

# 100ギガビットイーサネットについて

株式会社インターネットイニシアティブ  
ネットワークサービス部技術開発課  
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# 話の流れ

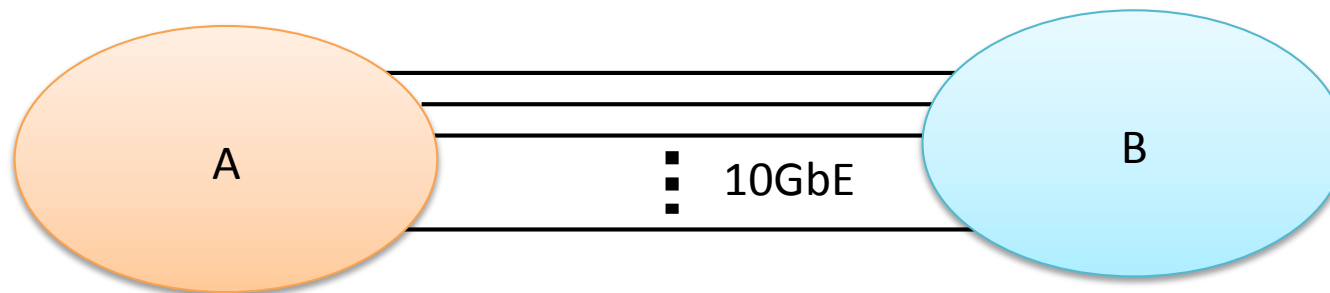
- 100GbE導入の必要性
- 100GbEの仕組みの概要
- IIJでの導入事例
- 運用上の問題点
- 100GbEの今後の動向

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# 100GbE導入の必要性

- IIJでは10Gを超えるトラフィックの拠点間は10GbE x N で接続
  - 安価なコストで大量にトラフィックを処理できる



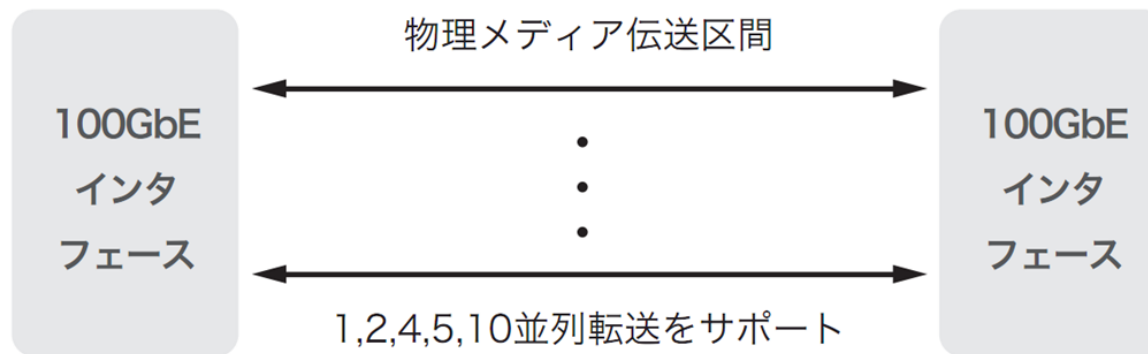
- 運用上の問題点
  - リンク数/ルータ数が多くなる
  - Link Aggregation(LAG)/L3 マルチパスの弊害
    - ユーザトラフィックがどこを通過しているのか追いきれない
  - トラフィックバランスの偏り
- 100GbE化で集約することでシンプルな構成に
  - 安定した運用可能な堅牢なネットワーク

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# 100GbEの重要な点

- 物理メディアの伝送区間を任意のレーン数で運べるようにした
  - 100Gを1波長は技術的/コスト的に厳しいものがあるため
  - MLD (Multi Lane Distribution) で実現
    - これ以外はほぼ 10G Ethernet の技術を利用
- 物理メディア/レーン数によって規格が複数存在



利用されている並列伝送

- 10x10Gbps: 複数の光ファイバを利用
- 4x25Gbps: 波長多重で一对の光ファイバを利用

# 主要な規格

|                | IEEE 40G    | IEEE 100G     | 10x10 MSA 100G |
|----------------|-------------|---------------|----------------|
| Backplane 1m   | 40GBASE-KR4 | N/A           | N/A            |
| Copperケーブル 7m  | 40GBASE-CR4 | 100GBASE-CR10 | N/A            |
| MMF(OM3) 100m  | 40GBASE-SR4 | 100GBASE-SR10 | N/A            |
| SMF 2km        | 40GBASE-FR  | N/A           | 10x10-2km      |
| SMF 10km       | 40GBASE-LR4 | 100GBASE-LR4  | 10x10-10km     |
| SMF 40km(30km) | N/A         | 100GBASE-ER4  | 10x10-40km     |

