Security Level:

Four wavelength mixing Analysis in 100G-EPON wavelength plan

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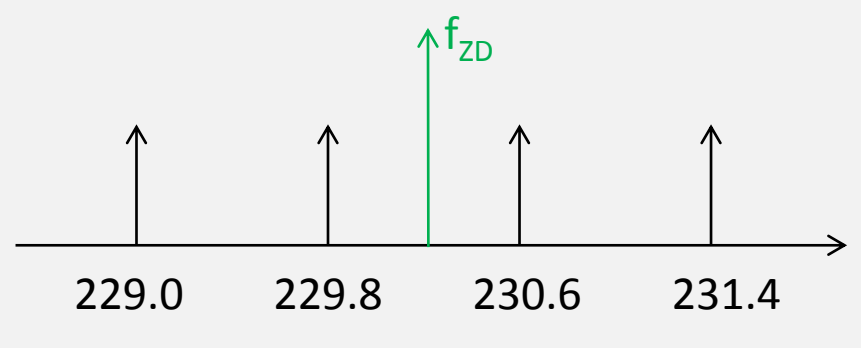
Background

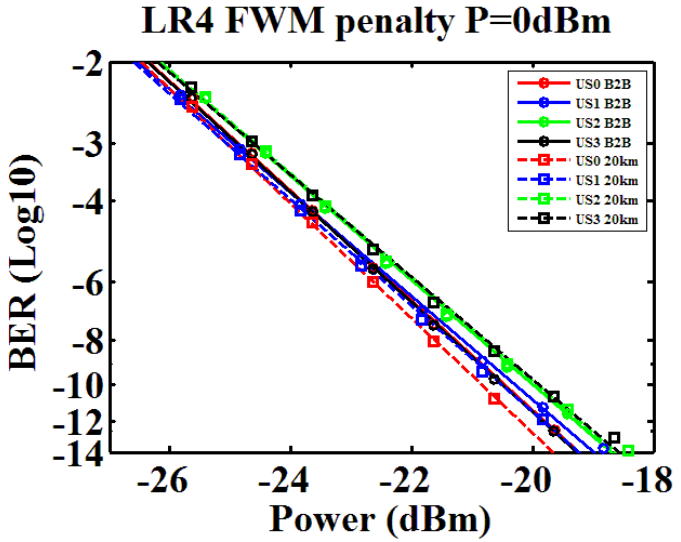
- Four wavelength mix is an important issue we need to take care for 100G EPON wavelength plan.

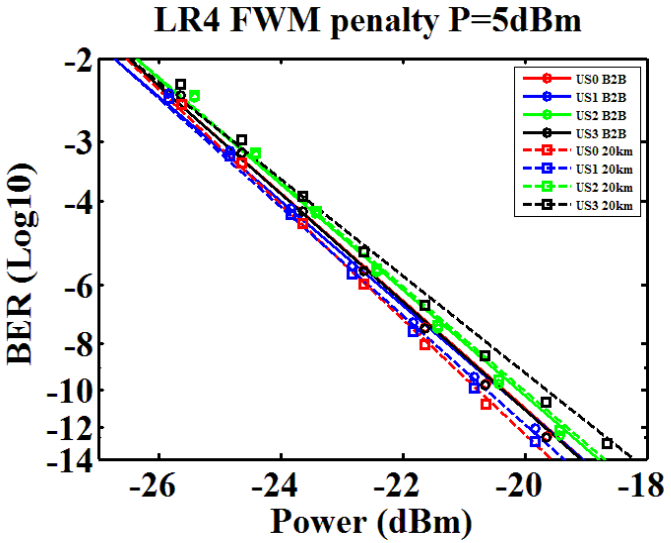
- This contribution analyzes the FWM effect for different wavelength grids.

FWM in 100G LR4 grid



Description	100GBASE-LR4	100GBASE-ER4	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm		GBd
Lane wavelengths (range)	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19		nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Total average launch power (max)	10.5	8.9	dBm
Average launch power, each lane (max)	4.5	2.9	dBm
Average launch power, each lane[a] (min)	–4.3	–2.9	dBm

