PMD architecture with skew compensation mechanism for parallel link

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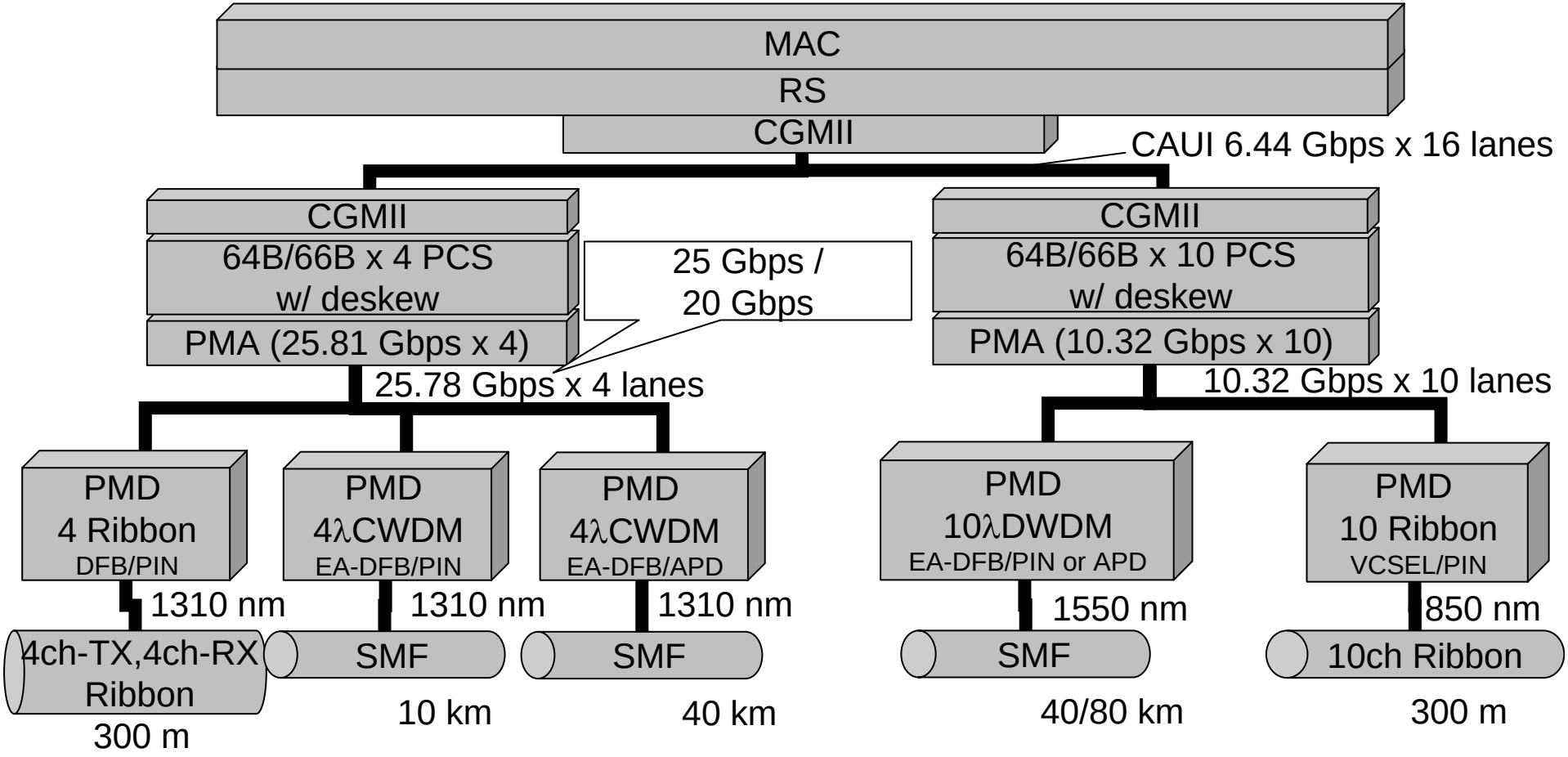
Outline

- Proposal of parallel PMD architectures
  - Transmission rate and reach
  - Physical coding sublayer
- Quantity of skew
- Mechanism of skew compensation
  - Mechanism
  - Structure of data pattern
  - Block diagram

Requirements

- Wider bandwidth: ~ 100 Gbps
- Longer reach: 100 m ~ 80 km
- Low cost:
  - Small number of optical components
  - Compact CMOS-ICs
- Low power consumption
- Low latency
- High reliability (BER: < 10^{-15})