(注1) MMF(OM3) 100m は、MPOコネクタ/ケーブルを利用  
40Gは12芯、100Gは24芯

(注2) xxx-LR4/ER4 は4波長 CWDM を利用

(注3) 10x10 MSA は IEEE 準拠ではない独自規格

# 100GbEのOSI参照モデル

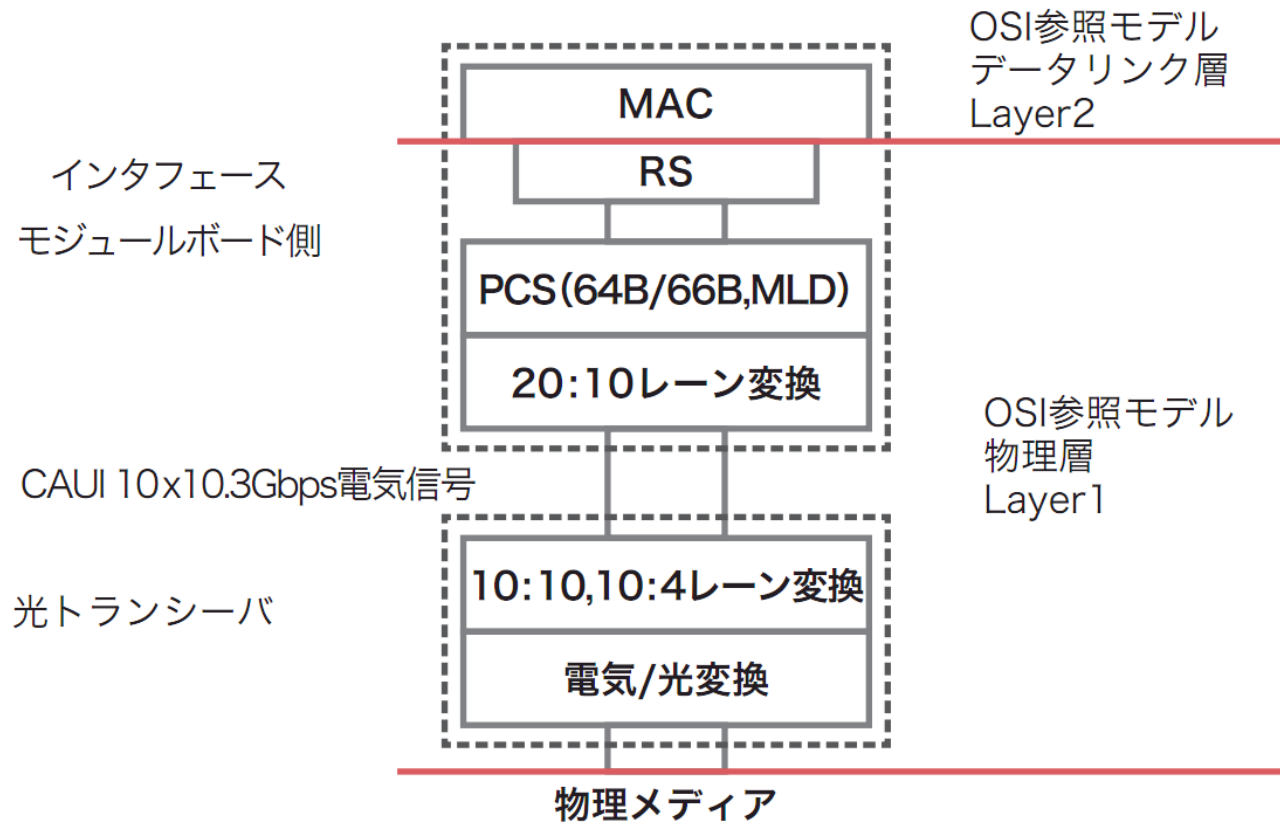


図-2 100GBASE-SR10/LR4/ER4概略図

# RS+PCS(64B/66B,MLD)

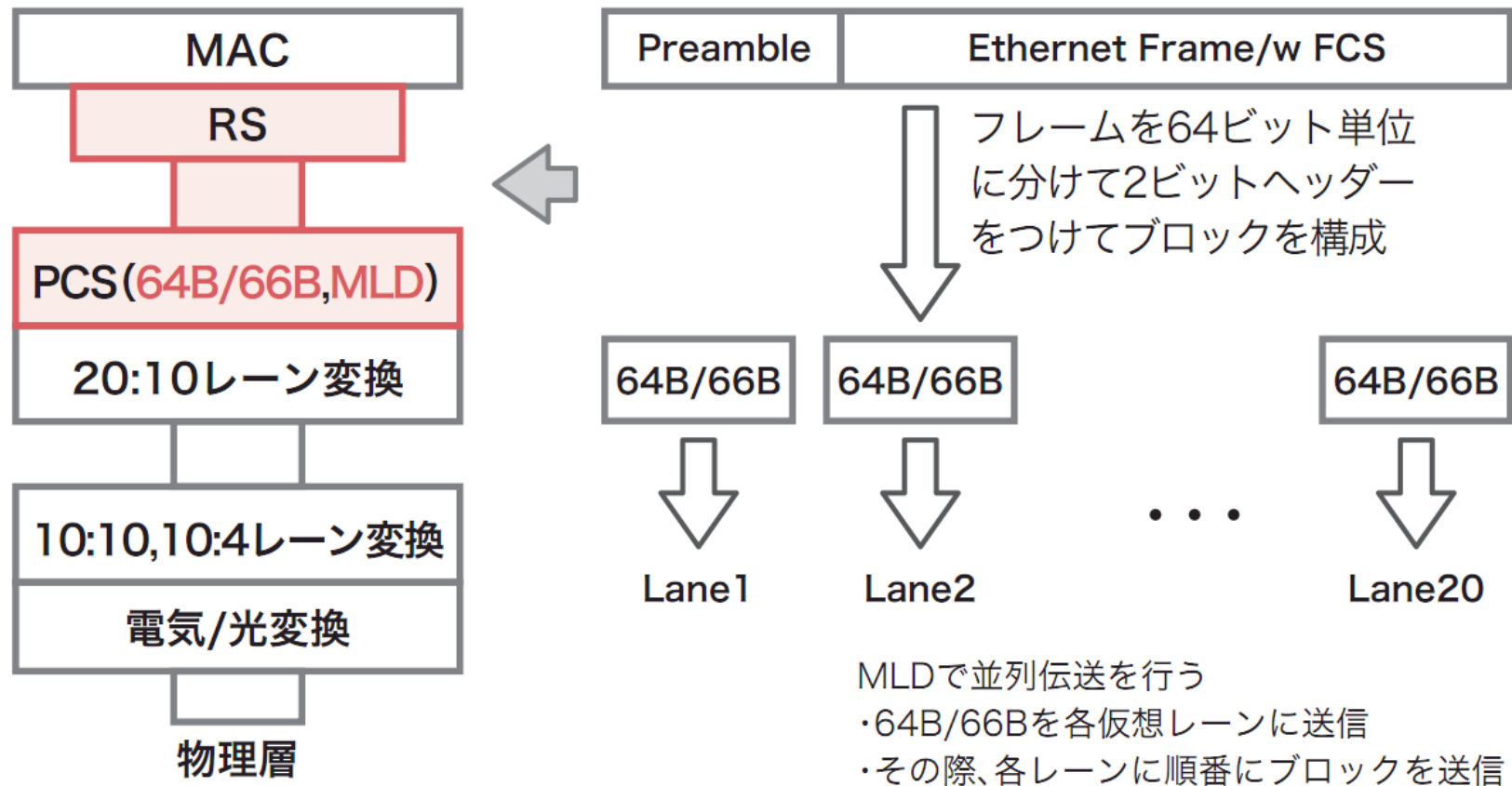


図-3 RS+PCS(64B/66B, MLD)

