Considerations on an 800G-LR1 and 800G-ER1 Baseline

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Recap (williams_3df_01_220222.pdf)

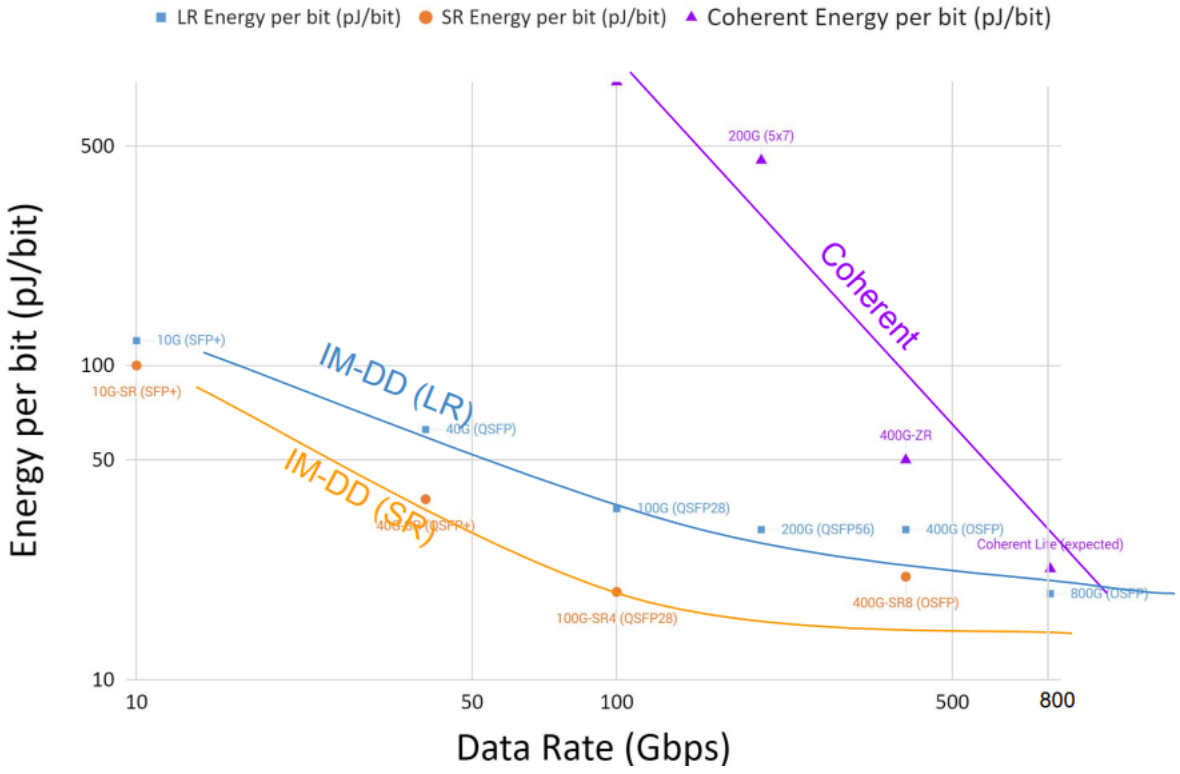
- Coherent technology will likely be adopted for 40 km objective and is the lowest risk technical proposal for 10km
- Coherent optical technology has matured and become more highly integrated over the 10+ years since initial solutions came to market
- This integration has driven cost, size, power reductions resulting in pluggable modules being widely deployed based on optimizations for shorter reaches (simplifications)
- IEEE 802.3 has successful history of grouping technical solutions to enhance economies of scale and compatibility
- Given that a 800 GbE @ 10km solution is unlikely to be compatible with a 2km solution, a coherent solution leveraging the 40km solution is attractive both economically and commercially

Overview

- Previous contribution addressed feasibility of coherent for LR and ER applications
- It is assumed that technical feasibility is accepted, so focus here is on commercial feasibility
- This contribution aims to provide some clarity on the complexity difference between coherent and IMDD
  - Separating the additional complexity introduced by DWDM applications

