75GHz-spaced MUX/DMUX Test Results Based on 3-Channel 400GBase-ZR Signals

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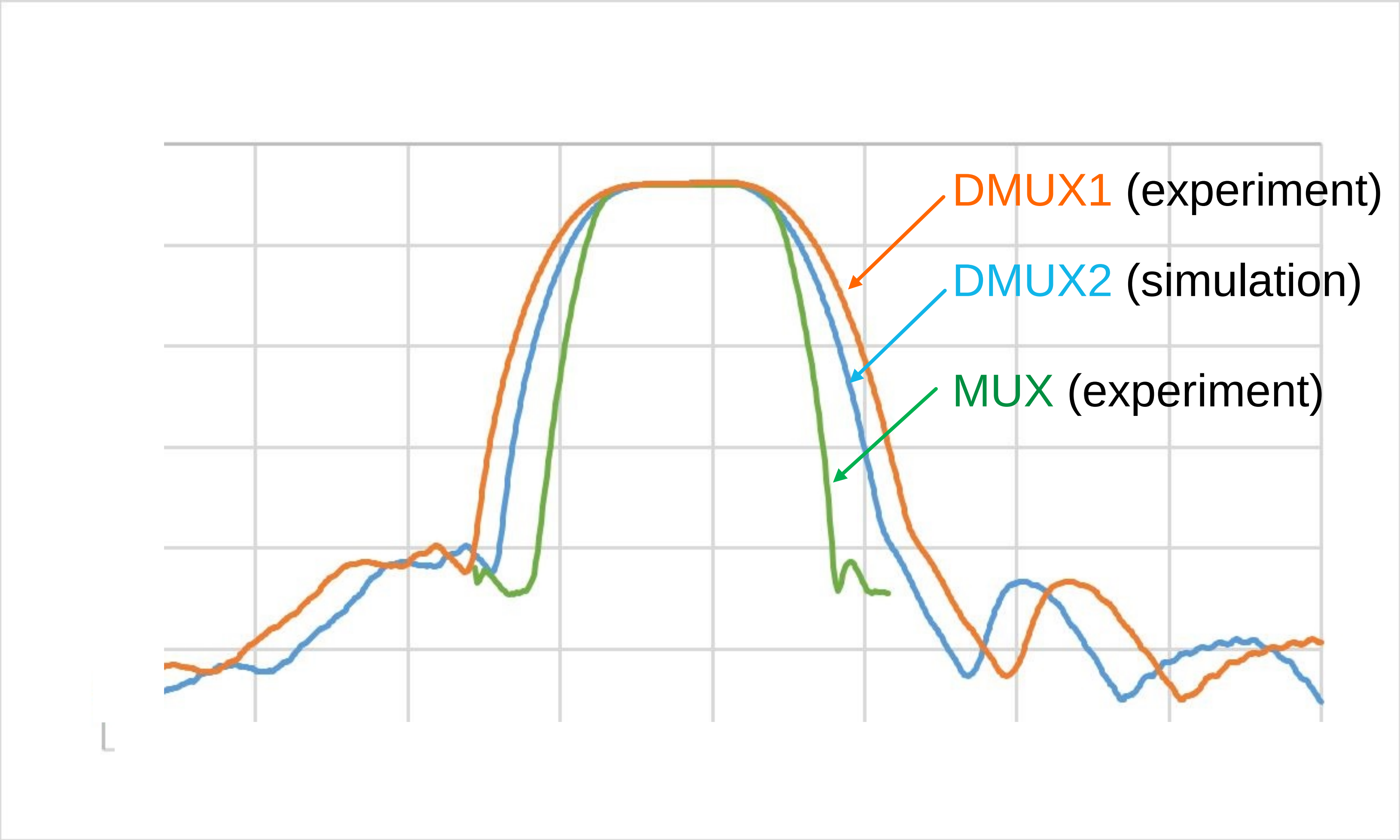
Motivation of 75GHz Channel-Spacing for 400GBase-ZR Signals

- DCI demand is clear, see du_3ct_01b_0919
- Single-carrier 400Gb/s signal has been transported over 75GHz-spaced systems for a few years, but pulse shaping is typically applied to a line-card.
- 400GBase-ZR will be used in a small form factor pluggable, and pulse shaping needs to be avoided to save power consumption.
- The DWDM mux/dmux design should accommodate the 75GHz-spaced 400GBase-ZR signal with no pulse shaping with a minimum OSNR penalty.

