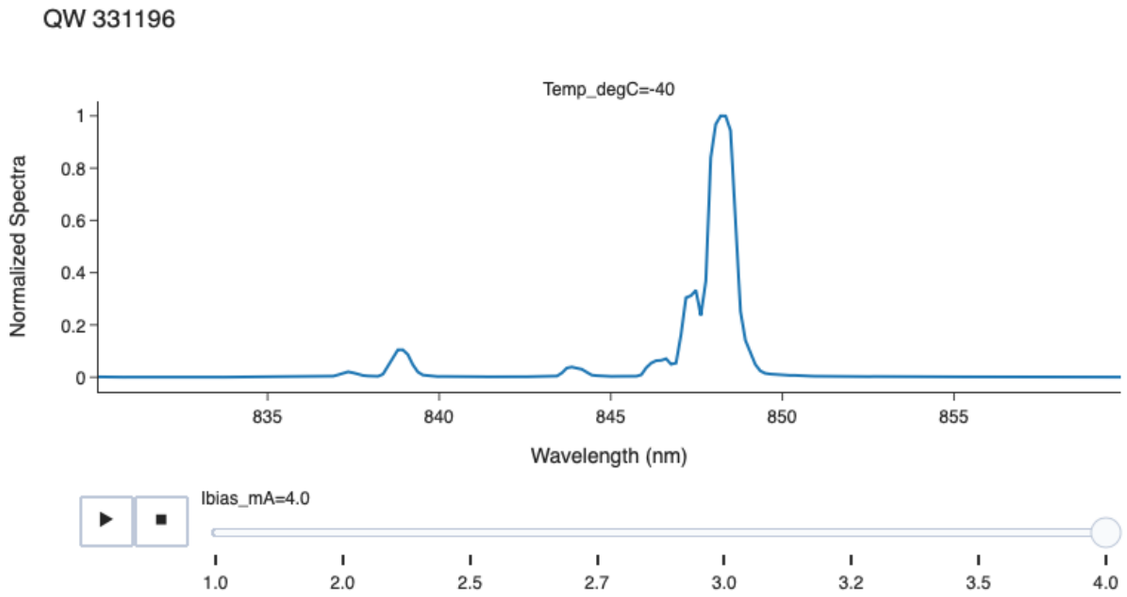


Spectrum characteristic @ -40°C — Bin 2

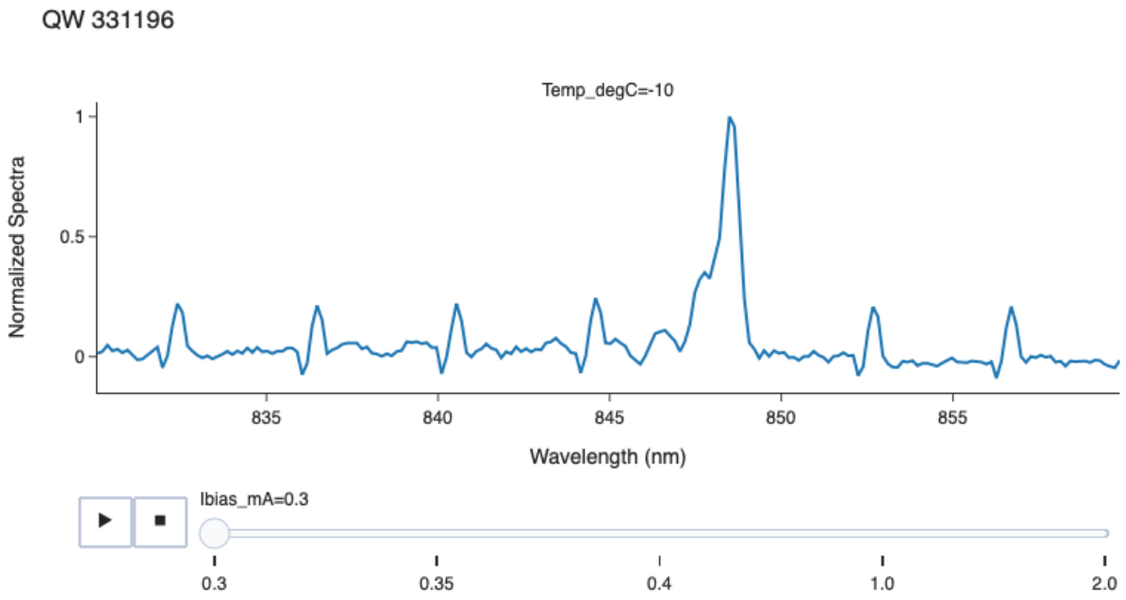


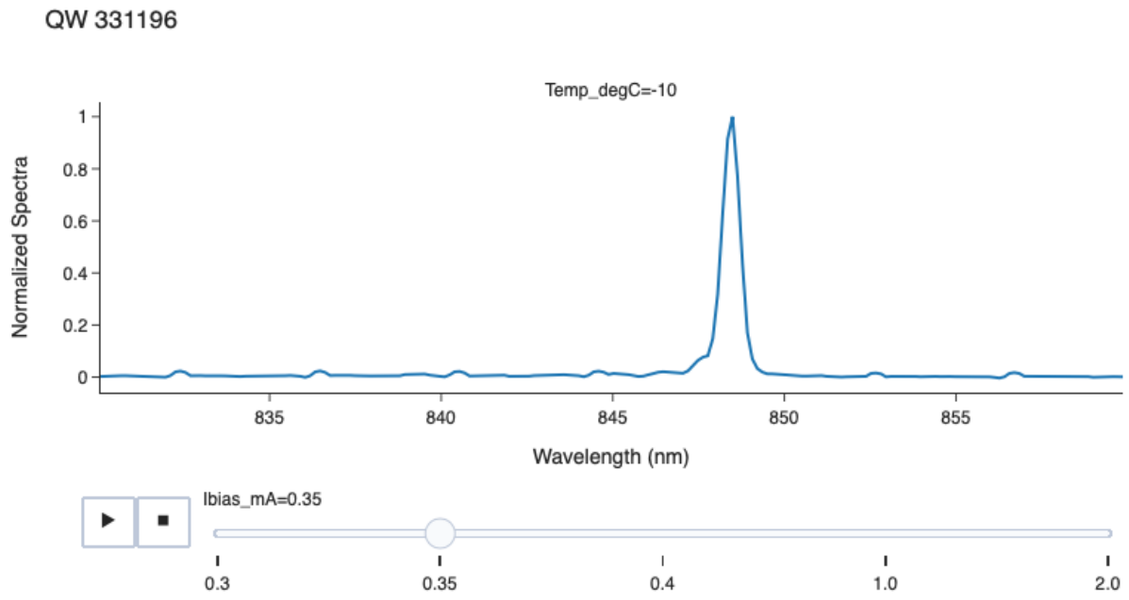


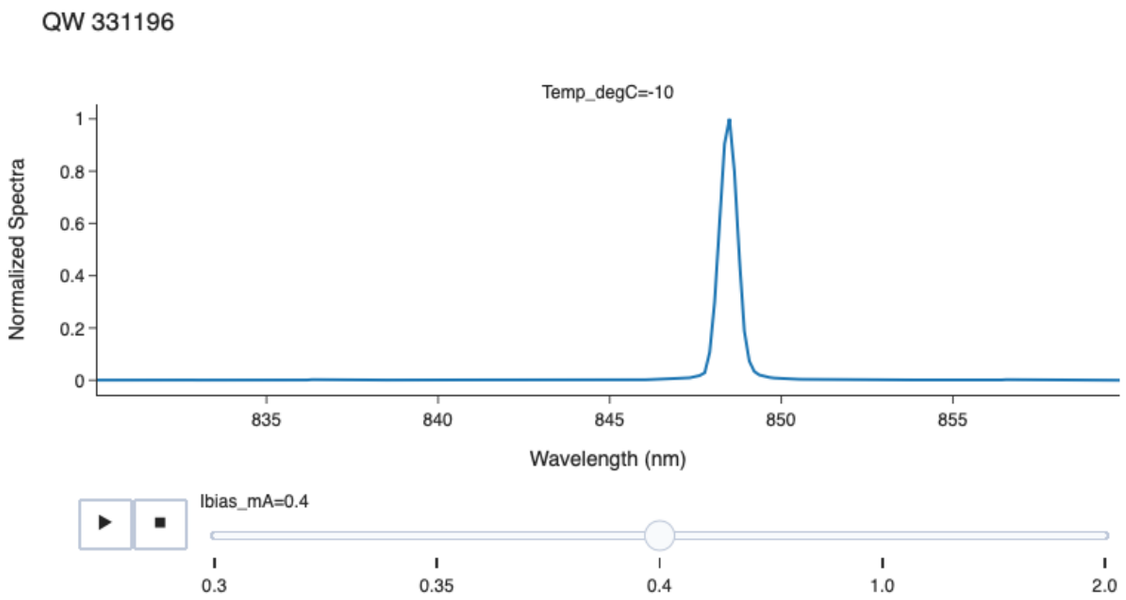


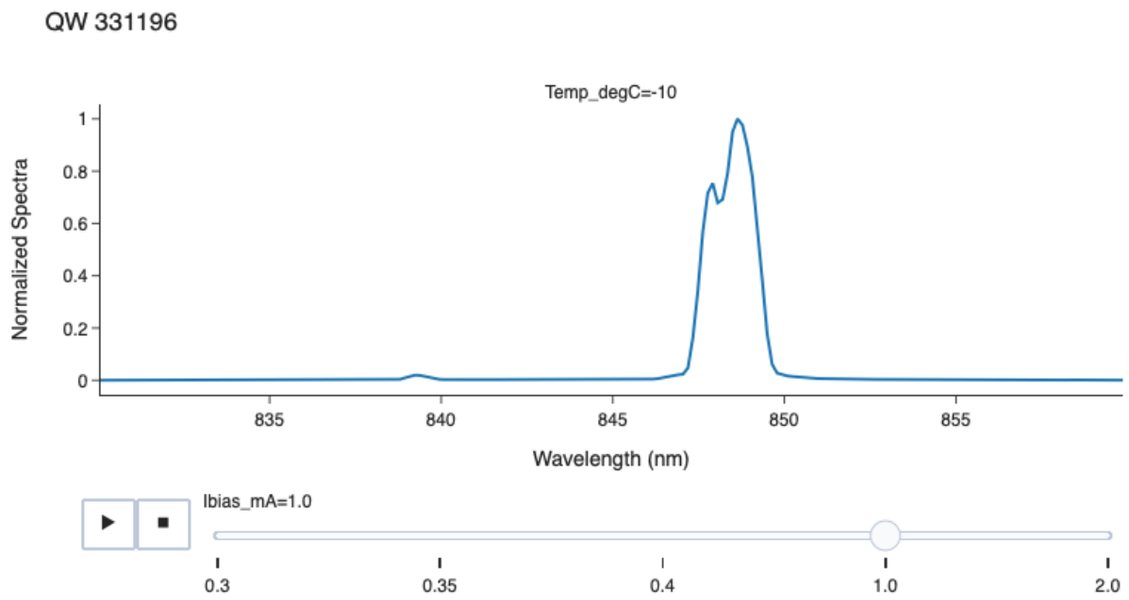


Spectrum characteristic @ -10ºC — Bin 2

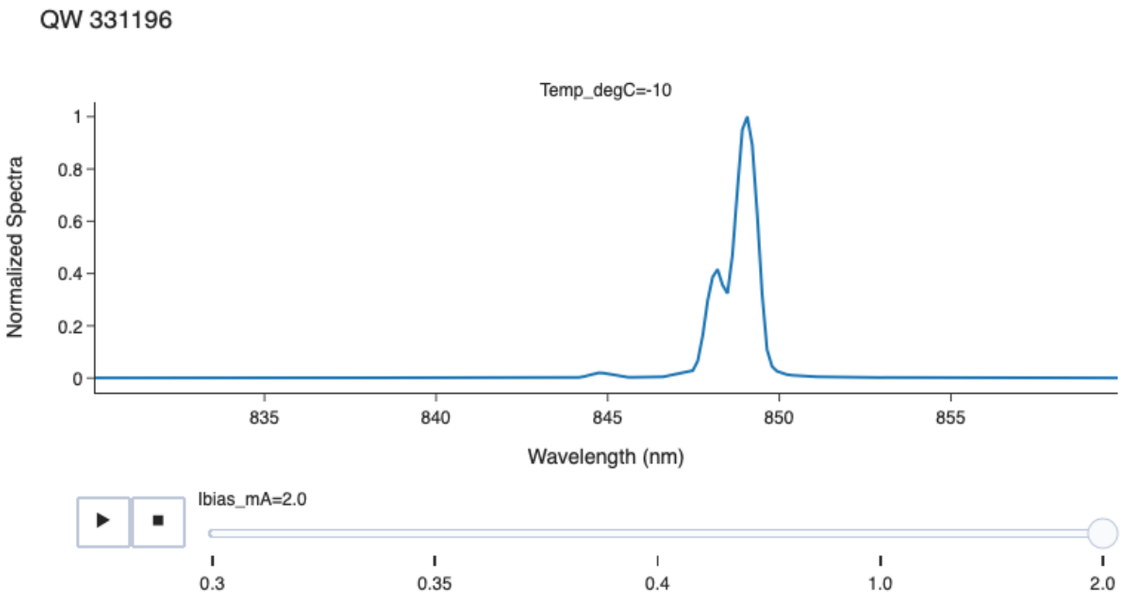




