Feasibility analysis of DML with 7nm Pass band

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Accelink Technologies Co., Ltd.

Contributors

Xuguang Chen, Qiangpeng Hu, Jie Zhao, Jun Zhang, Wanhui He, Yi Jiang, Qijin Duan - Accelink

Dekun Liu - Huawei

Dezhi Zhang – China Telecom

Background

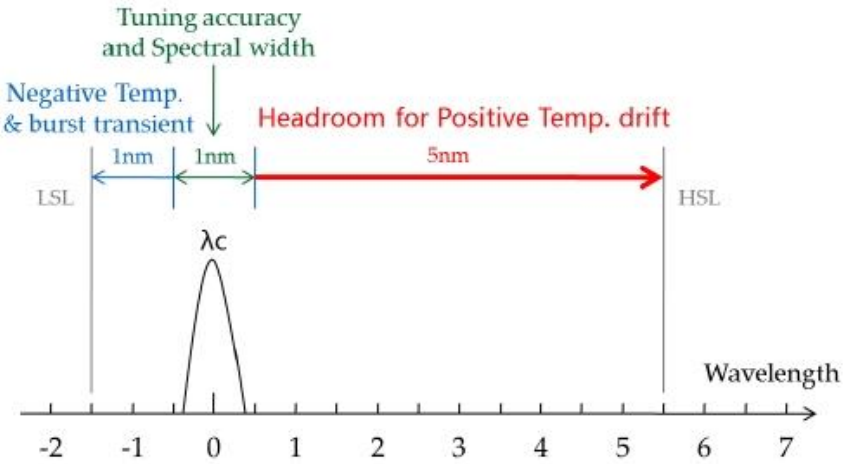
Last meeting Mr. Zhang from CTC presented the idea 7nm Pass band for US0 instead of 3nm (Plan A) in his contribution Multi-rate receiver Survey and analysis (Zhangdezhi_3ca_1_0317). Due to DMLs can be used in ONUs for low cost purpose, further investigation need to be analyzed.

This presentation demonstrates one of implementation approaches without the TEC and some potential application scenarios based on the DML with 7nm Pass band.

7nm Pass band for US0

Extra points on wavelength plan in the survey (zhangdezhi_3ca_1_0317),

- **7nm Pass band for US0, instead of 3nm (PLAN A),** to balance performance and cost
  - Lower power dissipation of TEC may be used
  - Under C-Temp condition, TEC might be avoid as low cost heating-only technique might be enough for temperature control
  - Relative cost comparison of "Collimated lens" V.S. "TEC device&controller" : 1x V.S. 2.2x



Zhangdezhi_3ca_1_0317

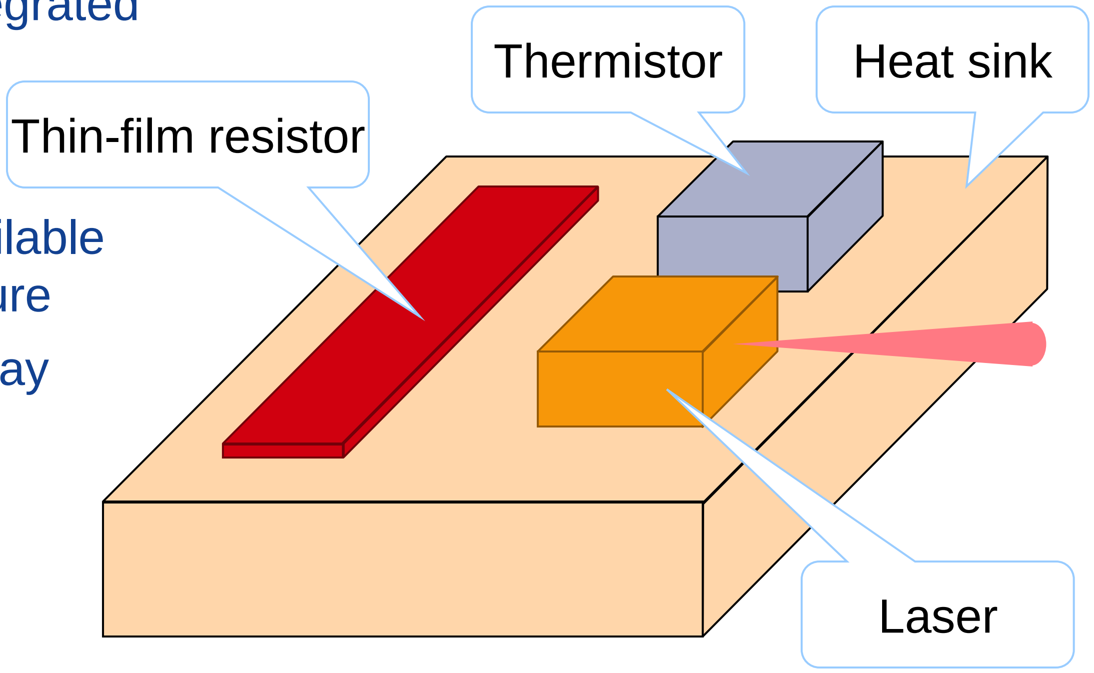
One of heating-only implementation approaches