Brainstorming possible PMD architectures

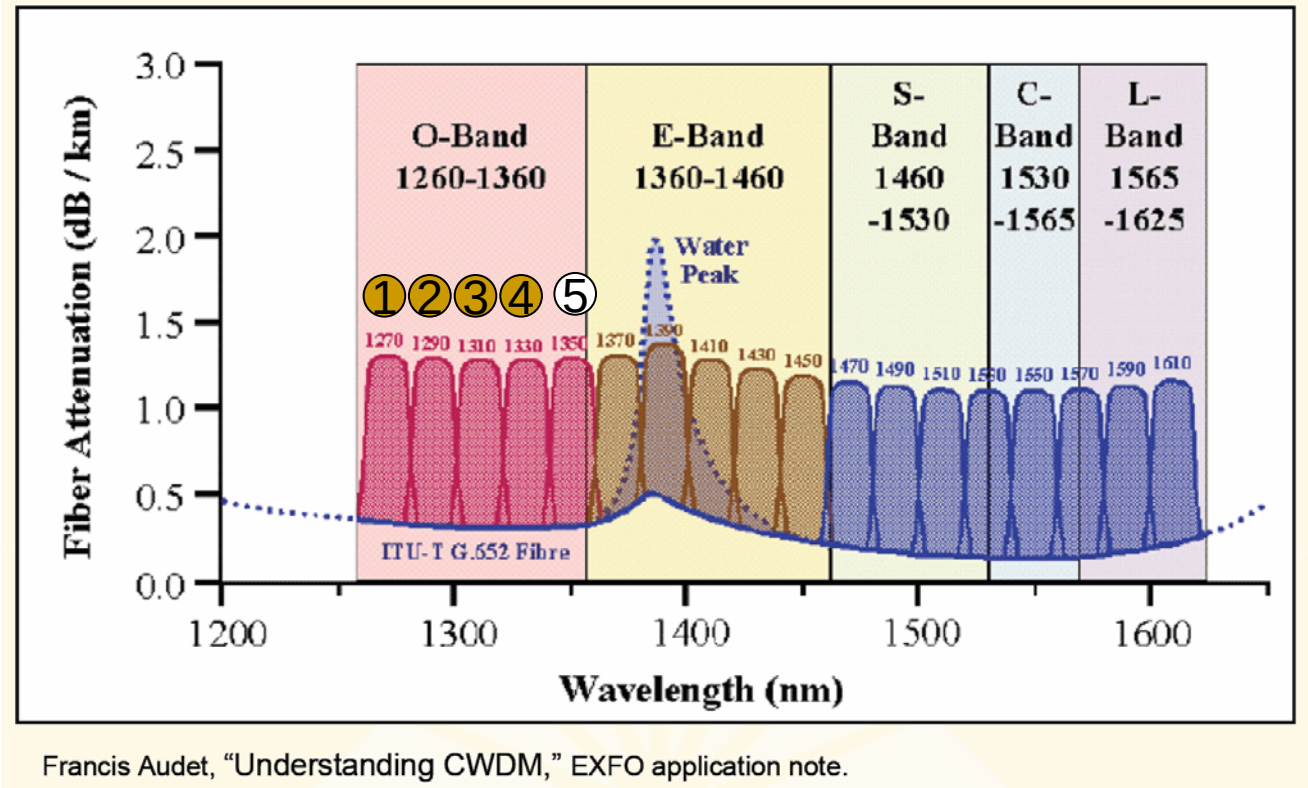


- 10-ch architectures (technically easy)
  -> 4-ch architectures (cost effective)
  25-Gbps Electrical Interface: compatible with CEI-25Gbps
  (20-Gbps x 5-ch: double rate of XFI)

EA-DFB: DFB integrated with electroabsorption modulator

Wavelength assignment of 4λCWDM

- CWDM (ITU Grid): 1270,1290,1310,1330 nm



Francis Audet, "Understanding CWDM," EXFO application note.

Ref: Chris Cole, cole_01_0906.pdf

Quantity of skew (1.3-um CWDM)

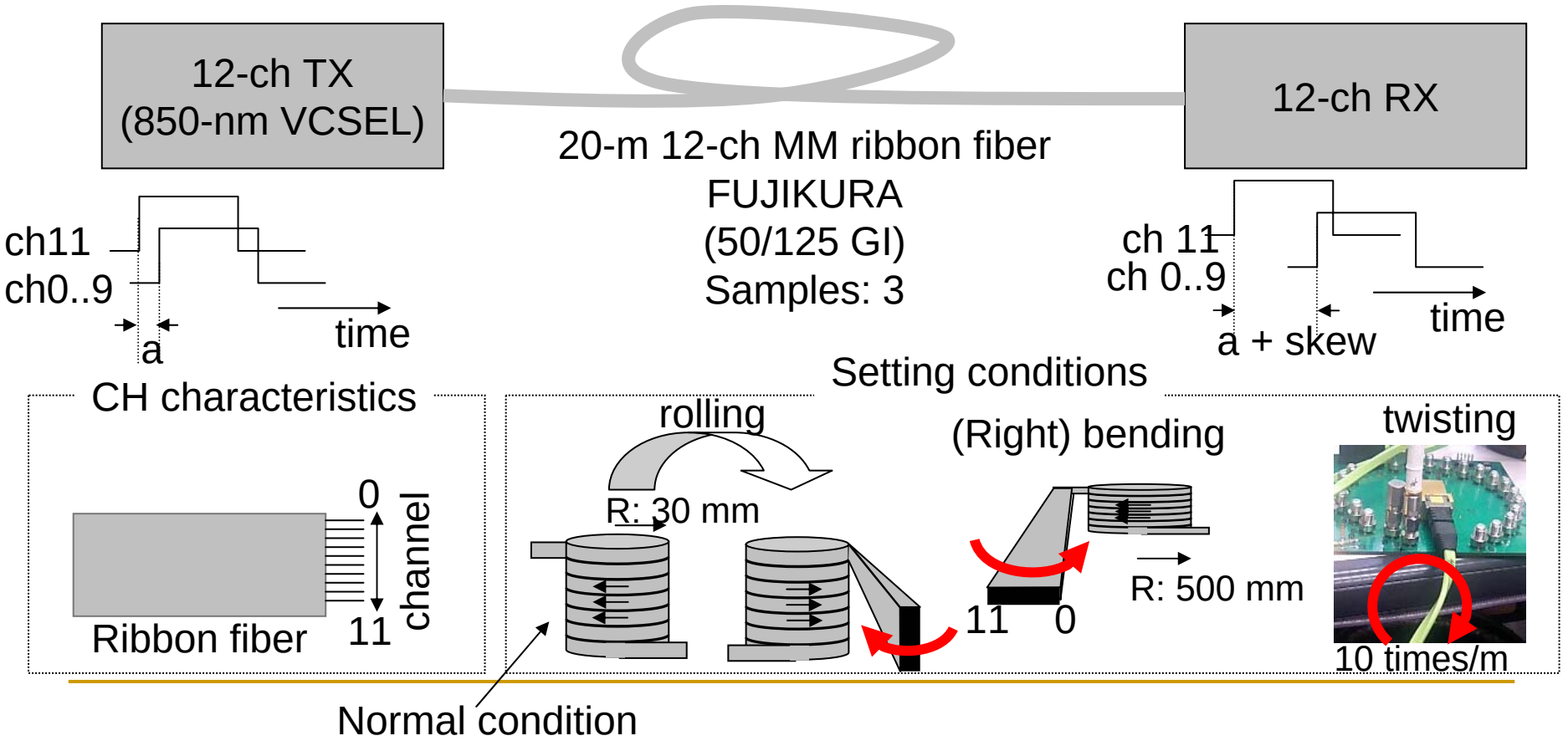
- Wave length 1270 nm–1330 nm
- Skew (80 km) 33.6 ns (105 Bytes @ 25 Gbps)