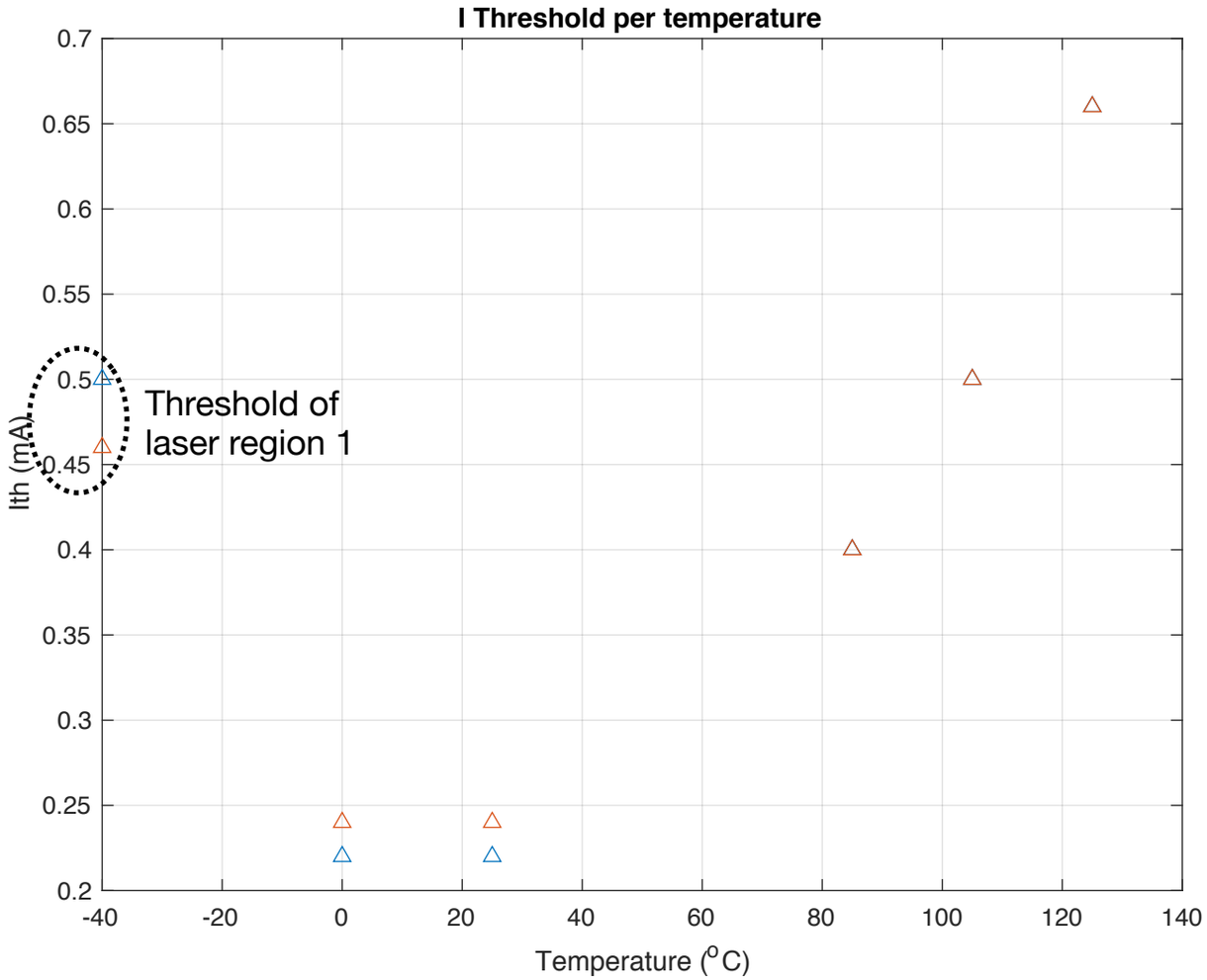




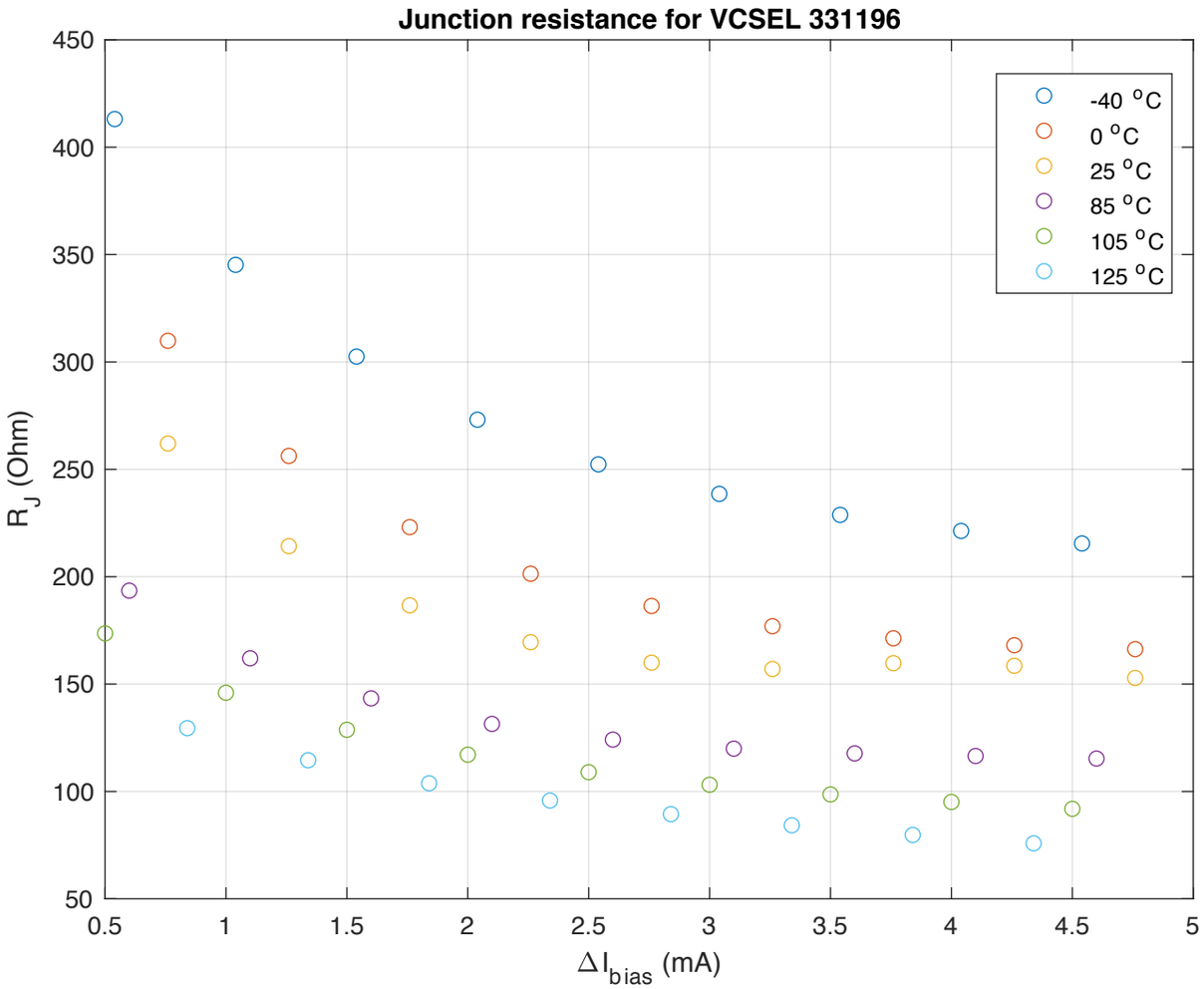
Spectrum characteristic @ -10ºC — Bin 2

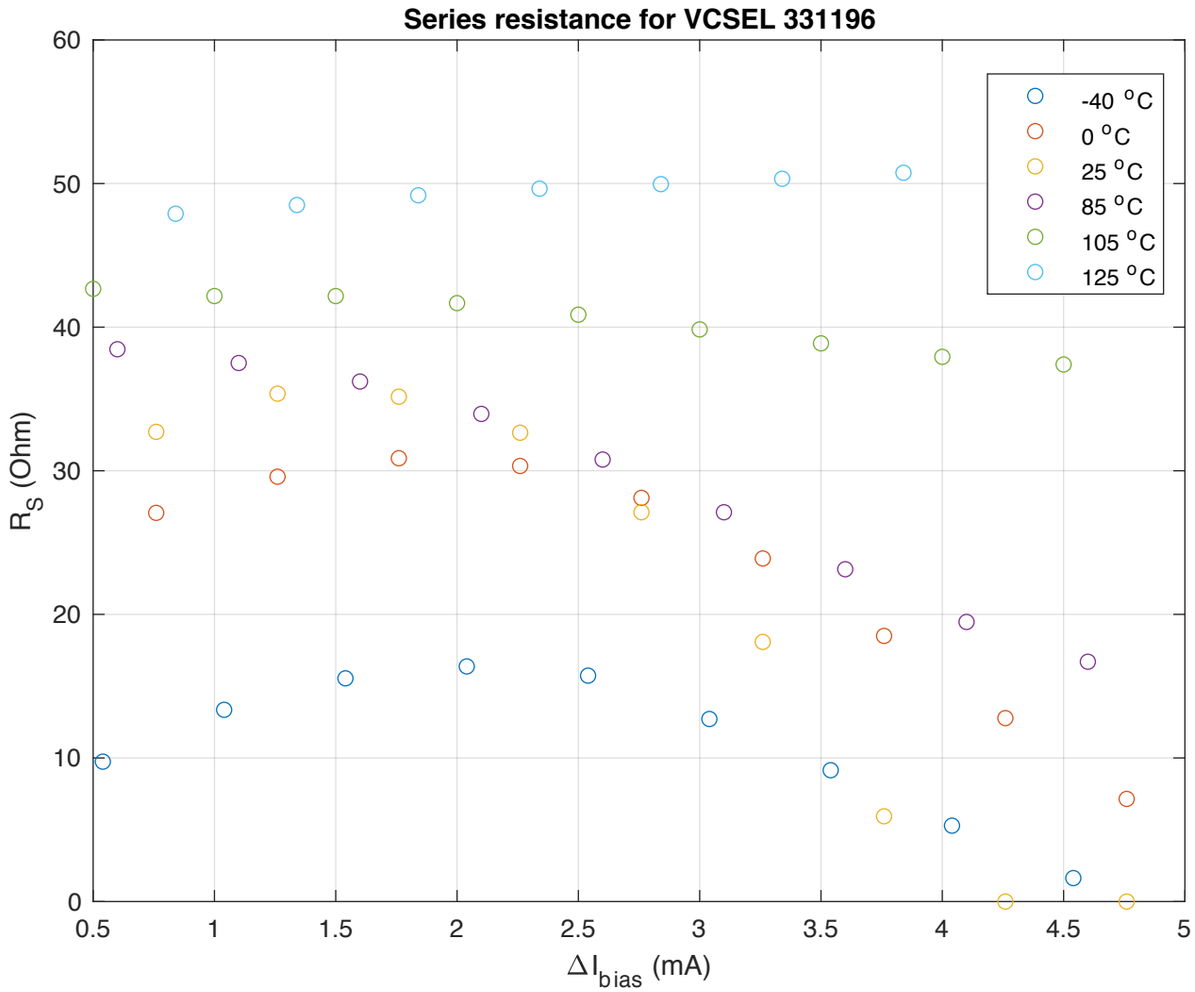


Threshold current characteristic — Bin 2

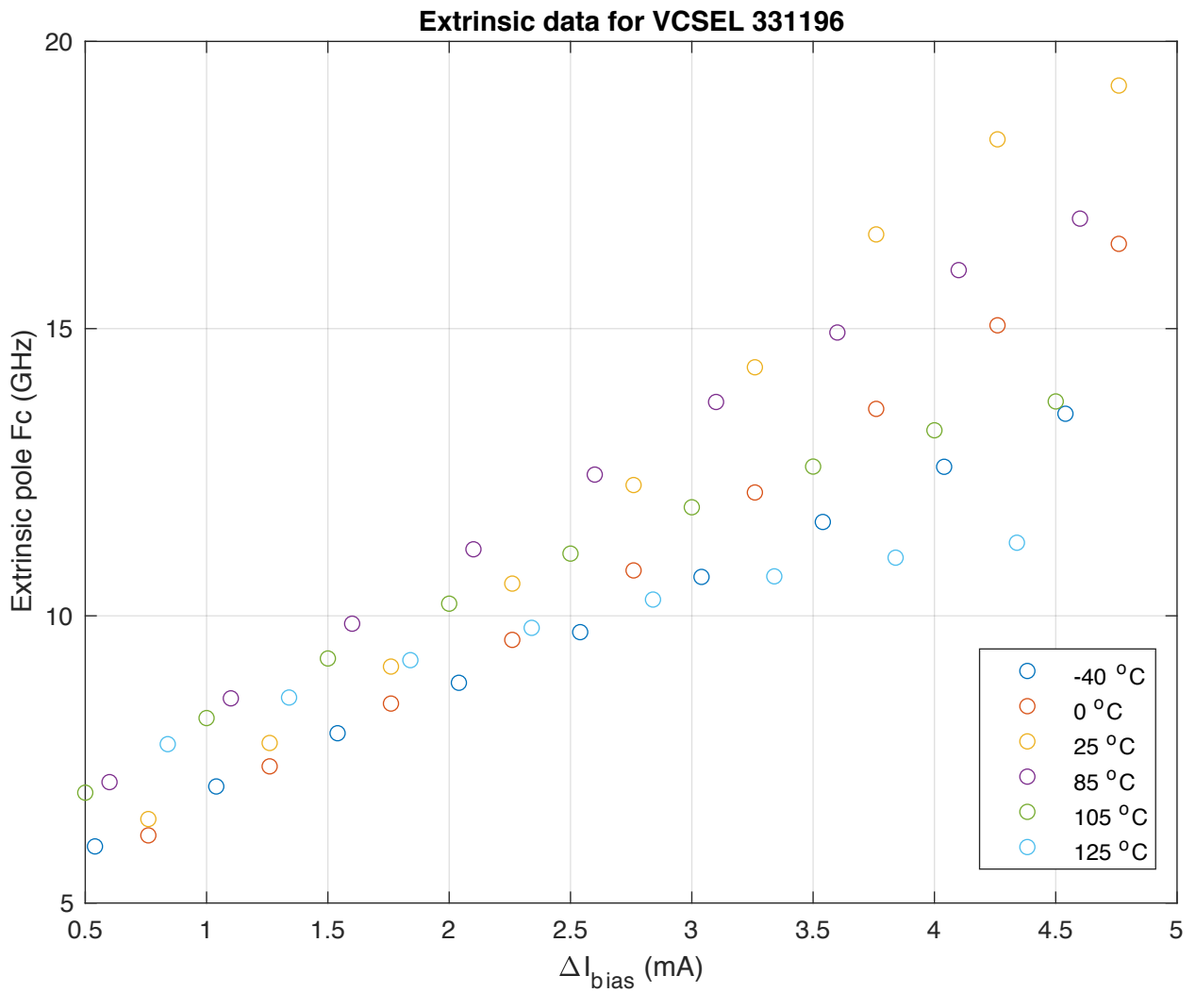


Small signal frequency response — Bin 2