Pros

- A Thin-film strip resistor is more cheaper than a TEC
- Actuator for heating resistor is simpler than TEC controller
- Compact and easy to be integrated

Cons

- Wavelength control is unavailable for higher ambient temperature
- Additional heating resistor may impact layouts



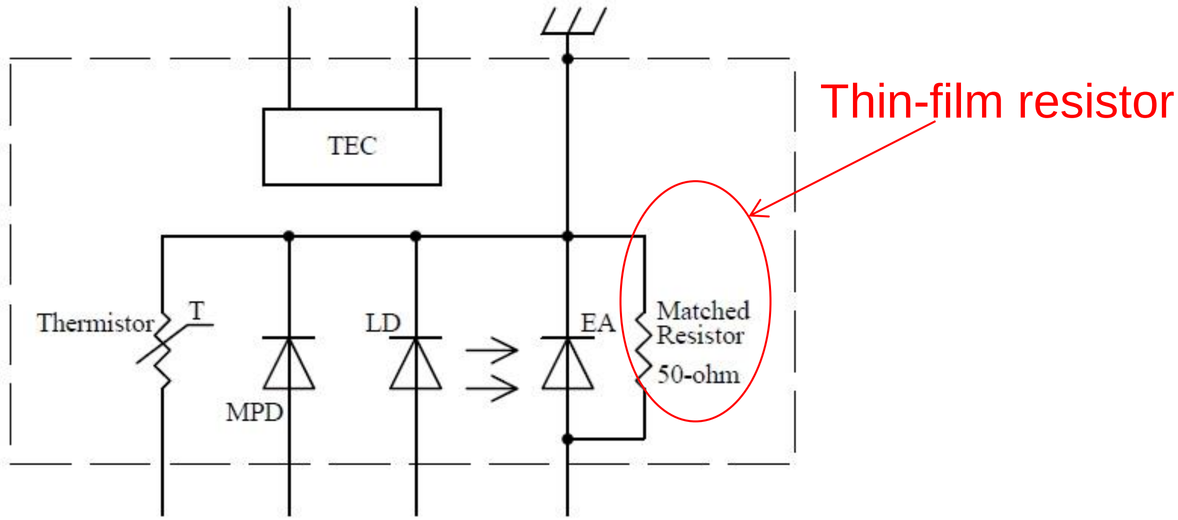
7nm PB DML without any TEC

Industry support of Thin-film resistor

Thin-film resistors are widely used in high speed optical devices for matched impedance purpose, resistors of various impedance values can be integrated with the sub-mount in TOSA, for example:

- Approx. 50-ohm resistor is parallel connected with EA in an EML TOSA
- A resistor <50-ohm is series connected to Cathode in a DML TOSA

Specified heating resistor can be implemented with similar method



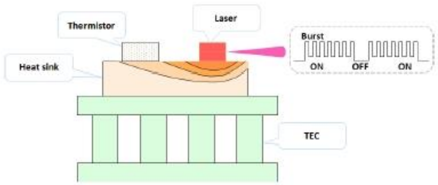
Typical EML TOSA

Wavelength allocation of 7nm Pass band (1)

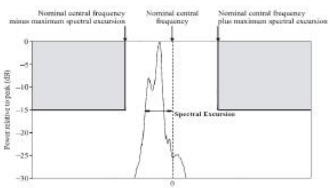
Example: DML with heating resistor

- Central wavelength of DML: (λc–1.5nm) to (λc+1.5nm), @45Deg.C, corresponding to +/-1.5nm Tolerance in continuous mode
- Wavelength temperature dependency: 0.1nm/Deg.C
- Maximum Burst mode wavelength drifting and spectrum extension after modulation: 0.8nm (liudekun_3ca_3_0317)
- Ambient Temperature: -5 to 55Deg.C
- Maximum heating temperature rise: 60 - (-5) = 65Deg.C
- Assumption: Features of DML will be degraded dramatically over 85Deg.C