# レーンの多重/分離

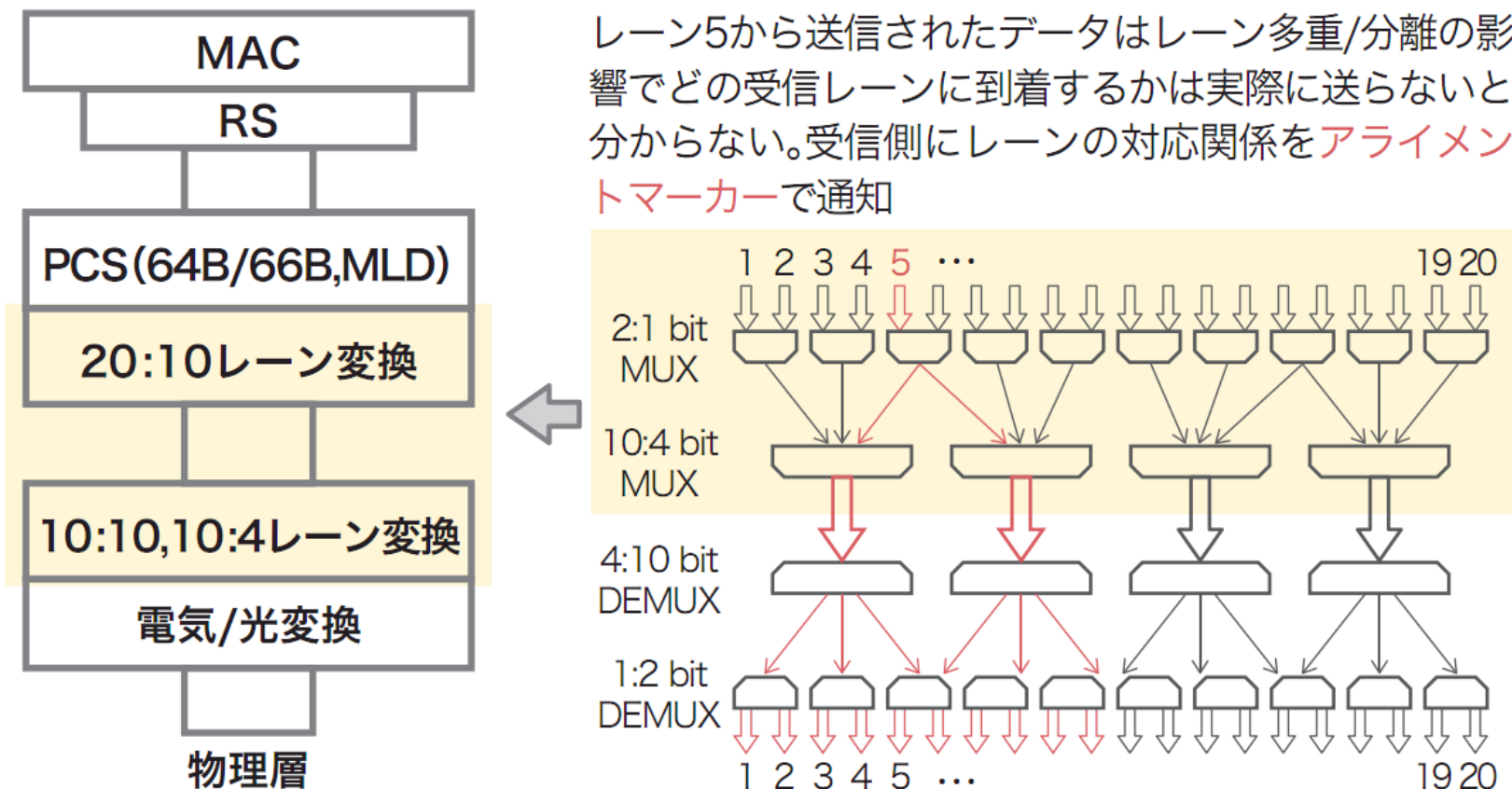


図-4 レーン多重/分離による送受信レーンの関係

# アライメントマーカー

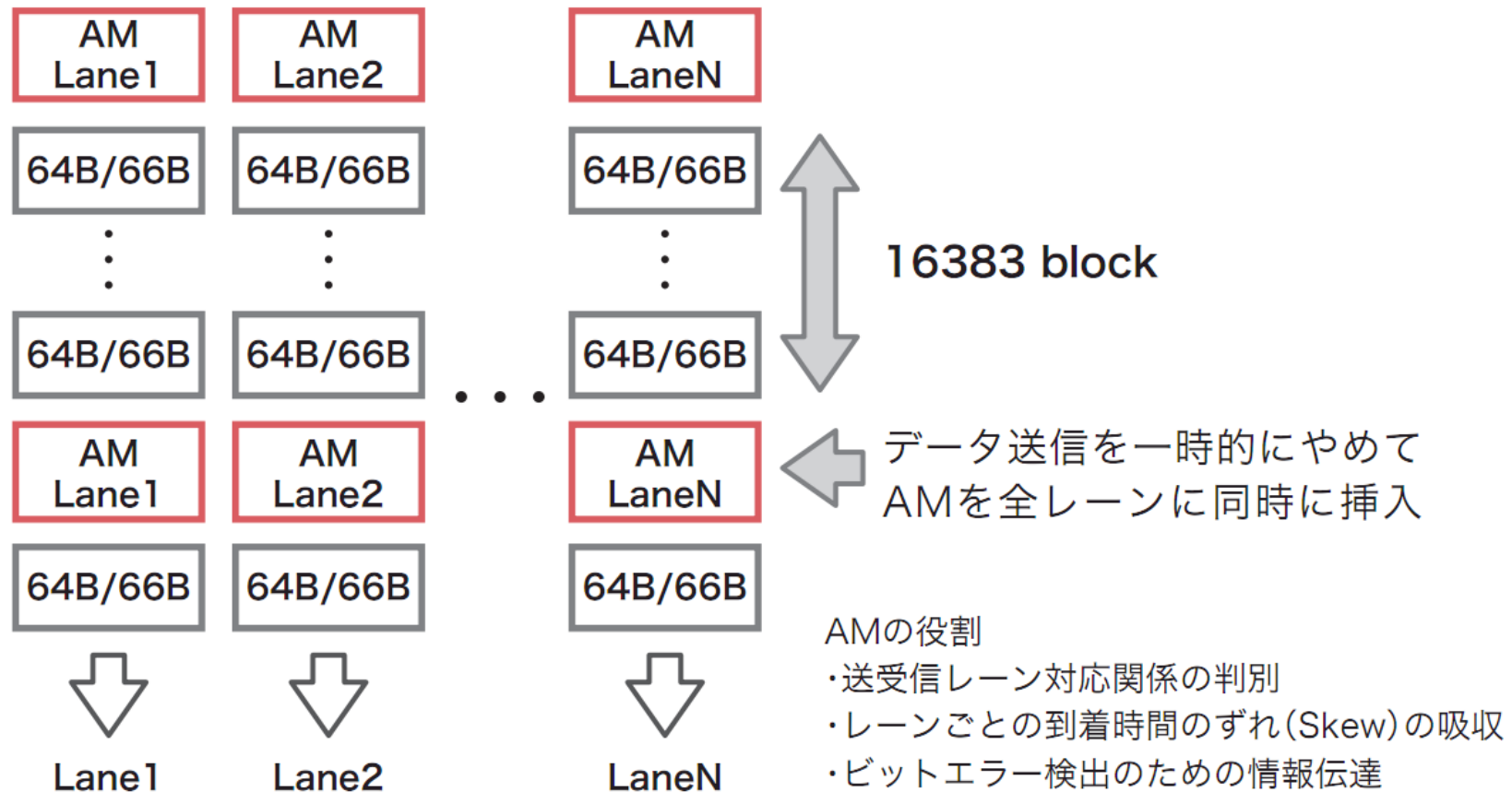


図-5 アライメントマーカー(AM)