Presentation Highlights

- **Experiment and Simulation**
- **Test signal:** 3 neighbor 75GHz-spaced channels of 60 Gbaud/DP-16QAM without pulse shaping
- **Coherent modulators:** One with a 3dB BW of 30GHz and the other 40GHz to cover a wide range of possible signal bandwidths, both exhibit <23dB OSNR at CFEC pre-FEC threshold for BtB
- **75GHz-spaced 64-ch athermal MUX/DMUX**
- **Test condition:**
  - Worst-case laser frequency drift directions and up to 1.8GHz off-center (experiment)
  - Worst-case MUX frequency drift (simulation)
    - Dater Center: ±2 GHz (15 ~ 40^{o}C)
    - Telecom: ±5 GHz (-5 ~ 65^{o}C)

Experimental and Simulation MUX/DMUX Filter Shapes (Typical)



Experiment and Simulation Conditions

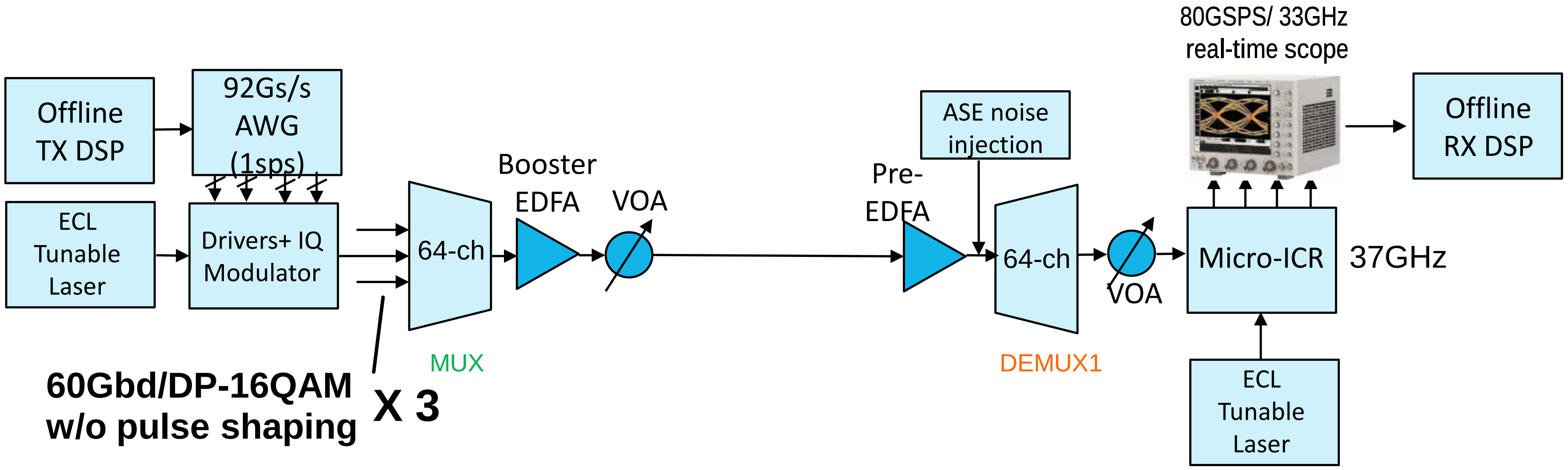
- **Experimental Condition (MUX + DMUX1, used typical specs)**
  - Middle channel shifted 1.8GHz toward right
  - Right channel shifted 1.8GHz toward left
  - Left channel shifted 1.8GHz toward right

Use an optical spectrum analyzer with a resolution of 125MHz to ensure the precise frequencies of the 3 channels

