Longer distance solutions for bidi objectives

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Introduction

- As explained in my January 2023 presentation, fiber dispersion makes achieving 100 Gb/s per wavelength signaling infeasible for 40 km.
  - Using conventional laser devices, there is no wavelength range that has assured low enough dispersion
- Therefore, 50 Gb/s per wavelength becomes the prime candidate for 40 km variants
- Let's first consider the hardest problem (200 Gb/s at 40 km), and then consider how we might reduce that to handle 100 Gb/s as 40 km

200 Gb/s using 50 Gb/s /wavelength

- Obviously, we will need 8 wavelengths to achieve the desired throughput
- There is a large industrial base built up on the 800 GHz wavelength plan used for various Ethernet PMDs
- Coincidentally, ITU-T is also working on standardizing this grid in the G.owdm standard
- Channels 5 through 12 (inclusive) are favored
  - Channels 1 through 4 have too much dispersion

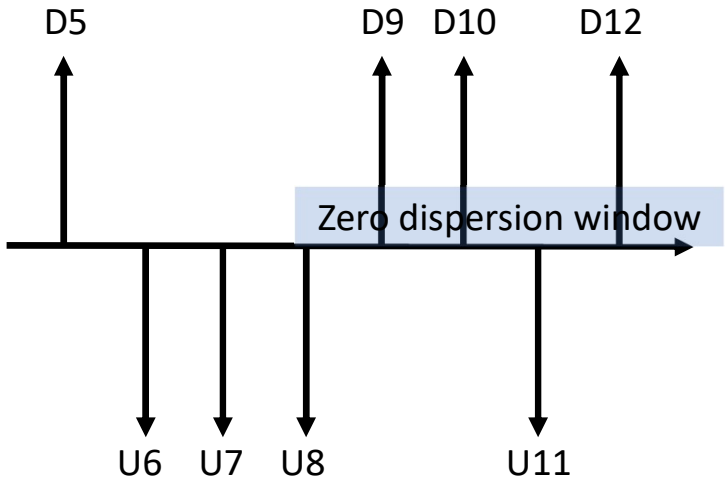
Ch	Freq	Wavelength
1	236.2	1269.23
2	235.4	1273.54
3	234.6	1277.89
4	233.8	1282.26
5	233.0	1286.66
6	232.2	1291.10
7	231.4	1295.56
8	230.6	1300.05
9	229.8	1304.58
10	229.0	1309.14
11	228.2	1313.73
12	227.4	1318.35

How to arrange the wavelengths?

- Given the grid channels 5 to 12, we need to choose which wavelengths are upstream, and which are downstream
- Simplest schemes
  - Block wise: upstream 5 to 8, downstream 9 to 12
  - Interleaved: upstream 5, 7, 9, 11; downstream 6, 8, 10, 12
- Unfortunately, these periodic wavelength arrangements result in very bad four wave mixing (FWM) effects, which will be made worse
  - Given the high powers likely to be needed to go 40 km
  - Using PAM4 modulation that is more sensitive to coherent crosstalk