Channel	Wavelength (nm)	Band	Dispersion (psec/nm-km)		n(eff)		Speed of Wavelength (km/s)		Propagation Delay @ 100 km (us)		Propagation Delay @ 10,000 km (us)	
			G.655	G.652	G.655	G.652	G.655	G.652	G.655	G.652	G.655	G.652
1	1270	O	-20.1	-3.8	1.464500	1.467617	204,706	204,272	488.505	489.544	48,850.462	48,954.423
2	1290	O	-18.4	-2.2	1.464750	1.467658	204,671	204,266	488.588	489.558	48,858.801	48,955.812
3	1310	O	-16.7	-0.6	1.465000	1.467700	204,636	204,260	488.671	489.572	48,867.140	48,957.202
4	1330	O	-15.1	1.0	1.465250	1.467742	204,602	204,254	488.755	489.586	48,875.479	48,958.592
5	1350	O	-13.3	2.6	1.465500	1.467783	204,567	204,248	488.838	489.600	48,883.818	48,959.982
6	1370	E	-11.6	4.2	1.465750	1.467825	204,532	204,243	488.922	489.614	48,892.157	48,961.372
7	1390	E	-9.9	5.8	1.466000	1.467867	204,497	204,237	489.005	489.628	48,900.496	48,962.762
8	1410	E	-8.2	7.4	1.466250	1.467908	204,462	204,231	489.088	489.642	48,908.835	48,964.152
9	1430	E	-6.5	9.0	1.466500	1.467950	204,427	204,225	489.172	489.655	48917.175	48,965.541
10	1450	E	-4.8	10.6	1.466750	1.467992	204,392	204,219	489.255	489.669	48925.514	48,966.931
11	1470	S	-3.1	12.2	1.467000	1.468033	204,358	204,214	489.339	489.683	48933.853	48,968.321
12	1490	S	-1.4	13.8	1.467250	1.468075	204,323	204,208	489.422	489.697	48942.192	48,969.711
13	1510	S	0.3	15.4	1.467500	1.468117	204,288	204,202	489.505	489.711	48950.531	48,971.101
14	1530	C	2.0	17.0	1.467750	1.468158	204,253	204,196	489.589	489.725	48,958.870	48,972.491
15	1550	C	3.6	18.6	1.468000	1.468200	204,218	204,190	489.672	489.739	48967.209	48,973.880
16	1570	L	5.4	20.2	1.468250	1.468242	204,184	204,185	489.755	489.753	48,975.548	48,975.270
17	1590	L	7.0	21.8	1.468500	1.468283	204,149	204,179	489.839	489.767	48983.887	48,976.660
18	1610	L	8.8	23.4	1.468750	1.468325	204,114	204,173	489.922	489.781	48992.226	48,978.050
	1630				1.469000		204,079					