ONU burst mode wavelength drifting can be : 0.3~0.4nm



ONU DML laser spectrum extension after modulation ~0.4nm@15dB



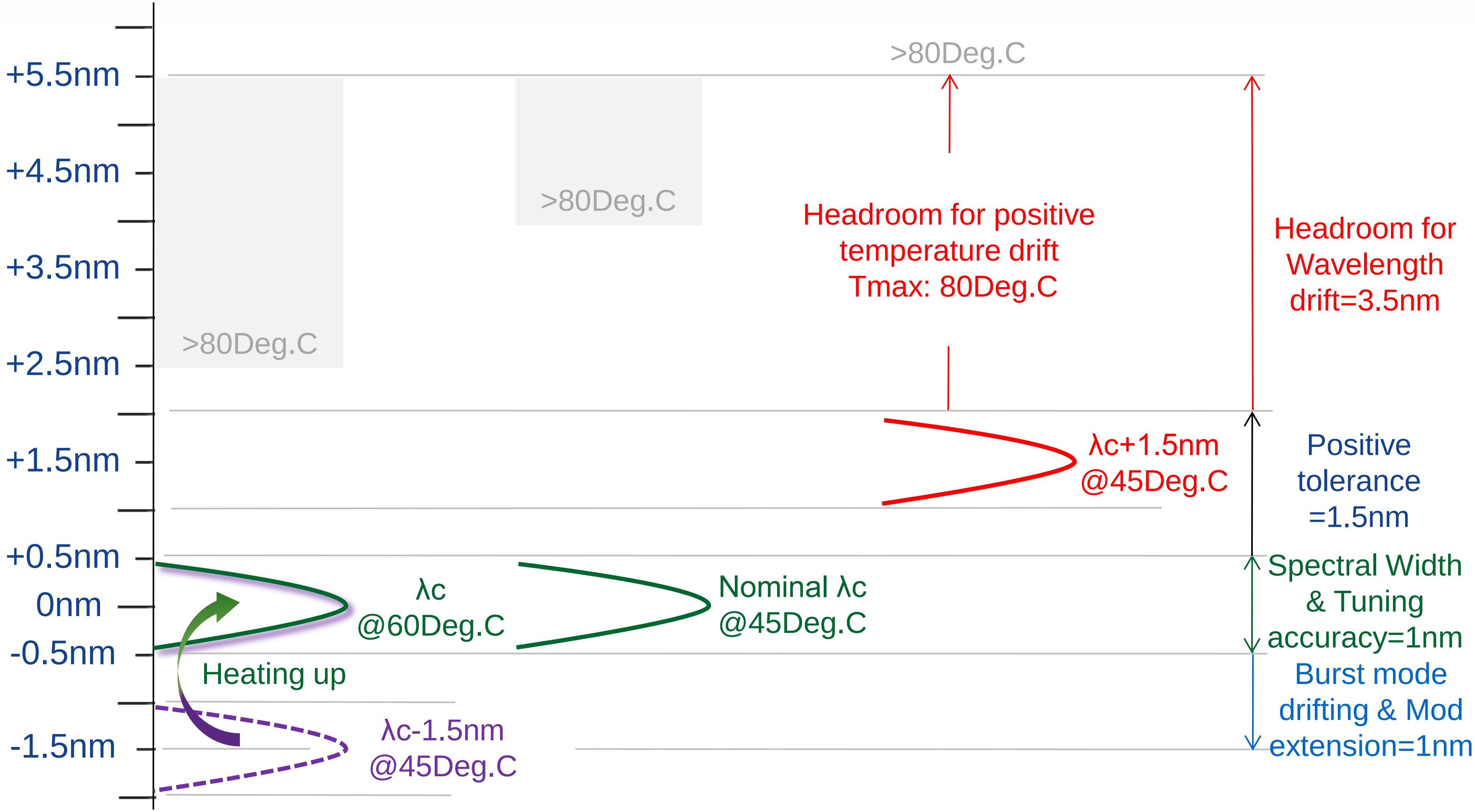
Central Wavelength Tolerance	±3nm	±2nm	±1.5nm	±1nm	± 0.5nm
1st vendor's view	X	1.2X	1.6X	2.3X	3.5X
2nd vendor's view	Y	1.4Y	--	2.1Y	--

Note: the spectrum extension , such as by modulation, burst mode wavelength drifting , hasn't been taken account in here.

So 2nm upstream wavelength width only allows : ~ +/-0.6nm central wavelength distribution tolerance of the laser

Liudekun_3ca_3_0317

Wavelength allocation of 7nm Pass band (2)



Comparison: Heating resistor and TEC

DML with heating resistor

- Operation temperature range will shrink to high temperature zone

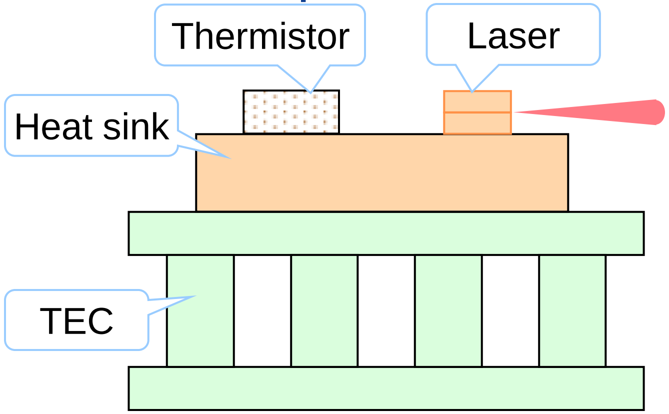
Comparison		TEC	Heating resistor	Uncooled
Operating Temperature range (Deg.C)		Set-point, i.e. ~ 45	45 to 80 *	Total
Key component/Technology		Peltier/Semiconductor	Resistor/Passive	-
Temperature sensor		Y	Y	N
Controller	Control	MCU & Complex controller	MCU & Simple controller	-
	Current polarity	Bipolar	Unipolar	-
	Pin-outs	TEC+, TEC-, Rth	Vout, Rth	-