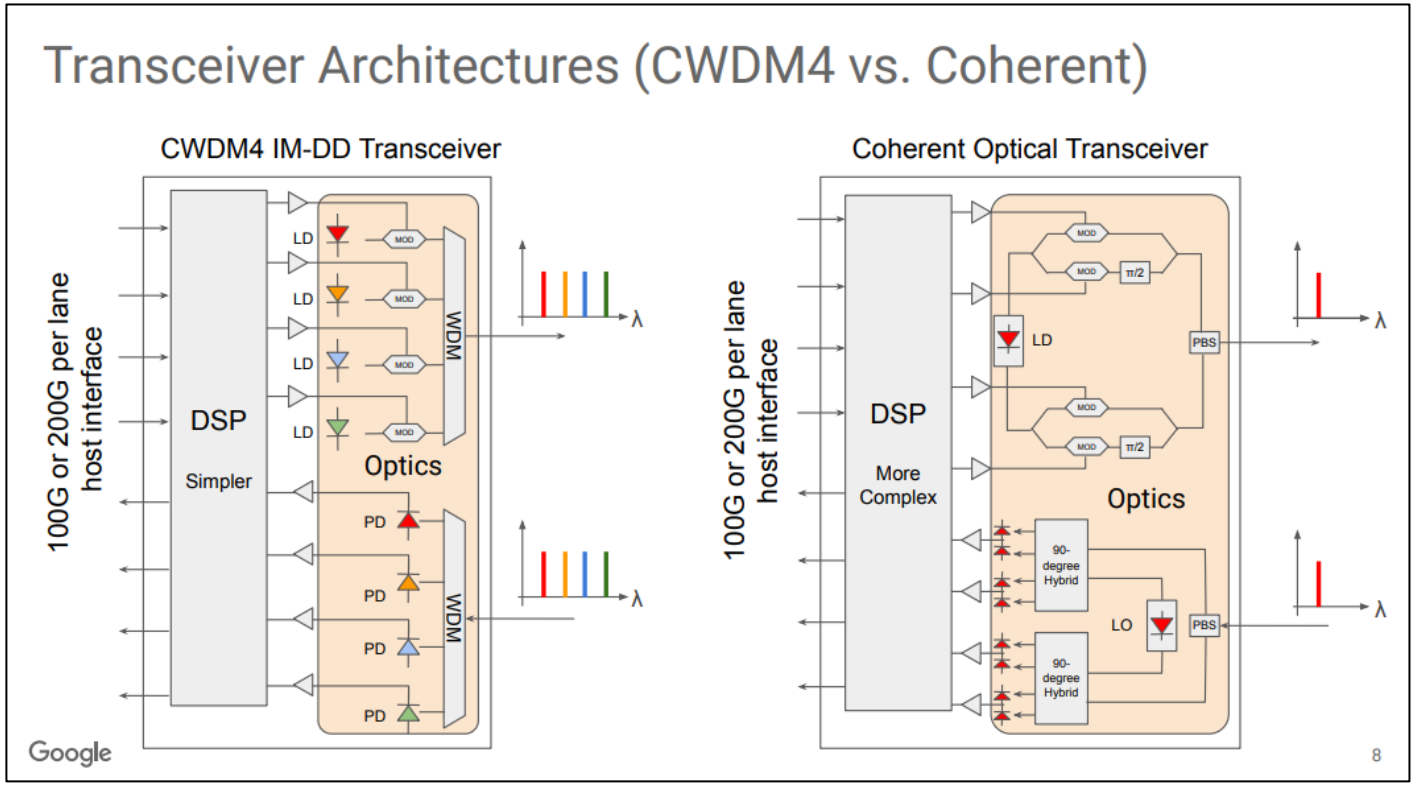
Coherent and IMDD Converging

- DSP power reduces with smaller CMOS nodes
  - Coherent DSP has smaller impact relative to IMDD DSP complexity
- IMDD & coherent modulators are similar at higher baud rate
- Baud rates don’t scale at same pace as port speeds
  - Higher order modulation
  - Parallel IMDD with higher lane counts
  - Shift to coherent with fewer lasers
- Dispersion increasingly challenging at higher baud rates
  - Tighter channel spacing requiring temp control
  - Electronic compensation in DSP



Lam et al., “Coherent-Lite for Beyond 400GbE”, July 2021
https://www.ieee802.org/3/B400G/public/21_07/lam_b400g_01a_210720.pdf