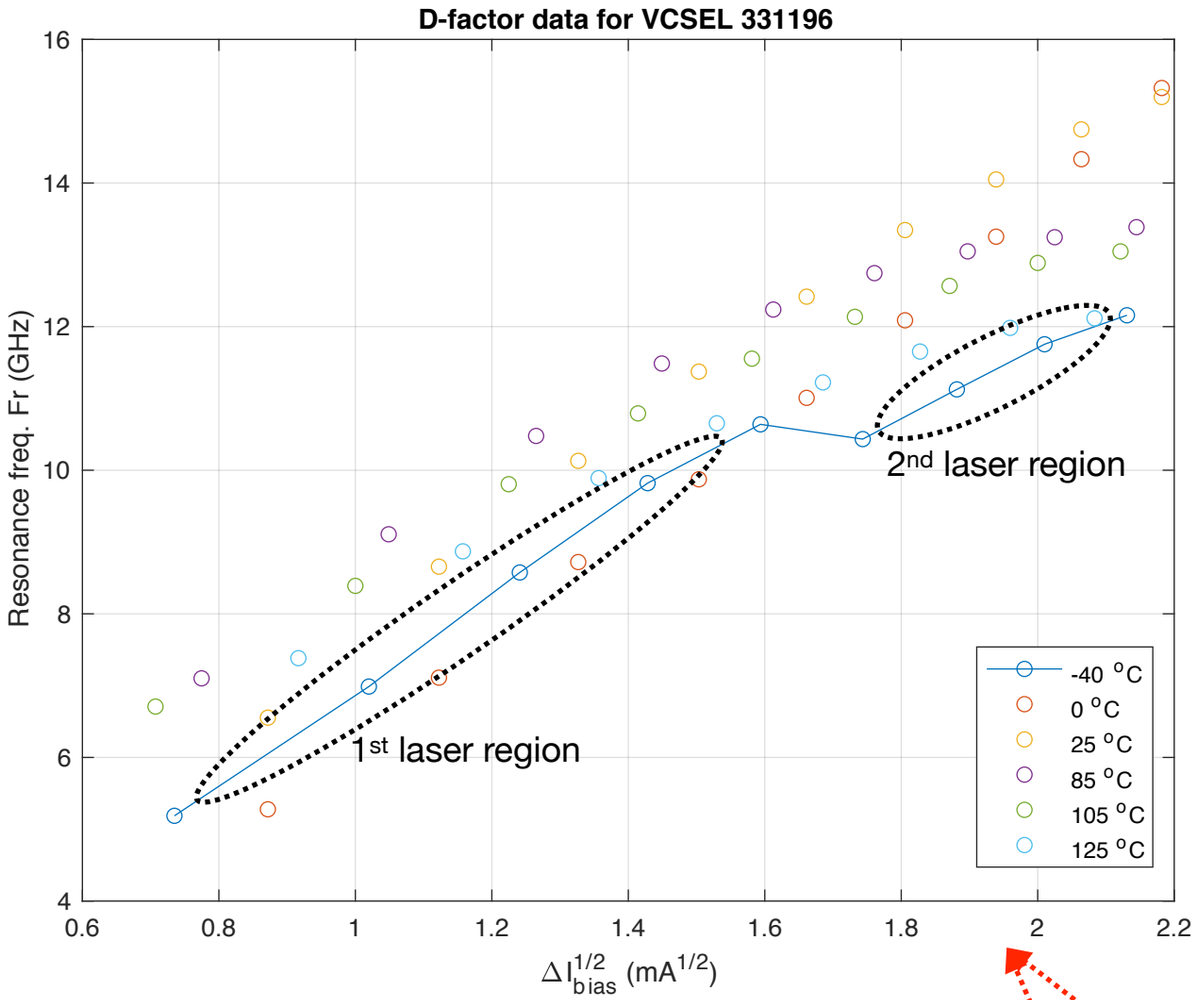


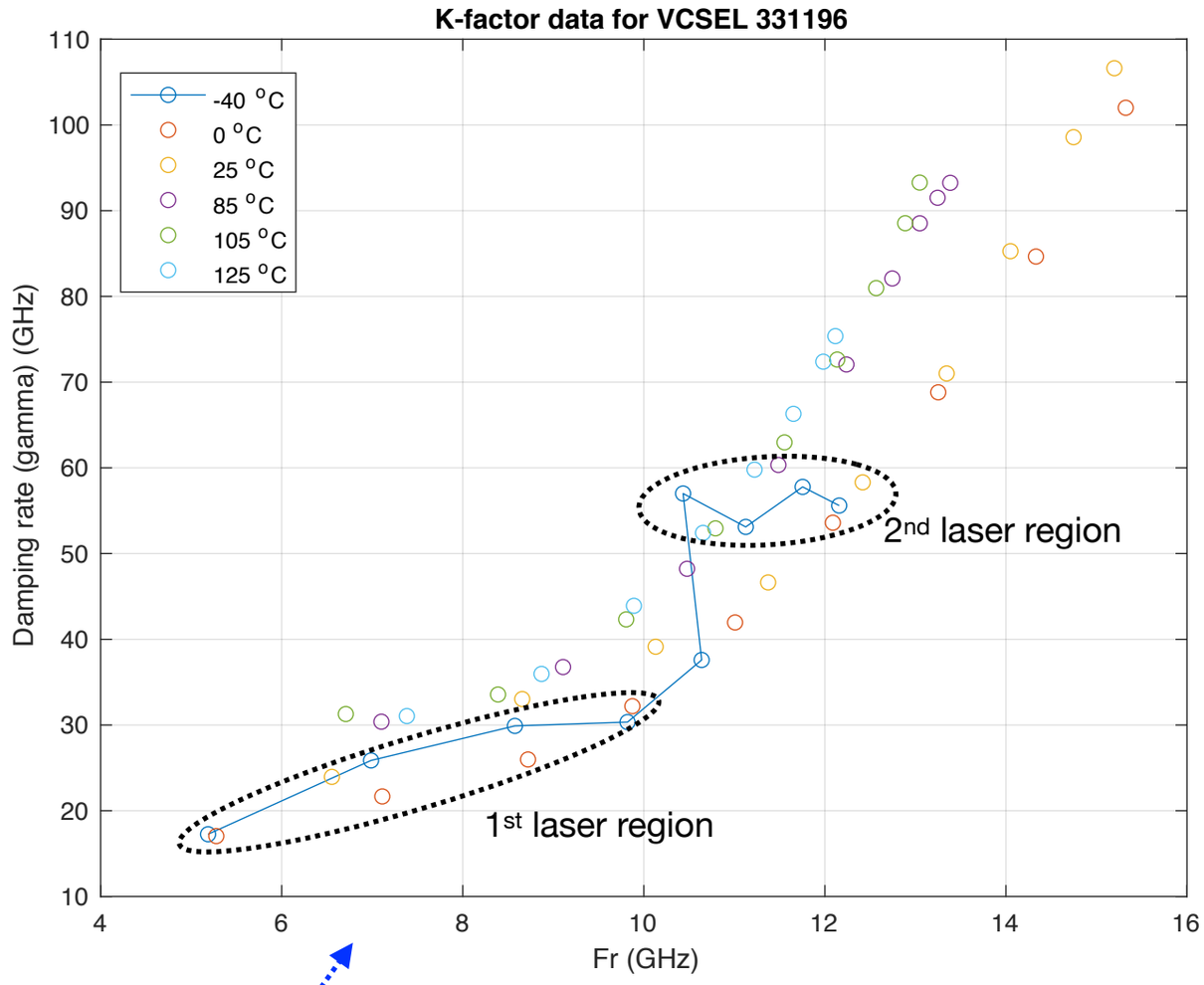
Small signal frequency response — Bin 2



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

Small signal frequency response — Bin 2

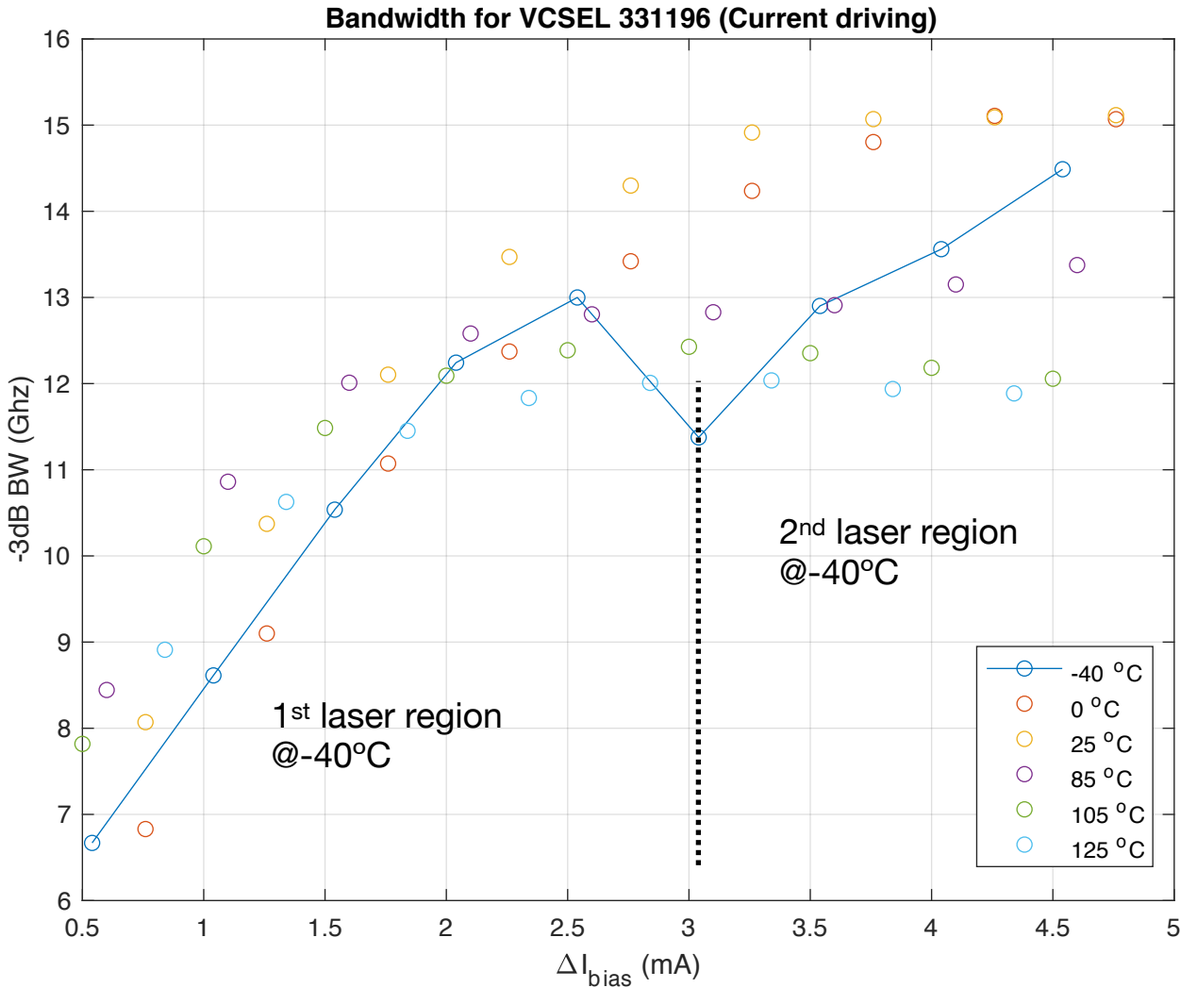


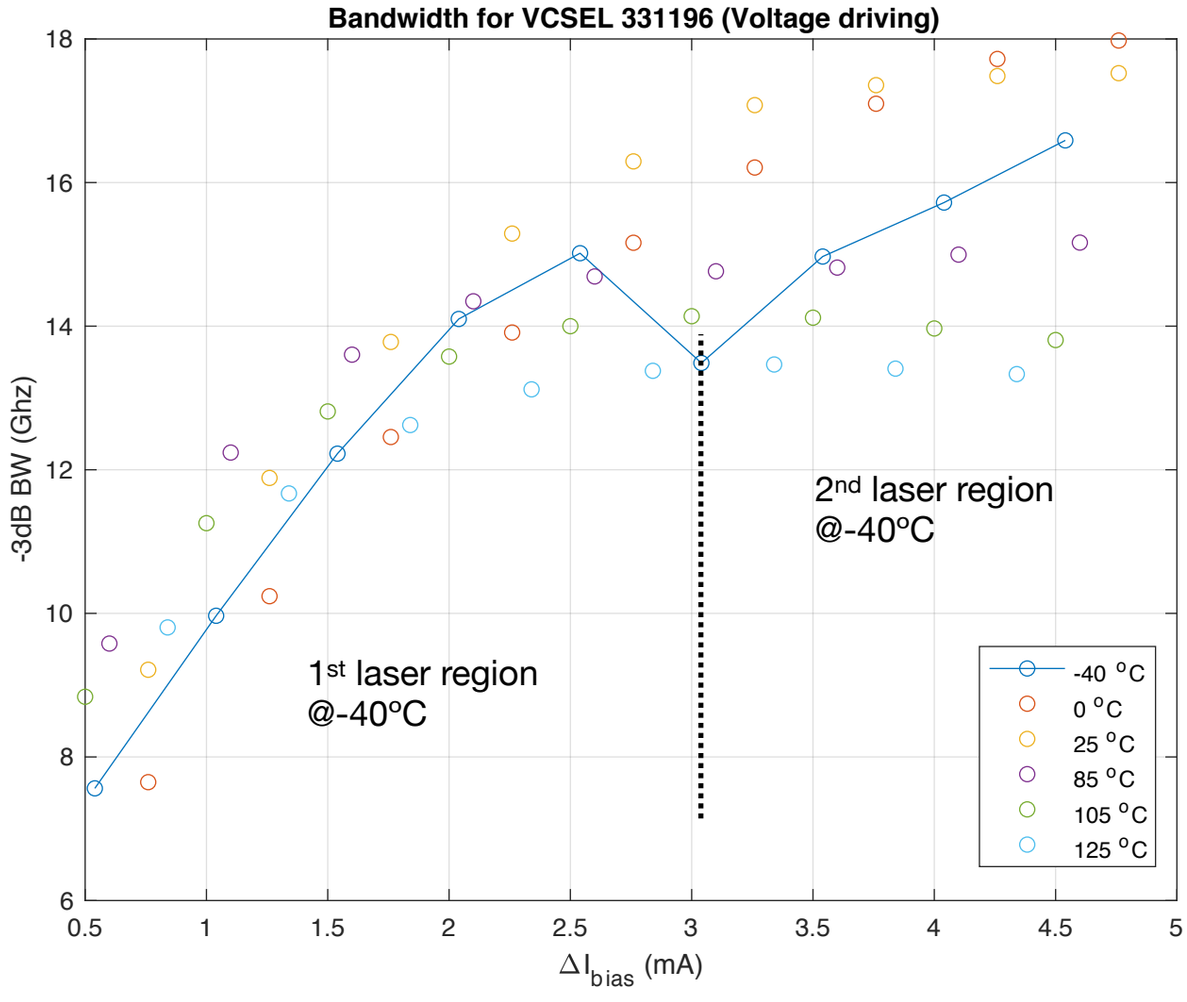


ΔI_{bias} wrt threshold of the first laser region for -40ºC

