Required Spectrum Mask for 25Gb/s Burst Mode Signal

Moon S. Park

May 2017

OE SOLUTIONS AMERICA

Supporter:

Comcast: Phil Miguelez

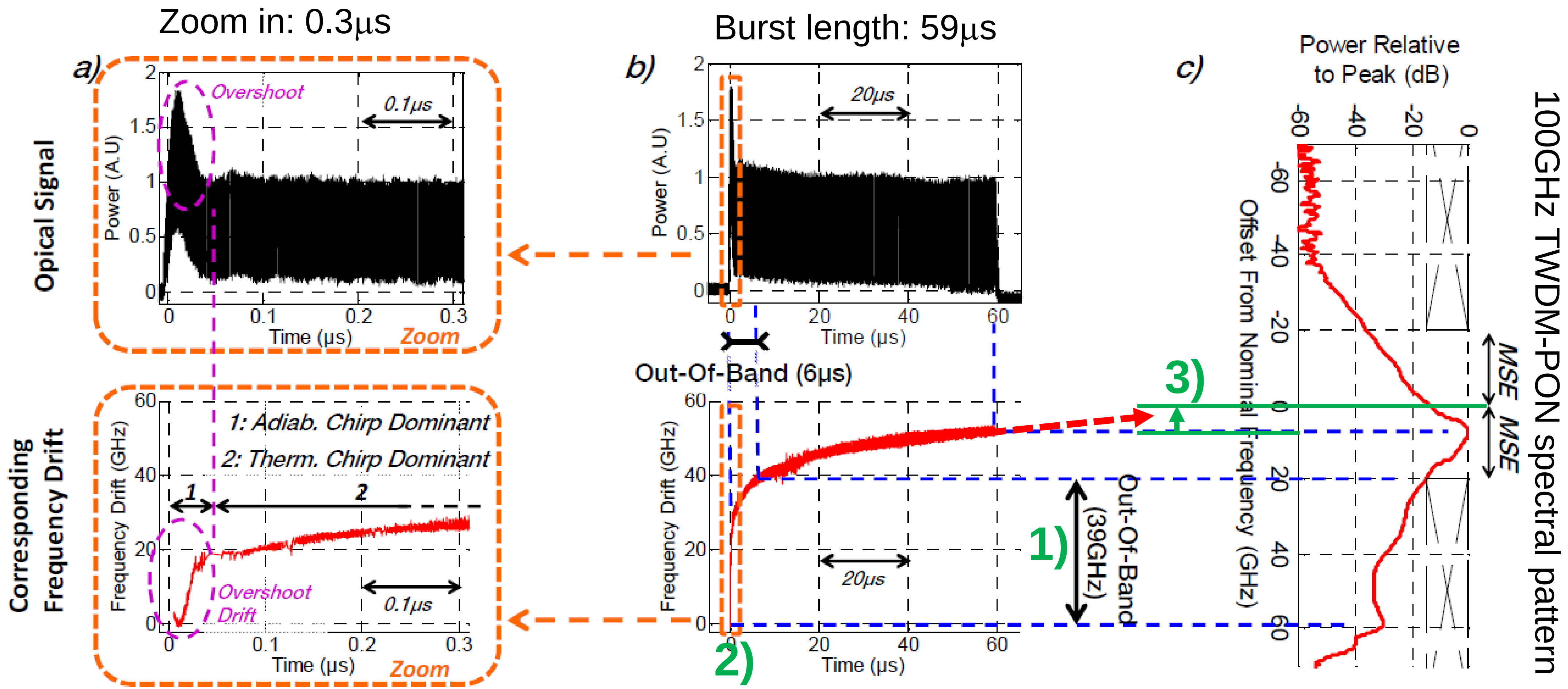
Background

1. Wavelength excursion with BM (burst mode) modulation was briefly addressed in liudekun_3ca_2_0317

2. Wavelength excursion with 25Gb/s BM modulation seems to be more serious than 10Gb/s BM modulation
   - Higher speed modulation: 10Gb/s to 25Gb/s. 25Gb/s NRZ produces wider sideband spectra (DSB).
   - Laser technology is different: smaller laser chip size, high driving current/current density etc..