Comparison of Complexity



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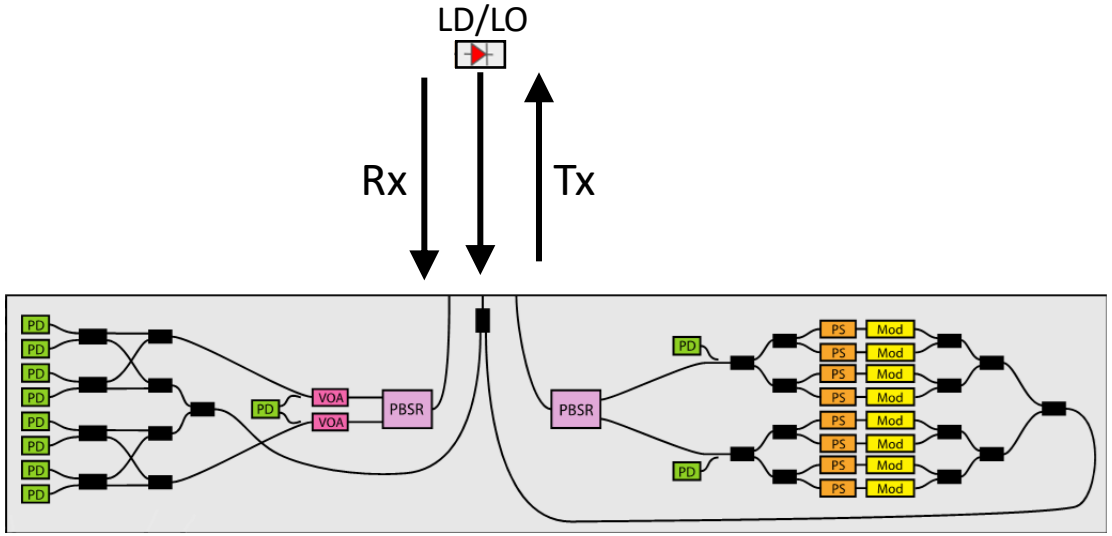
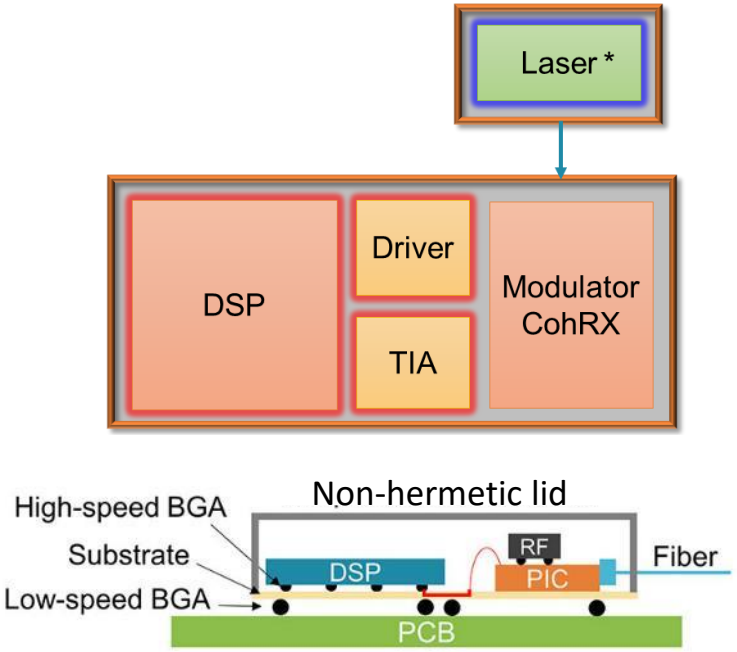
https://www.ieee802.org/3/B400G/public/21_07/lam_b400g_01a_210720.pdf

- One laser can be used for LD and LO
- Serdes and DAC/ADC determine die size
  - Less than 10% difference between approaches
- Monolithic integration on PIC includes any additional optical functions for coherent
- Discrete optical components (e.g. lasers) reduced for coherent

Coherent Integration Advances



Monolithically integrated PIC



2.5D Stacking

Standard Electronics Packaging

Utilizing many of the same integration technologies as IMDD makes coherent implementations very manufacturable – complexity handled by integration