Note *: Temperature ranges are variable for different tolerance Central wavelength at 45Deg.C. For Central wavelength=(λc+1.5nm) at 45Deg.C, operating temperature range may be typ. 45~80Deg.C or 30~80Deg.C for power saving purpose. For Central wavelength=(λc-1.5nm) at 45Deg.C, operating temperature range may be 60~80Deg.C

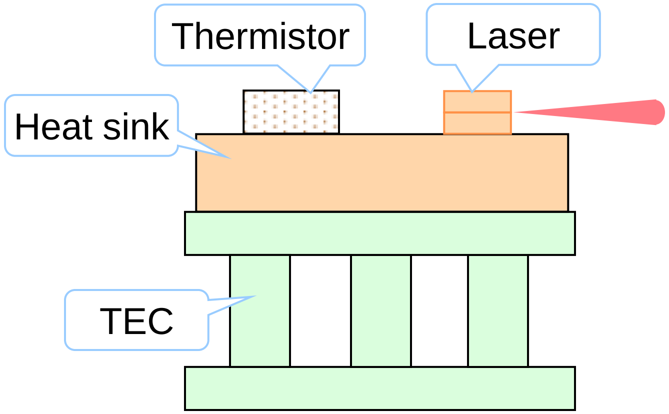
To balance O/E performance and cost of DML (1)

Low cost component and method can be candidates for temperature control technique

- 7nm Pass band can relax over 40Deg.C temperature control range in contrast with 2 or 3nm Pass band. Typical wavelength temperature dependency of DML is 0.095nm/Deg.C ~ 0.1nm/Deg.C(liu_3ca_3_0716).
- In TEC in use situation, 7nm Pass band will consume less TEC power in contrast with 3nm Pass band, because of relaxed temperature range. The lower power dissipation for TEC, the smaller TEC size and lower cost.
- In commercial-temperature situation, heating-only technique may be used. Lower cost and compact heating component may be integrated into the laser package, such as thin-film strip resistor, SMT chip resistor.



3nm PB DML with a TEC

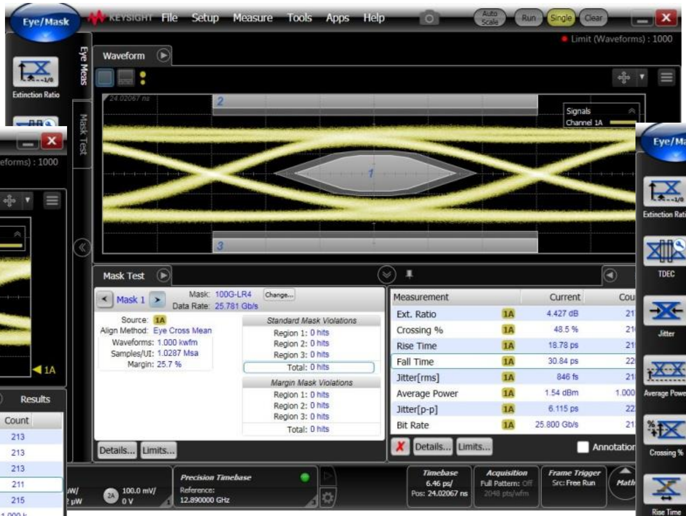


7nm PB DML with miniature TEC

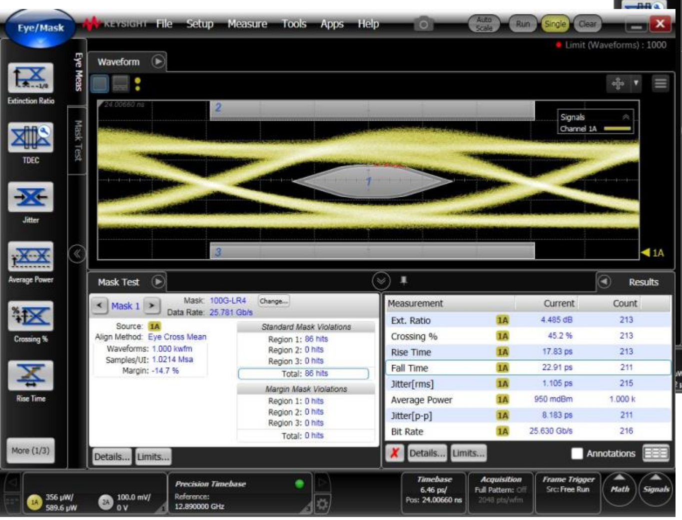
To balance O/E performance and cost of DML (2)