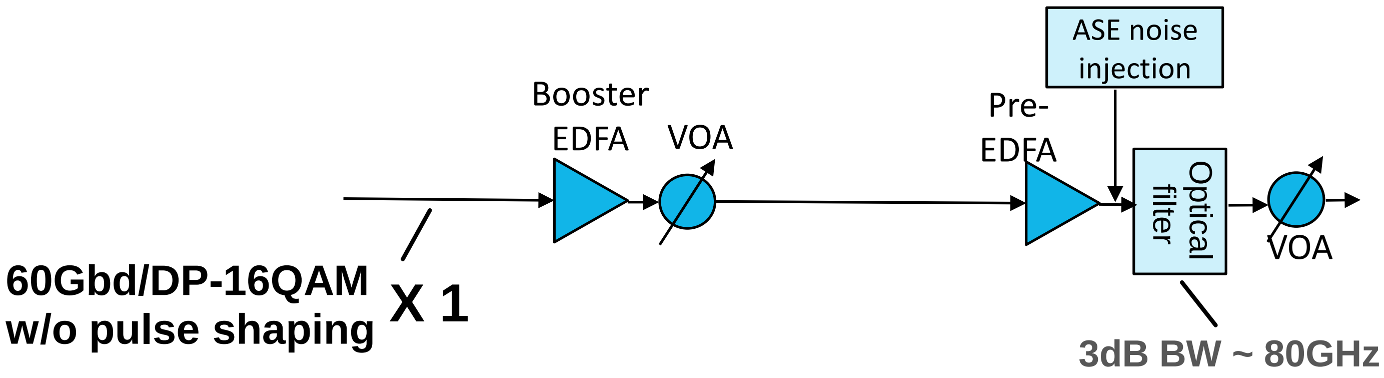
- **Simulation Condition (MUX + DMUX2, used worst specs)**
  - Add ±2 GHz drift to the MUX filters
    (±2 GHz wavelength accuracy under 15 ~ 40^{o}C DCI ambient temperature)
  - Add ±5 GHz drift to the MUX filters
    (±5 GHz wavelength accuracy under -5 ~ 65^{o}C telecom ambient temperature)

Experimental Setup

3-channel with MUX & DMUX



1-channel BtB with ASE filter



OSNR penalty is referenced to the BtB setup

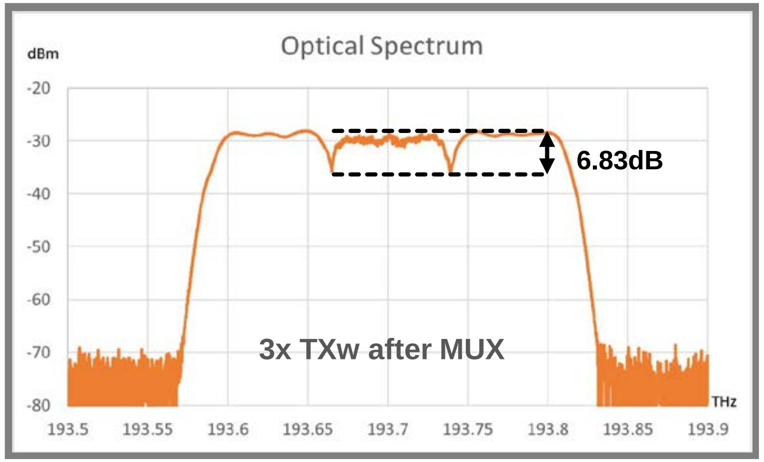
60Gbaud/DP-16QAM Test Signals

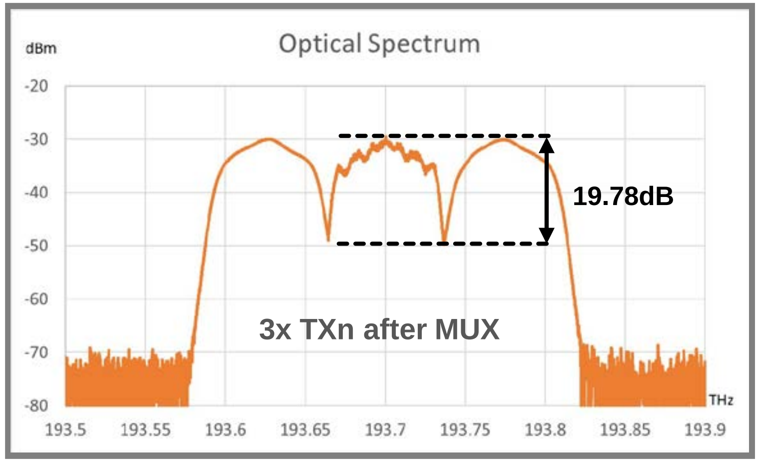
- TX_w signal (wider transmitted signal)
  - DAC 3dB BW=24GHz, driver+modulator 3dB BW= 40GHz
  - Optical signal 3dB bandwidth after 7-tap pre-equalization= 68GHz
  - Frequency excursion (including laser frequency of ±1.8GHz) would be 35.8GHz, exceeding the typically defined 32GHz limit

