OMEGA 10 Gb/s link budget analysis

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Introduction and assumptions

Introduction

- This contribution presents a link budget analysis for transmission of 10 Gb/s in extreme automotive temperatures for all the characterized 850 nm VCSELs reported in July and August TF meetings
- Due to the key role of the bias current in the VCSEL reliability, the link budget analysis is parametrized based on I_{BIAS}
- The link budget analysis is based on the link model presented in perezaranda_OMEGA_01_131020_link_model.pdf

Baseline for link budget analysis

- The following parameters are a small subset of a complete baseline that will be presented in a future meeting
- These parameters are the minimum information of the communications system needed to carry out link budget analysis according to the used link model
  - Data-rate: 10 Gb/s
  - **Modulation: NRZ, PAM M = 2**
  - FEC: RS(544, 522) GF(2^{10})
    - Error correction capability: t = 11
    - Code-rate: CR = 0.96
    - Coding-gain: CG (for BER = 10^{-12} after FEC) = 5.55 dB
    - BER before FEC (for BER = 10^{-12} after FEC) = 0.00017
  - F_s = 10.625 GBd
  - SNR_d > 11.07 dB for BER < 10^{-12} after FEC
  - RX equalization: DFE
  - RIL = 0.4 dB (extracted from time-domain simulations of the complete system)

Simulations conditions

- Fiber is OM3: BW_{eff} = 1665 MHz·km @ 850nm
  - EMB = 2000 MHz·km @ 850nm
  - BW_{CD} = 3008 MHz·km @ 850nm
- Fiber length = 40 meters
- Number of inline connections: $N_{IC} = 4$
- VCSEL ER = 3 dB
- VCSEL drivers:
  - Current driver w/o FFE
  - Voltage driver w/o FFE
- VCSEL RIN_{OMA} = -120 dB/Hz, BW_n = 20.9 GHz
- VCSEL I_{BIAS}: from 2 to 6 mA in 0.5 mA steps
- VCSEL temperatures (T_{AMB}) :
  - -40 ºC
  - 125 ºC
- RX conditions: worst production corner, T_J = 125 ºC

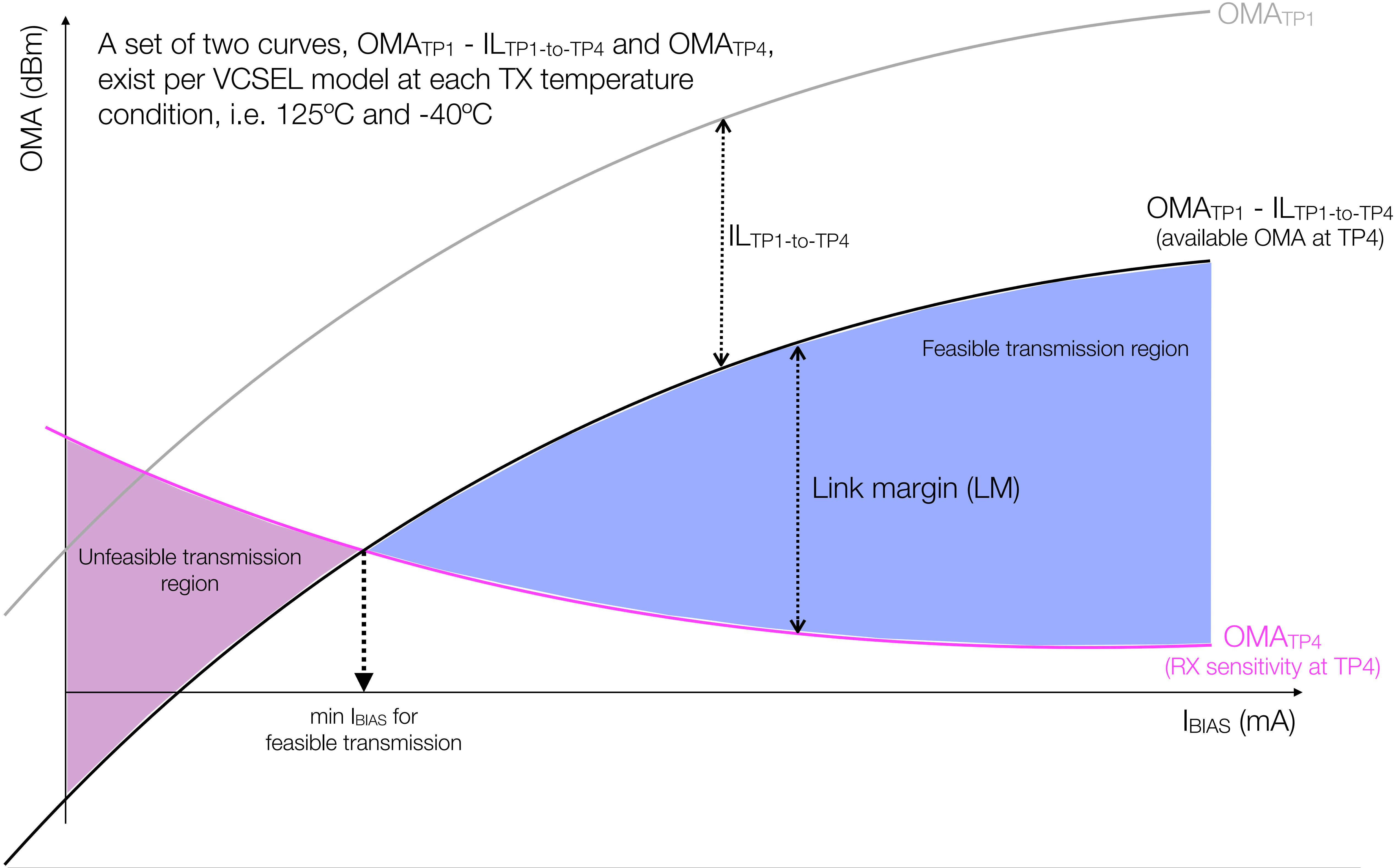
Channel insertion losses

Channel insertion losses

Parameter	Value	
VCSEL SE variation in the same bin (dB)	0.50	A
VCSEL aging (dB)	1.50	B
VCSEL to TP2 max coupling loss (dB)	3.50	C
$IL_{TP1\text{-}to\text{-}TP2}$, max (dB)	**5.50**	D = A + B + C
$IL_{TP3\text{-}to\text{-}TP4}$, max (dB)	**2.50**	E
Insertion loss per inline connection, IL_{IC} max (dB)	**2.00**	F
Number of inline connections (N_{IC})	**4**	G
Macrobend insertion loss, max (dB)	0.20	H
Microbend insertion loss, max (dB)	0.00	I
Bending insertion loss, IL_{BEND} max (dB)	0.20	J = H + I
Fiber attenuation (dB/km)	3.50	K
$IL_{TP2\text{-}to\text{-}TP3}$, max (dB)	**8.34**	L = (F × G) + J + (40/1000 × K)
$IL_{TP1\text{-}to\text{-}TP4}$, max (dB)	**16.34**	M = D + E + L

- See perezaranda_OMEGA_01_131020_link_model.pdf slides 5 and 26 for the definition of the test points, insertion losses and link budget
- In orange are indicated the values changed wrt the 25 Gb/s link budget analysis. The rational behind of increasing the insertion losses in 10 Gb/s is to give more flexibility to implementor for scaling the relative cost with the data-rate for market acceptance

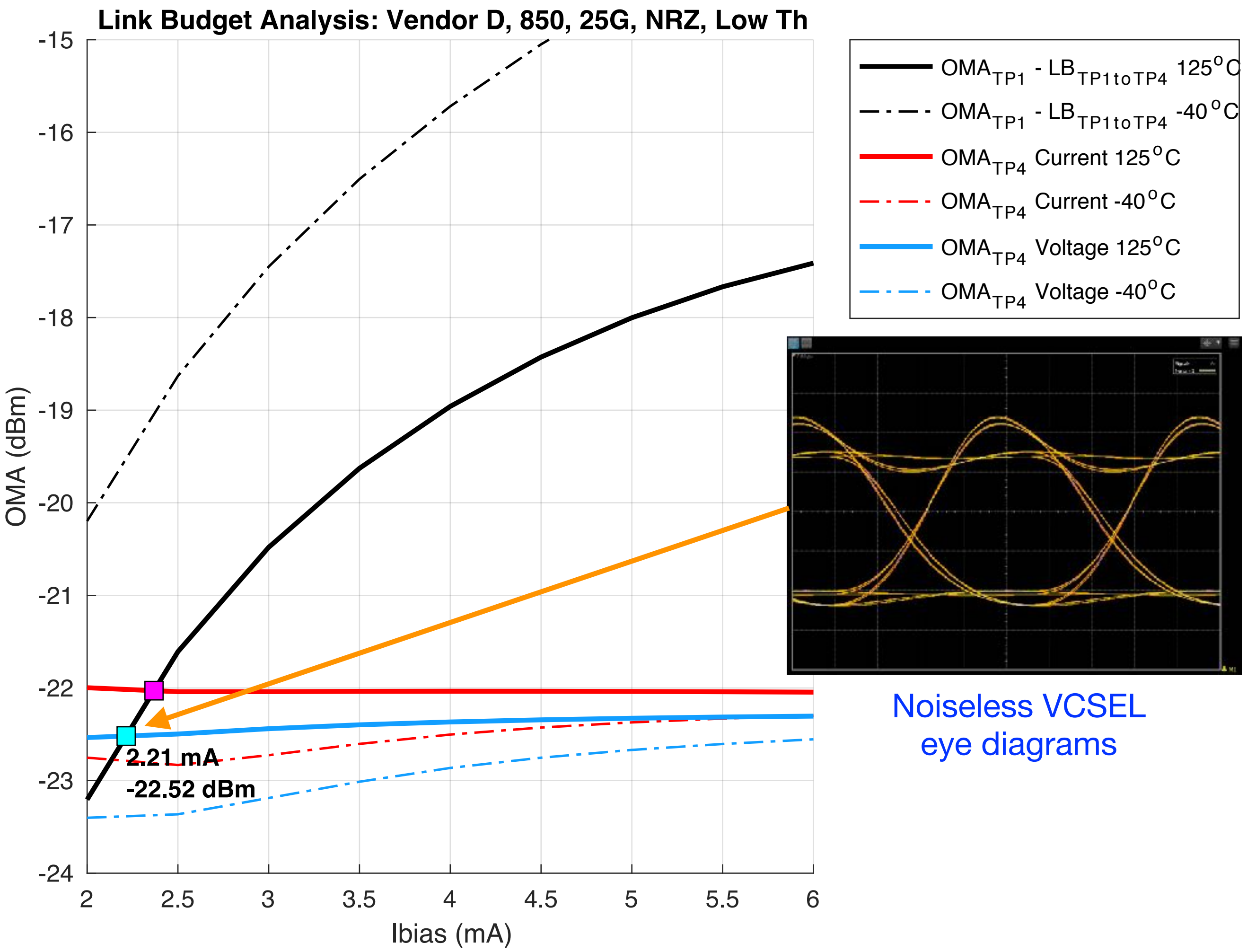
How to do the link budget analysis?