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

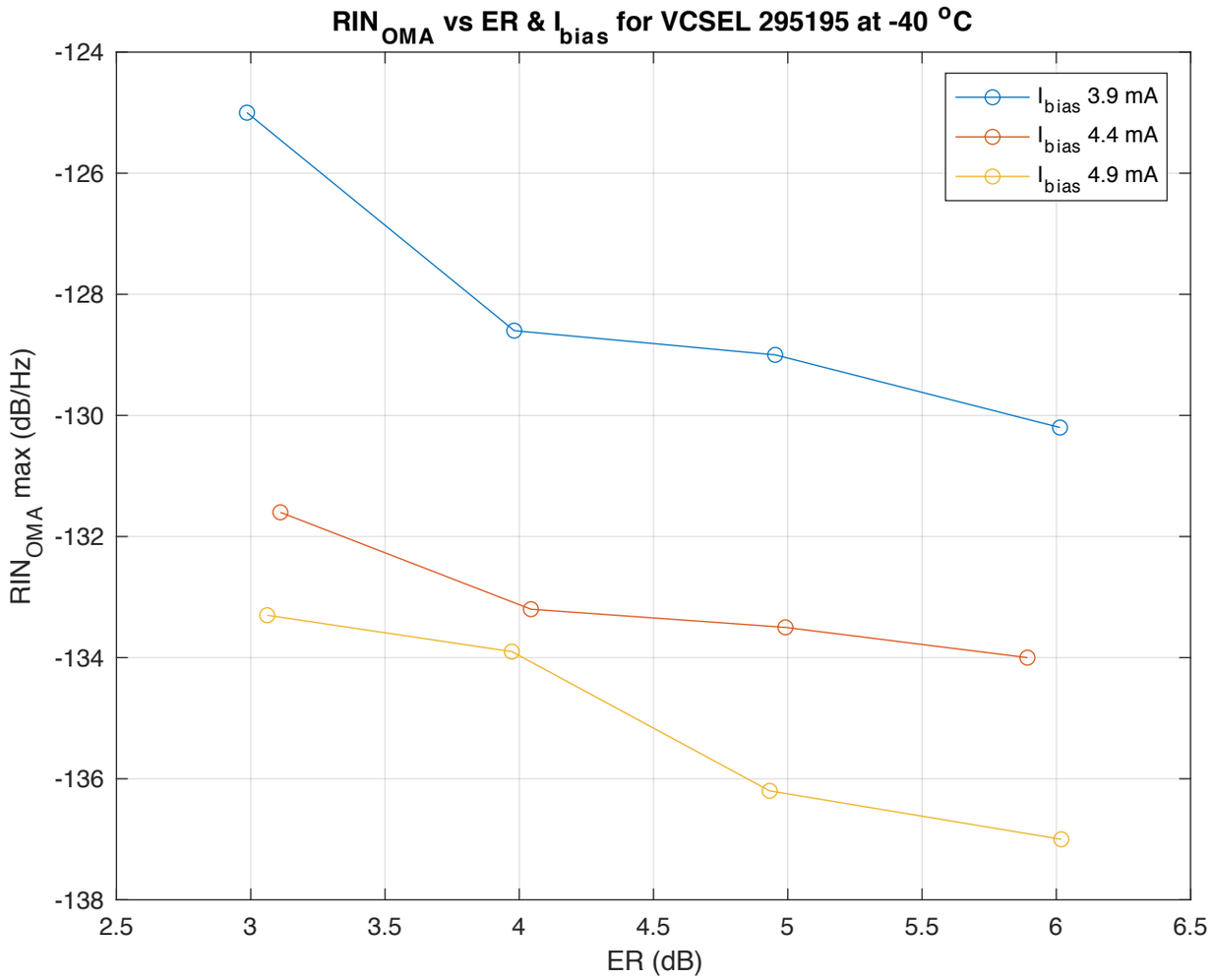
Small signal frequency response — Bin 2

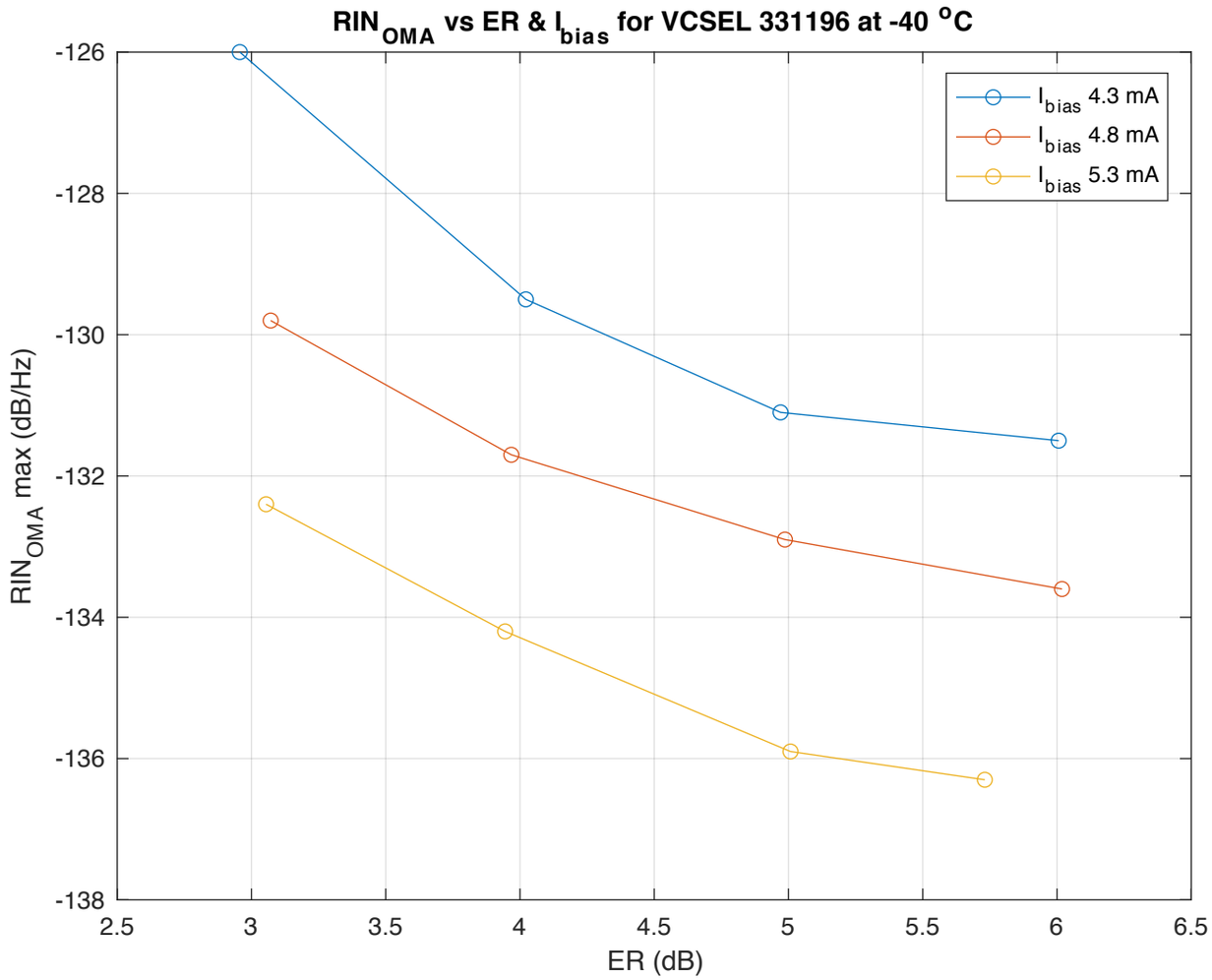




Considered source impedance 100 Ω

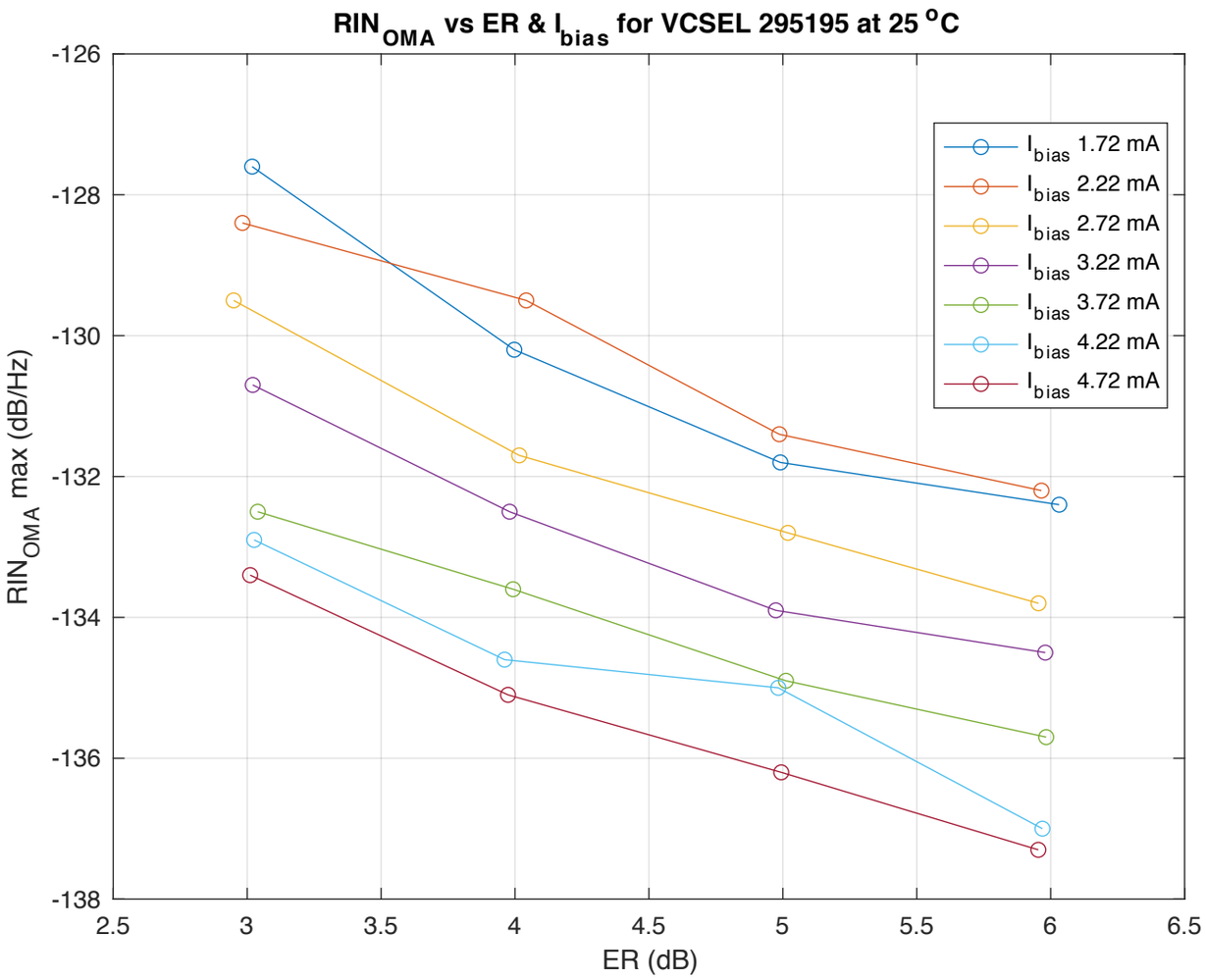
Relative intensity noise (RIN_{OMA}) at -40ºC — Bin 2