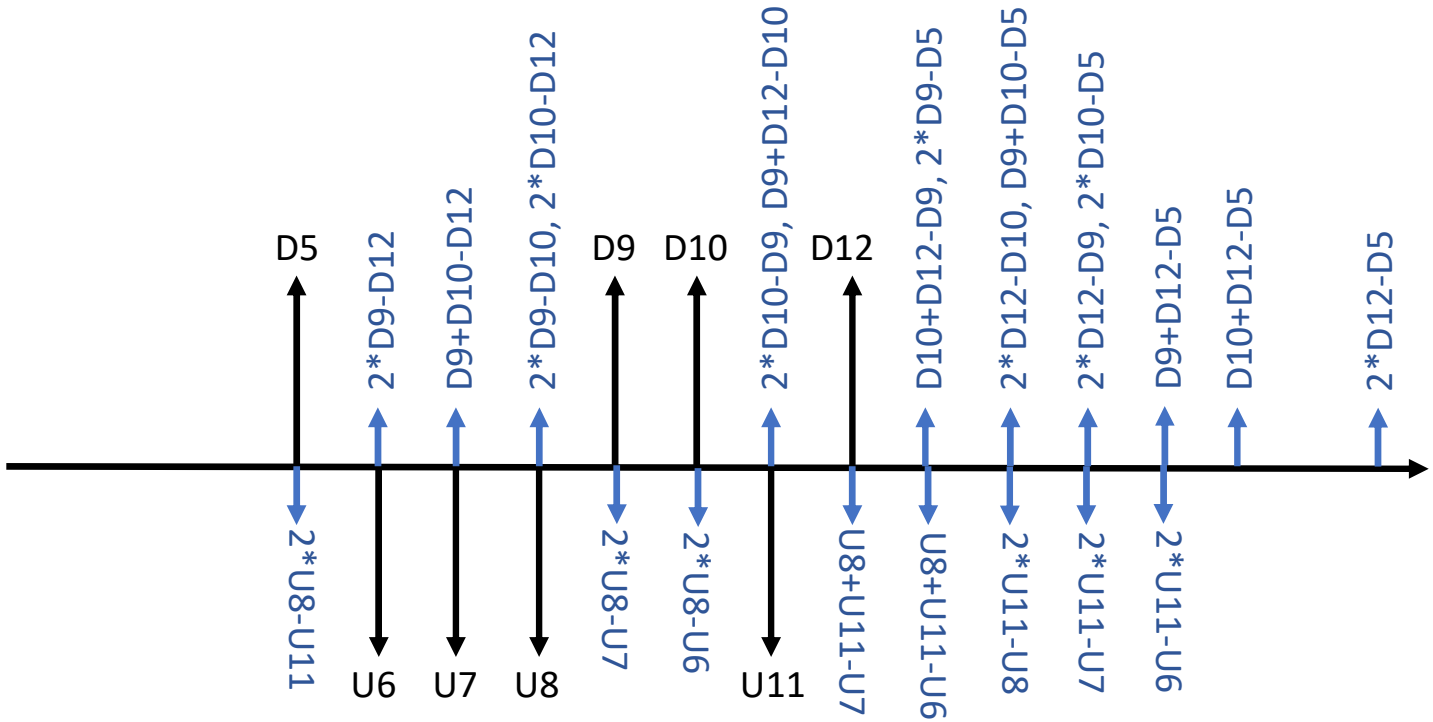
Arrangement to avoid FWM

- The arrangement shown below manages to avoid all strong FWM interferences, provided the maximum spectral excursion of each carrier has a tolerance range of ±200 GHz