# BIP(Bit Interleaved Parity)

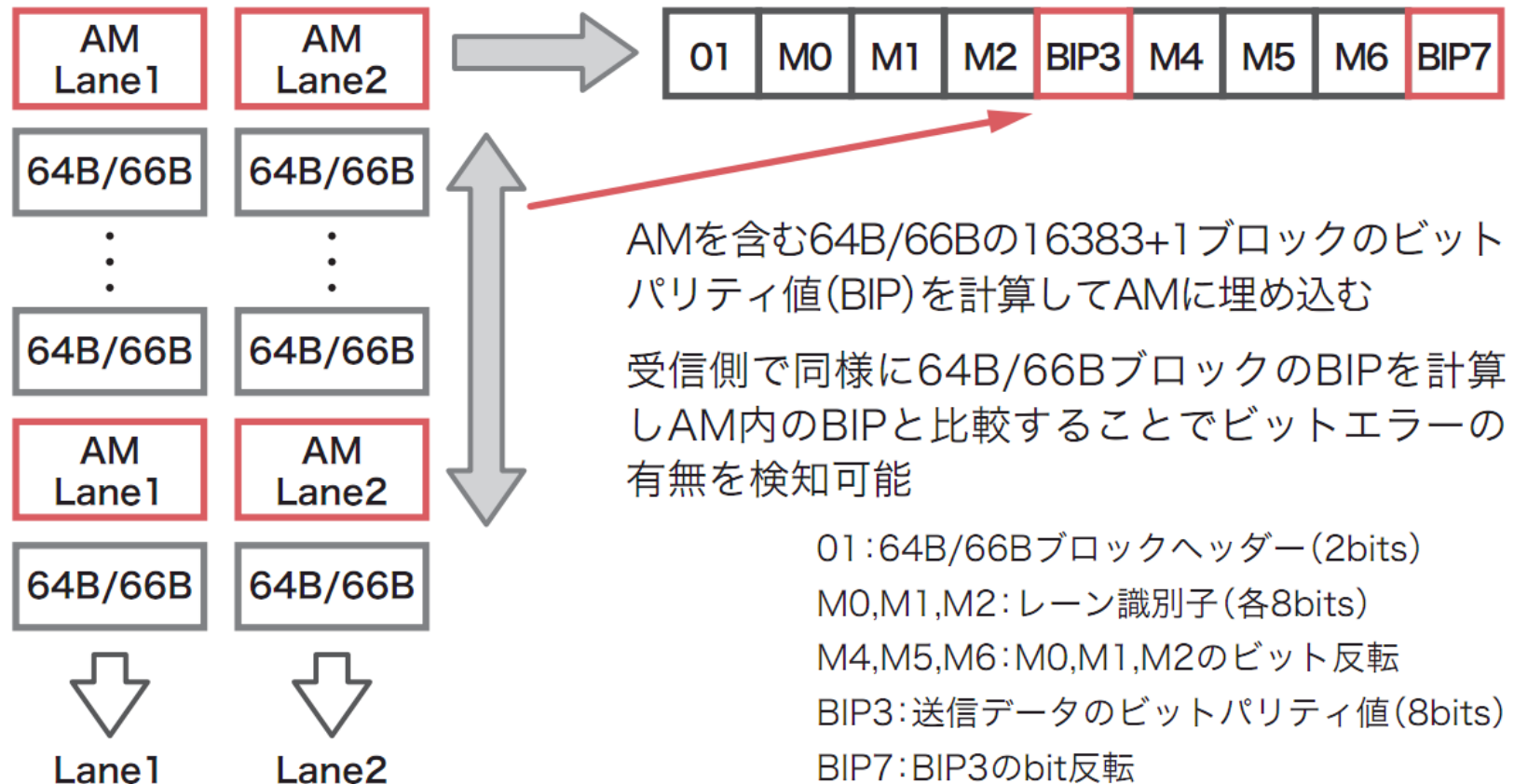
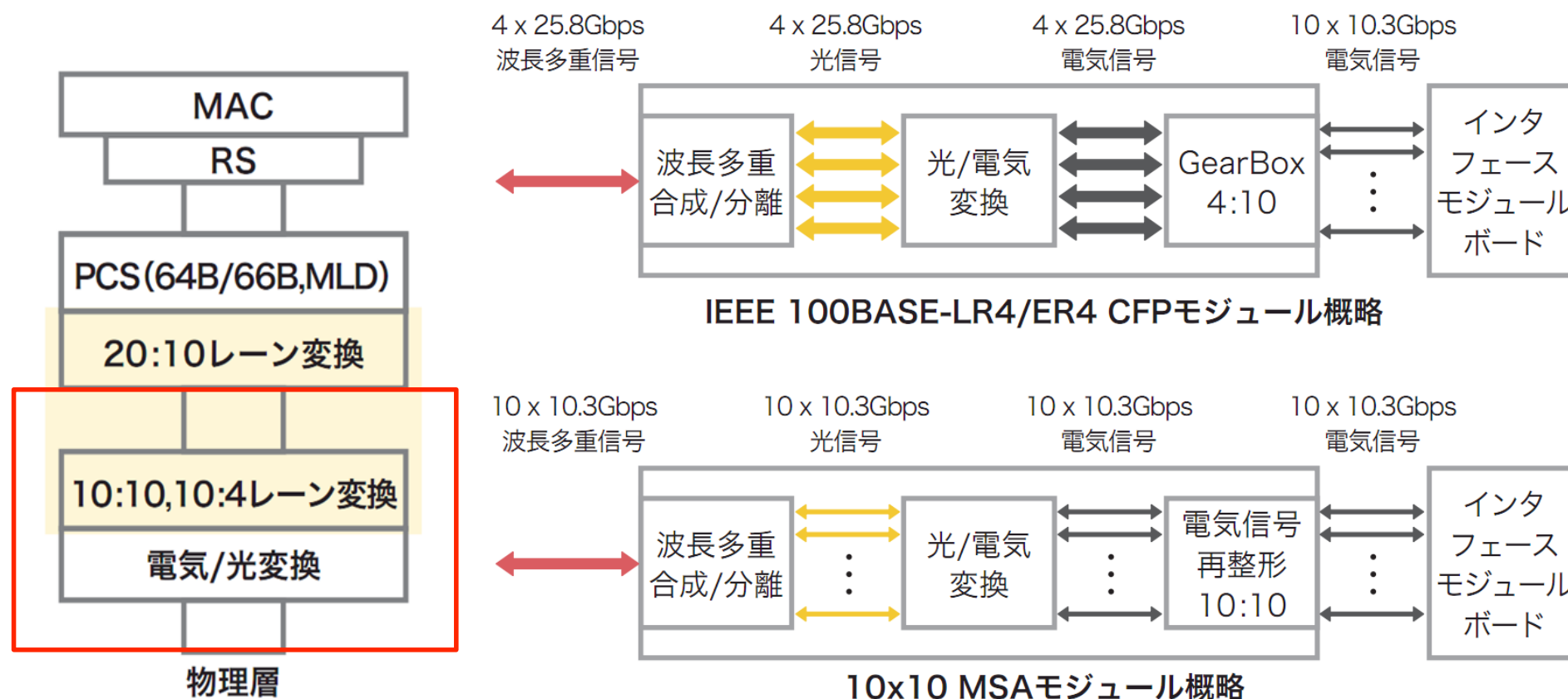


図-6 アライメントマーカとBIPの関係

# 光トランシーバ部分



(注1) 100GBASE-SR10 CFPは10x10 MSAの波長多重をなしで、ファイバx20で送受信

(注2) 100GBASE-SR10 CXPはCFP版から電気信号再整形部分を削除したもの

# 100GbEの光トランシーバ

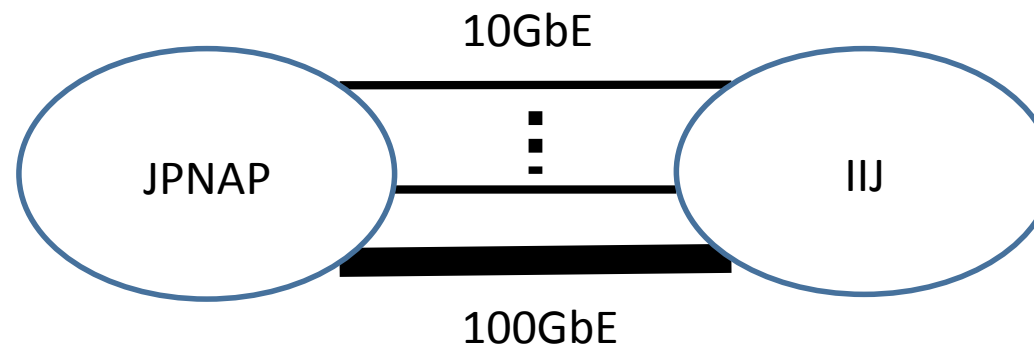
- 光トランシーバの形状等の詳細な規格はIEEEでは規定していない
  - 業界団体が詳細を規定
- CFP → <http://www.cfp-msa.org/>
  - 40GBASE-SR4/40GBASE-LR4
  - 100GBASE-SR10/100GBASE-LR4
- 10x10 MSA → <http://www.10x10msa.org/>
  - IEEE非準拠CFP
  - 10x10-2km/10x10-10km
- CXP → [http://members.infinibandta.org/kwspub/specs/register/publicspec/CXP\\_Spec.Release.pdf](http://members.infinibandta.org/kwspub/specs/register/publicspec/CXP_Spec.Release.pdf)
  - 100GBASE-SR10
- QSFP+ → <ftp://ftp.seagate.com/pub/sff/SFF-8436.PDF>
  - 40GBASE-SR4/40GBASE-LR4