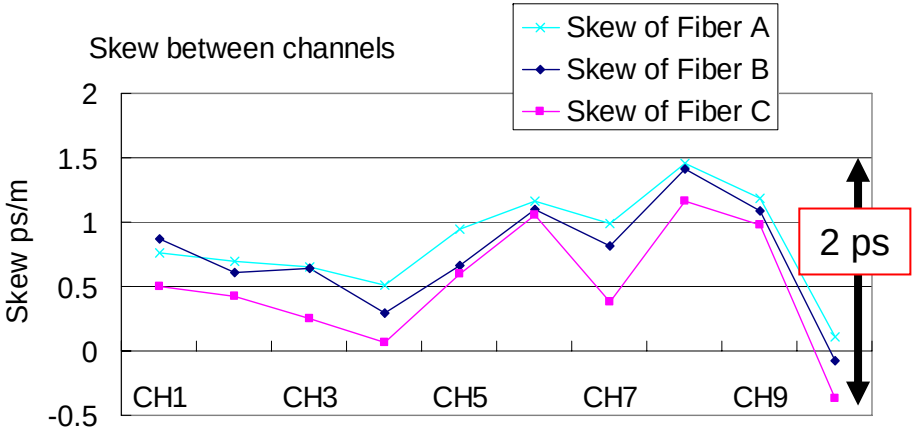
Ref: Drew Perkins, perkins_03_0906.pdf

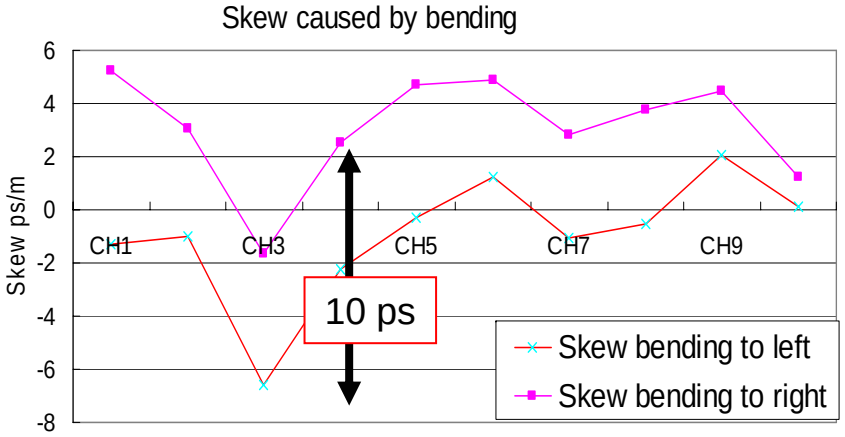
Ribbon-fiber skew measurement setup

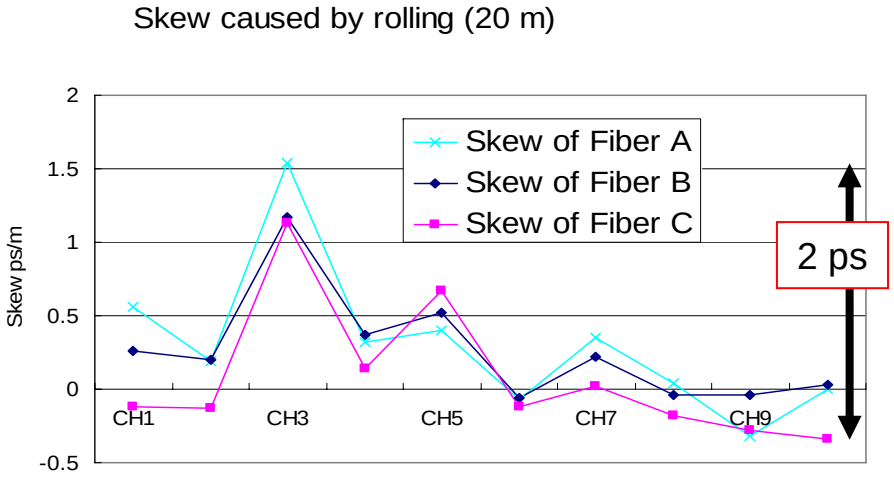
- Skew: measured based on pulse edges
  - Data rate: 3 Gbps
  - Skew (optical modules, board) (with 0.5-m ribbon fiber) is calibrated

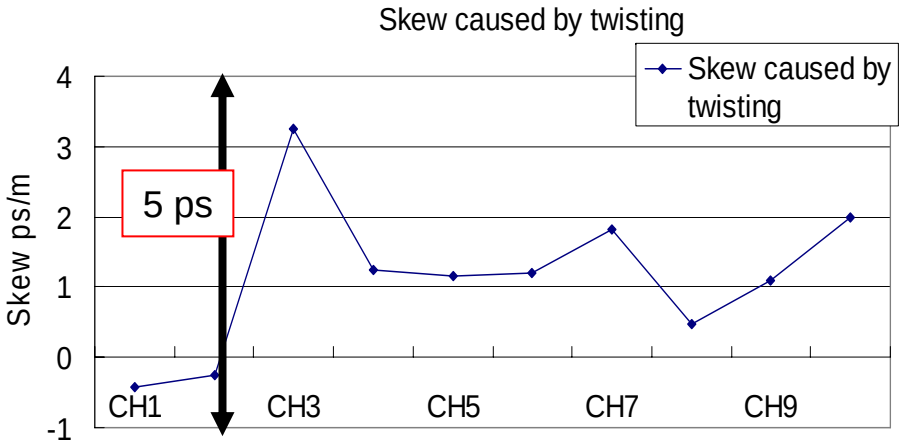


Quantity of skew (ribbon)