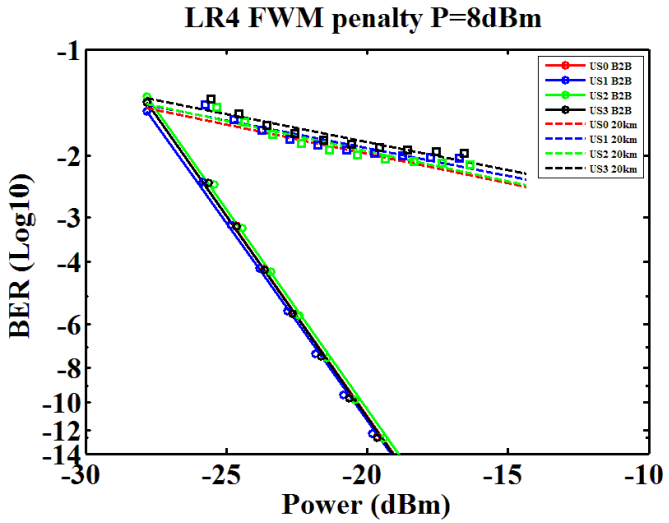


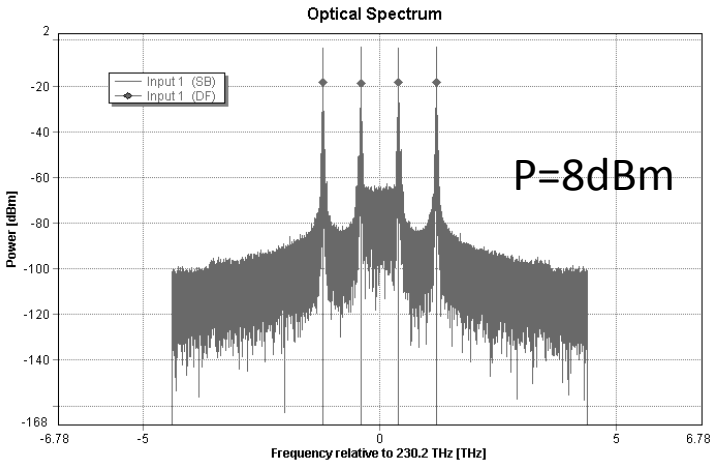


- Due to the low power levels in LAN WDM, FWM penalty doesn't happen there

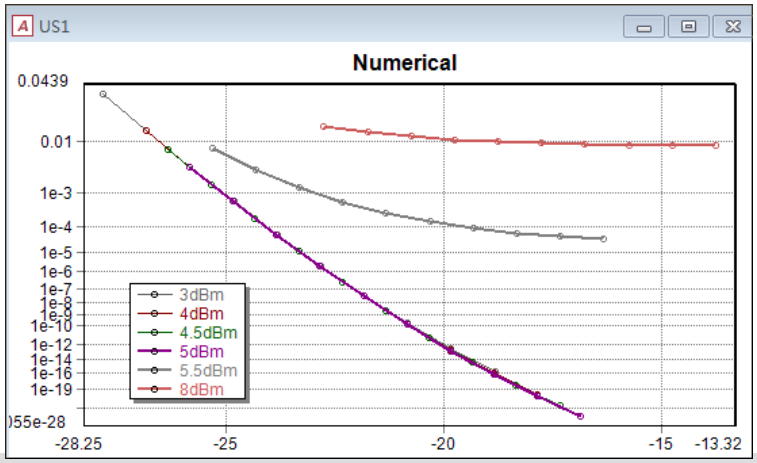
LR4 grid FWM with different input Power

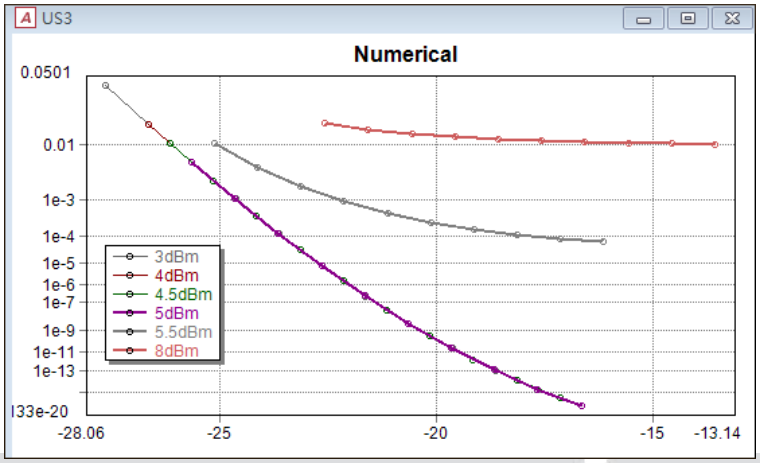
FWM penalty 8dBm input power





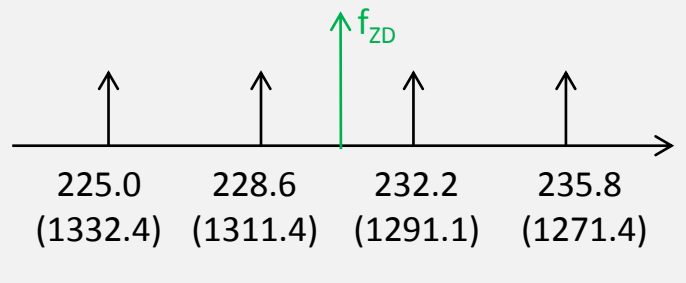