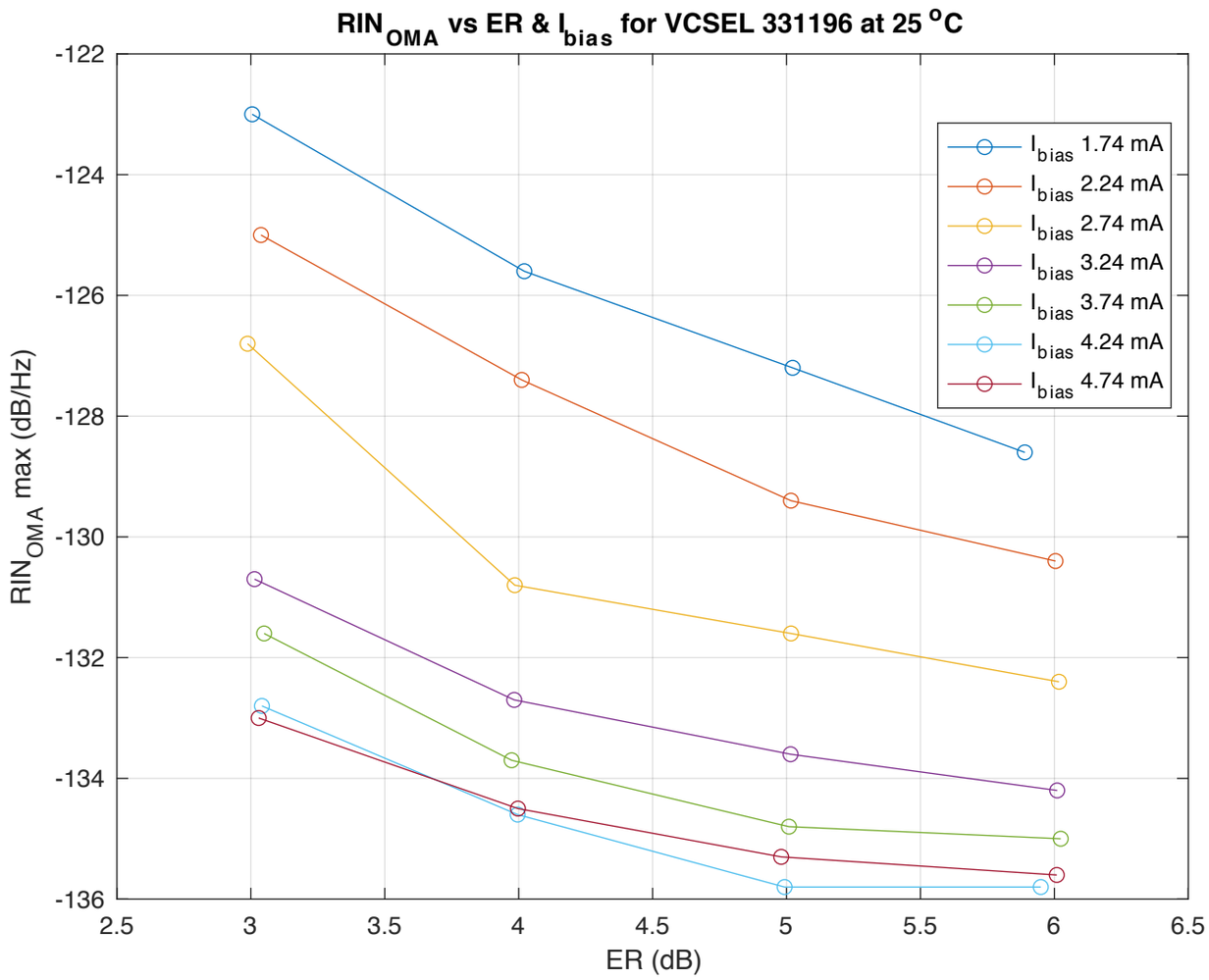




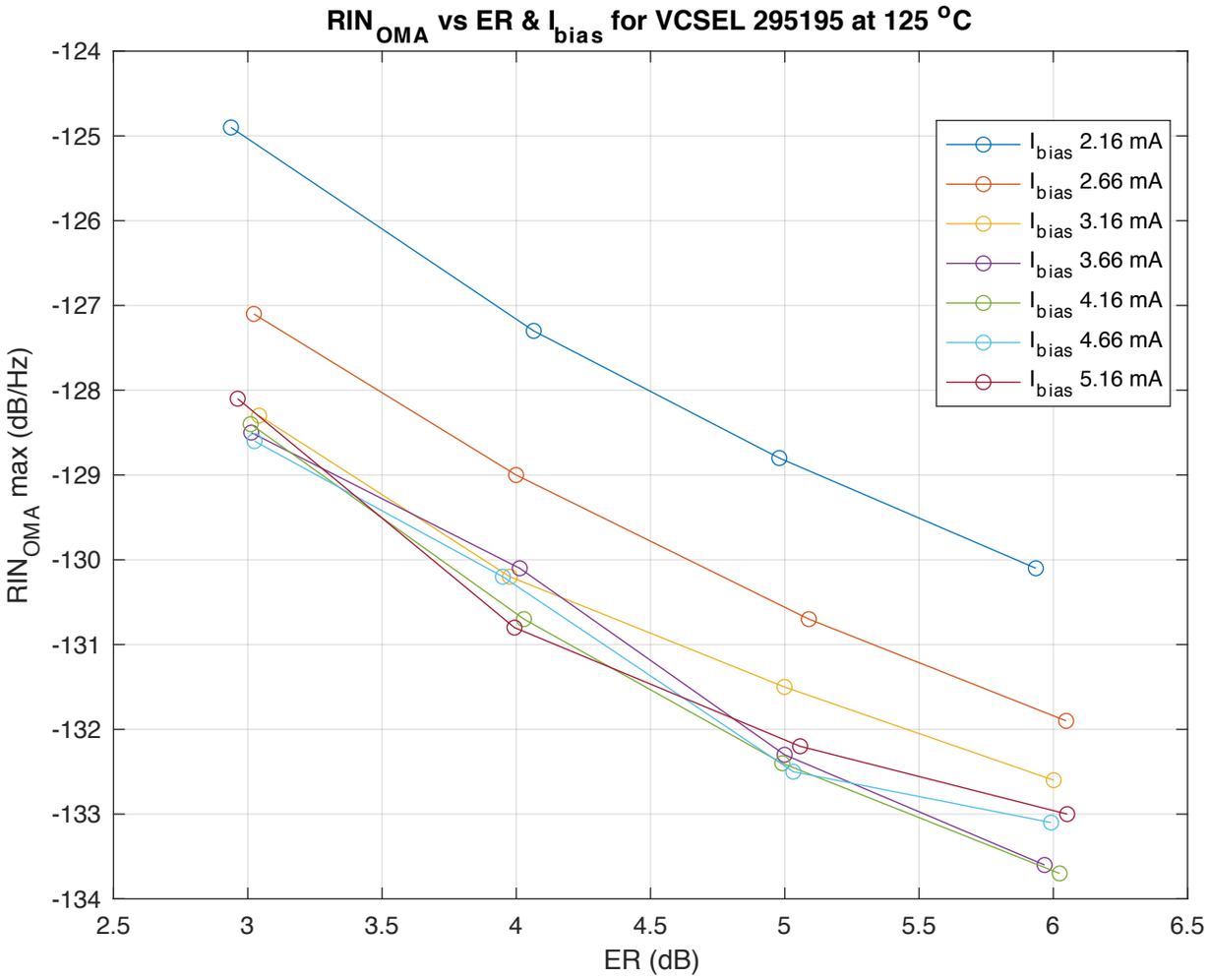
RIN is only measured and reported for the 2nd laser region

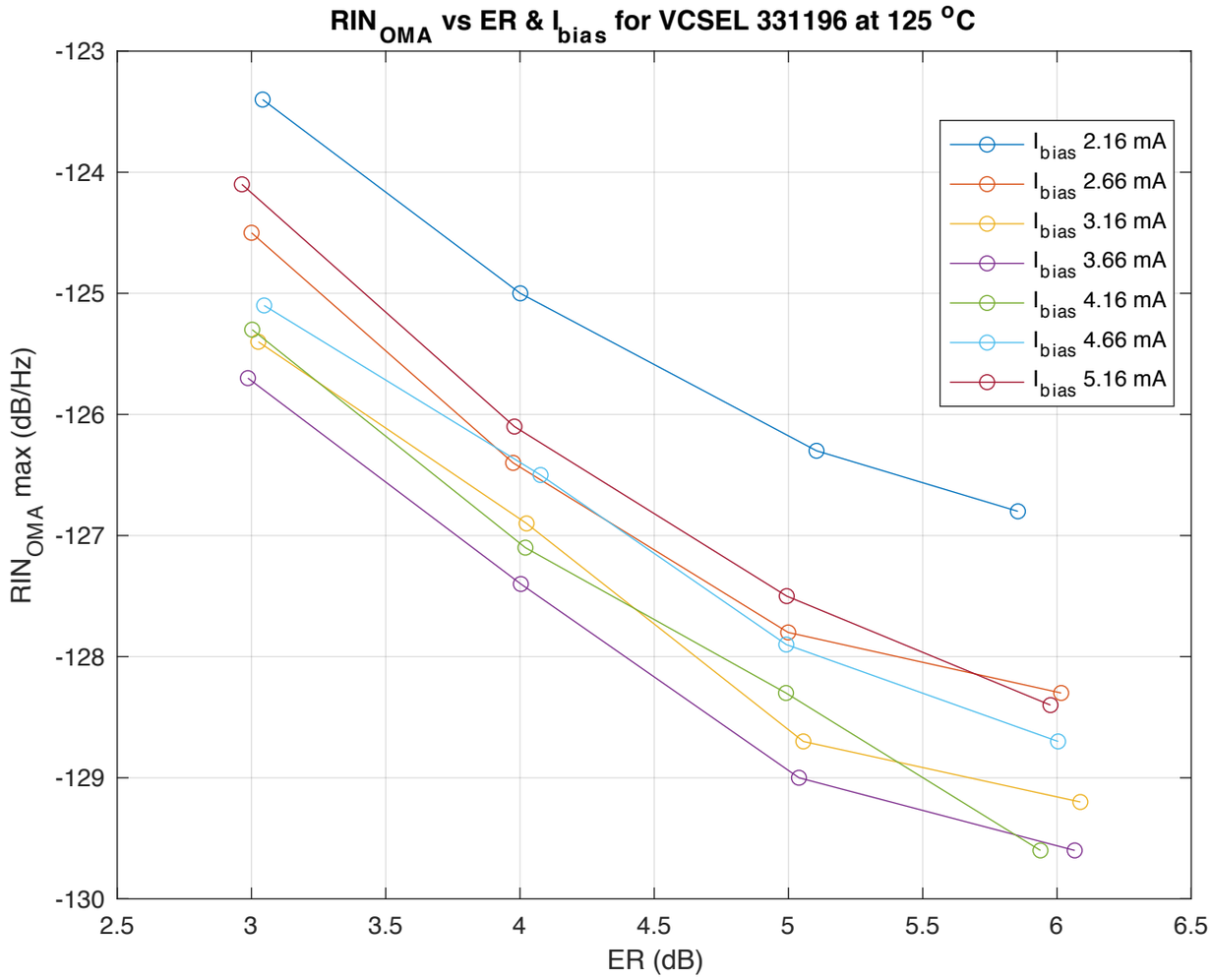
Relative intensity noise (RIN_{OMA}) at 25ºC — Bin 2