- TX_n signal (narrower transmitted signal)
  - DAC 3dB BW= 24GHz, driver+modulator 3dB bandwidth= 30GHz
  - Optical signal 3dB bandwidth after 7-tap pre-equalization= 42GHz
  - Frequency excursion (including laser frequency of ±1.8GHz) would be 22.8GHz, within the typically defined 32GHz limit

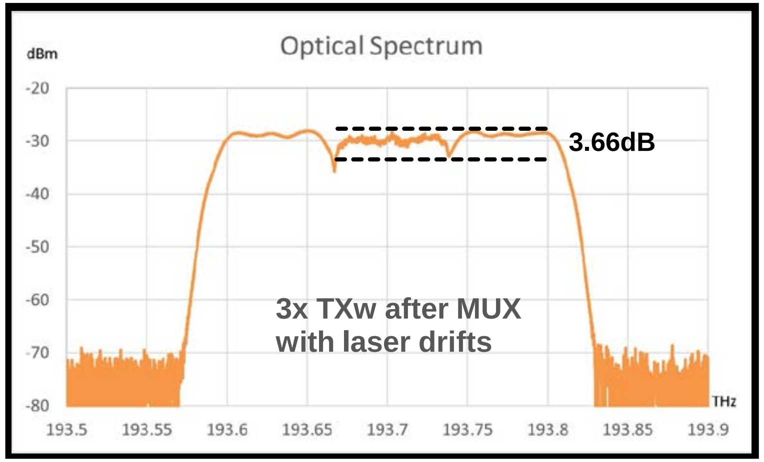
Optical Spectra After MUX without and with laser frequency shifting

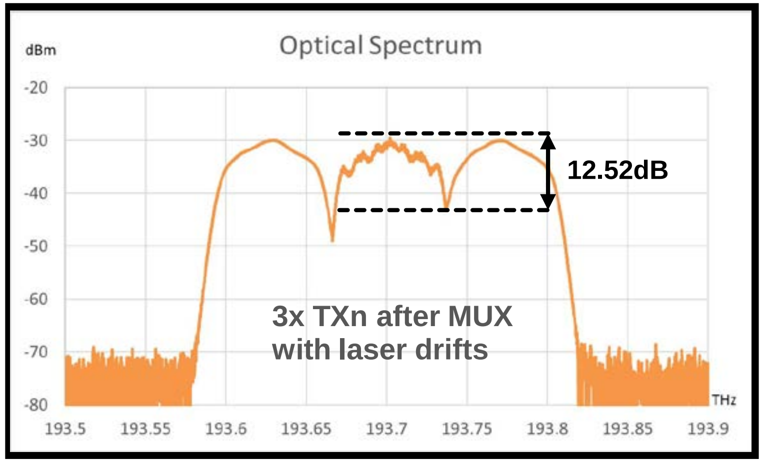
No Laser Frequency Shift





3 Lasers' Frequency Shifts (+1.8, +1.8, -1.8GHz)





The dip level clearly shows that (a) TW_n signals have less inter-channel Xtalk than TW_w; and (b) Xtalk increases after 3 laser frequency shifts

Summary of Experimental Results (MUX+ DMUX1, used typical specs)

Worst-case (with laser drifts) OSNR penalty (dB) @ 1.25e-2

	TXn with 3dB optical BW of 42 GHz after 7-tap pre-equalization
Simulation	**0.33**
Experiment	**0.39**

Summary of Simulation Results (MUX+DMUX2, used worst specs)

Laser frequency drifts (+1.8, +1.8, -1.8GHz)

Data Center Ambient Temperature

OSNR penalty (dB) @ BER = 1.25e-2	MUX + DMUX2
TXn -2GHz Mux offset	0.44
TXn +2GHz Mux offset	0.41

Telecom Central Office Ambient Temperature

OSNR penalty (dB) @ BER = 1.25e-2	MUX + DMUX2
TXn -5GHz Mux offset	0.58
TXn +5GHz Mux offset	0.54

Conclusions

- Typical 400ZR transceivers should have driver+modulator 3dB bandwidth around 28-33GHz (before pre-equalized), similar to that of TXn in our experiment. Therefore, under the worst-case condition, the OSNR penalty due to new 75GHz-spaced MUX/DMUX should be <0.5dB for data center ambient temperature.
- The OSNR penalty should be <0.6dB for telecom ambient temperature.
- 75GHz frequency plan: $193.1 + 3n \times 0.025$ (THz) where $3n = 120$ to -69.

Thank You!