3. A paper had presented detailed explanations on wavelength excursion with BM modulation in the TWDM NGPON2.
   - G. Smith., et al., “Spectral and temporal analysis of the NGPON2 short-term wavelength drift for 10Gb/s Bursts”, Proc. OFC 2016, W4C.2, Anaheim, CA

Example of Wavelength excursion with BM modulation (10Gb/s)



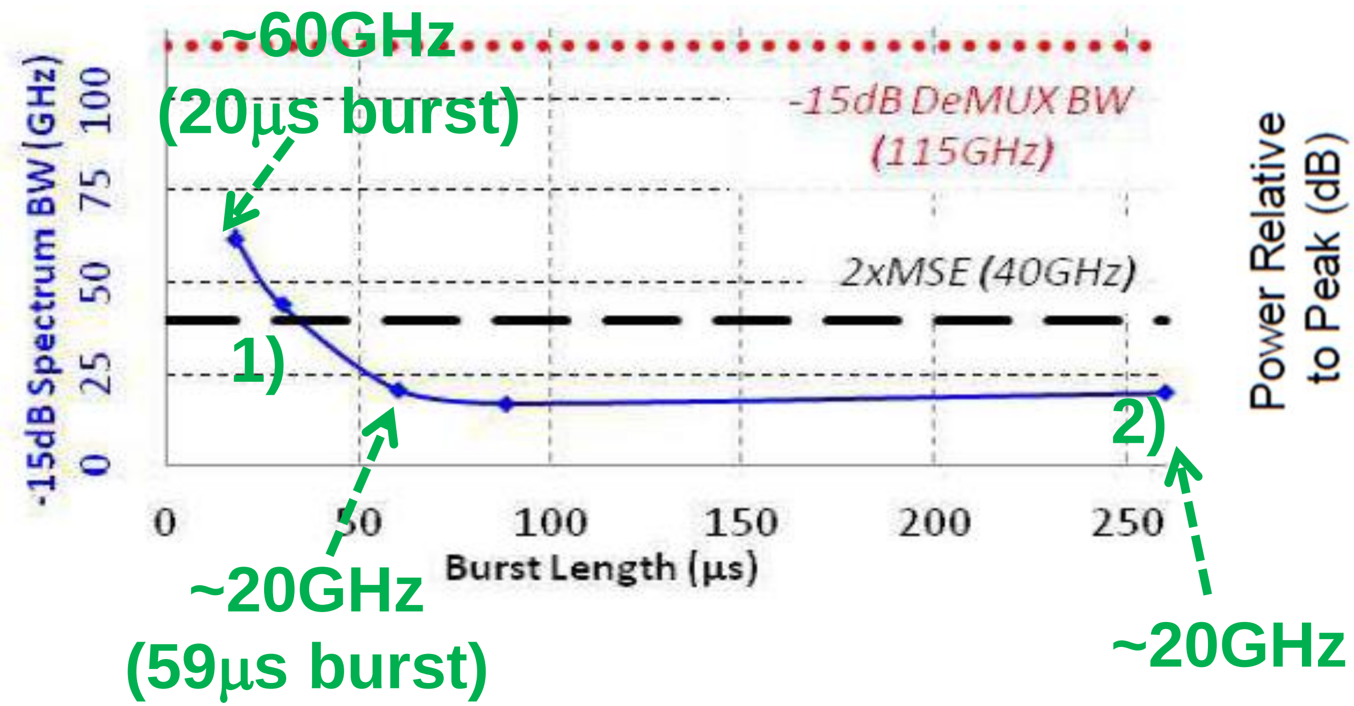
Proc. OFC 2016, W4C.2, Anaheim, CA