FWM penalty with different input power after 20km

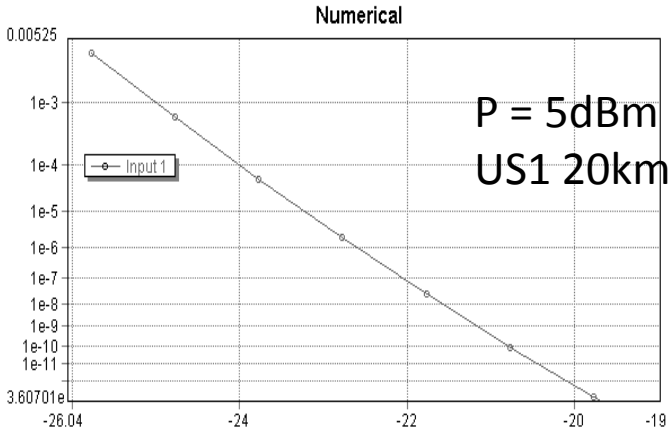


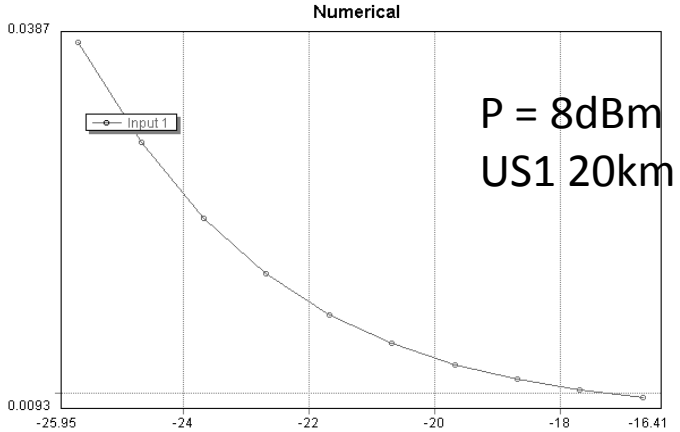


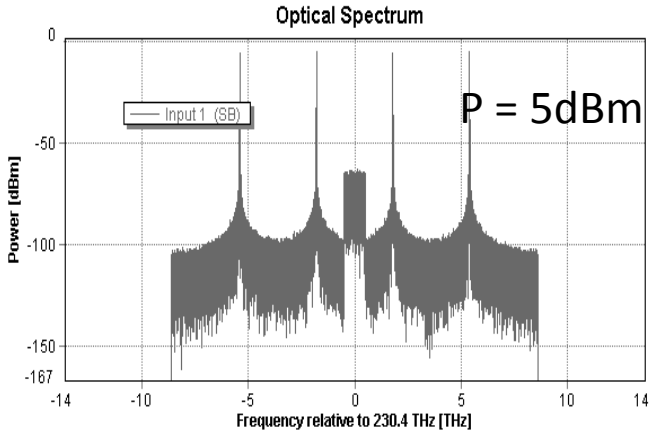
CWDM grid FWM effect

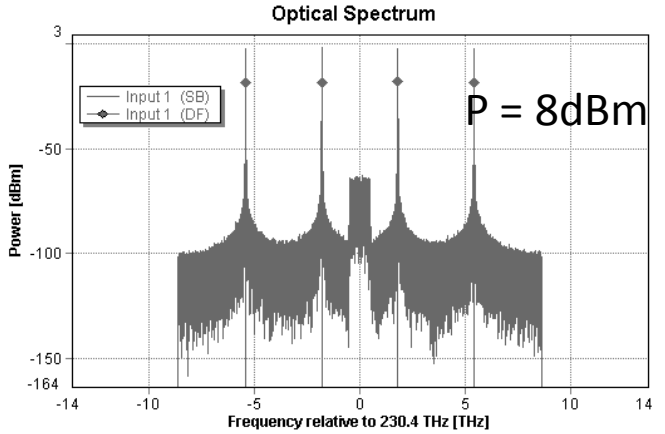
- 5dBm is OK for CWDM, but FWM will still happen when launch power increases to 8dBm.