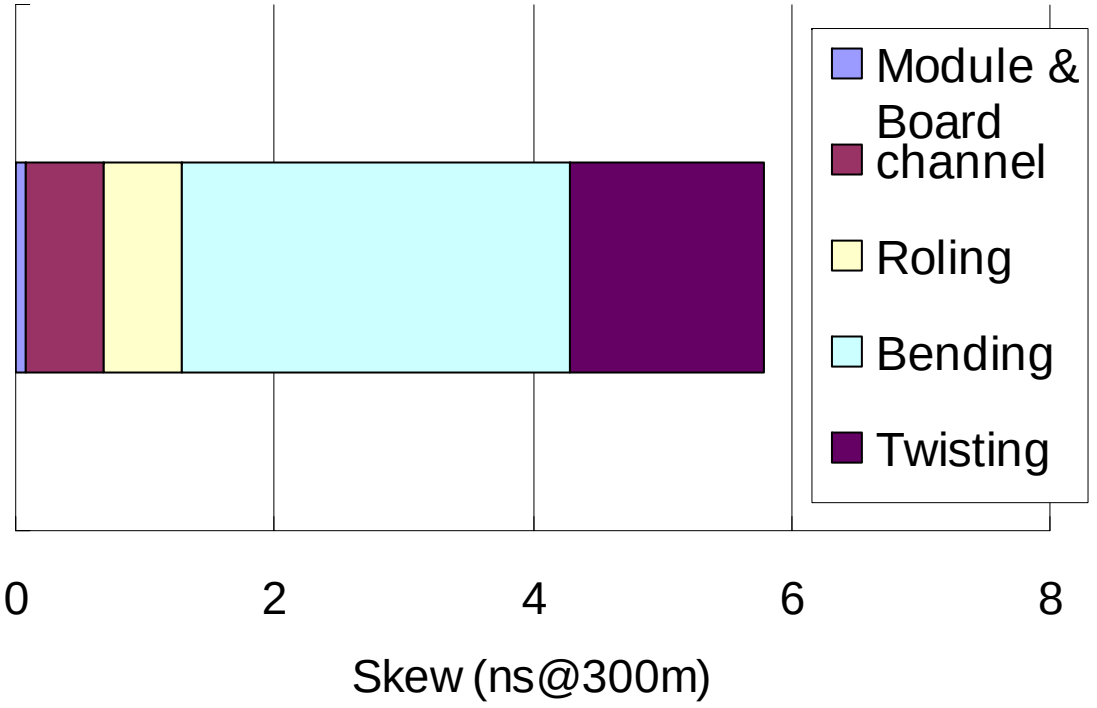






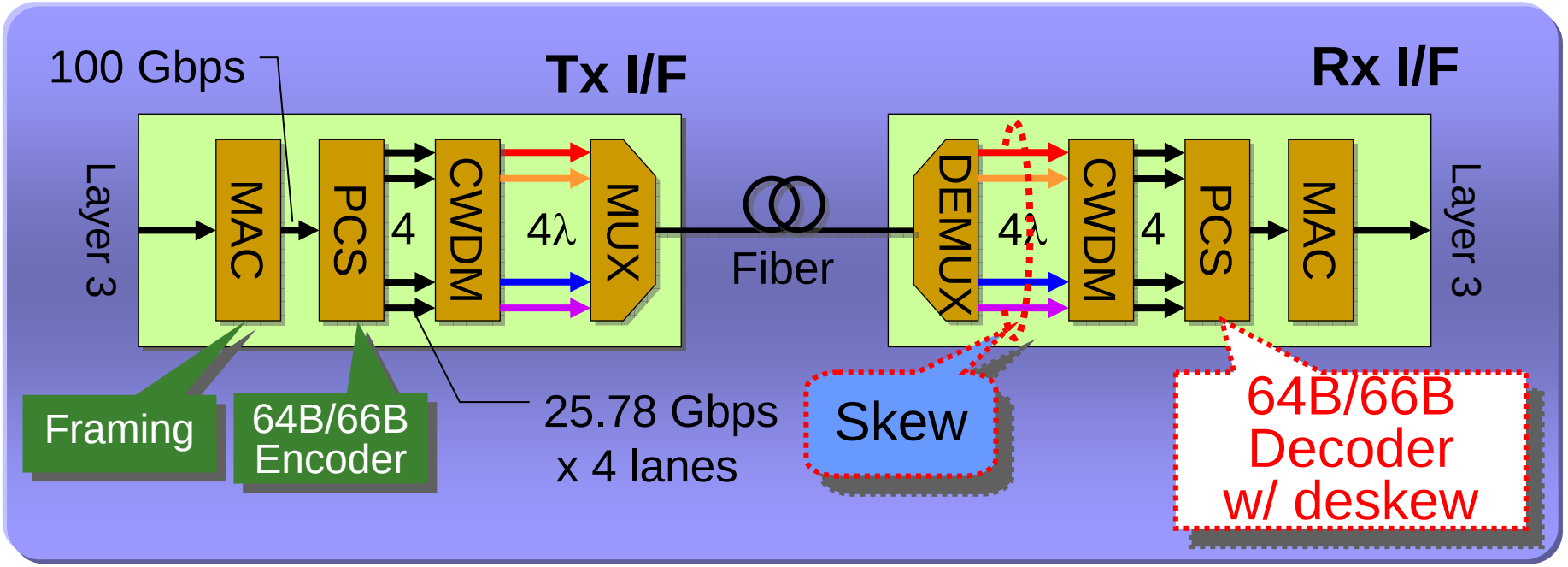
Quantity of skew (MMF-ribbon)

- Experimental skew results: 5.8 ns @ 300 m
- Many samples with different specifications, lots & coating structures (vendors) should be measured
  - Max. skew of ribbon fiber: < 30 ns (?) @ 300 m



Skew compensation

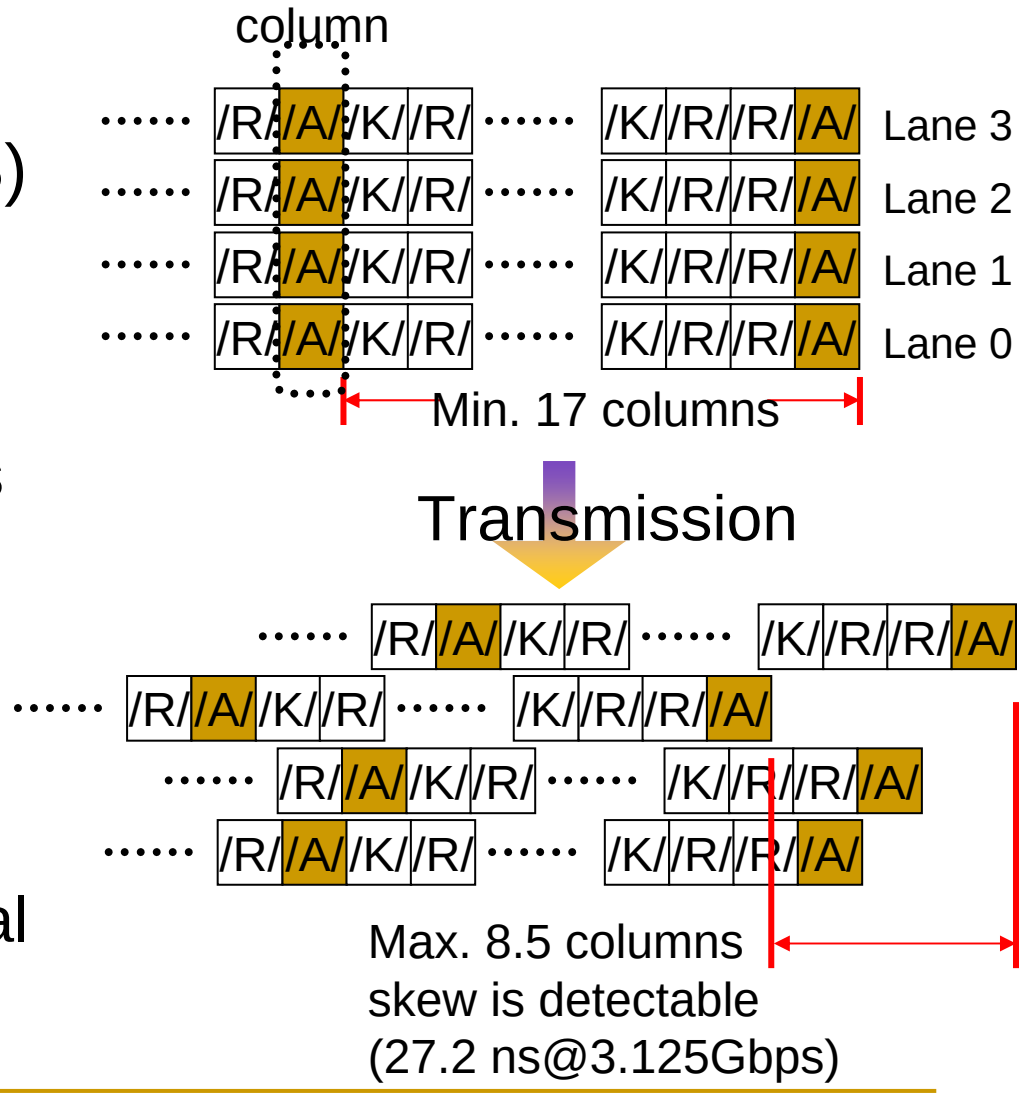
- Max. skew
  - CWDM (4 wavelengths: 13xx nm): 34 ns (80 km)
  - Short reach: 10 ribbon fiber: 30 ns (300 m)