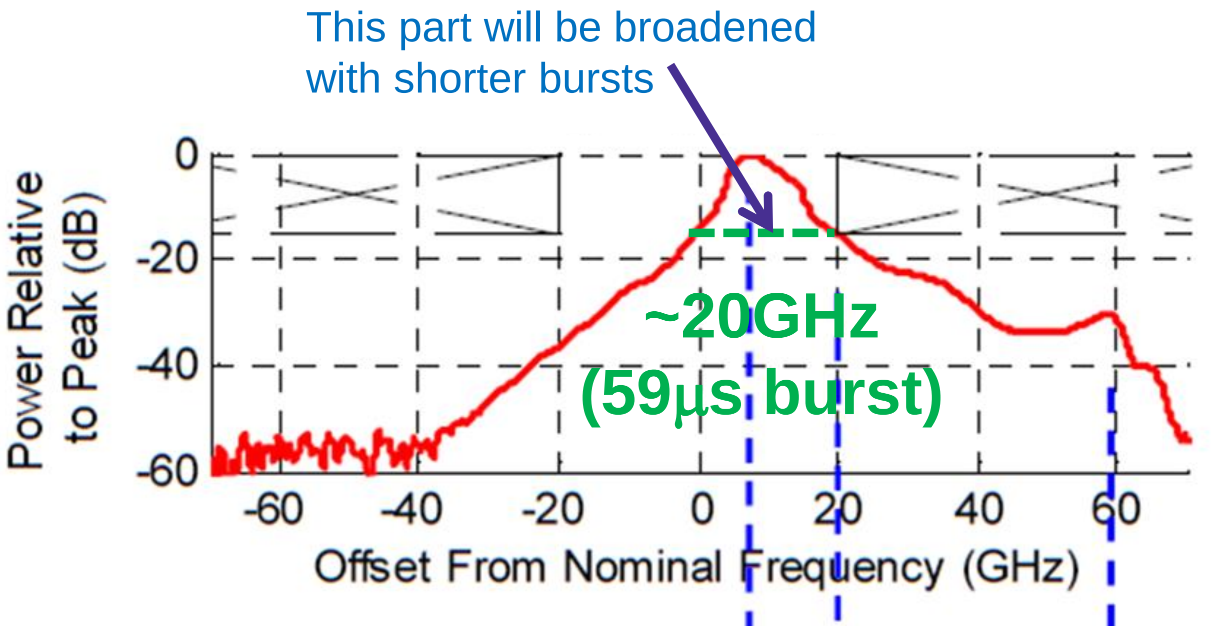
MSE: Maximum Spectral Excursion

1) Majority wavelength excursion happens during the burst-on period.
2) Overshoot of burst signal affects wavelength excursion greatly.
3) If the burst length is long enough, the peak of frequency will converge to the center.

OE SOLUTIONS AMERICA

Spectrum Bandwidth @-15dB of DML ONU Transmitter (10Gb/s)