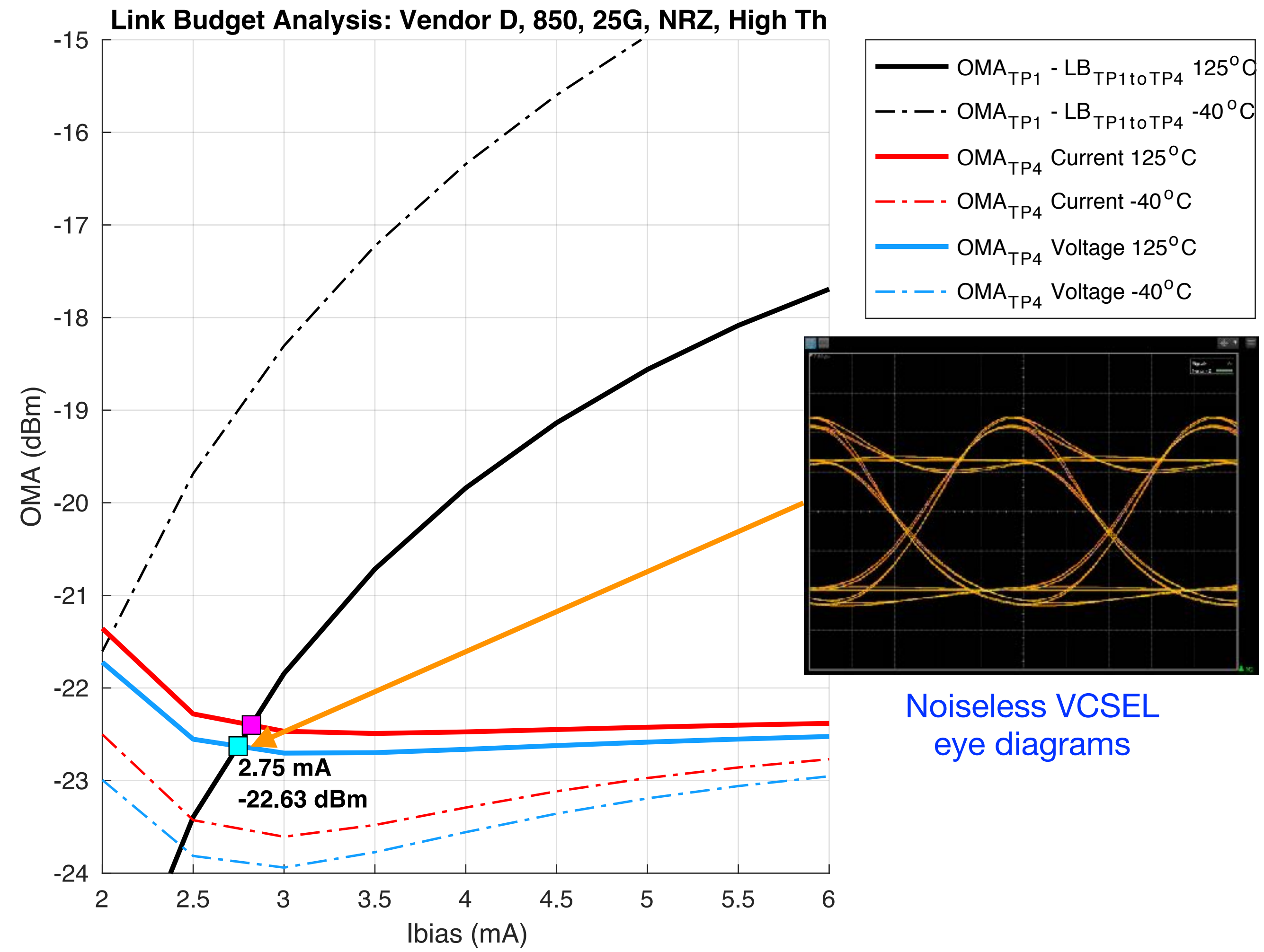


10 Gb/s link budget results

Minimum I_{BIAS} for 125ºC operation and feasibility for -40ºC

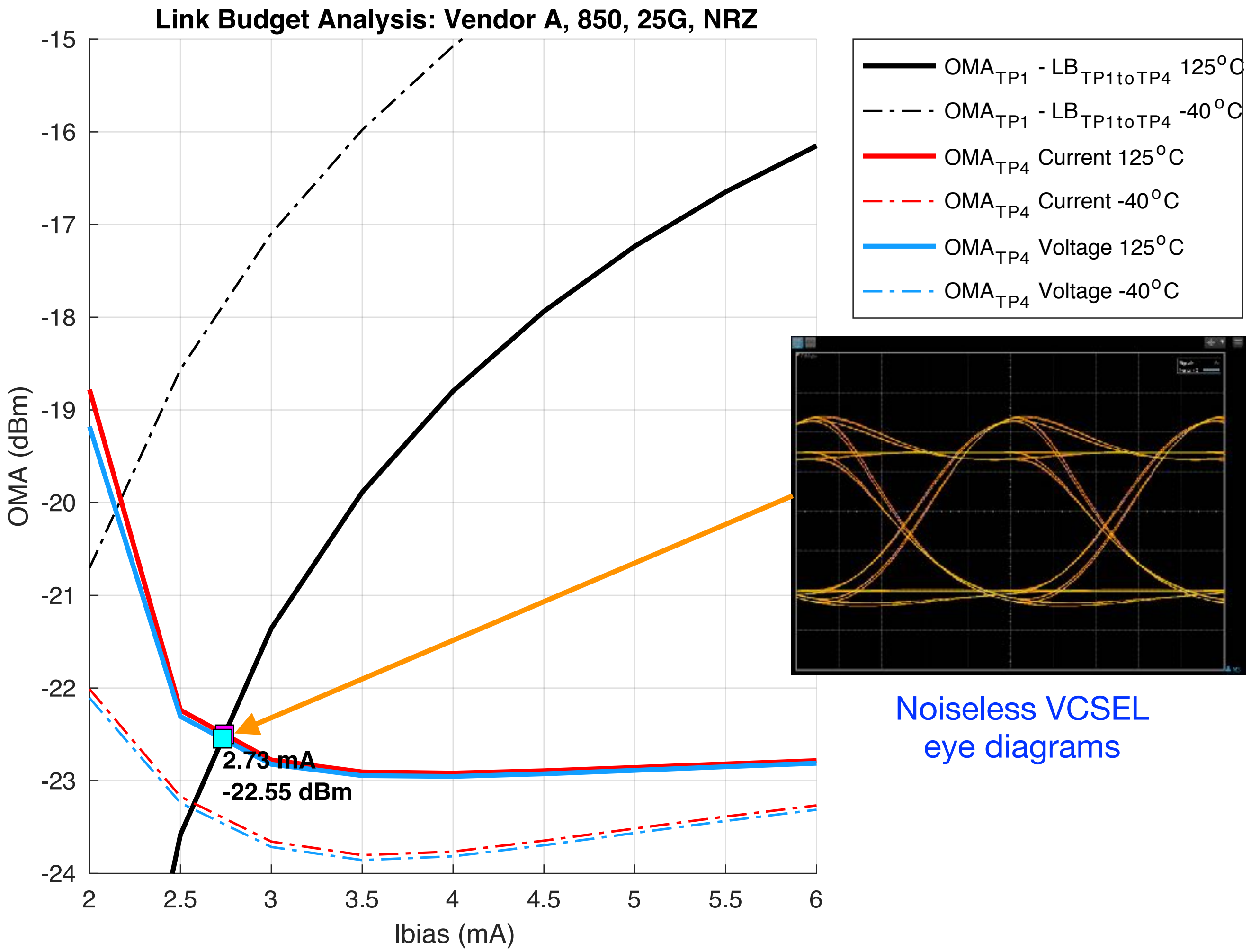
Minimum I_{BIAS} @ 125 °C and feasibility @-40°C