Example: 25.78 Gbps x 4 lanes

Skew compensation mechanism (in case of XAUI)

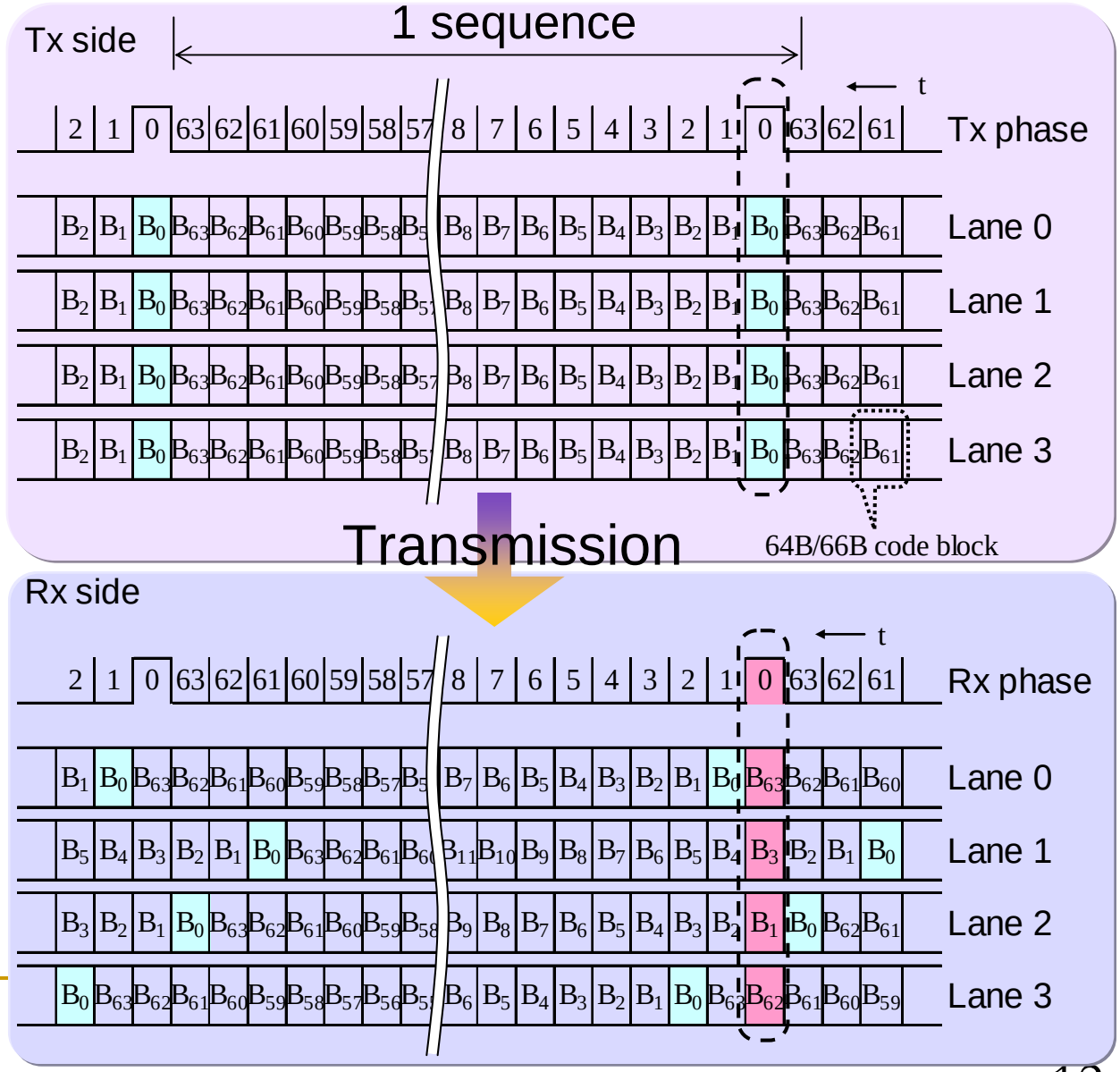
- XAUI (10GBASE-X PCS) uses the Idle sequence for skew compensation
  - Transmitter: outputs the periodical align columns
  - Receiver: detects skew based on phase difference of received sequences
  - Maximum skew value is less than half the interval between align columns