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- 100GbE導入の必要性
- 100GbEの仕組みの概要
- IIIでの導入事例
- 運用上の問題点
- 100GbEの今後の動向

# IIJでの導入事例

- IIJは2012年8月6日から商用IX「JPNAP東京」との100GbE接続を開始



- IX接続10GbExNの一部を 100GbE で
- 接続まで
  - 動作検証: 4月～6月
  - 接続準備: 6月～8月
  - 8/6 JPNAP接続をアナウンス

# 話の流れ

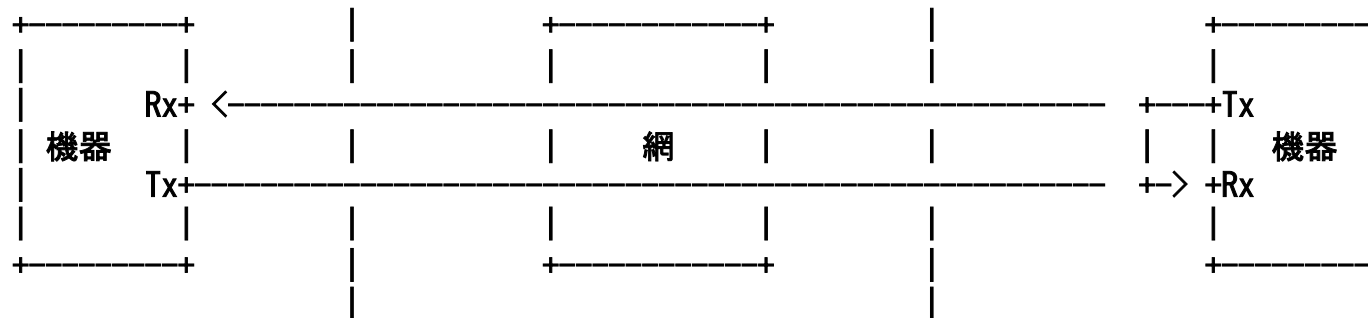
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# 1. ルータの安定性

- ファームウェア問題
  - 100GbE インターフェースを収容するカードは最新のファームでないに対応してない
    - 最新ファームは不具合が...
    - 100GbEの利用ユーザが少ないため不具合が...
      - IIIでもかなり苦労しています
  - 導入ユーザが増えてバグ出しが進んで安定することを期待

## 2. 100GbEでリンクエラーの切り分け

- BIPカウンター表示対応していない機器が多い
  - BIPカウンターでリンクエラーの切り分けが容易に
    - 100GbEではEthernetフレームを送信してない場合でも、空データを送信し続けている
    - ハードループ作り、BIPを見ればエラーの有無がわかる



- 隠しコマンドでBIPが見れる場合も...
  - ベンダーに正式対応してもらえるように働きかけが必要
- SNMPでBIPエラーをとれる実装は今だになし

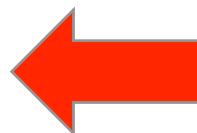
## 2. 100GbEでリンクエラーの切り分け2

(BIPカウンター参考)

```
RP/0/RP0/CPU0:cisco_CRS#sh controller hundredGigE 0/1/0/0 phy
```

PCS Lane BIP Error Counters:

|             |              |
|-------------|--------------|
| Lane-0 : 0  | Lane-10 : 0  |
| Lane-1 : 31 | Lane-11 : 0  |
| Lane-2 : 0  | Lane-12 : 0  |
| Lane-3 : 0  | Lane-13 : 39 |
| Lane-4 : 52 | Lane-14 : 0  |
| Lane-5 : 0  | Lane-15 : 0  |
| Lane-6 : 0  | Lane-16 : 0  |
| Lane-7 : 0  | Lane-17 : 46 |
| Lane-8 : 39 | Lane-18 : 0  |
| Lane-9 : 0  | Lane-19 : 0  |



可変アッテネータを入れ信号を劣化させた場合の試験

5レーンでBIPエラーが発生  
→ 特定の1波長で正常に受信が出来なくなっている可能性を示す

```
Total PCS Lane BIP Error Count : 207
Total PCS Lane Sync Header Error Count : 13
Total PCS Lane Bad 64/66 Code Count : 204
```

# 3. 100GBASE-LR4の運用問題

- CWDM4レーン。シングルモードファイバー
  - CWDMのため光が強い
    - 規格上TXパワー : +4dBm - +10dBm
    - パワーメータの受光レベル上限を超えることも
  - CWDM光から波長毎の強さがわからない
    - 通常の光パワーメータで測れない
    - 1波長の光が消えていてもCWDM光が強いので分からない
    - 機器側でのレーン単位での受光確認機能がないと困る
- 端面の汚れに非常に敏感
  - エラーが乗りやすいので扱い要注意