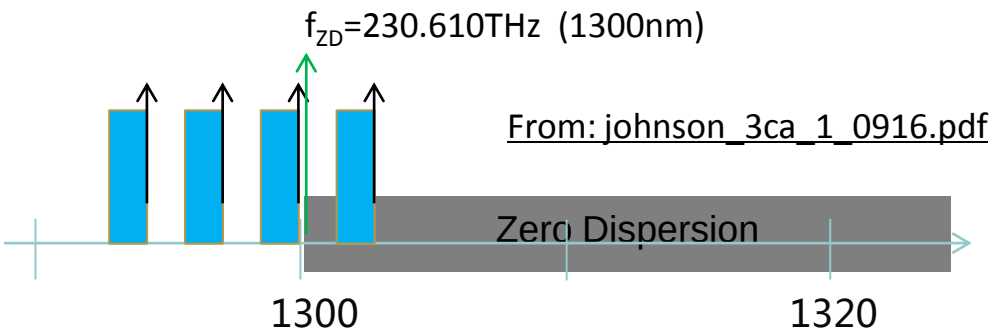




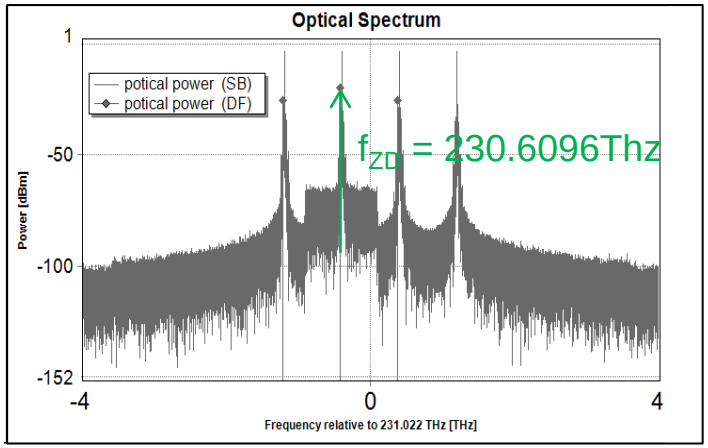




Worst FWM case for Plan A

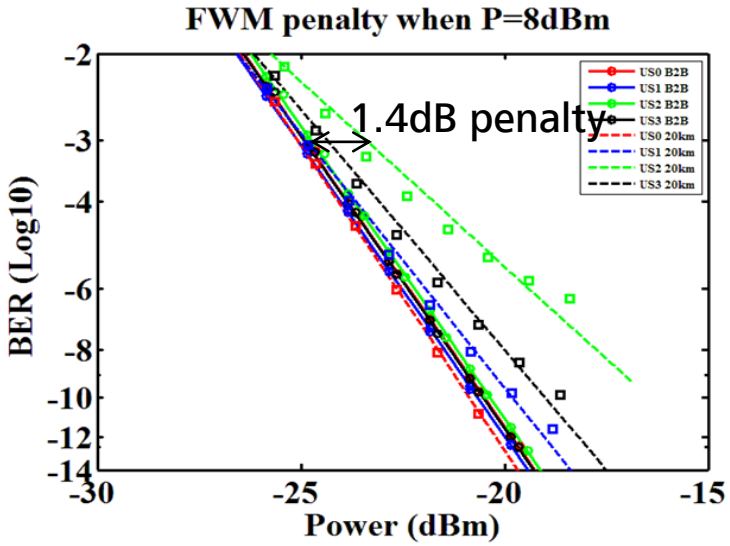


f_0=232.222, f_1= 231.422, f_2=230.622, f_3 = 229.822 THz

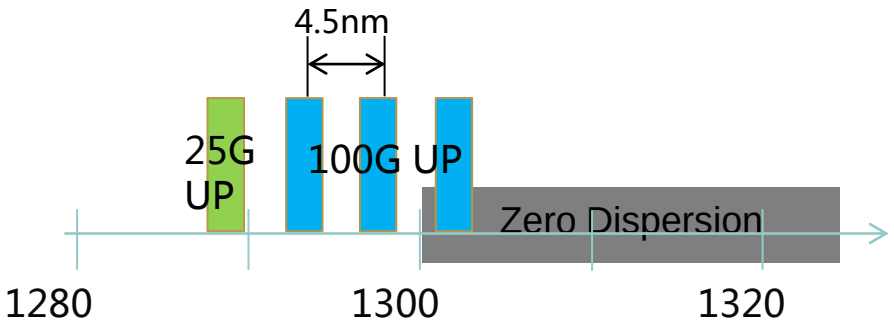


	f(THz)	λ(nm)
25G UP	232.4	1289.98 +/-1
100G UP	231.6	1294.44 +/-1
	230.8	1298.93 +/-1
	230	1303.45 +/-1

- Due to in worst case, f2 is only 12GHz(0.07nm) away from the zero dispersion point, so some extent FWM penalty will still happen, especially in US2 channel (1.4dB@1E-3).