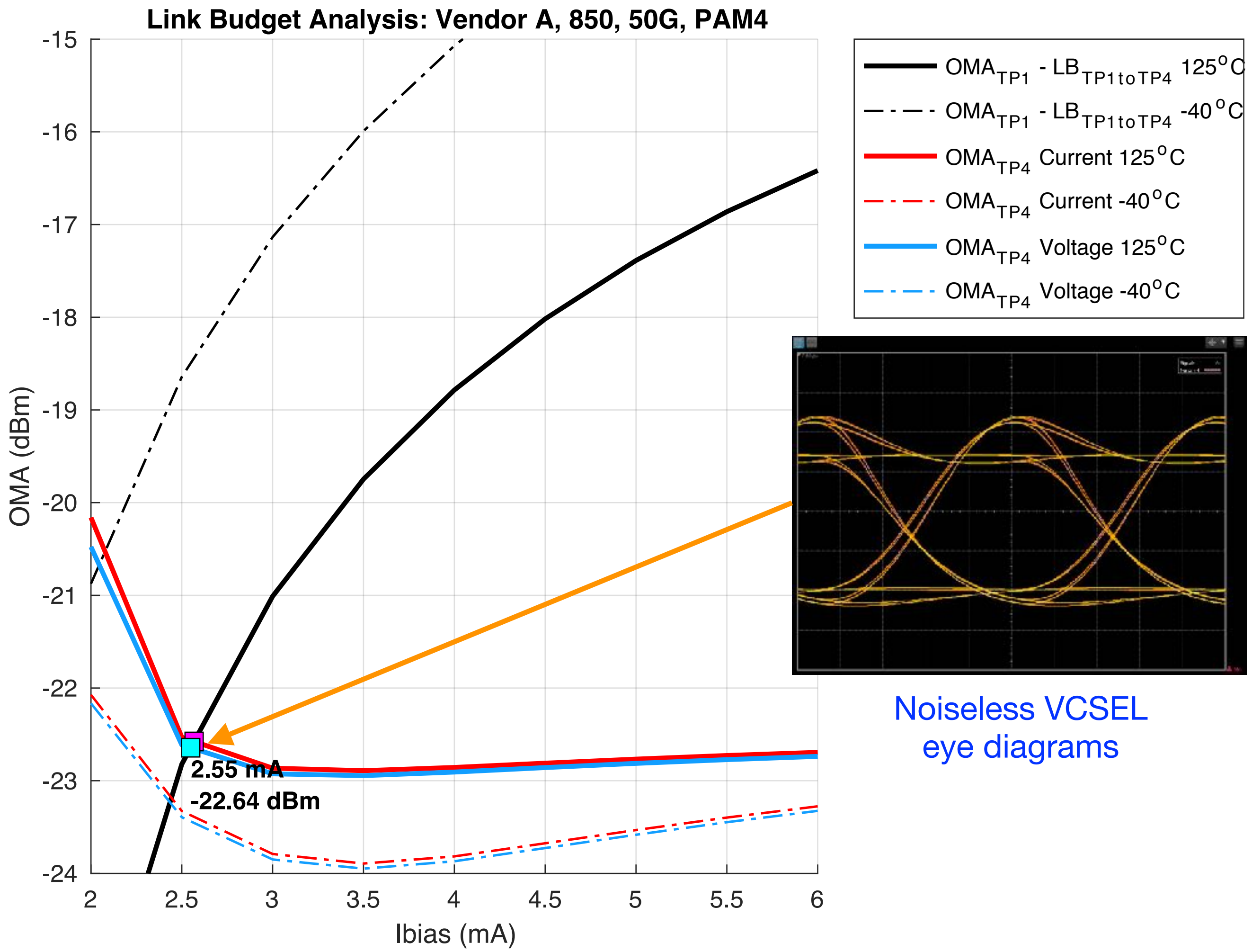




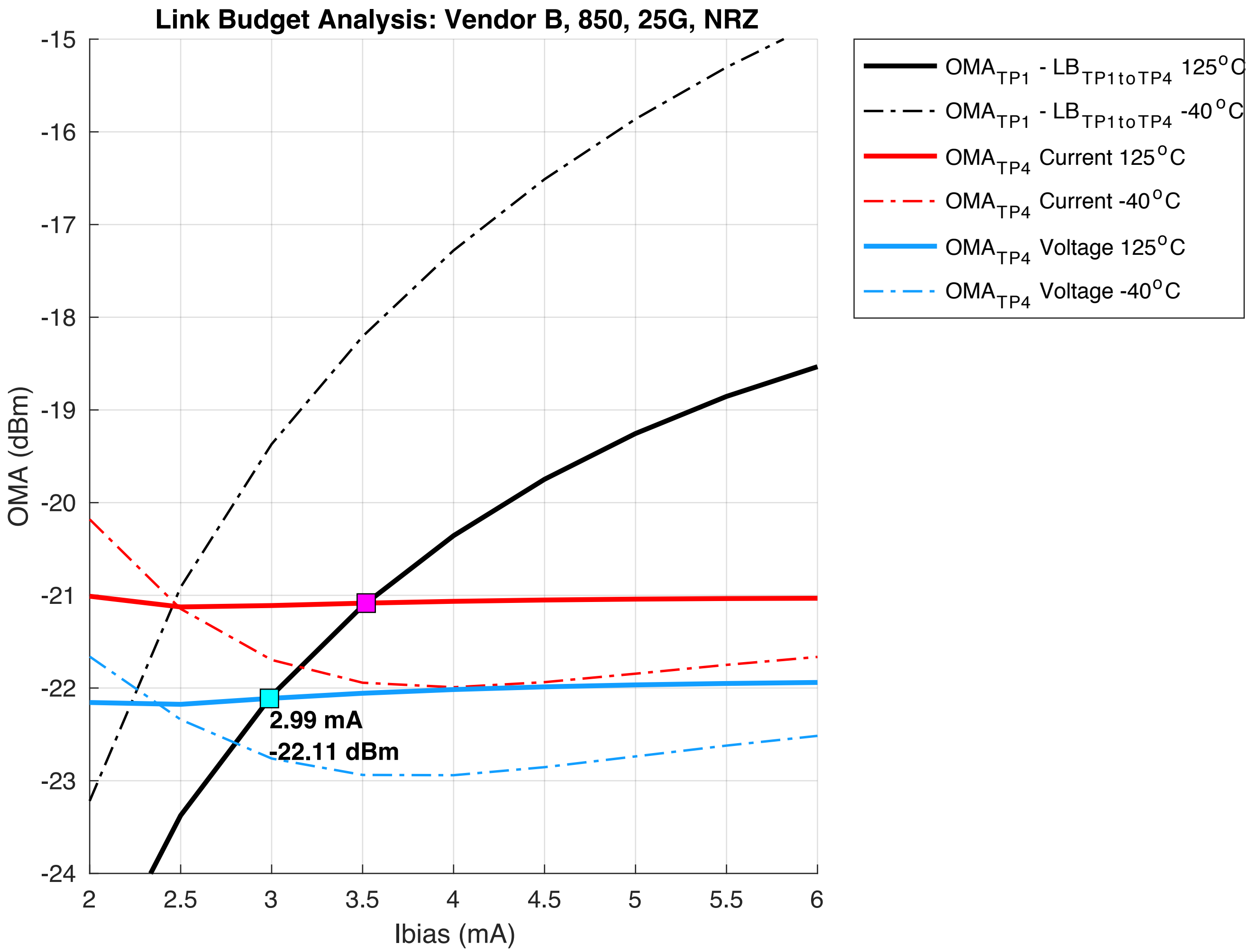
- Note: the RX implementation is common for all the simulations. Worst production corner and T_J = 125°C conditions
- At T_{VCSEL} = 125°C, squares are used to indicate the crossing points of OMA_{TP4} sensitivity curves of different VCSEL driving options with the OMA_{TP1} - $IL_{TP1\text{-to-}TP4}$ curve.
- The squares represent the minimum I_{BIAS} for feasible transmission in each case.

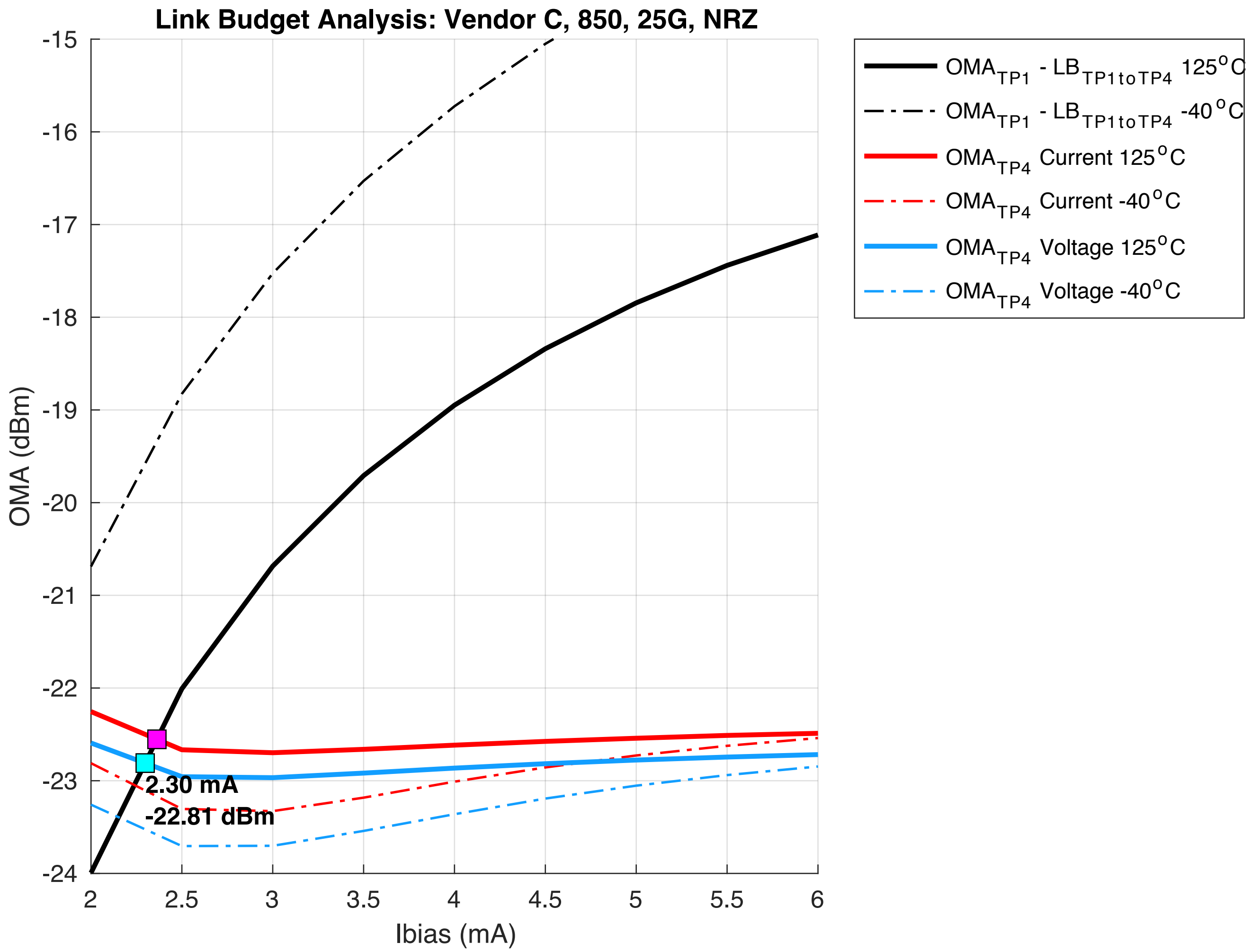
Minimum I_{BIAS} @ 125 °C and feasibility @-40°C