7nm Pass band may improve ONU's TX SPECs in contrast with common 20nm Pass band

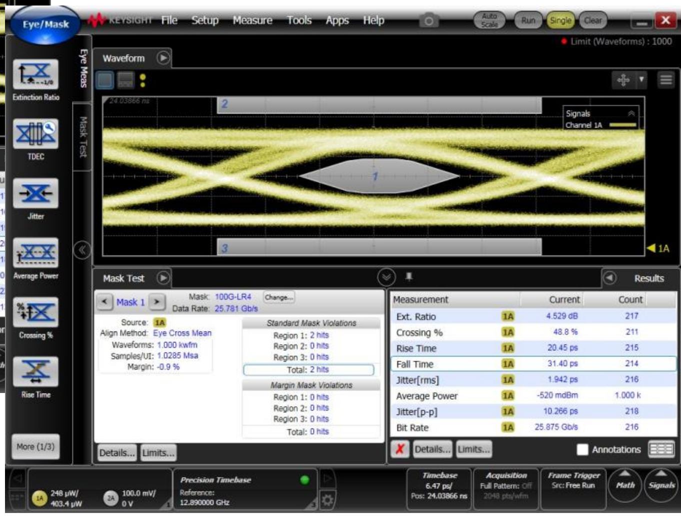
- Better TX SPECs may be achieved, i.e. Optical Launch power, Extinction ratio, TDP etc.
- Eye diagrams of a 20nm Pass Band Uncooled DML sample (Made by Vendor A)



25Deg.C., Margin= 25.7%



-40Deg.C., Margin= -14.7%



85Deg.C., Margin= -0.9%

To balance O/E performance and cost of DML (3)

When link budget of US0 is insufficient, 3nm Pass band may be better choice

- Cooled DML technique benefits to all yield of wavelength width, launch power, TDP and mitigates filter pressure, so that total cost of cooled DML transmitter might be cheaper than uncooled DML transmitter under the same tight SPECs

Zhang_3ca_1_1116

To improve SOA’s Sensitivity in contrast with common 20nm Pass band

Narrowed Pass band filter will benefit Sensitivity of PIN+SOA or APD+SOA receiver

Narrowed Pass band will benefit OLT’s receiver design

- Experimental results

	25G PIN	w. SOA	w. SOA+CWDM filter (16.8 nm)	w. SOA+LAN-WDM filter (4.09 nm)	w. SOA+DWDM filter (0.9 nm)
Rx. Sen. (@BER=1E-3)	-17 dBm	-28.2 dBm	-30.4 dBm	-31.8 dBm	-31.5 dBm
	25G APD	w. SOA	w. SOA+CWDM filter (16.8 nm)	w. SOA+LAN-WDM filter (4.09 nm)	w. SOA+DWDM filter (0.9 nm)
Rx. Sen. (@BER=1E-3)	-27 dBm	-29.2 dBm	-31.6 dBm	-33.1 dBm	-33.6 dBm

- Simulation results

	PIN	w. SOA	w. SOA +1000GHz	w. SOA +800GHz	w. SOA +400GHz	w. SOA +200GHz	w. SOA +100GHz
Rx. Sen. (@BER=1E-3)	-16.94 dBm	-29.58 dBm	-31.28 dBm	-31.45 dBm	-31.89 dBm	-32.18 dBm	-32.39 dBm
	APD	w. SOA	w. SOA +1000GHz	w. SOA +800GHz	w. SOA +400GHz	w. SOA +200GHz	w. SOA +100GHz
Rx. Sen. (@BER=1E-3)	-26.86 dBm	-29.65 dBm	-31.52 dBm	-31.71 dBm	-32.24 dBm	-32.62 dBm	-32.92 dBm

liu_3ca_1_0117

- Comparison:

	US0 wavelength tolerance		
Parameter	2-3 nm	7 nm	20 nm
Uncooled DML?	No	No	possible
25G ONU laser cost	Highest	Medium	Lowest
SOA+PIN performance relative to 2-3 nm (approximate)		-0.5 dB	-1.5 dB