# 4. 100GBASE-SR10の運用問題

- 光10レーンx2。MPOコネクタ24芯MMF利用

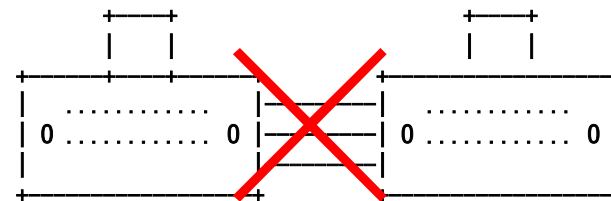
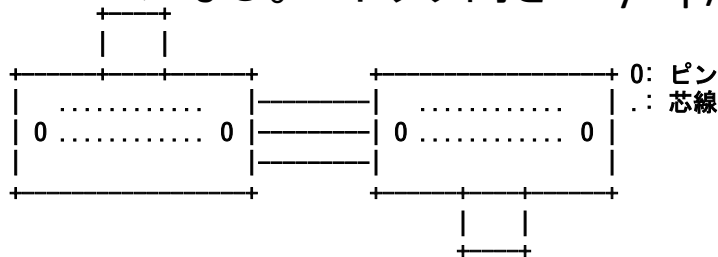
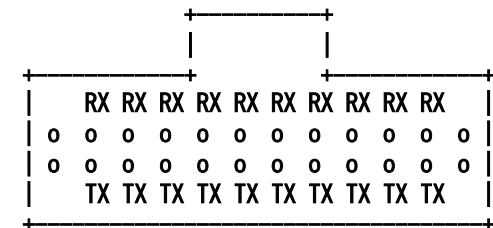
- 24芯MMFケーブルは高価
- 1芯線分でもだめになれば通信できない

- MPOコネクタ

- 光レベル測定に専用のパワーメータが必要
- 光トランシーバ/MPOコネクタ端面清掃に専用クリーナが必要

- 利用ケーブルに注意

- ピンなし。コネクタ向き Key Up/Key Down が必要。



- リンクエラー切り分けの際にループバックアダプタが必須

- TX<->RXを接続するコネクタ
- これなしで光トランシーバ/ケーブルの切り分けが難しい

## 5. 光トランシーバの予備をどうするか

- いざ予備を使おうとした時に使えないと困る
  - 100GBASE-LR4では内部で様々な部品が使われているので壊れる可能性が高くなる
  - 基本予備を持つ必要がある
    - 価格が高いため予備をたくさん持てない
  - 予備が壊れていた場合、代替品の入手がすぐに難しい場合も
    - 100GBASE-LR4のCFPは急速に出荷数が増えて製造が追いついてないとの話も
  - 予備であっても、自分の光を自分でループバックしてトランシーバの正常性を常時監視しておく必要性も

## 6. 中距離伝送が難しい問題

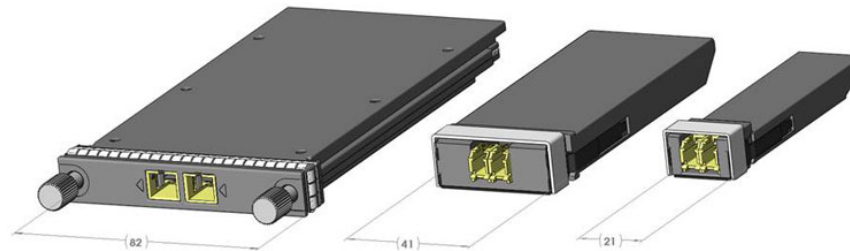
- 拠点間のトラフィックを100GbE で集約して飛ばしたい
  - 10GbExNと比較して経済的な価格である程度の距離を飛ばす必要が
- 100GBASE-LR4 -> 6.3dBのロス进行想定
  - 構内接続はOK
  - ダークファイバーで拠点間接続では厳しい
- 100GBASE-ER4 -> 18dBのロス进行想定
  - ダークファイバーなどである程度の距離はいけそう
  - しかし、ルータベンダー側でまだ対応していない
  - 市場にも製品がほとんどでてない
  - 価格問題
- 100GbEのキャリア回線
  - コストは...
- 100GbE対応伝送装置
  - 現状拠点間接続したいならこれ。コストは...