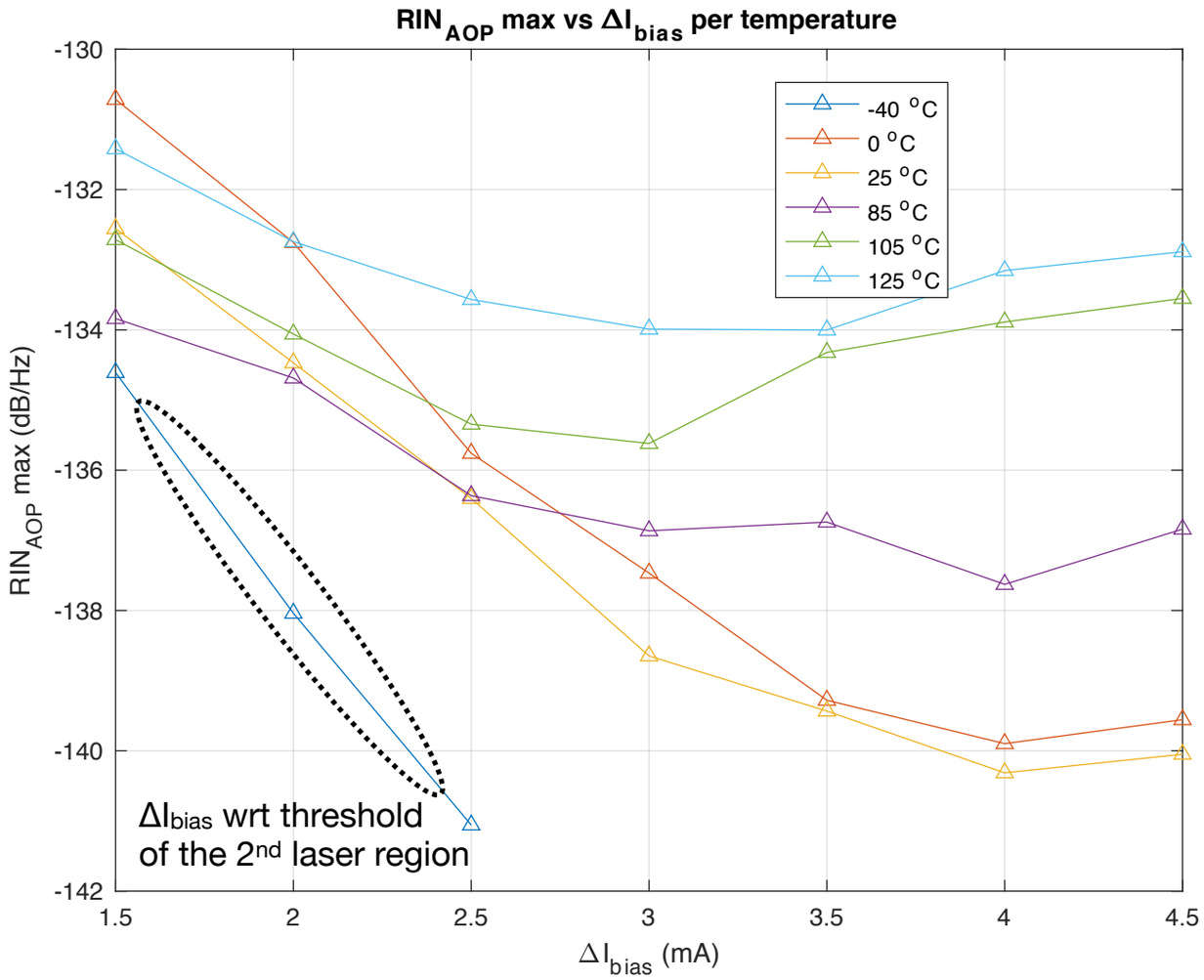


Relative intensity noise (RIN_{OMA}) at 125ºC — Bin 2





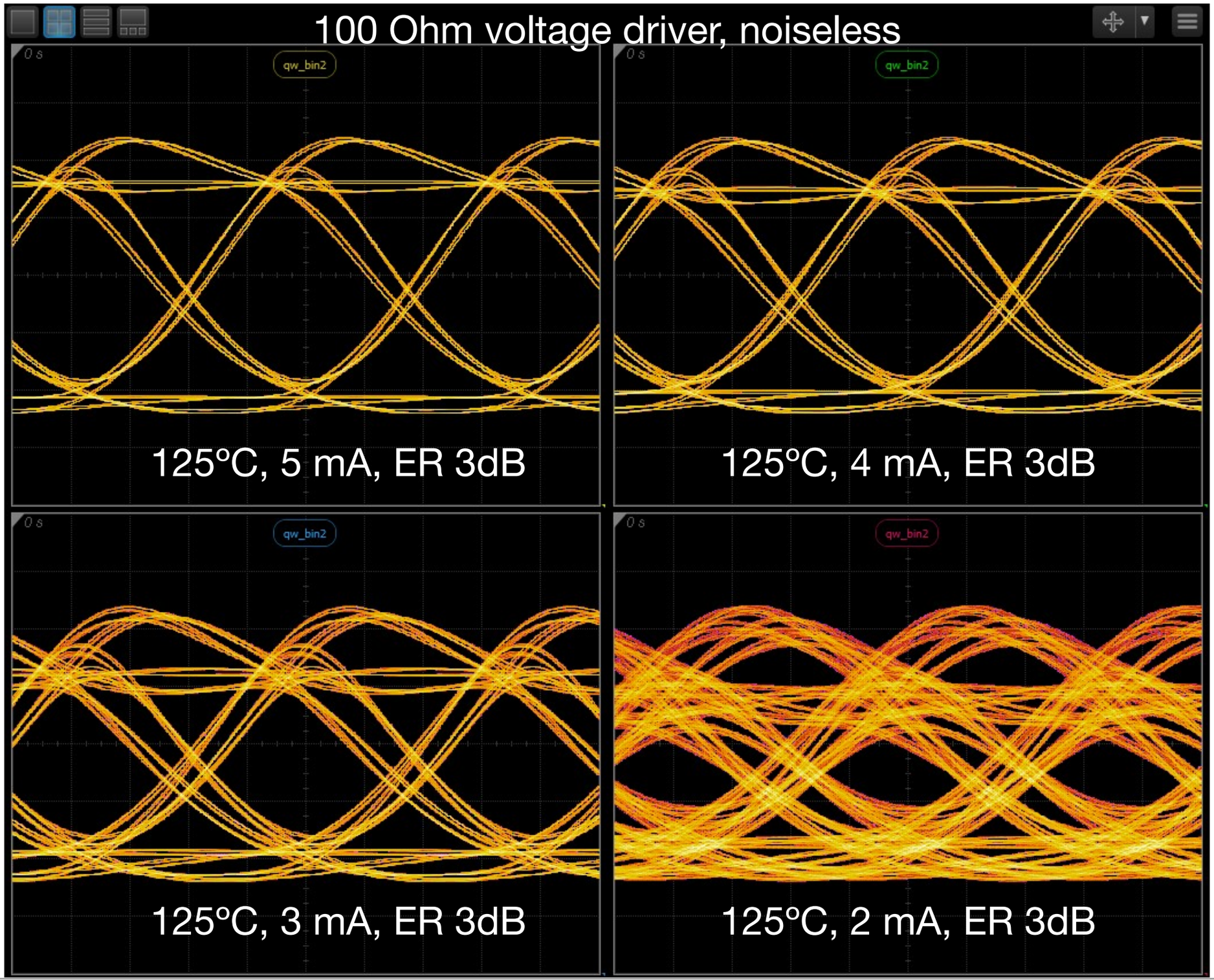
Normalized max RIN (RIN_{AOP}) — Bin 2



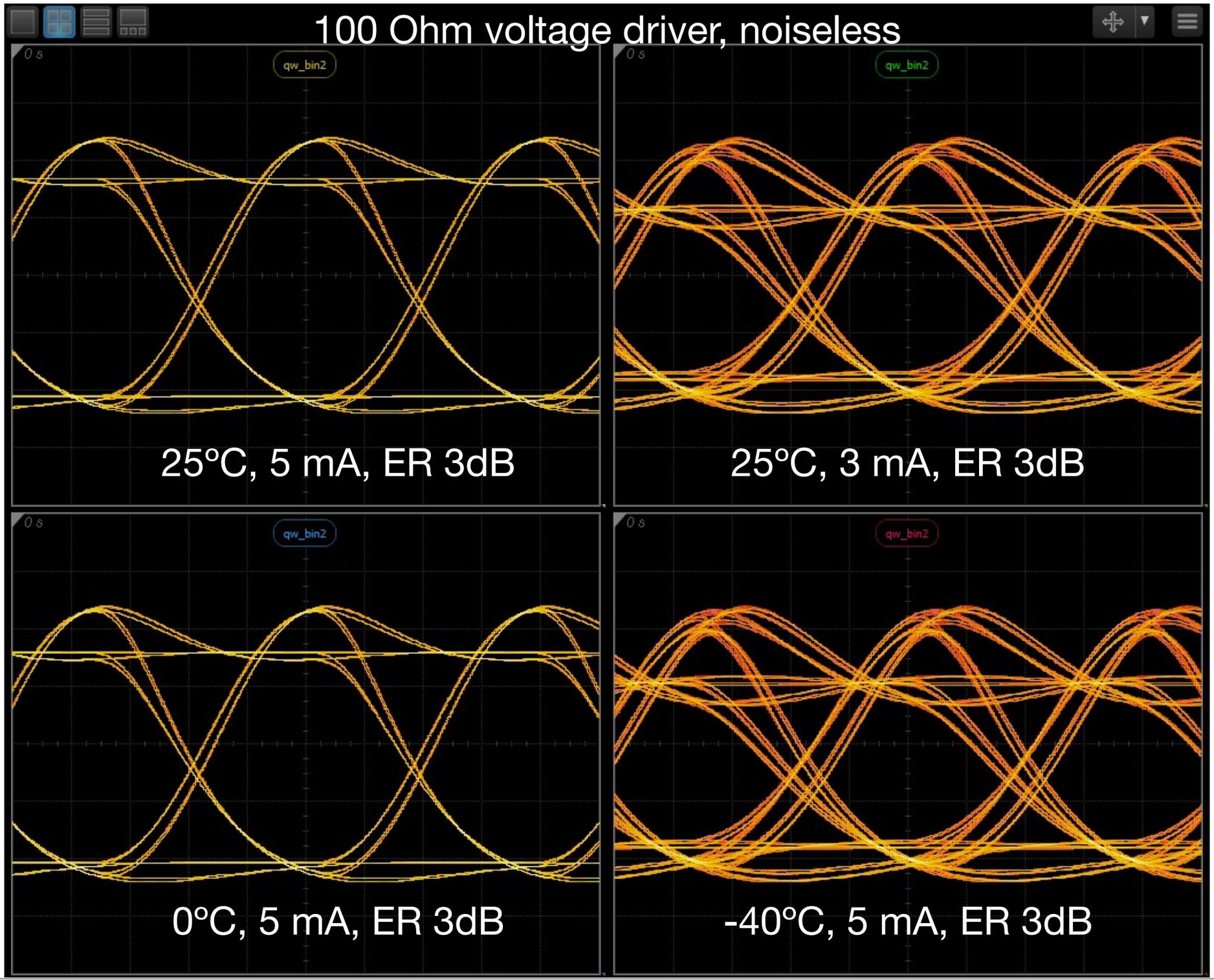
$$RIN_{AOP}\left(dB/Hz\right) = RIN_{OMA}\left(dB/Hz\right) - 20\cdot\log_{10}\left(\frac{ER_L+1}{ER_L-1}\right)$$