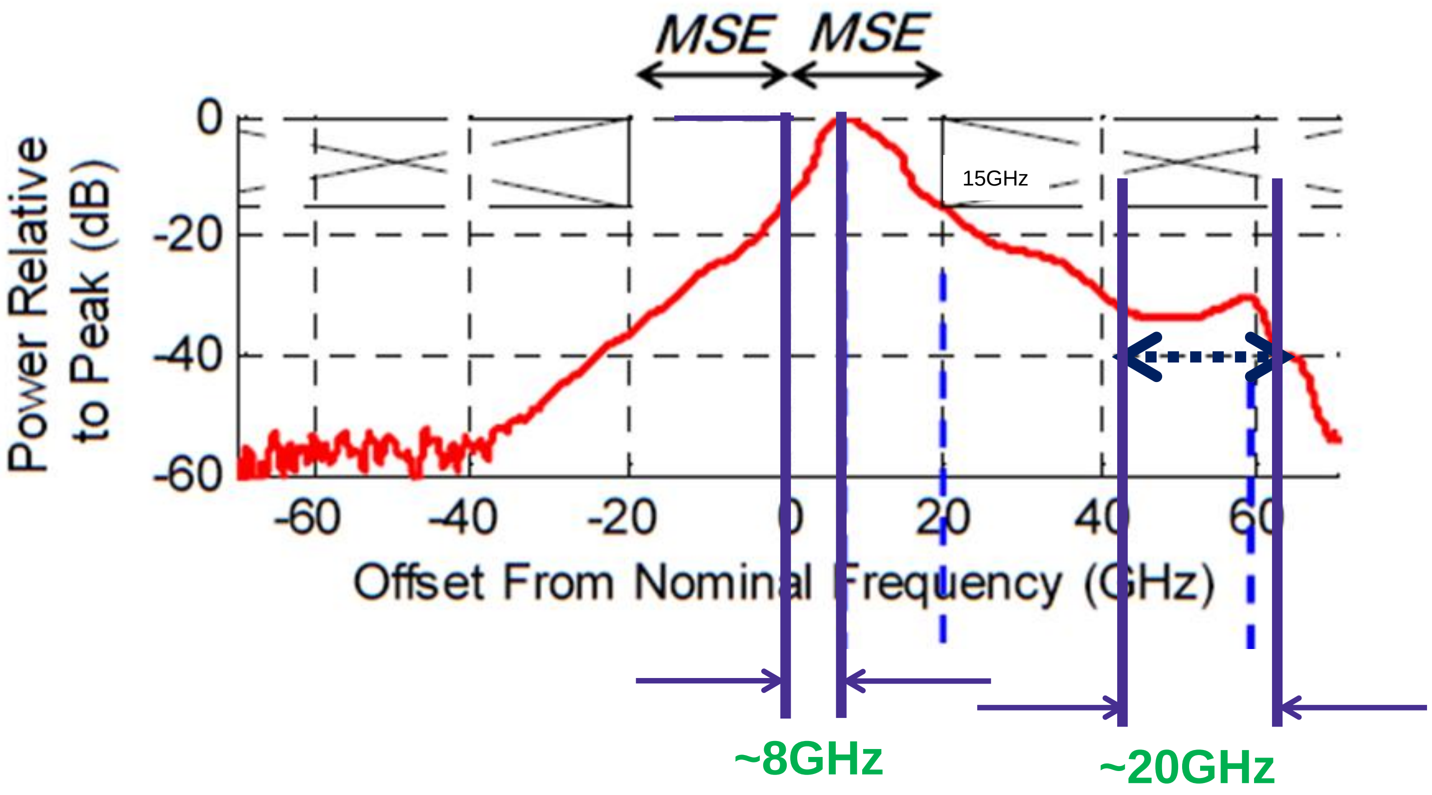


Proc. OFC 2016, W4C.2, Anaheim, CA

1) Burst length affects spectrum BW @ -15dB significantly
   - When burst length is 20µs, BW @-15dB is ~ 60GHz.
   - The difference between 20µs burst and 59µs (repetition: 125µs) is ~40GHz (+/-20GHz)

2) When the burst length is longer, @-15dB BW is roughly ~20GHz which is roughly 2x of bit rate frequency

Frequency Shift (Wavelength Excursion) Due to Burst Signal