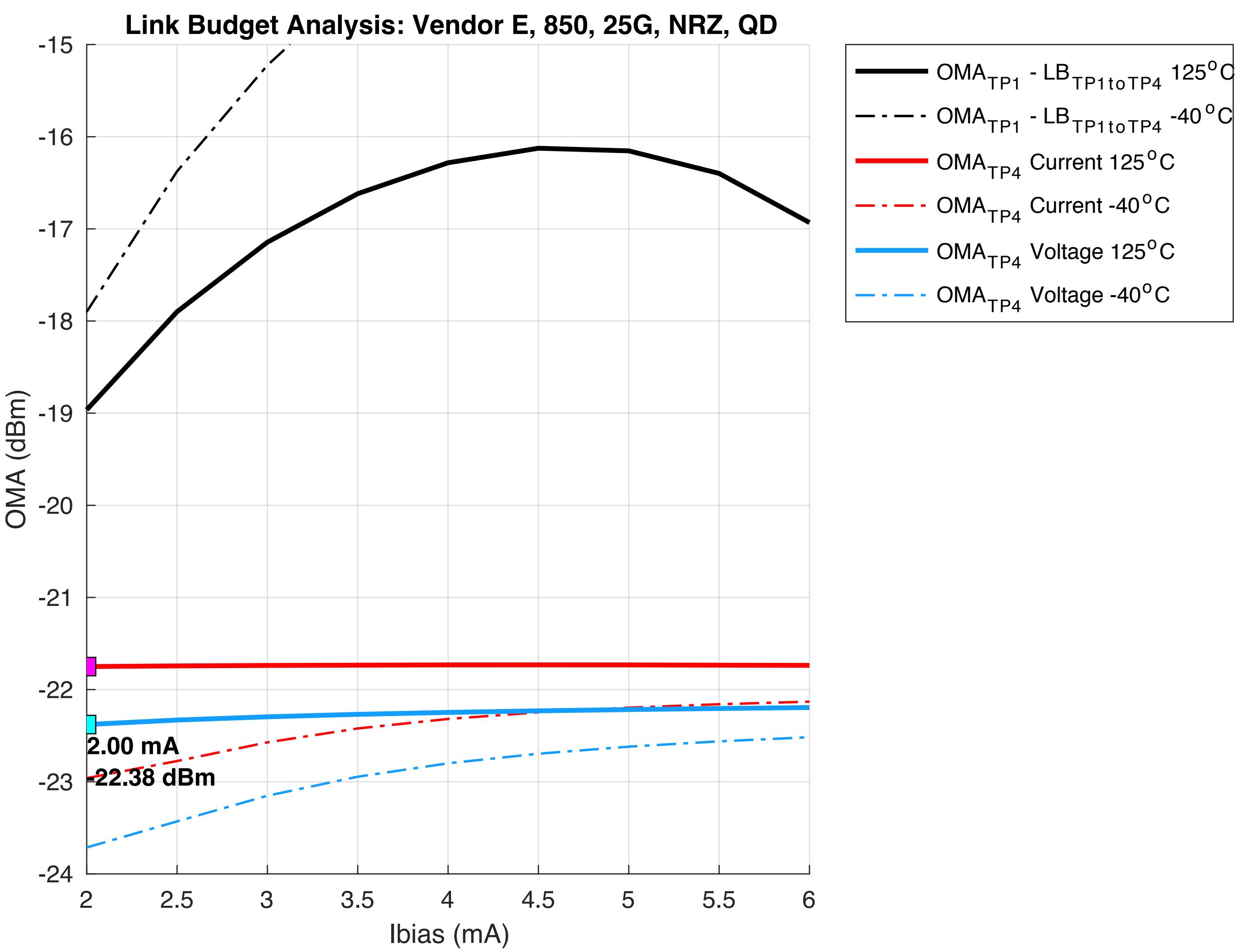


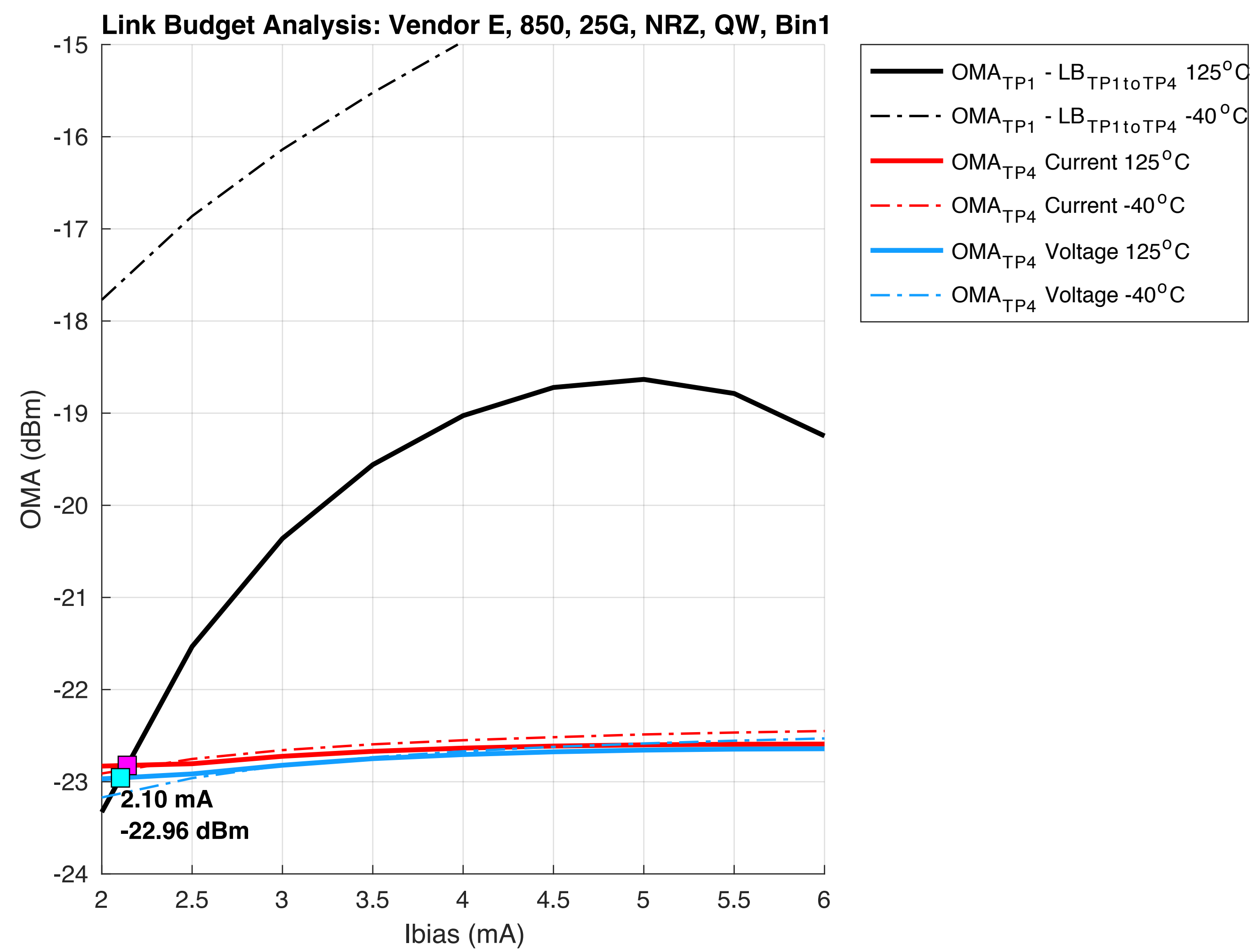
Minimum I_{BIAS} @ 125 ºC and feasibility @-40ºC