bonk_3ca_1_0117

harstead_3ca_2b_0317

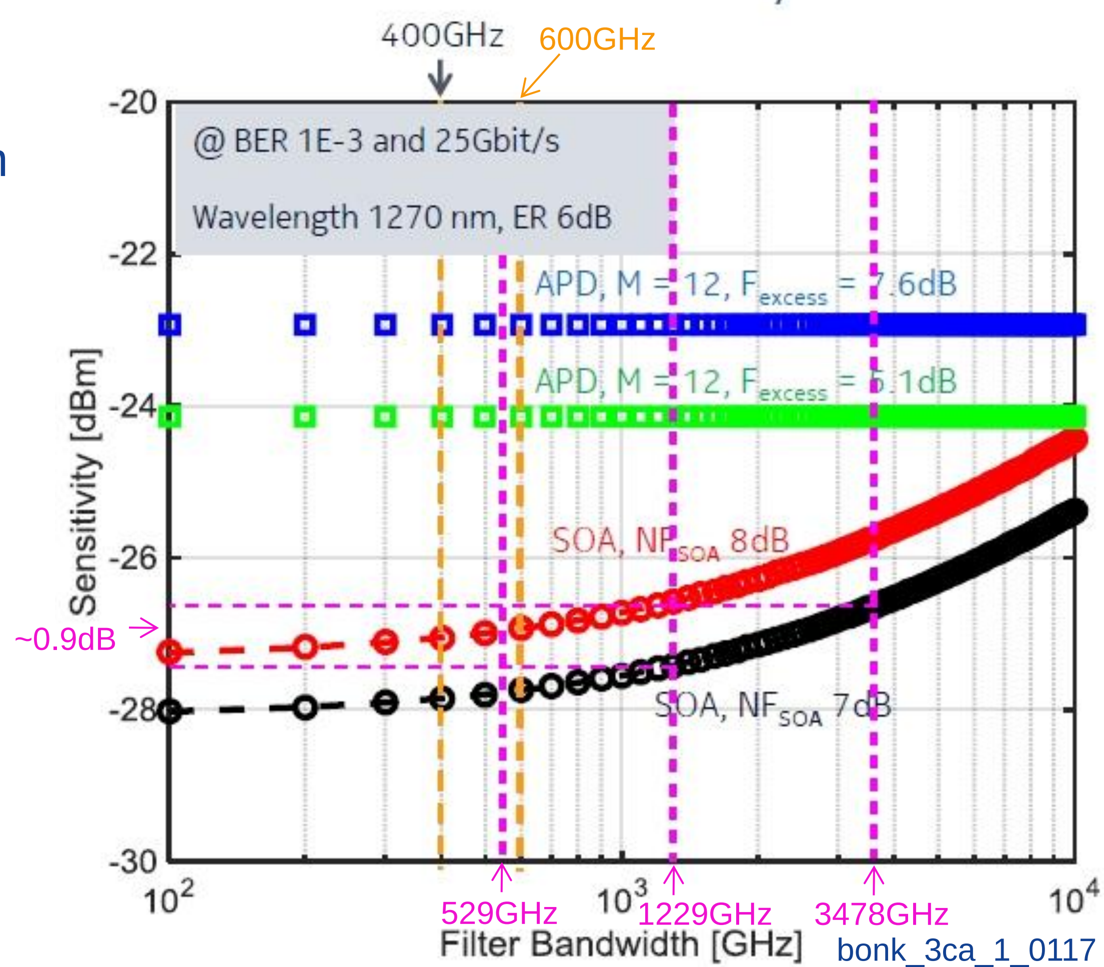
Estimated sensitivity improvement from 20nm to 7nm Pass band filter with PIN+SOA receiver

Based on the figure in bonk_3ca_1_0117(Page 8)

- Approx. 0.9dB improvement at Start Wavelength>1303nm
- Some indicators are added on this figure

Start WL. (nm)	Stop WL. (nm)	PB in WL. (nm)	PB in Freq. (GHz)
1277	1280	3	550.2
1273	1280	7	1287.9
1260	1280	20	3717.7
1303	1306	3	528.5
1303	1310	7	1229.4
1303	1323	20	3478.1

4x25G OLT receiver sensitivity: ...λ3-- Results



To optimize wavelength allocation in O-band

Due to all upstream and downstream channels need to be considered and existent Zero dispersion zone, 7nm Pass band of US0 may be more flexible for wavelength plan than 20nm Pass band

- Obviously 7nm PB US0 can be placed in 1260~1280nm (TDM coexistence)

US0 placed in Zero dispersion zone will increase availability of O-band

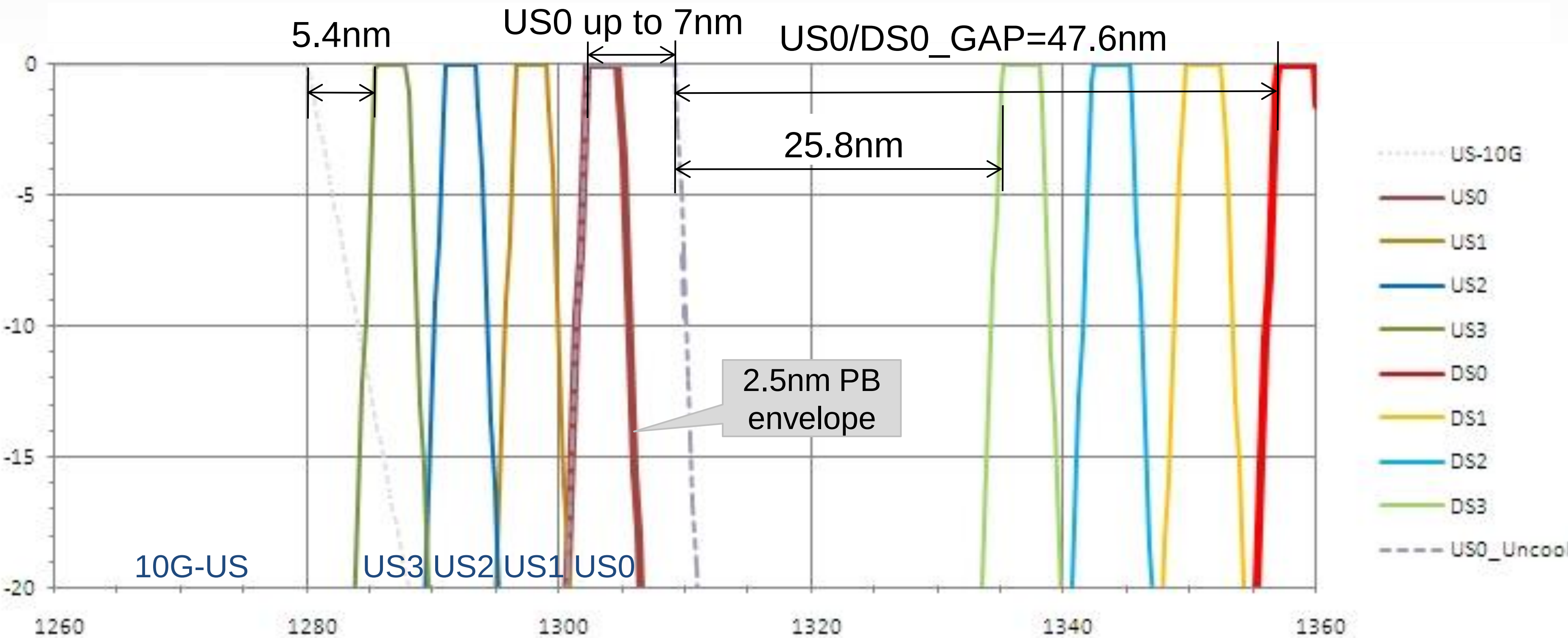
- Also 7nm PB US0 can be placed in 1300~1310nm zone, where is unavailable for 20nm PB upstream
  - ✓ US0 placed in Zero dispersion zone will increase availability of O-band
  - ✓ WDM coexistence can be supported, although collimated beam technique has to be used
  - ✓ WDM and TDM Hybrid coexistence can be supported, so that Triple-rate APD receiver will be unnecessary