59μs burst
(repetition: 125μs)

1. With long burst, peak frequency converges to the center frequency, frequency shift: ~8GHz
2. Frequency shift due to burst signal: ~20GHz @-40dB
3. OES measurement with 205μs (repetition: 2,765μs) burst is ~24GHz @ -40dB

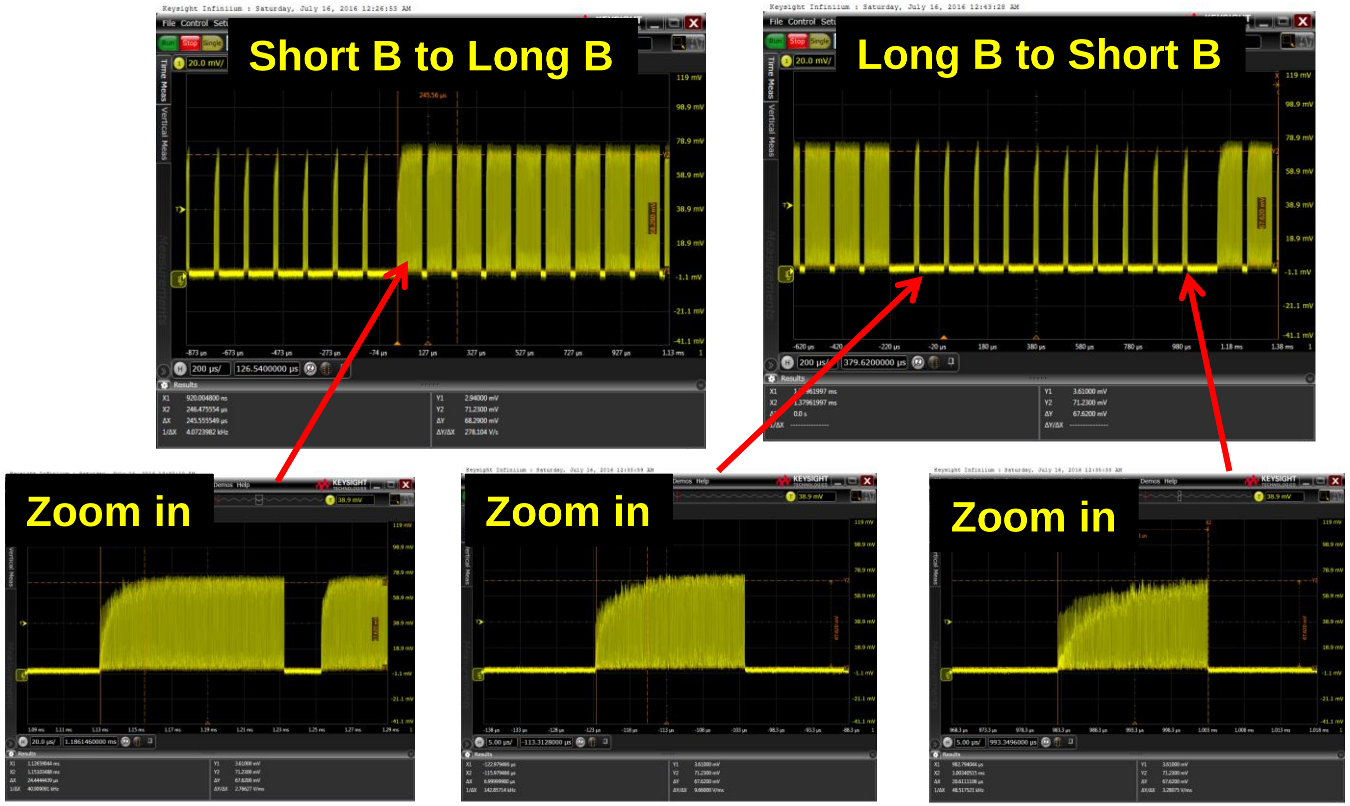
Example of Time Domain Signal of Burst Modulation to Observe Wavelength Shift with TO Type TOSA (10Gb/s)