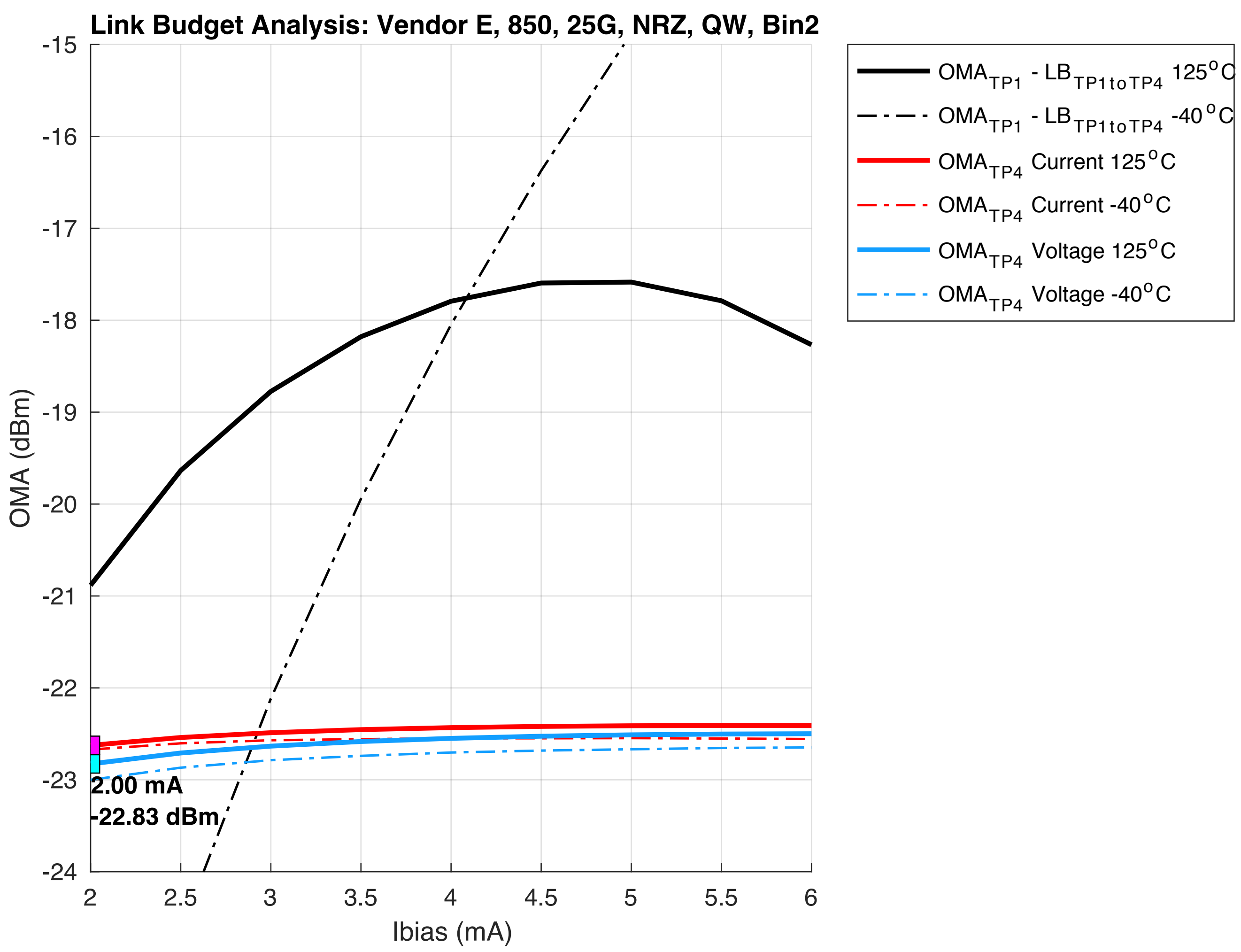


Minimum I_{BIAS} @ 125 ºC and feasibility @-40ºC





Minimum I_{BIAS} @ 125 °C and feasibility @-40°C



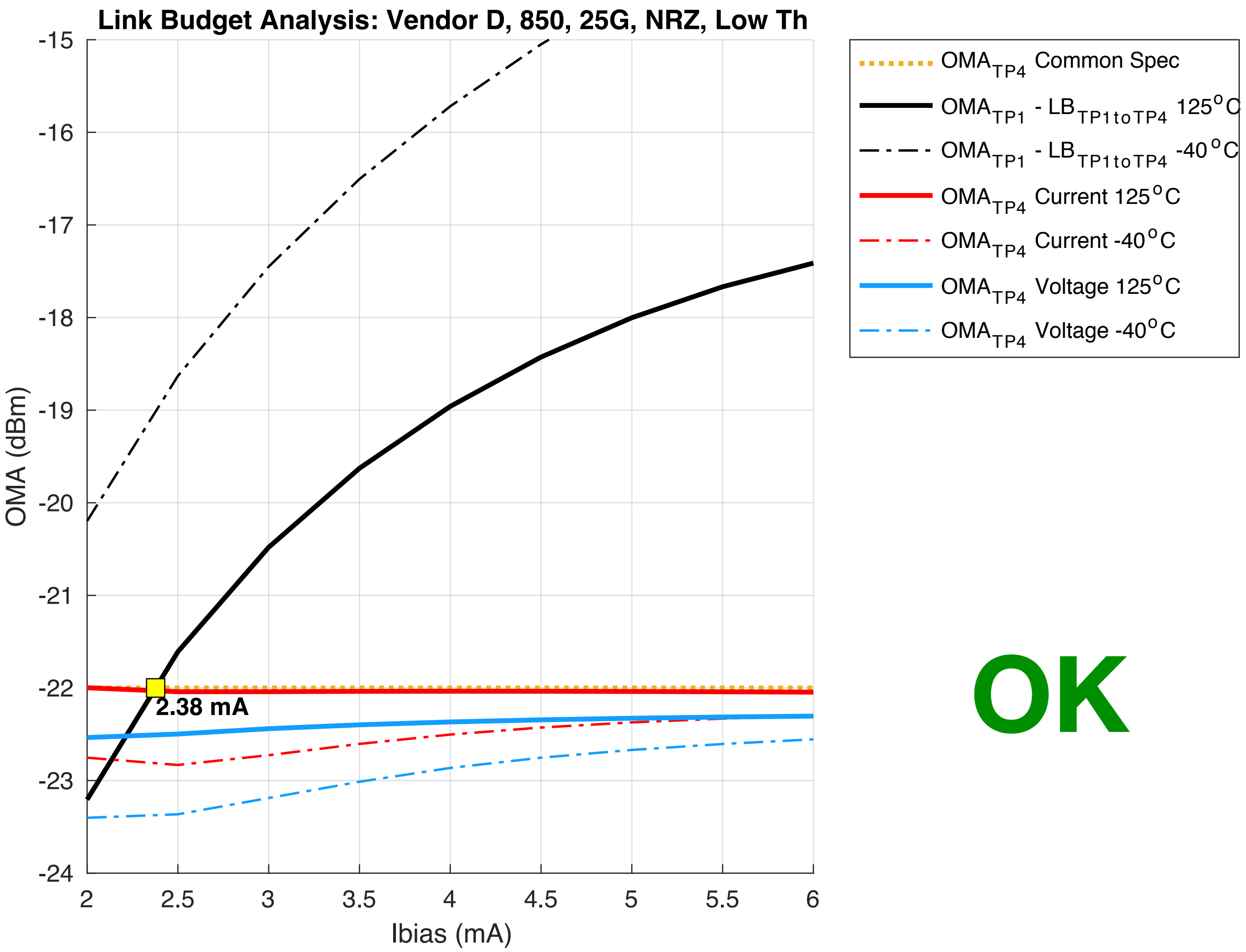
10 Gb/s link budget results

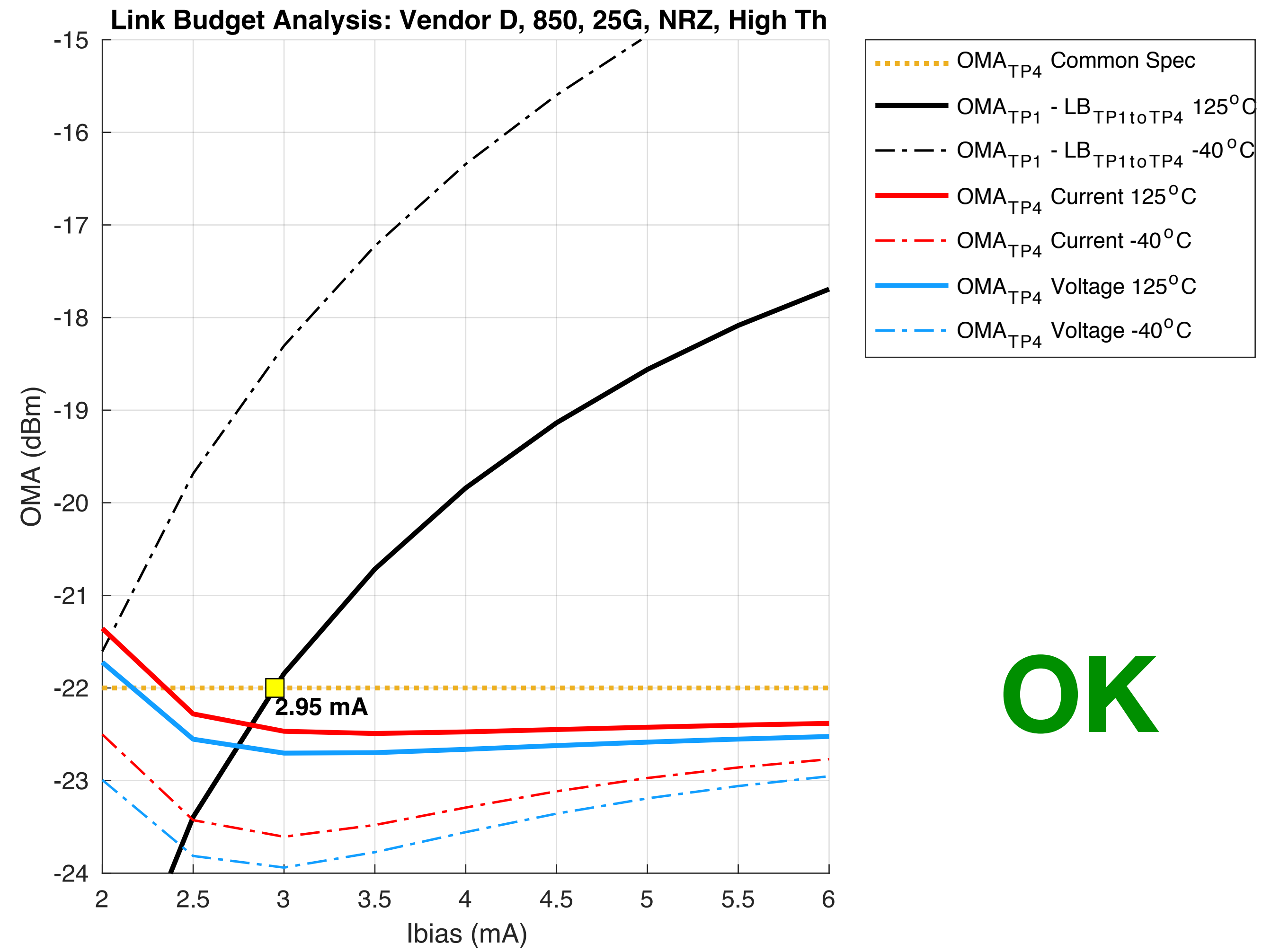
Towards a common receiver sensitivity

Is it possible a common receiver sensitivity?