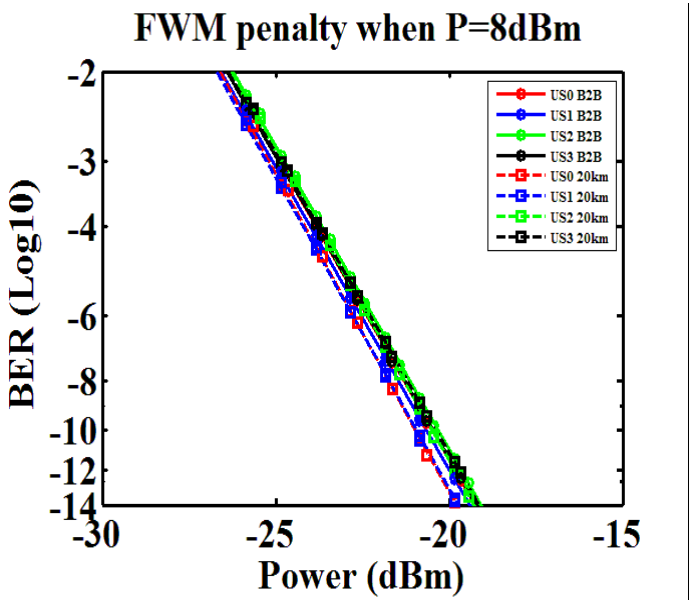
Shift US channels by 200GHz



	Center freq	Center WL	PB width (THz)
US0	232.600	1288.876	0.368
US1	231.800	1293.324	0.368
US2	231.000	1297.803	0.368
US3	230.200	1302.313	0.368

- US0, US1,US2 and US3 are shifted to the short wavelength by 200GHz, to avoid FWM penalty in worst case .
- 2nm width for each US channel is still very tight.
- The guard band between 10G EPON and 25G EPON is only 7nm, which may bring in extra difficulty on Wdm1r in OLT, especially for 25G&10G combo modules.