- TOSA wavelength is set at the center of f-3dB 30GHz filter, 1542.174nm

Short Burst		Long Burst	
OFF	ON	OFF	ON
100us	20us	20us	100us

1. After long sequence of short bursts, the 1st long burst lose data at the beginning of the burst
2. The 1st burst of short bursts lose less at the beginning of the burst compared to the last one

3. To recover whole signal without losing data at rising edge, whole spectra should pass through optical filters(mux/de-mux) at the receiver



OE SOLUTIONS AMERICA

Parameters Affecting Wavelength Shift : DFB Laser

- **Wavelength shift due to the injection current(I_f)**

$$\lambda(I_f) = \lambda_0 + \frac{\partial\lambda}{\partial T} R_{th}(I_f V_f - P_o)$$
$$\cong \lambda_0 + \frac{\partial\lambda}{\partial T} R_{th}\{I_f(V_{th} + RI_f) - P_o\}$$

λ_0: Virtual wavelength under no current injection
$\delta\lambda / \delta T$: Wavelength temperature coefficient(typically 100pm/°C)
R_{th}: Thermal resistance
V_f and V_{th} : Forward and threshold voltages of the laser diode
R: Differential resistance
P_o: Chip output power

Parameters affecting wavelength

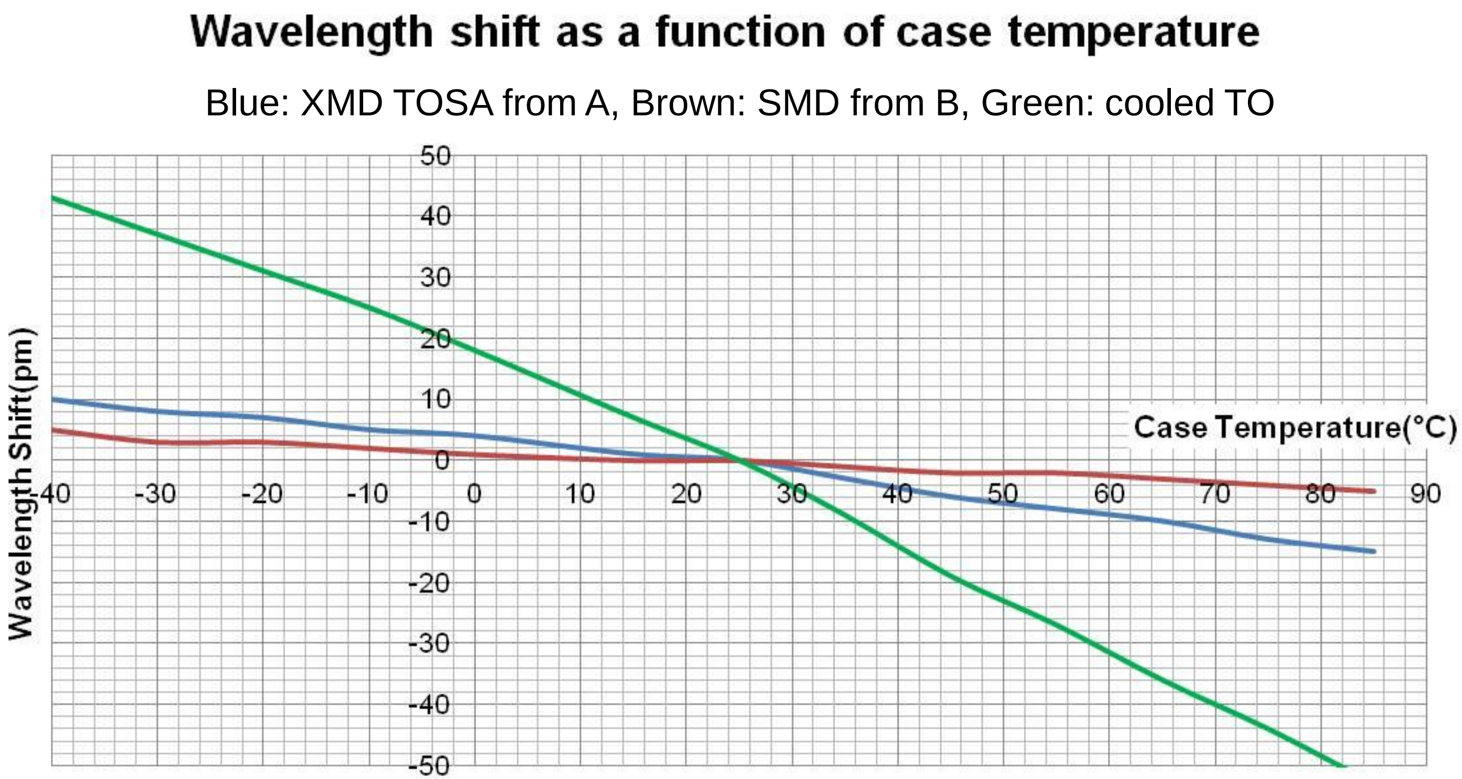
25G DFB laser:

- **Cavity length** is smaller than 10G lasers, which increases **R_{th}**
- **Higher output power and high temperature** require higher current modulation, which produce **more heat**, and then possibly more wavelength shift.
- **Smaller cavity length** may increase **differential resistance R**

Wavelength Shift of Cooled TOSA (XMD, TO)

Package:

- DFB laser is packaged in cooled TO for low cost PON Trx.
- TO package is more sensitive to outside environment (temperature), this affects thermistor temperature, and then wavelength shift