$$ER_L = 10^{ER(dB)/10}$$

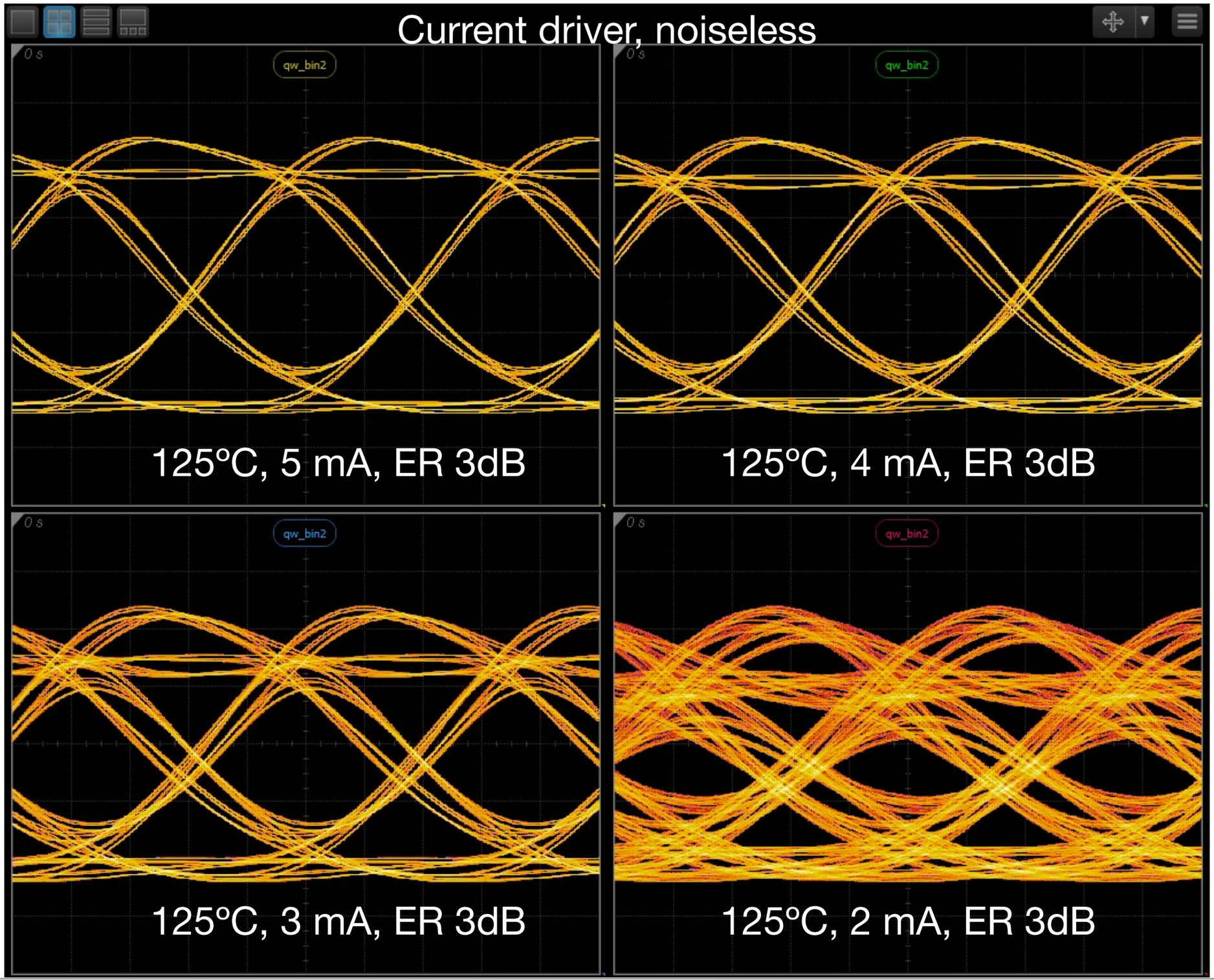
Eye diagram for 26.5625 GBd NRZ — Bin 2



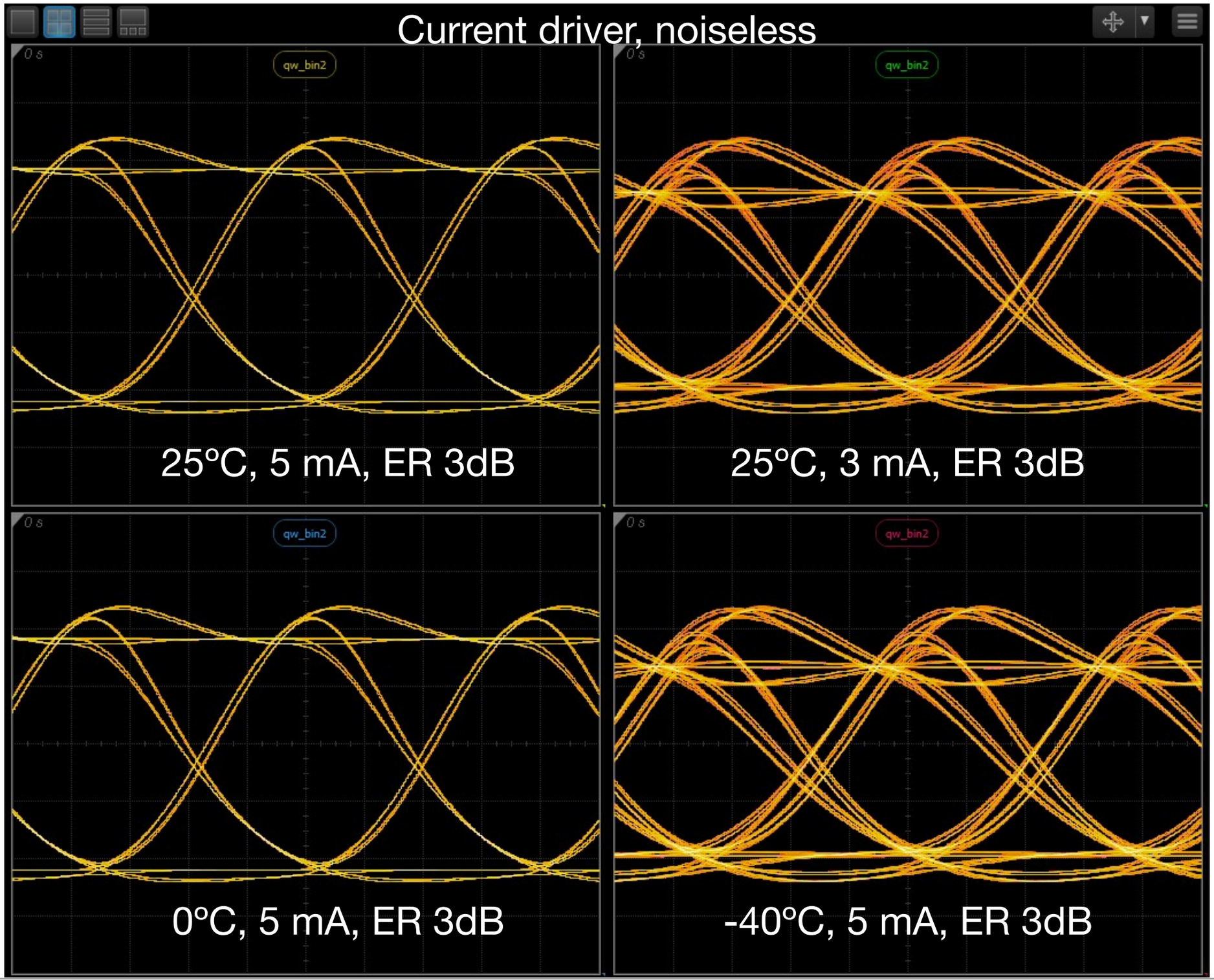
Eye diagram for 26.5625 GBd NRZ — Bin 2



Eye diagram for 26.5625 GBd NRZ — Bin 2



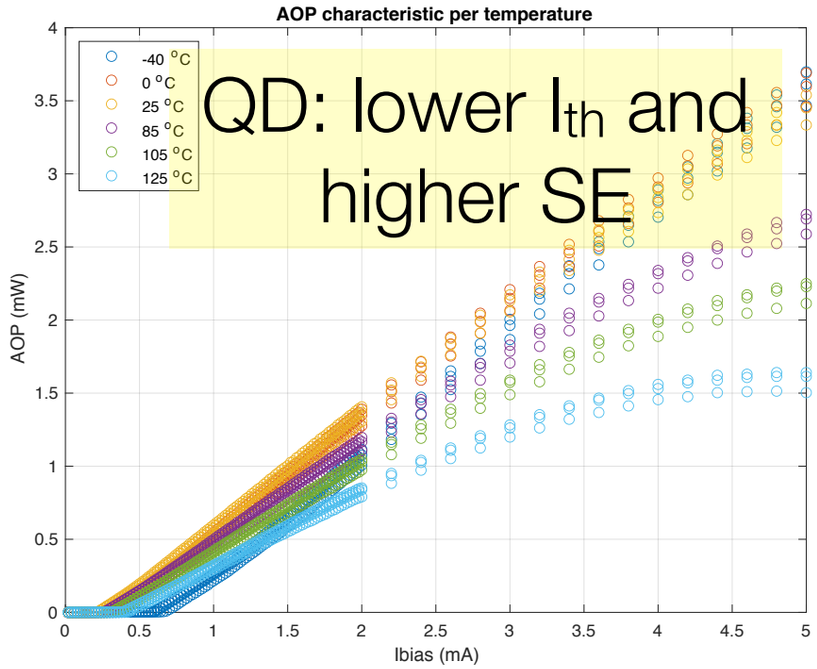
Eye diagram for 26.5625 GBd NRZ — Bin 2



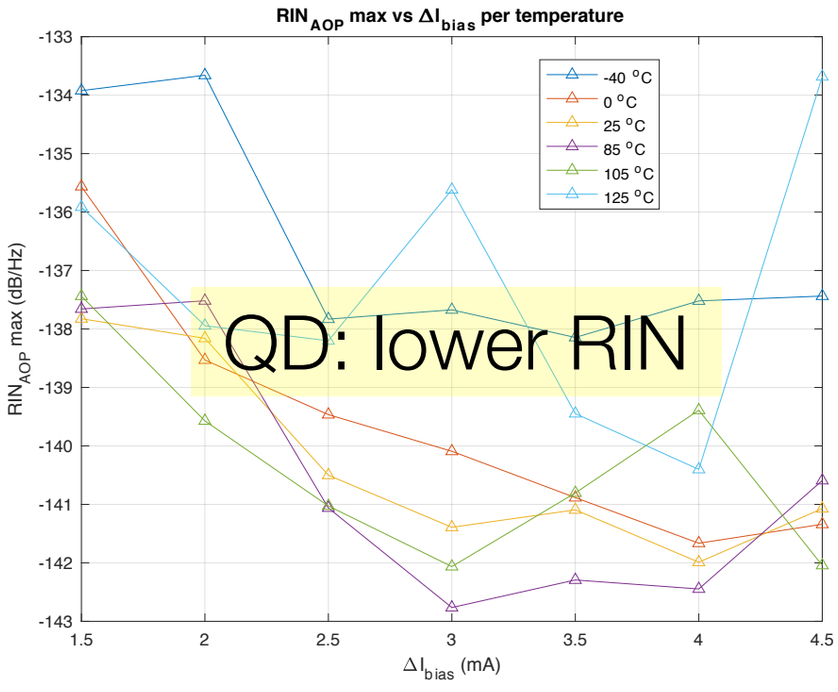
Comparison

Comparison — LI & RIN

QD

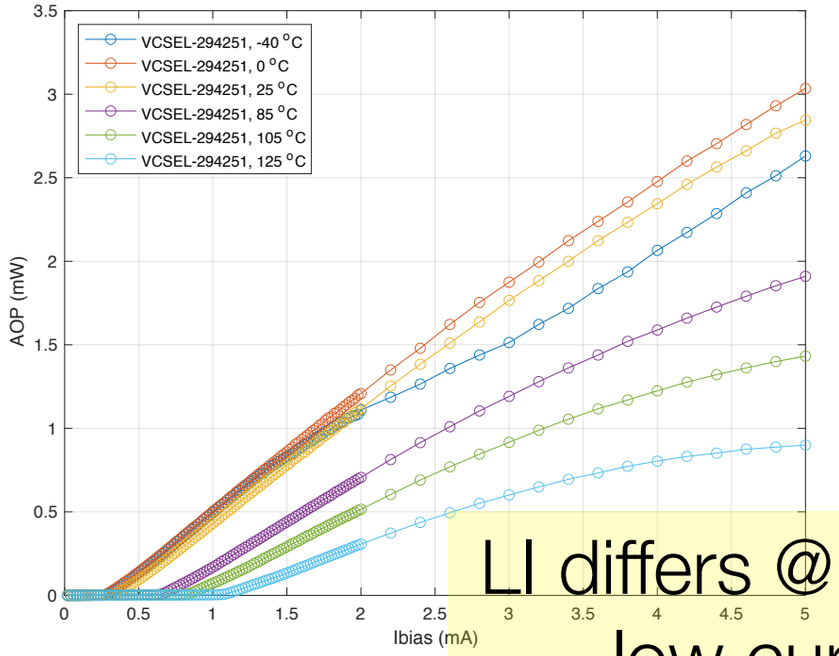


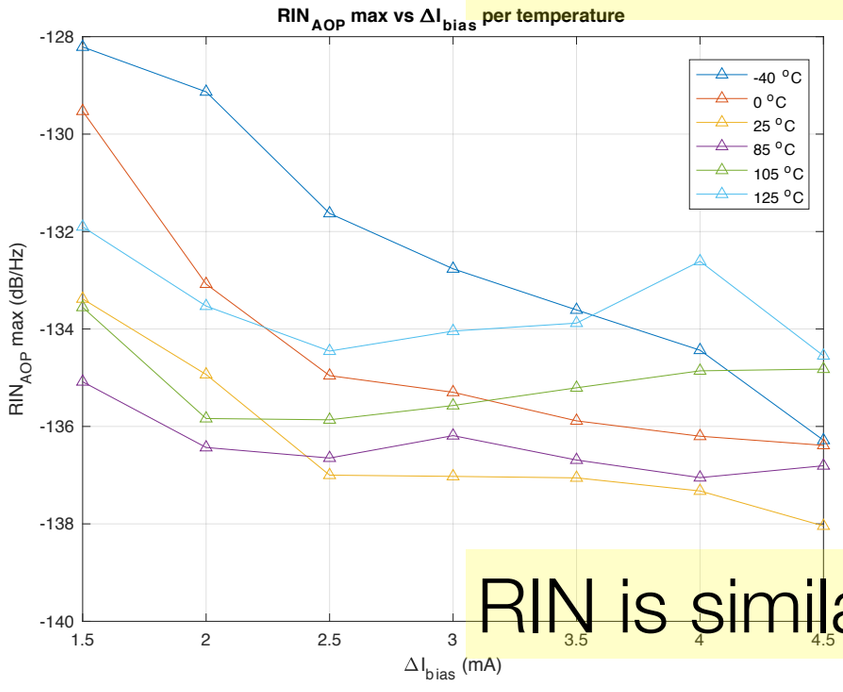
QD: lower I_{th} and higher SE