- The presented results showed that for T_{VCSEL} = 125 ºC different VCSELs in minimum I_{BIAS} operation produce different sensitivity levels in the receiver (OMA_{TP4}), as well as different transmit optical power levels (OMA_{TP1})
- If a VCSEL that produces worse RX sensitivity can compensate the budget with higher transmit optical power, then the link is feasible
- On the other hand, a VCSEL with lower transmit power may produce better RX sensitivity, making the link also feasible
- Questions:
    - Q1: Is there a common receiver sensitivity level for low VCSEL I_{BIAS} operation (i.e. high reliability) valid for the most part of the evaluated VCSELs?
    - Q2: Is the same common receiver sensitivity level valid for -40ºC
- The answer is YES, as it will be demonstrated in the following slides
- Disclaimer:
    - The sensitivity levels in this contribution assumes an specific RX implementation
    - Criteria for testing the RX sensitivity is needed to be defined by the TF to guarantee interoperability. It is not in the scope of this contribution

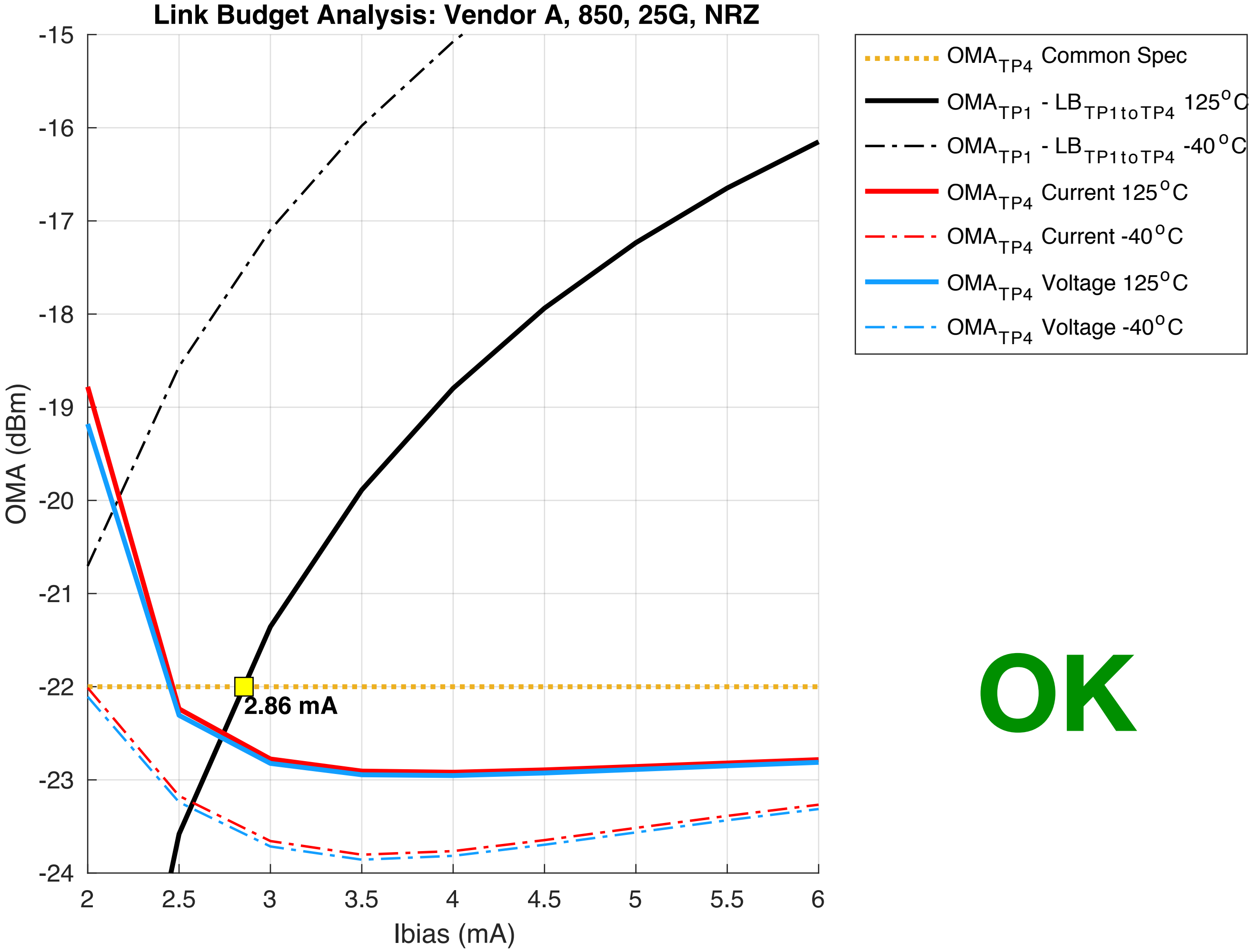
Common RX sensitivity: OMA_{TP4} = -22 dBm

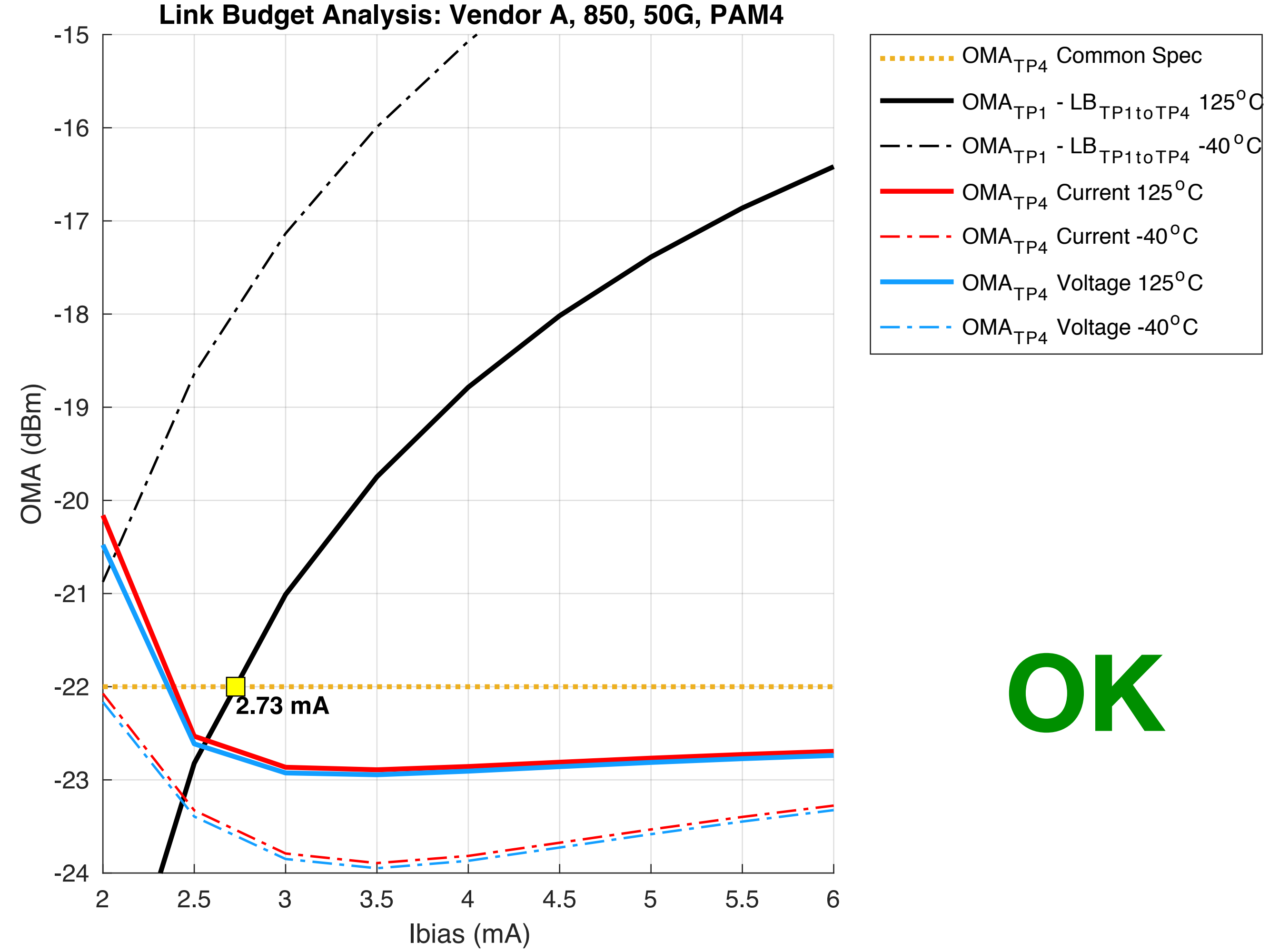




- OMA_{TP4} common specification needs to be higher than or equal to OMA_{TP4} sensitivity curve obtained for at least one of the VCSEL driving options, in both -40ºC and 125ºC in order to consider a particular VCSEL part is compatible with such a common specification
- OMA_{TP4} common specification needs to lower than or equal to OMA_{TP1} - $IL_{TP1\text{-to-}TP4}$ for feasible transmission, per definition of slide 7
- The yellow square is used to show the crossing point of OMA_{TP4} common specification with the curve OMA_{TP1} - $IL_{TP1\text{-to-}TP4}$ at 125ºC indicating the resultant minimum I_{BIAS} for feasible transmission at 125ºC that meets such common specification. If no intersection exists, the yellow square just indicates the min I_{BIAS} over the OMA_{TP1} - $IL_{TP1\text{-to-}TP4}$ curve.
- In -40ºC, high bias can be used w/o affecting reliability