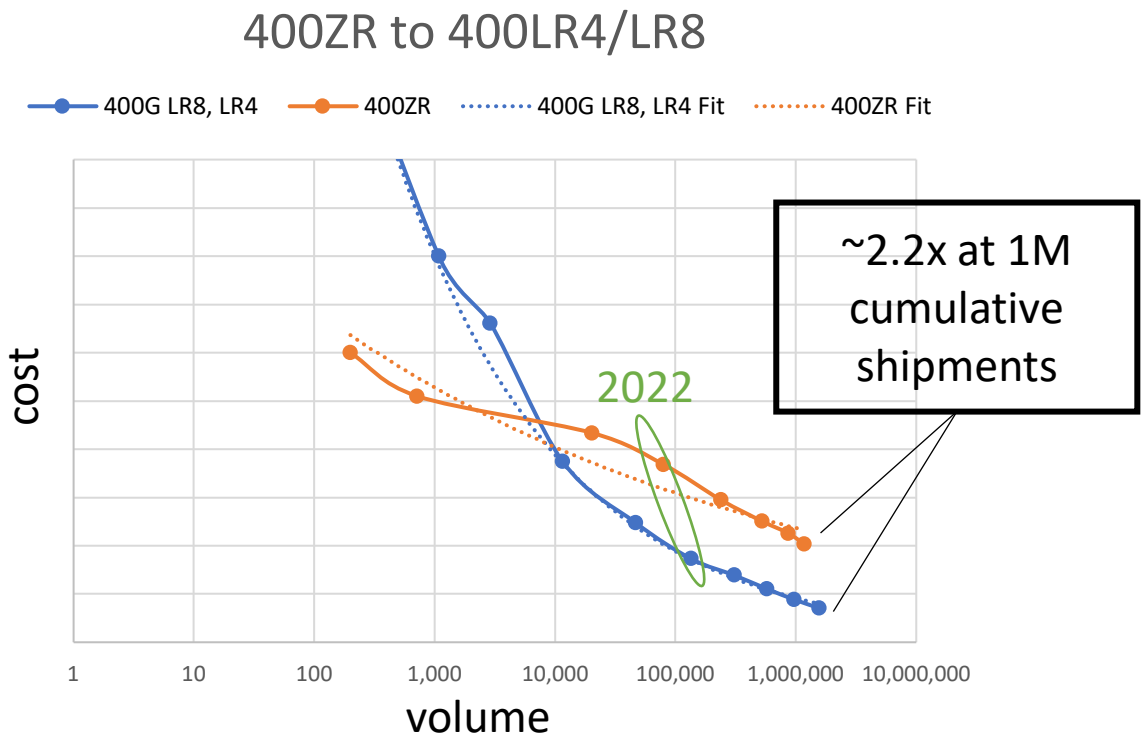
Comparing complexities for an 800GbE 10km solution

- Coherent: Shorter reach requires less complexity
  - Single tunable laser → Single fixed DFB
    - Temperature controlled DFB lasers can support 10km application
  - Eliminate OSNR testing
    - Shorter test time on less expensive equipment
  - Significantly higher specification margin reduces test time and increases yields
- IMDD: Increased length requires greater complexity
  - IMDD gets more complex
    - Requires 4 (or 8) lanes
    - Dispersion tolerance and link budget more challenging for 4 lane implementations
      - If tighter wavelength grid needed, may require temperature-controlled lasers and raises concerns with four-wave mixing
    - Dispersion tolerances and manufacturing complexity more challenging for 8 lane implementations
- Cost structures compared to 400G
  - Coherent
    - Same number of components
    - Link budget margin gives design flexibility to improve power and cost
  - IMDD
    - Increased complexity
    - Lack of compatibility with higher volume 2km

Impact of Tunability

- Tunable laser can contribute more than 25% BOM cost for DWDM coherent
  - Longer test times than fixed DFB
  - Lower production yields
- Coherent LR laser requires similar specifications as IMDD lasers
  - 1MHz linewidth
  - Relaxed frequency accuracy
  - Extra link budget allows for lower laser power
  - 1550nm assumed for commonality with ER/ZR, but 1310 could be considered

Using 400G coherent vs IMDD cost comparison to gain insights into 800G



Source: LightCounting, October 2021 Market Forecast report

Note: Chart based on publicly available data and includes estimates. Implementers' actual or relative acquisition costs may vary.

- Looking at LightCounting's report on 400G module data
- Complexity drives initial cost and manufacturing improvements and volume drive the reduction over time
- At 400G, a 100km DWDM 400ZR module is projected to only have a 2.2x cost difference at comparable volumes with 400G 10km IMDD

- Predicting what an 800G equivalent curve would look like:
  - Coherent complexity reduces
  - IMDD complexity increases
  - Volume of IMDD less leverage from 2km
  - Coherent volume increases (if adopted by 802.3df) with leverage from 40km

Summary

- Perceptions that coherent is big, bulky and expensive are out of date
  - Coherent does add additional elements (nested MZ, 90° hybrid, PBS, etc.)
    - These additional functions monolithically integrated on PIC
    - The increase in PIC size can be balanced against the benefit of fewer lasers
    - Laser complexity for LR applications is significantly reduced compared to ZR
      - Laser specifications are similar to IMDD
    - Eliminates optical mux/demux
  - At 400G, Coherent DWDM ZR introduces about 2.2x complexity compared to IM-DD LR. At 800G, this difference reduces.
    - Tunability and OSNR testing contribute significantly to this cost difference
    - Scaling to 800G has a bigger cost impact on IMDD than coherent
    - Extra link budget can be used to improve cost and power (i.e. lower power lasers)