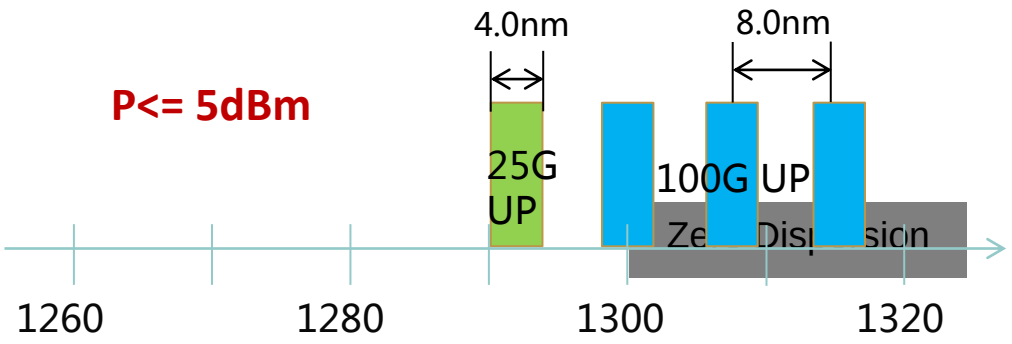
Worst case FWM simulation



f0,f1,f2,f3=232.416, 231.616, 230.816, 230.016THz

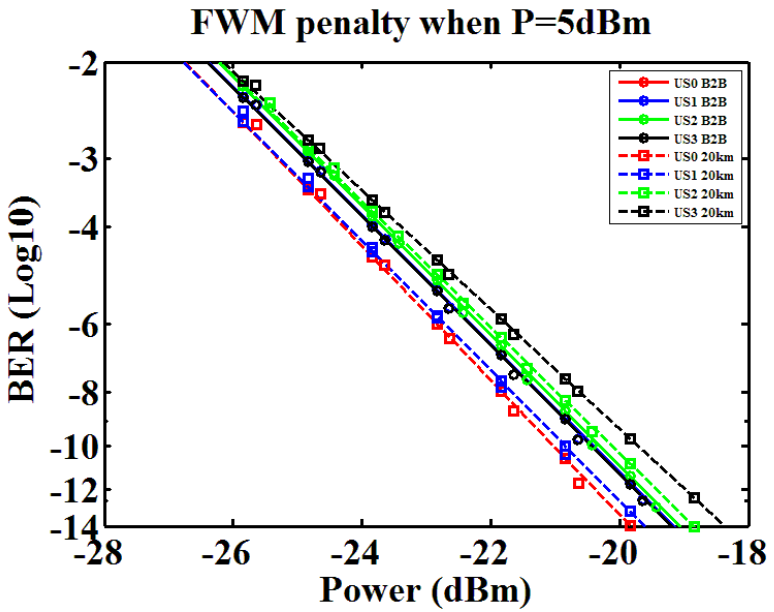
f_{ZD}=230.610THz(1300nm)

Another possible solution(1)

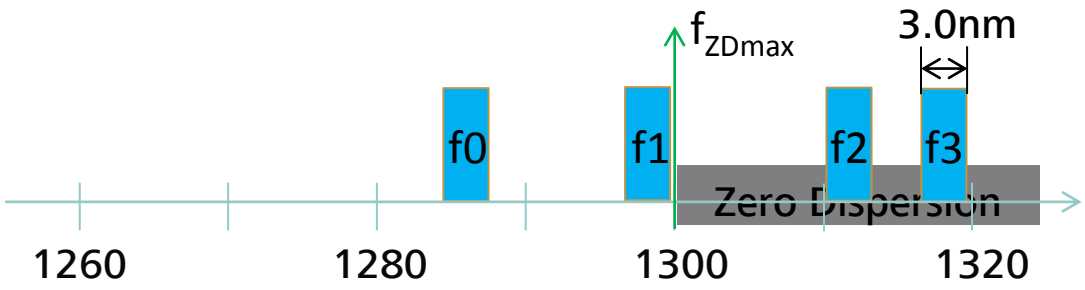


	Center freq	Center WL	PB width (THz)
US0	232	1292.21	0.7
US1	230.6	1300.05	0.7
US2	229.2	1308.00	0.7
US3	227.8	1316.03	0.7

- 5dBm maximal power for each channel is limited to avoid FWM penalty risk .
- 4nm width for each US channel distinctly decrease the cost of optics .
- 10nm guard band is left between 10G EPON and 25G EPON upstream.
- 5dBm maximal launch power limitation's impact on power budgets and optics cost needs further study.



Another possible solution—uneven spacing



	US0		US1		US2		US3	
	f_{max}	f_{min}	f_{max}	f_{min}	f_{max}	f_{min}	f_{max}	f_{min}
λ(nm)	1285.00	1288.00	1296.80	1299.80	1310.00	1313.00	1316.00	1319.00
f(THz)	233.301	232.758	231.179	230.645	228.849	228.326	227.806	227.288

- f2 and f3 are in zero dispersion zone, while f0 and f1 are kept outside zero dispersion zone (f0, f1, f2 won't generate FWM crosstalk)
- The following conditions are satisfied to avoid FWM

$$f1 > \max(2f2 - f3) = 2f2_{max} - f3_{min} \quad (f1 + f3 \neq 2f2)$$

$$f0 > \max(f1 + f2 - f3) = f1_{max} + f2_{max} - f3_{min} \quad (f0 + f3 \neq f1 + f2)$$

- More possibilities and the impact of uneven channel spacing need further study.

Summary

- The FWM effect in different wavelength girds and launch power have been analyzed.
- There are no FWM crosstalk in LAN WDM and CWDM system due to the launch power is low.
- There are still some FWM risk in worst case for plan A in johnson_3ca_1_0916.pdf, further migration is need if FWM risk must completely excluded.
- Some more solutions which can help to overcome FWM penalty are proposed. More possibilities and consequent impact needs more study.

Thank you

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