Common RX sensitivity: OMA_{TP4} = -22 dBm





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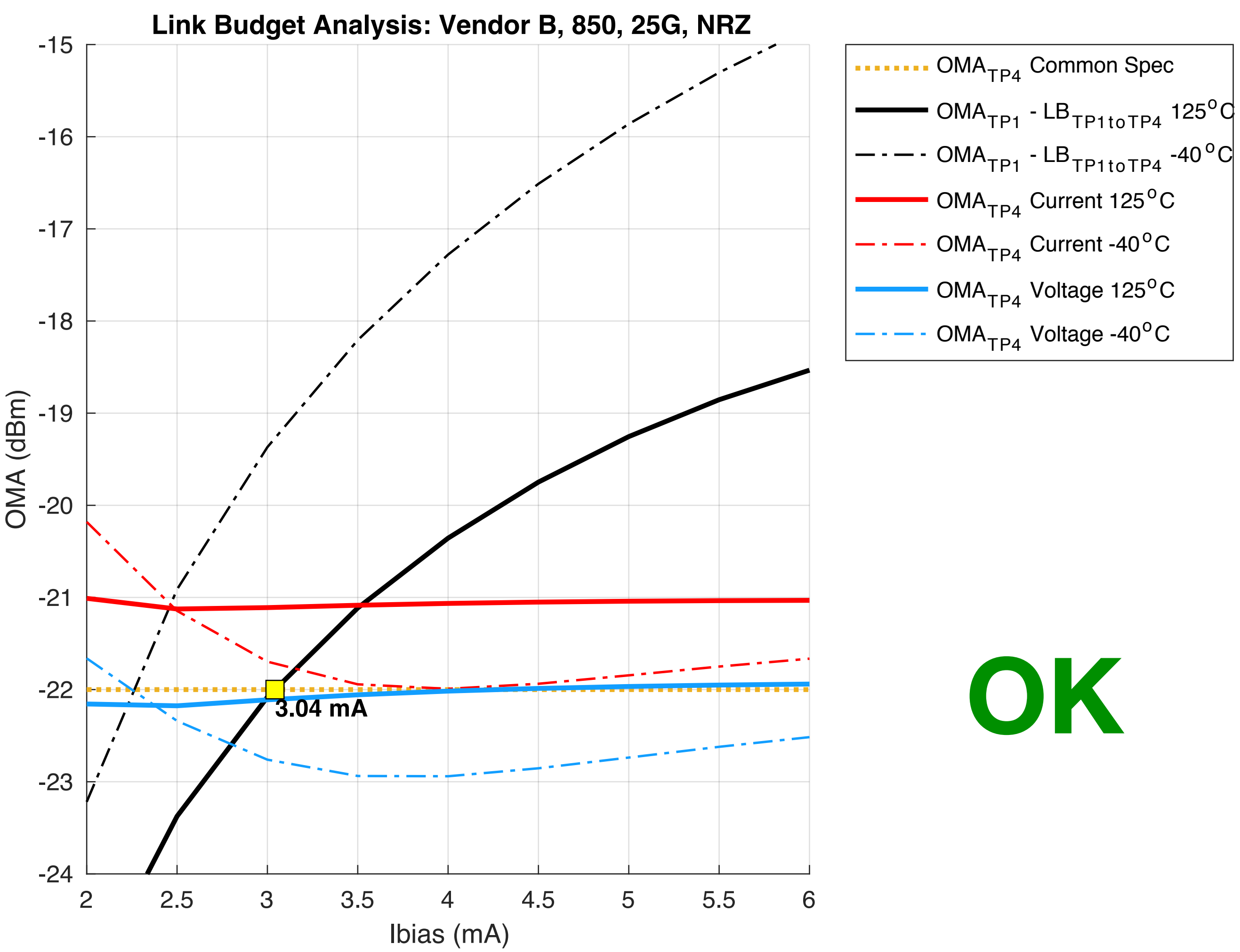

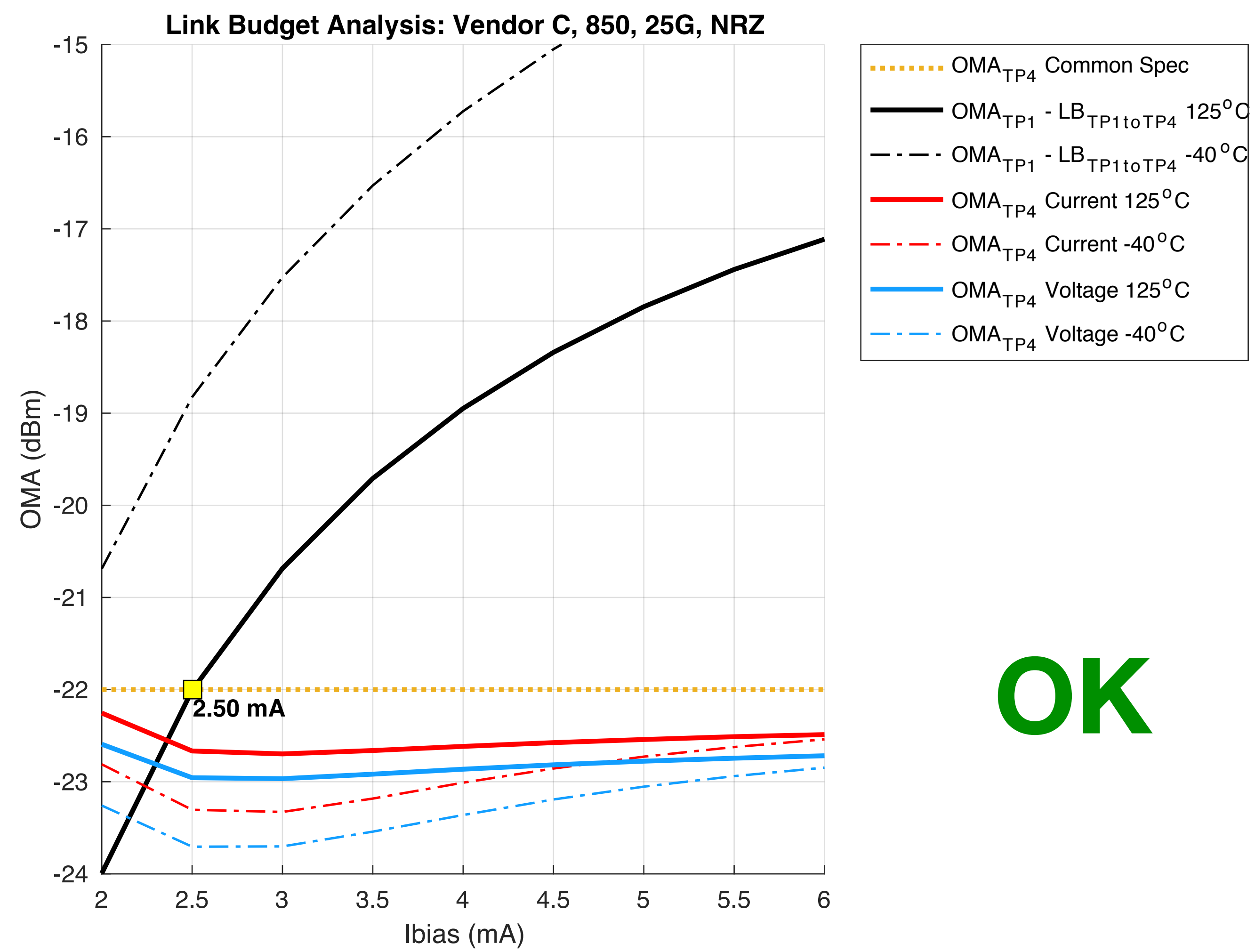

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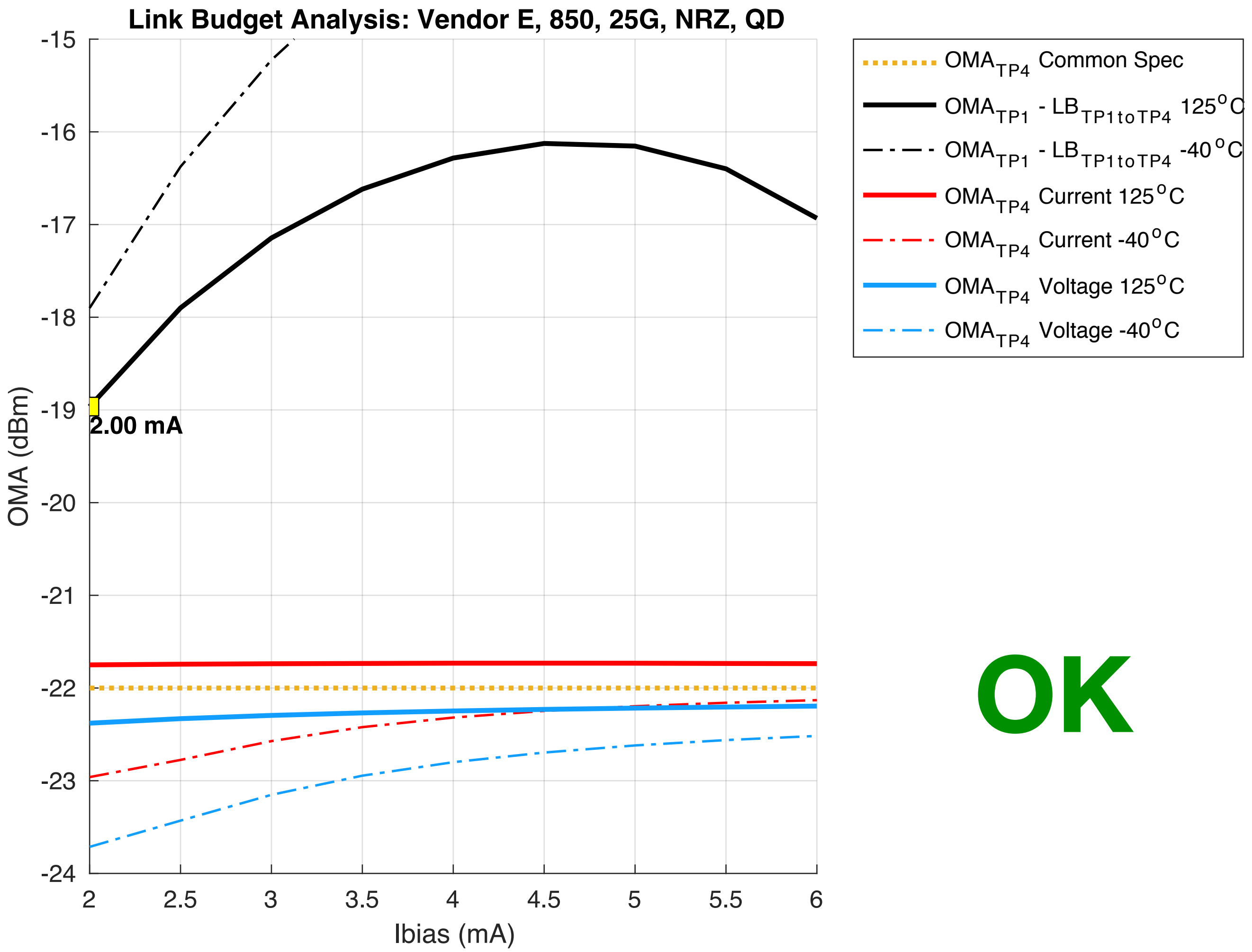