➤ Relative cost comparison of "Collimated lens" V.S. "TEC device&controller" : 1x V.S. 2.2x

Zhangdezhi_3ca_1_0317

  - ✓ More bandwidth margins for US1/US2/US3, it means lower cost DMLs are available

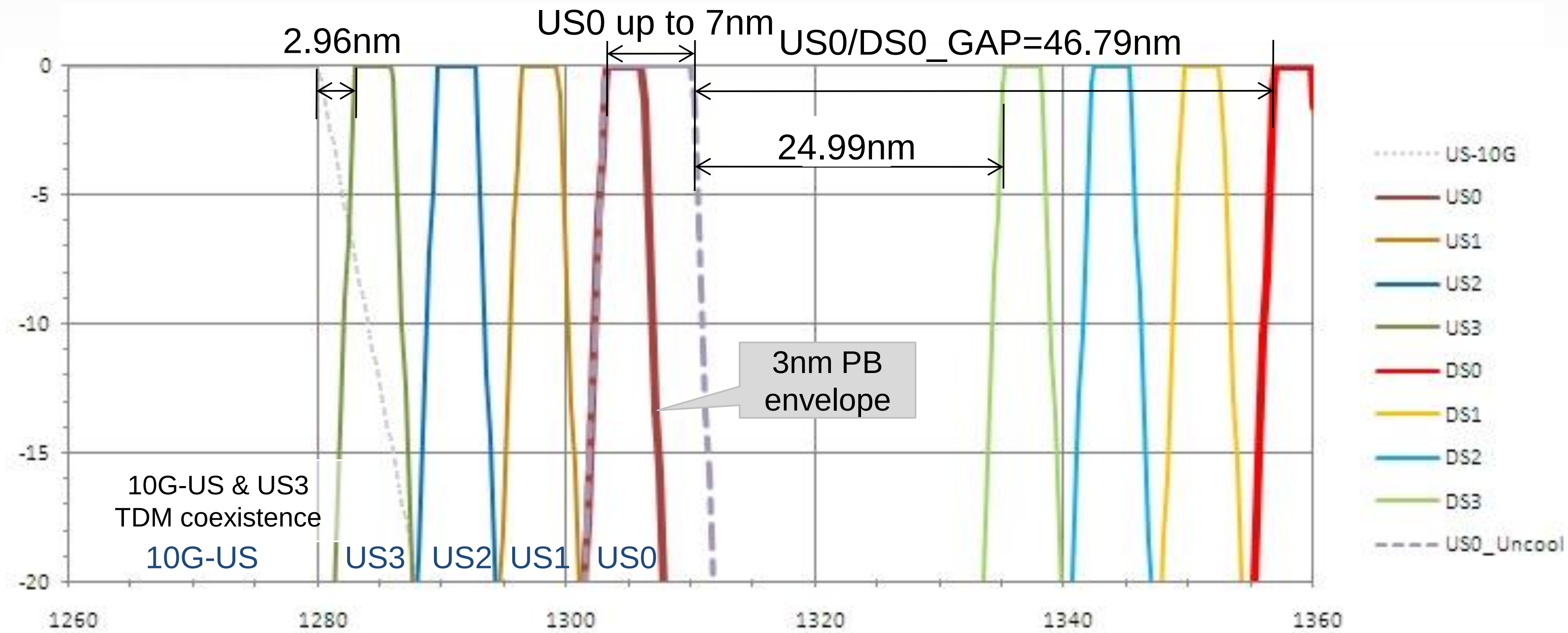
US0 placed in 1300~1310nm, WDM coexistence example derived from Revised plan A1(Page 5, liudekun_3ca_3_0317)