/A/: Align character (10 bits)
/K/: Sync character
/R/: Skip character

Skew compensation mechanism (for HSSG)

- Uses Idle sequence like the XAUI, but uses 64B/66B code
- TX side:
  Same regular idle sequence is output to all lanes at the same time
- RX side:
  Skew between lanes is detected based on phase difference between received sequences and internal phase in Rx



Example of IDLE sequence patterns

- Max skew: 34 ns (840 bits @25 Gbps, 14 blocks of 64B/66B code
  - Period of idle sequence pattern: >28 sets
  - Example: 64 sets of 64B/66B code blocks (8 Bytes per block)
    - Each 64 codes consist of combinations of six '/I/'s and '/K/'s
- Idle sequence patterns consist of '/I/' and '/K/' defined in 64B/66B
  - /K/ is reserved control character in 10GBASE-R PCS

Phase	Block	Block payload							
		C_0	C_1	C_2	C_3	C_4	C_5	C_6	C_7
0	B0	**/I/**	**/I/**	**/I/**	**/I/**	**/I/**	**/I/**	**DC**	**DC**
1	B1	**/K/**	**/I/**	**/I/**	**/I/**	**/I/**	**/I/**	**DC**	**DC**
2	B2	**/I/**	**/K/**	**/I/**	**/I/**	**/I/**	**/I/**	**DC**	**DC**
3	B3	**/K/**	**/K/**	**/I/**	**/I/**	**/I/**	**/I/**	**DC**	**DC**
4	B4	**/I/**	**/I/**	**/K/**	**/I/**	**/I/**	**/I/**	**DC**	**DC**
5	B5	**/K/**	**/I/**	**/K/**	**/I/**	**/I/**	**/I/**	**DC**	**DC**
6	B6	**/I/**	**/K/**	**/K/**	**/I/**	**/I/**	**/I/**	**DC**	**DC**
7	B7	**/K/**	**/K/**	**/K/**				**DC**	**DC**
56	B56	**/I/**	**/I/**	**/I/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**
57	B57	**/K/**	**/I/**	**/I/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**
58	B58	**/I/**	**/K/**	**/I/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**
59	B59	**/K/**	**/K/**	**/I/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**
60	B60	**/I/**	**/I/**	**/K/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**
61	B61	**/K/**	**/I/**	**/K/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**
62	B62	**/I/**	**/K/**	**/K/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**
63	B63	**/K/**	**/K/**	**/K/**	**/K/**	**/K/**	**/K/**	**DC**	**DC**

DC: Don't care

Idle sequence insert scheme

- No data: the IDLE sequences are continuously inserted
- Data frames : written over IDLE sequences.
- Skew detection
  - Over 32-byte IFG: detectable in all lanes
  - 12-byte IFG: detectable in only one lane