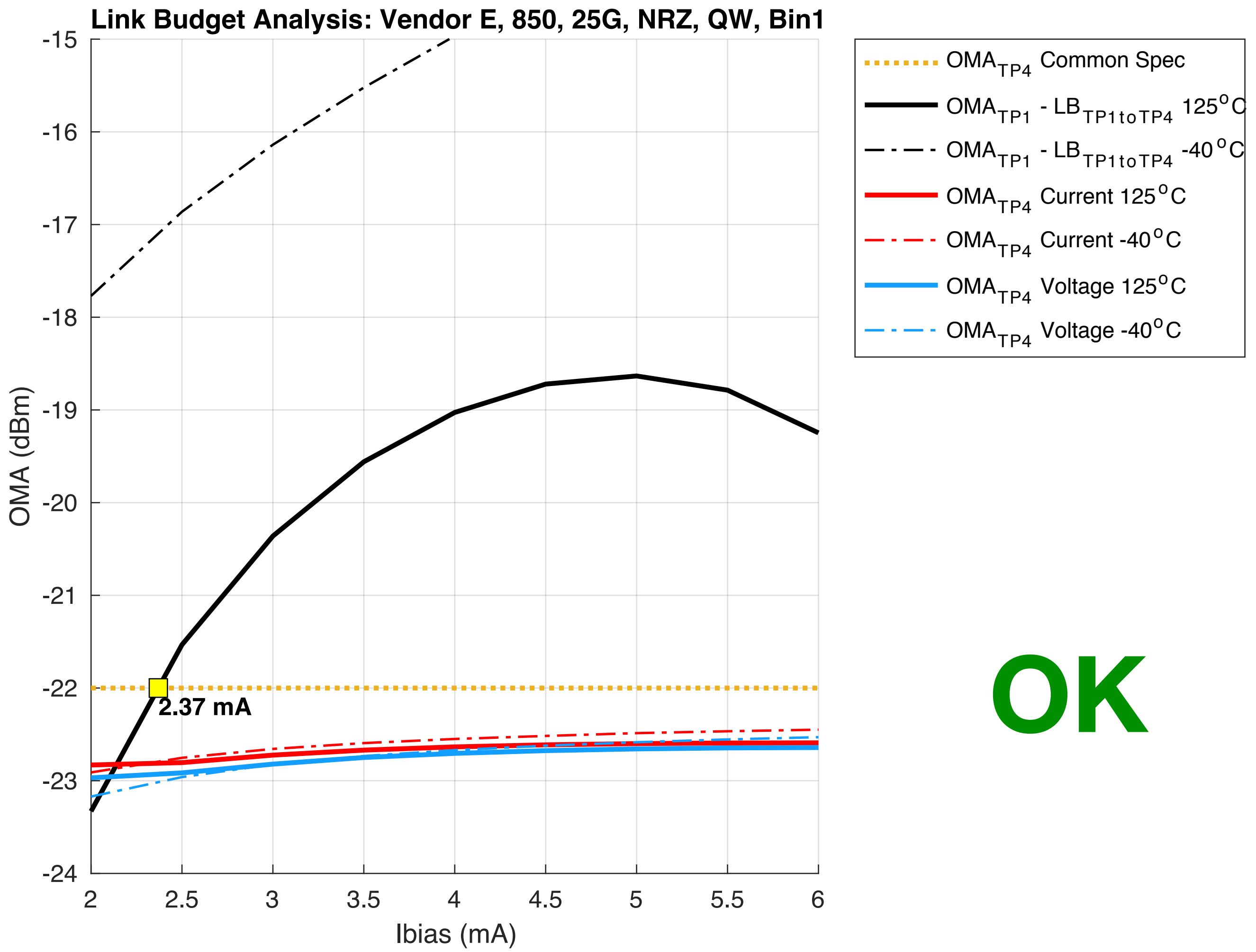

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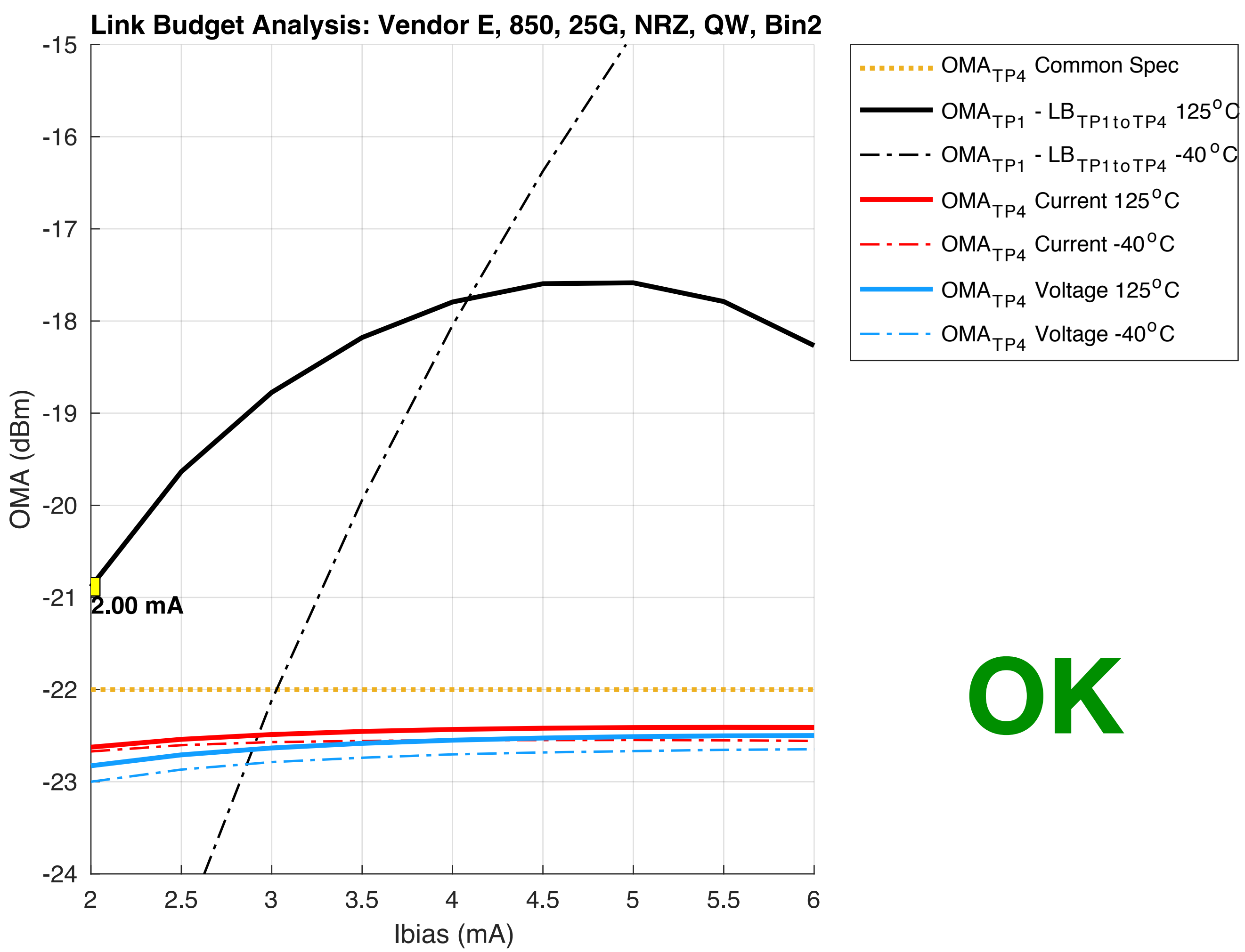

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Conclusions

- 10 Gb/s operation with very low VCSEL bias current has been demonstrated feasible for all the evaluated VCSELs, in temperatures of 125ºC and -40ºC
- Wear-out reliability data provided by VCSEL vendors is needed to confirm that bias currents found for each VCSEL are consistent to achieve automotive lifetime reliability requirements
- Link budget for longer wavelength VCSELs have not been reported because assembly of the tested 990nm device presented much larger thermal resistance than expected in real use, making the characterization pessimistic for 125ºC and optimistic for -40ºC (see perezaranda_OMEGA_05a_0720_VendorD_VCSEL.pdf)
  - Once solved this issue, link budget analysis for longer wavelength VCSELs will be presented

Thank you!