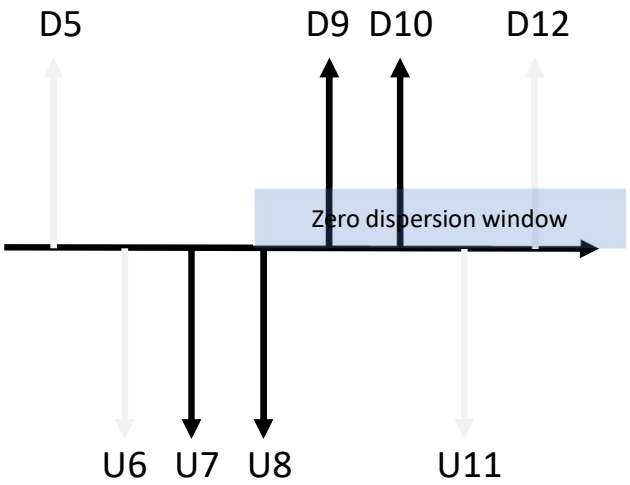
FWM products illustrated

- Black arrows show the channels
- Blue arrows show the FWM products

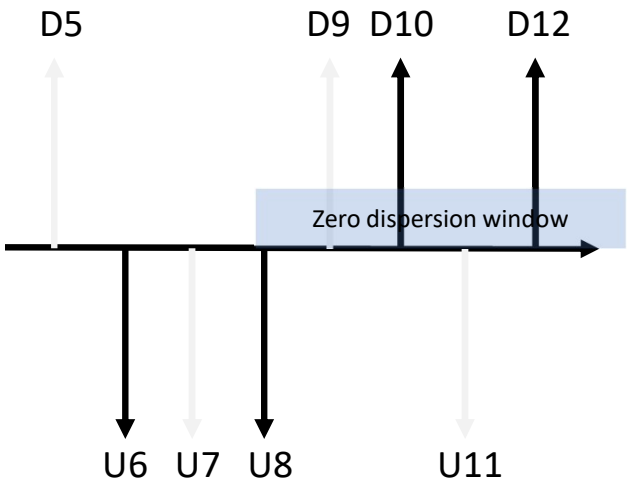


Channel reduction to obtain 100 Gb/s

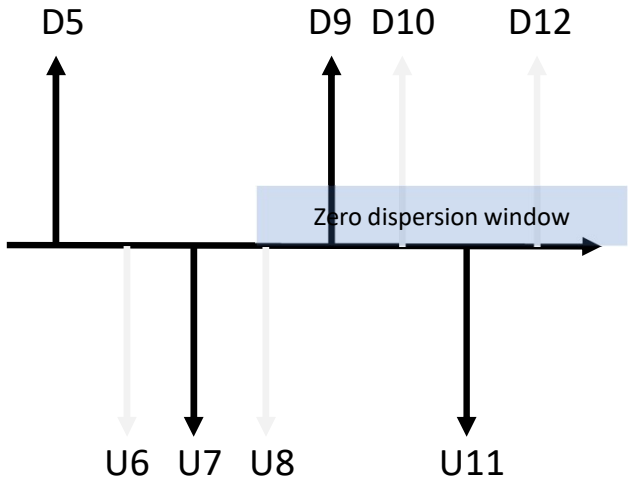
Use center channels



Use even channels



Use odd channels



Are two channel modules popular?

- What are the attractive module channel counts?
  - Single channel modules obviously nice
    - Couldn't be simpler, and typically fits within an SFP+ case
  - Quad channel modules are commercially very important
    - Four seems to be the magic number for high yield complexity limit
    - A significant ecosystem on QSFP has grown up
  - Dual channel modules are not so popular
    - Suffers the complexity of multiple channels without rewards of parallelism
- Do we really want to define a 2x50 Gb/s module for 100 Gb/s 40 km?
- Do we really want to define a 2x100 Gb/s module for 200 Gb/s 10 km?

Alternative way to 100 Gb/s 40 km

- Reuse the 8 channel plan from the 200 Gb/s design
- Operate each channel at 25 Gb/s NRZ

- This opens the possibility of making 100 Gb/s and 200 Gb/s field compatible by changing the modulation on each channel
- The link could also auto-negotiate the maximum rate depending on channel conditions
  - 100 Gb/s NRZ will have significant loss budget advantage over 200 Gb/s PAM4

- Admittedly, using 8 channels for 100 Gb/s does not give us the lowest channel count

Summary

- The 200 Gb/s 40 km objective will require 50 Gb/s per channel
  - An 8-wavelength plan that avoids FWM impairment is shown
- There are multiple ways for 100 Gb/s 40 km
  - A four wavelength down-selection from the 200 Gb/s PMD
  - Reuse 8 wavelength PMD and operate it at 25 Gb/s NRZ
- 200 Gb/s 10 km and 20 km objectives
  - A four wavelength down-selection, operating at 100 Gb/s per channel
  - Reuse the PMD from 40 km, continuing to use 50 Gb/s PAM4
- 100 Gb/s 10 km and 20 km objectives:
  - A building consensus around single channel 100 Gb/s

Thank you

Any questions?