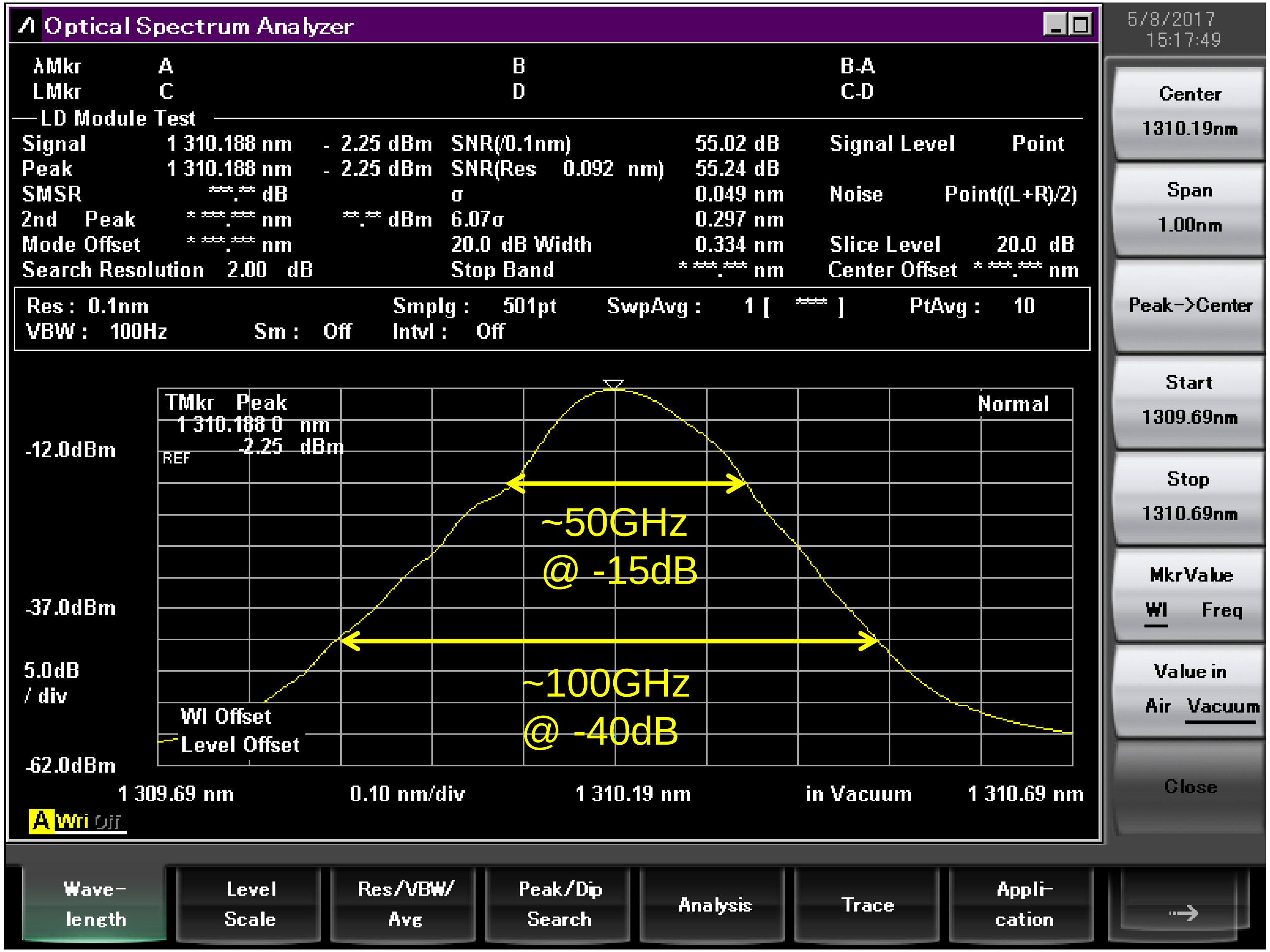
Wavelength shift of cooled DFB laser TO
$0^oC \sim 85^oC$: 70pm
$-40^oC \sim 85^oC$: 95pm

Assumption: the shift is **+/- 50pm (+/- 5GHz)** from temp. setting point

OE SOLUTIONS AMERICA

25Gb/s Modulation with Continuous NRZ Data

Span : 1nm
Res. BW : 0.1nm
VBW : 100Hz
Pout: -0.5dBm
ER: 4.5dB
Wavelength: 1310nm
Measured at room temperature