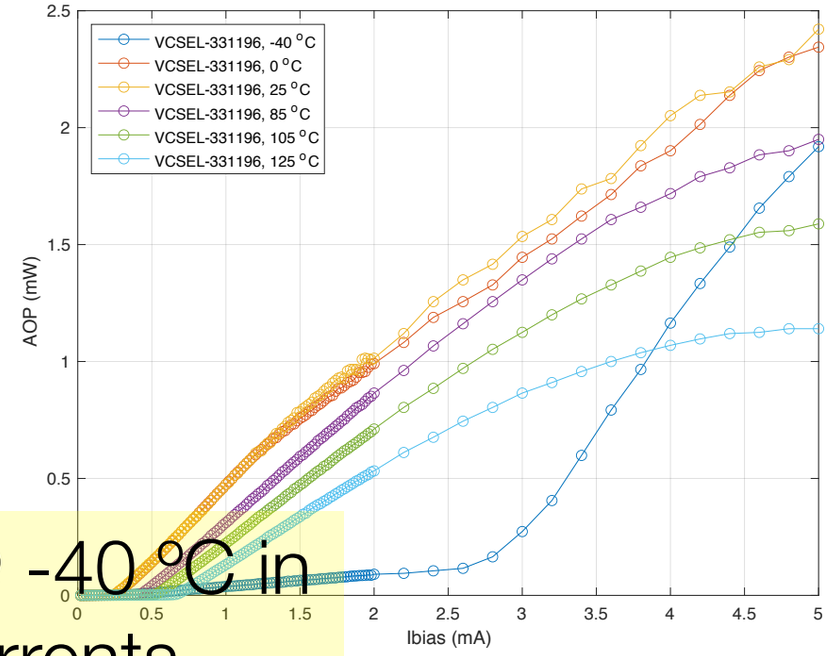
QD: lower RIN

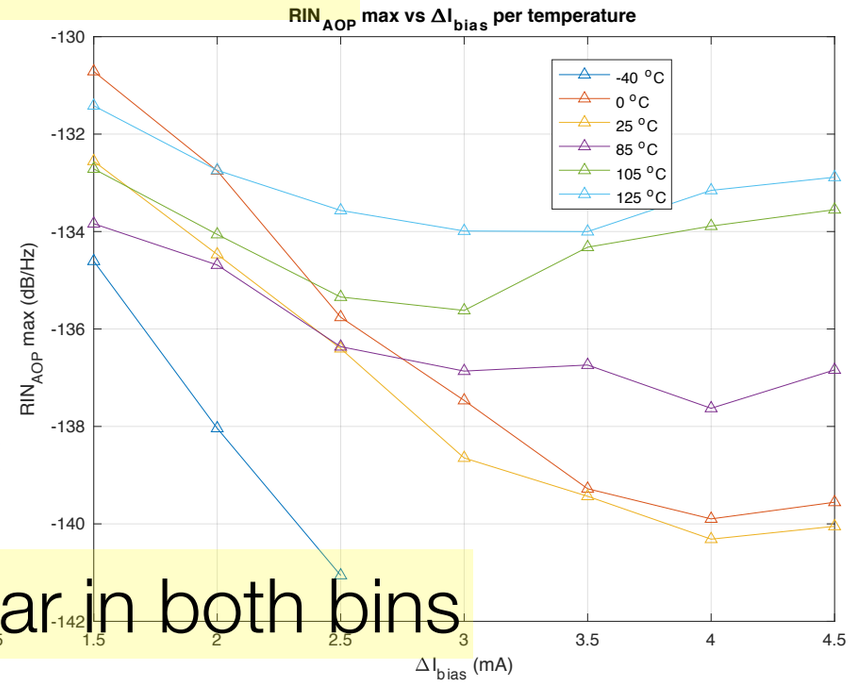
QW bin 1





QW bin 2



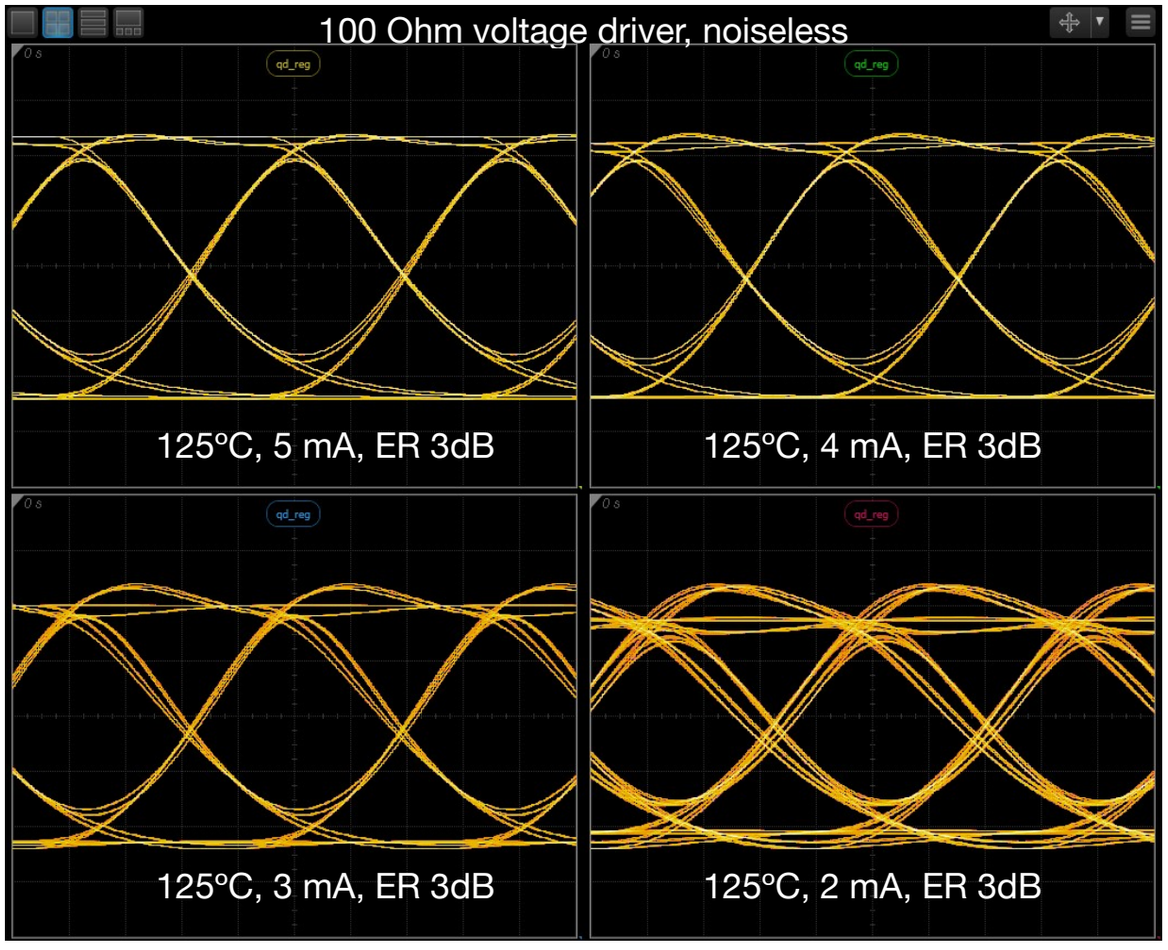


LI differs @ -40 °C in low currents

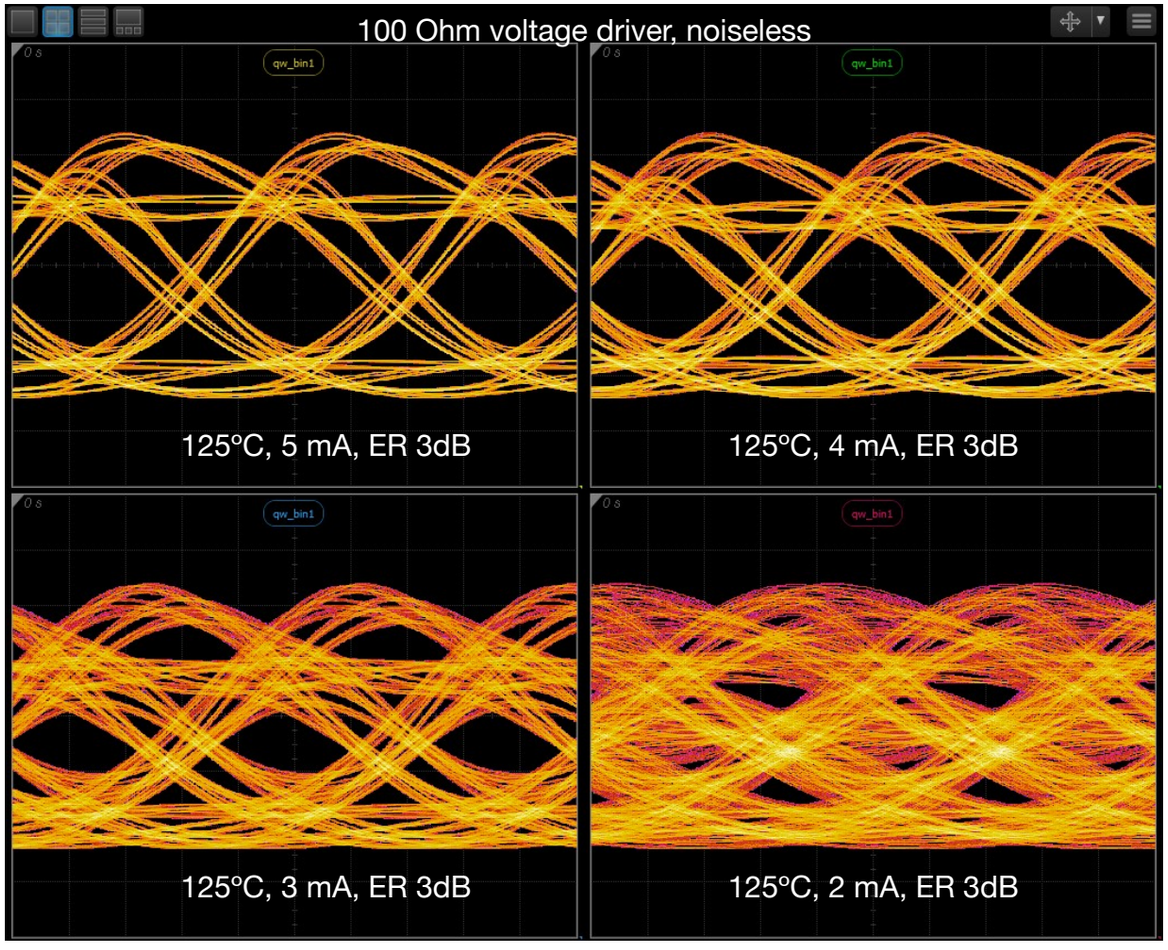
RIN is similar in both bins

Comparison — Eye diagrams

QD



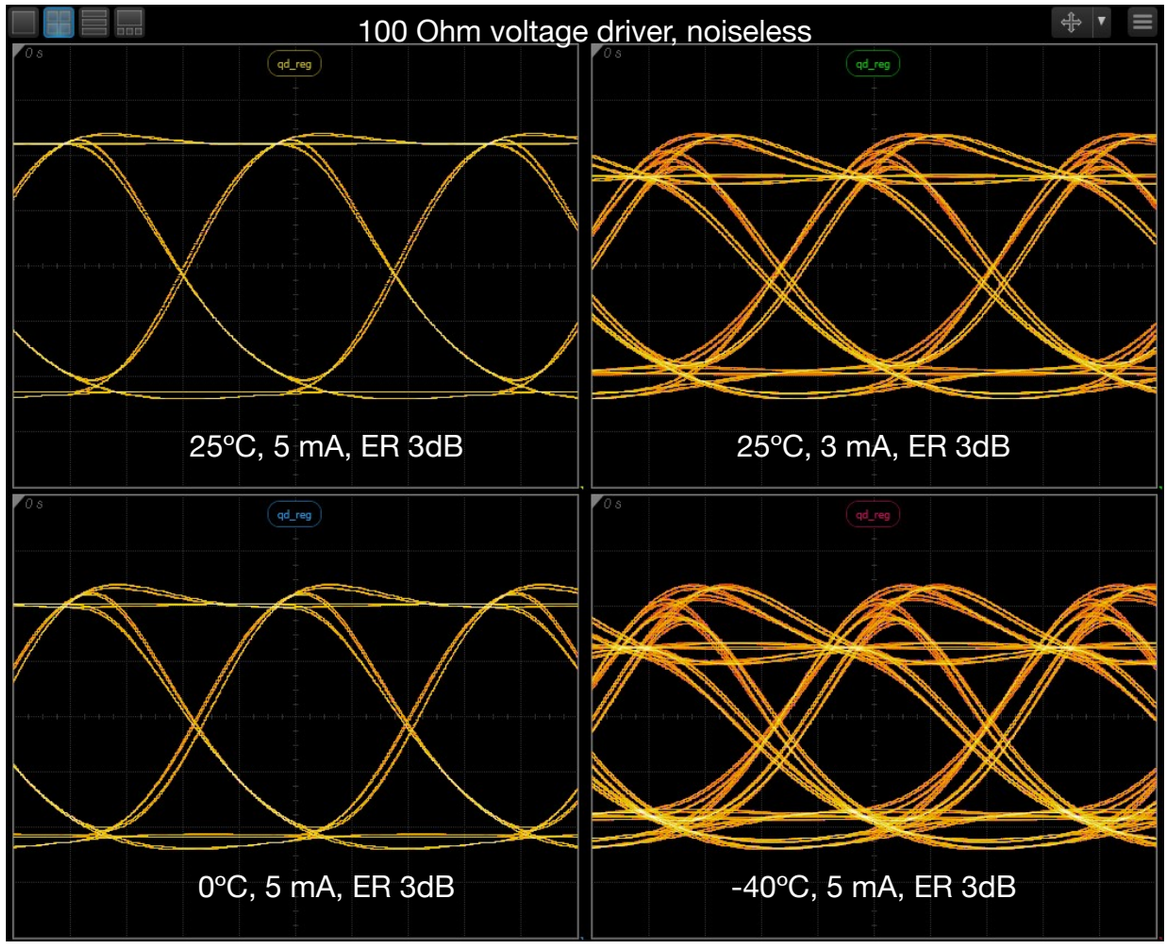
QW



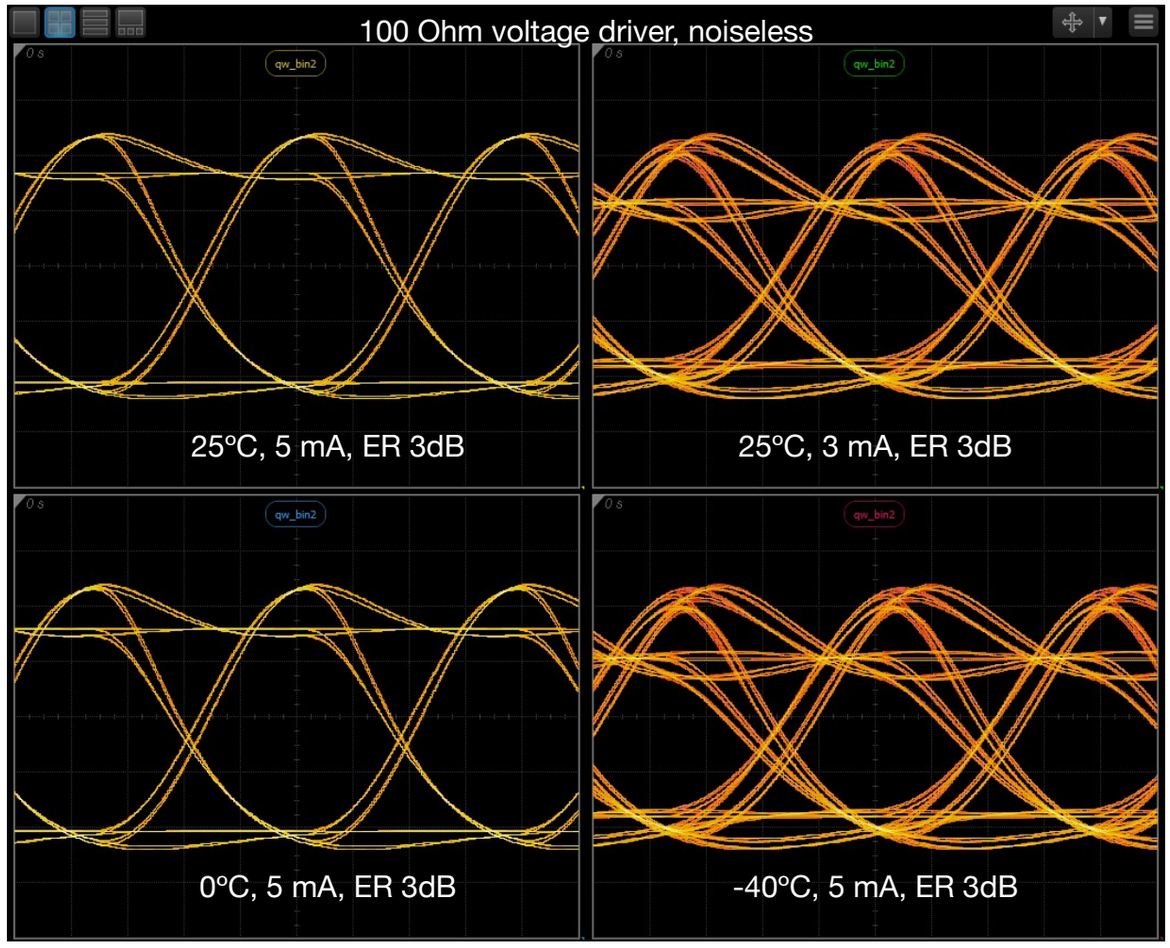
QD is better in high temperatures

Comparison — Eye diagrams

QD



QW



QD and QW are similar in RT and low temperatures