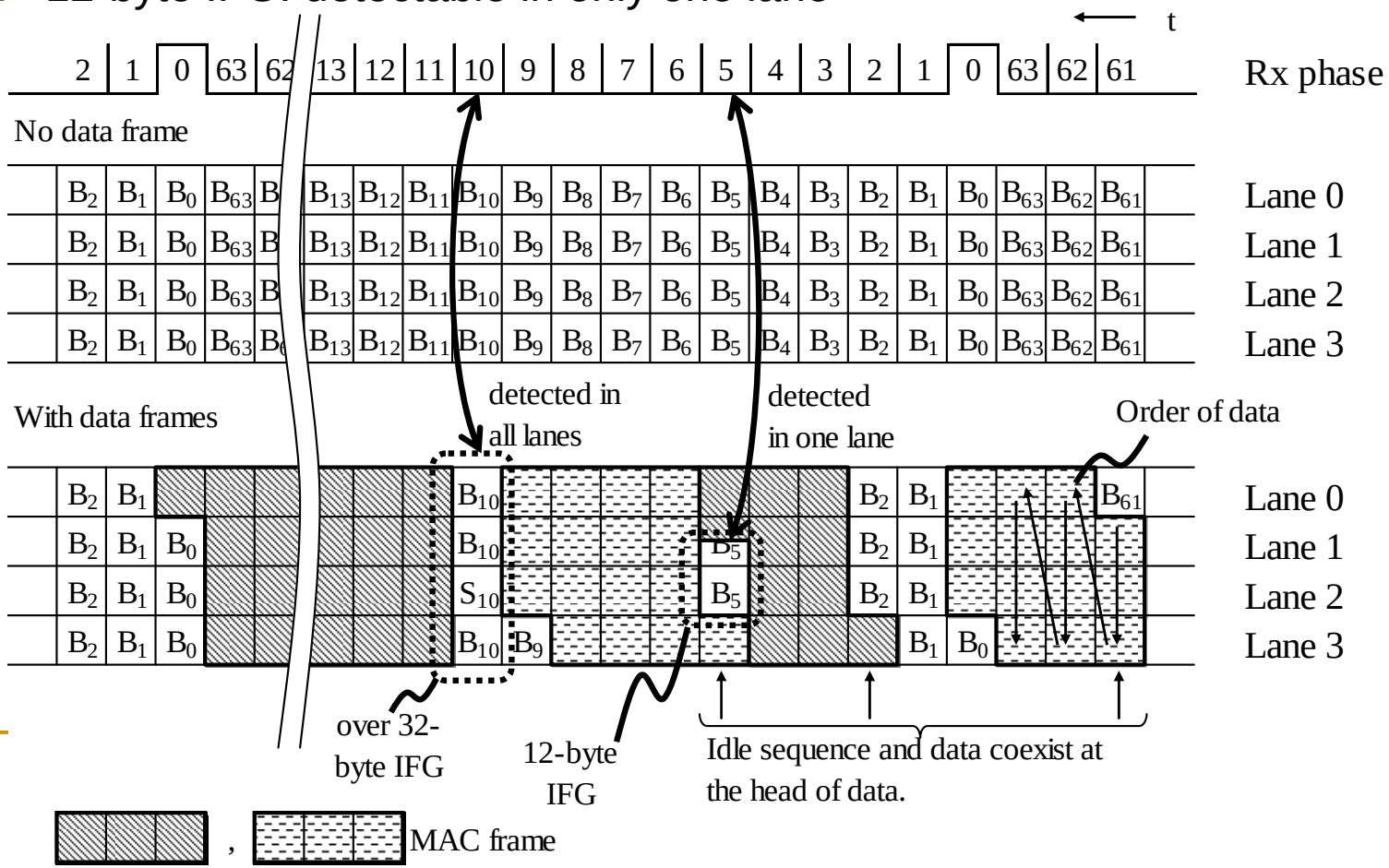
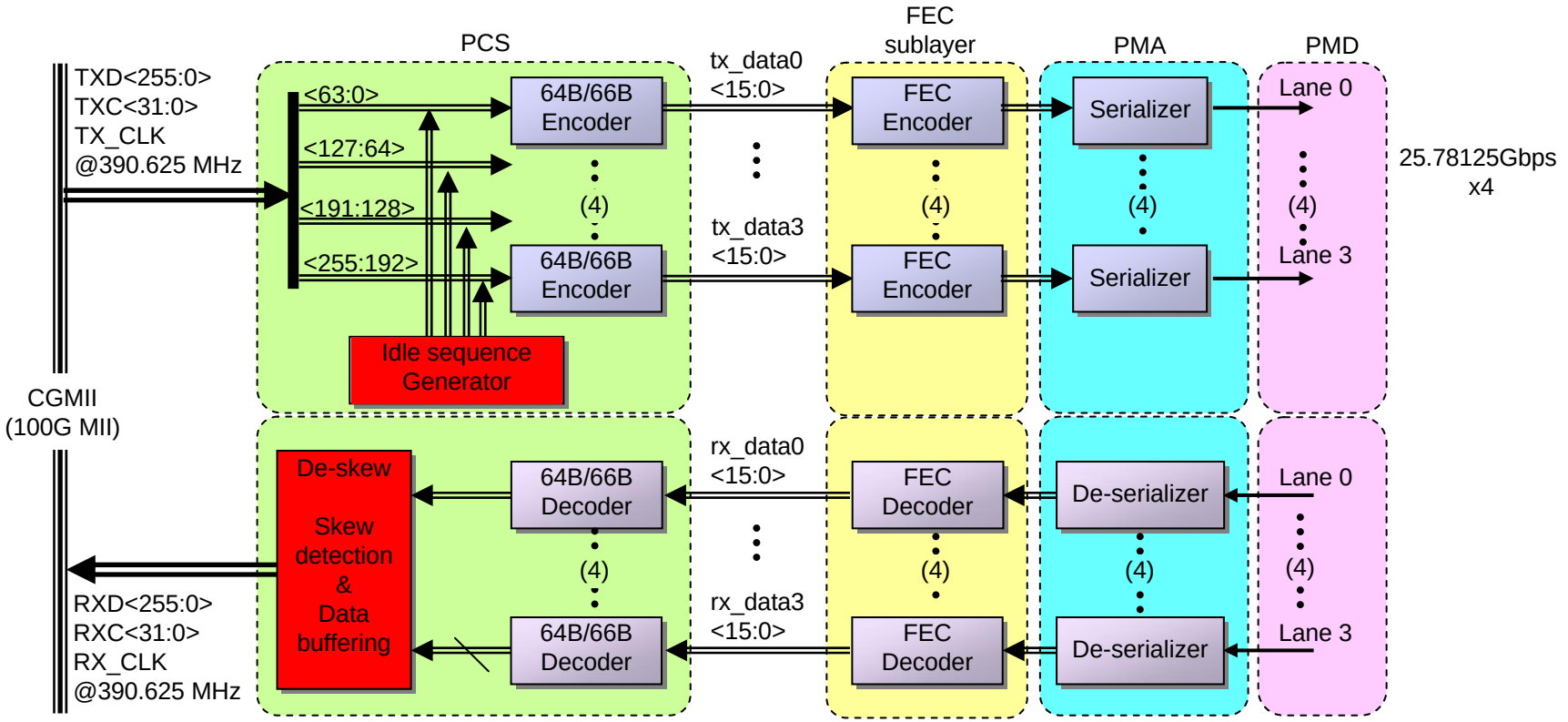


Diagram of physical coding sublayer



- Deskew: done after 64B/66B decoding (it uses idle sequence)
- FEC (for example, 10GBASE-KR)
  - FEC decoding is done before 64B/66B decoding
  - Well suited to 64B/66B coding, data rate is not increased

Benefits of skew compensation method

- No overhead of bandwidth
- No modification to 64B/66B code
  - We use idle and reserved control characters of 64B/66B
- Adjustable to any number of PMD lanes
  - PCS: specialized to each PMD
- Simple PMA (only SerDes)

Summary

- Skew of parallel link
  - CWDM: ~40 ns, Ribbon: ~30 ns
- Skew compensation mechanism
  - 64B/66B-based frame synchronization
    - Insert 64 sets of 8-byte special data pattern into IFG
    - Compensate for 82 ns of skew
    - Adjustable to any number of PMD lanes