Channel 1~3 1THz	Center Freq(THz)	Center WL(nm)
US0 +1.25/-1.25	230.0	1303.445
US1 +1.25/-1.25	231.0	1297.803
US2 +1.25/-1.25	232.0	1292.209
US3 +1.25/-1.25	233.0	1286.663

Channel 0~3 1.2THz	Center Freq(THz)	Center WL(nm)
DS0 +1.5/-1.5	220.7	1358.371
DS1 +1.5/-1.5	221.9	1351.025
DS2 +1.5/-1.5	223.1	1343.758
DS3 +1.5/-1.5	224.3	1336.569

US0 placed in 1300~1310nm, WDM & TDM Hybrid coexistence example derived from plan B1(Page 7, liudekun_3ca_3_0317)



Channel 1~3 1.2THz	Center Freq(THz)	Center WL(nm)
US0 +1.5/-1.5	229.8	1304.580
US1 +1.5/-1.5	231.0	1297.803
US2 +1.5/-1.5	232.2	1291.096
US3 +1.5/-1.5	233.4	1284.458

Channel 0~3 1.2THz	Center Freq(THz)	Center WL(nm)
DS0 +1.5/-1.5	220.7	1358.371
DS1 +1.5/-1.5	221.9	1351.025
DS2 +1.5/-1.5	223.1	1343.758
DS3 +1.5/-1.5	224.3	1336.569

Pass band comparisons: 3nm/7nm/20nm

Different temperature control techniques are corresponding to different TX SPECs and application scenarios

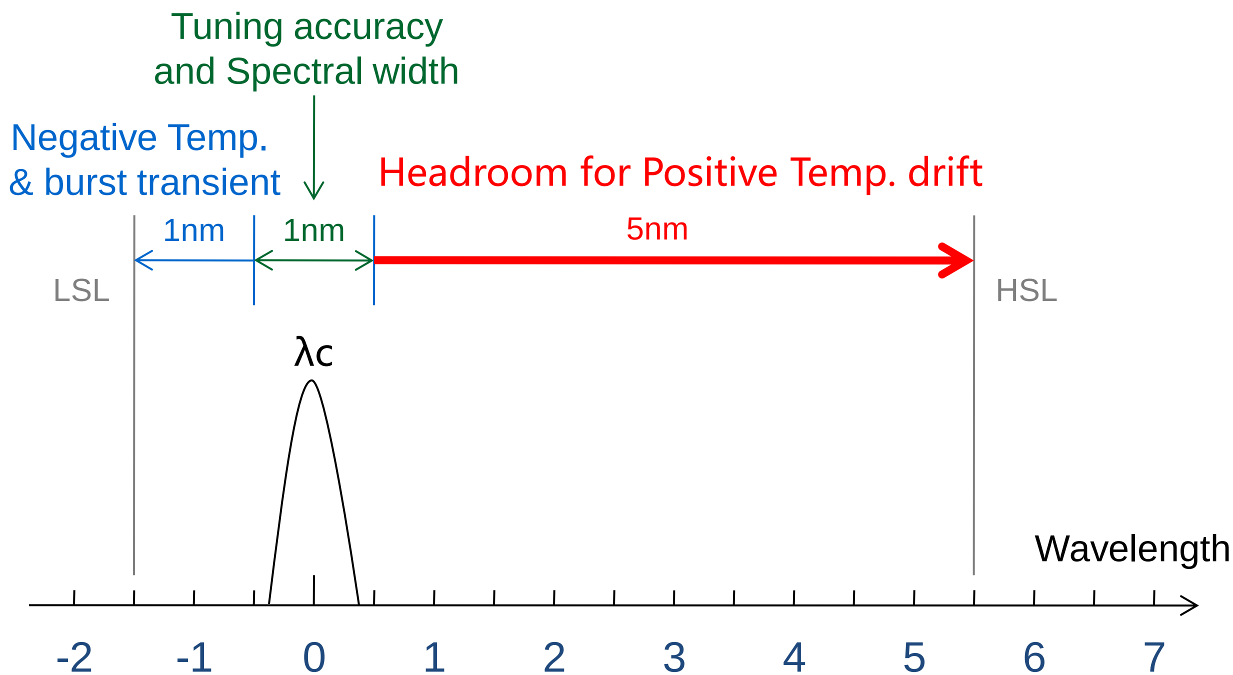
Upstream Pass band	**3nm**		**7nm**		**20nm without Temp. control**	
Temperature range	I-Temp.	C-Temp.	I-Temp.	C-Temp.	I-Temp.	C-Temp.
Lowest cost Temp. control method	Full-scale TEC	Full-scale TEC	Miniature TEC	Heater-only	Uncooled	Uncooled
Achievable TX SPECs	Best	Best	Better than BASIC	Better than BASIC	Worse than BASIC	BASIC
Candidate TX SPECs	Best		Better than BASIC		Worse than BASIC	
Candidate RX SPECs with SOA	Best		Better than BASIC		BASIC	

Conclusions on 7nm Pass band analysis

To balance O/E performance and cost of DML

To improve SOA's Sensitivity in contrast with common 20nm Pass band

To optimize wavelength allocation in O-band



Zhangdezhi_3ca_1_0317

THANKS