OE SOLUTIONS AMERICA

Estimation (min) of Frequency (Wavelength) Shift

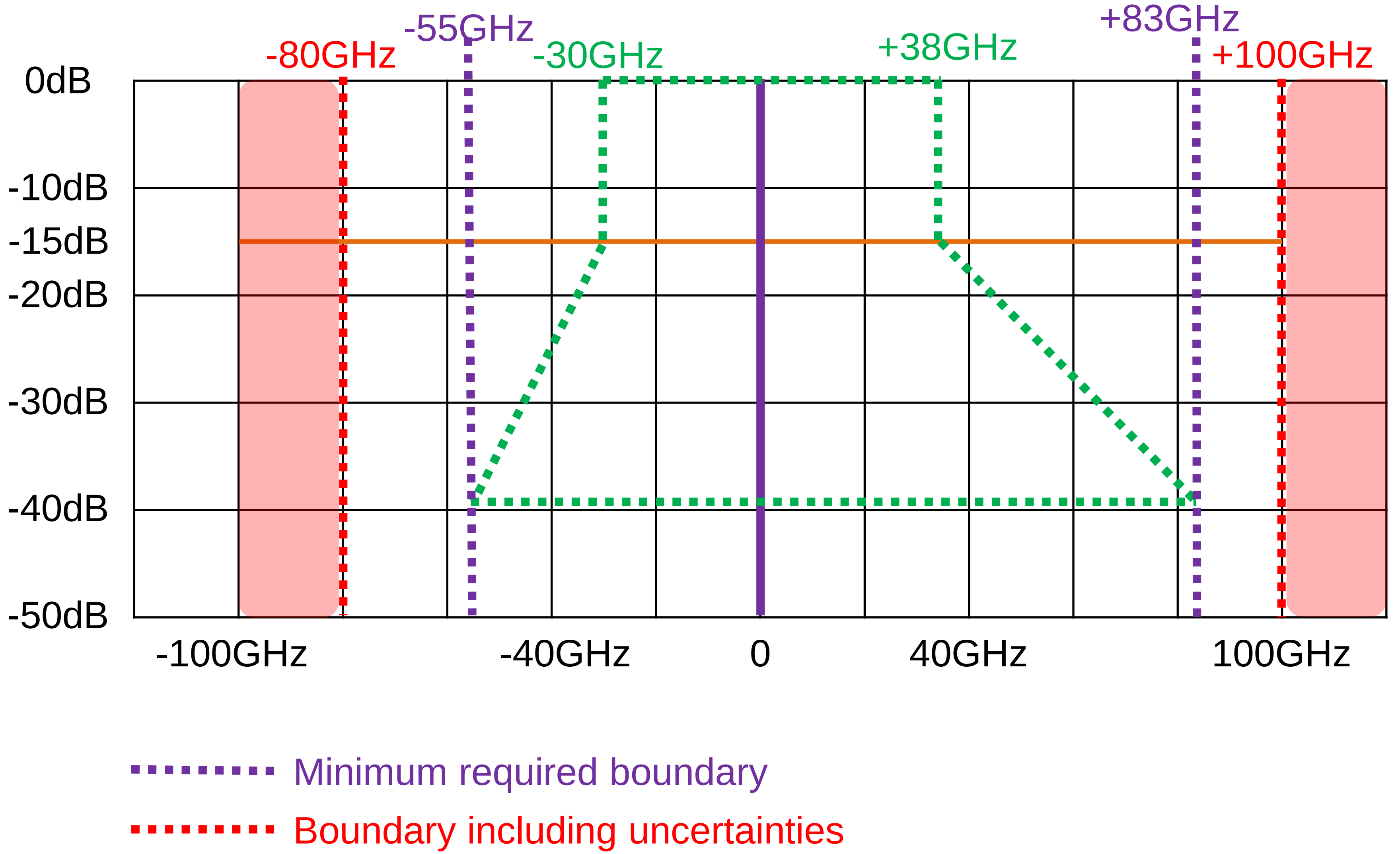
1. Center frequency shift due to BM: +8GHz
2. Frequency shift @-40dB due to BM: +20GHz
3. Sideband of 25Gb/s NRZ data: +/-25GHz @-15dB, +/-50GHz @-40dB
4. TOSA frequency shift over operating temperature: +/- 5GHz

	Left sideband	Right sideband
@-15dB	25GHz + 5GHz = 30GHz	25GHz + 5GHz + 8GHz = 38GHz
@-40dB	50GHz + 5GHz = 55GHz	50GHz + 5GHz + 8GHz + 20GHz = 83GHz

Uncertainty: some aspects affecting additional wavelength shifts

1. operation of 25G DFB laser at high temperature and high current driving may cause some variations of thermal resistance and differential resistance.
2. Modulation of laser with higher extinction ratio of transmitter.
3. Shorter burst (20μs) : **+/- 20GHz (diff.)**

Required Spectrum Mask for 25Gb/s Burst Signal



OE SOLUTIONS AMERICA

Summary

1. Starting with an example of 10Gb/s burst mode modulation, parameters affecting wavelength shift are discussed.
   - Sidebands generated with 25Gb/s NRZ data
   - Wavelength shift caused by burst mode modulation
   - Wavelength shift due to TO package
   - Potential wavelength shift due to 25G DFB laser (thermal resistance, differential resistance etc.)
   - Example of time domain burst signal with various burst / guard lengths are demonstrated

2. Estimated spectral shape and derived minimum required spectral width for 25Gb/s burst signal.

	Left sideband	Right sideband	Total
@-15dB	-30GHz	+38GHz	**68GHz**
@-40dB	-55GHz	+83GHz	**138GHz**

@1300nm	Left sideband	Right sideband	total
@-15dB	0.190nm	-0.214nm	**0.404nm**
@-40dB	0.310nm	-0.468nm	**0.778nm**

3. The wavelength shift might be alleviated if the amount of burst overshoot and the length of burst are limited.
4. Whole spectrum down to -40dB needs to pass through WDM filter from the transmitter to the receiver without attenuation to recover burst signals safely.
5. The required spectral mask derived in this contribution may be used as a basis to define the wavelength planning and the requirement of each channel by taking into account of the wavelength tolerance of DFB lasers and affordable filter characteristics.

Thank you.