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# 100GbEの今後の動向

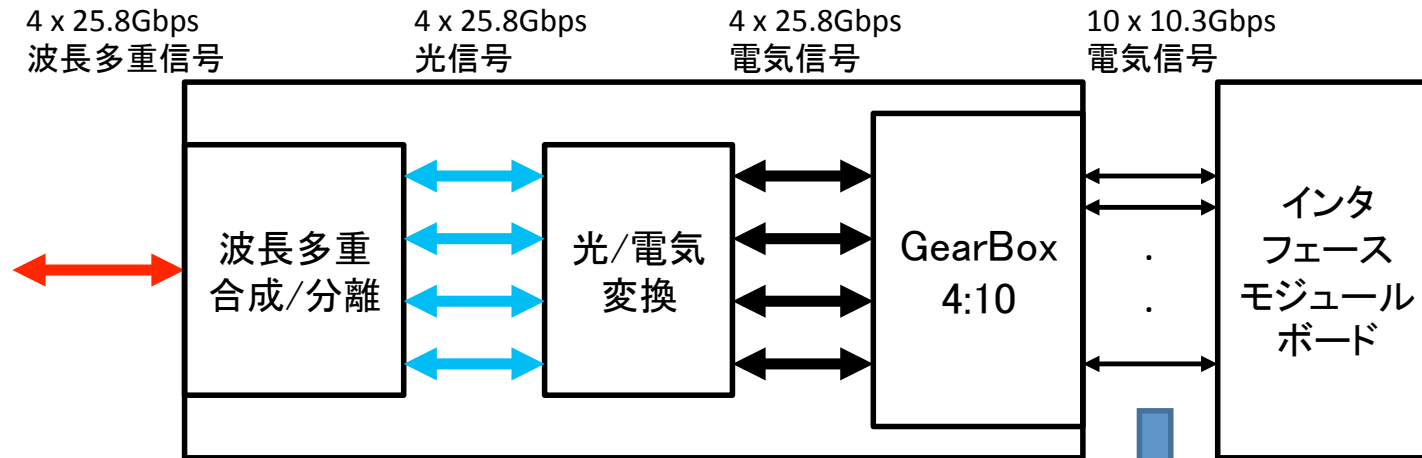
- 光トランシーバの小型化
  - CFP2/CFP4



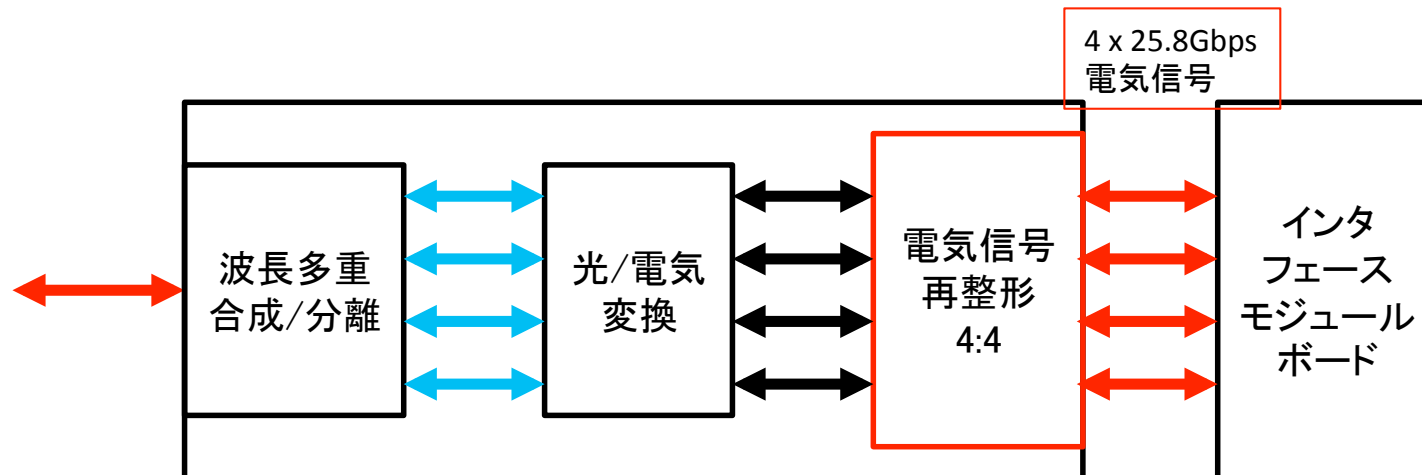
(引用元) <http://www.cfp-msa.org/>

- CAUI-4
  - 電気信号を 10x10.8Gbps -> 4x25.8Gbps に変更
  - 高価な Gearebox チップが排除可能に
- 新たな光インターフェース
  - 100GBASE-SR4
  - 100GBASE-nR4
  - 40GBASE-ER4

# CAUI-4とCFP2/CFP4



IEEE 100GBASE-LR4/ER4 CFPモジュール概略



IEEE 100GBASE-LR4/ER4 CFP2モジュール構造

# 新たな光インターフェース規格

- 新たな規格の策定
  - 100GBASE-SR4 : CFP2/4世代に向けて
  - 100GBASE-nR4 : LR4よりも低コストのI/F
  - 40GBASE-ER4 : 40Gでも距離を飛ばしたい

|                | IEEE 40G    | IEEE 100G                     | 10x10 MSA 100G |
|----------------|-------------|-------------------------------|----------------|
| MMF(OM3) 100m  | 40GBASE-SR4 | 100GBASE-SR10<br>100GBASE-SR4 | N/A            |
| SMF 2km        | 40GBASE-FR  | 100GBASE-nR4                  | 10x10-2km      |
| SMF 10km       | 40GBASE-LR4 | 100GBASE-LR4                  | 10x10-10km     |
| SMF 40km(30km) | 40GBASE-ER4 | 100GBASE-ER4                  | 10x10-40km     |

(参考) [http://www.itu.int/dms\\_pub/itu-t/oth/06/5B/T065B0000320014PDFE.pdf](http://www.itu.int/dms_pub/itu-t/oth/06/5B/T065B0000320014PDFE.pdf)

# 質疑応答

# 付録

- 光レベルのOMA表記について
- 100GBASE-LR4/ER4の光の仕様
- 40GBASE-LR4の光の仕様
- 10GBASE-Lの光の仕様
- 100GbEのBIPについて

# 光レベルのOMA表記について

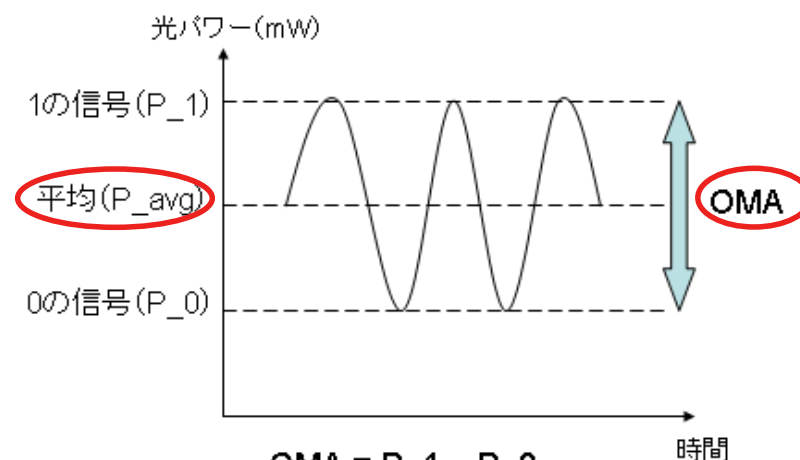
- IEEEの10G以降の規格では受光感度をOMAで定義
  - OMA (Optical Modulation Amplitude) の略
  - パワーメータやCLIで見れるのは平均パワーのみ
  - OMAが測定できないと受光レベルが規格値以上かの判定が出来ない

- 一般的なベンダーのCFPスペック  
受光平均パワー(波長単位)

min -10.6 (dBm) , max +4.5 (dBm)

**(注) 規格で光がこの範囲に収まっていることを要求しているが、受光感度を保障するものではない！**

- 受光感度 Stressed Receiver Sensitivity(OMA)  
= -6.8 (dBm)
- OMAから平均パワー換算での  
受光感度の下限(消光比=4(dB)で)  
= -6.2 (dBm)



$$OMA = P_1 - P_0$$

$$\text{消光比 } R_e = \frac{P_1}{P_0}$$

$$P_{ave} = (P_1 + P_0) / 2$$

$$P_{ave} = 0.5 \times OMA \times \frac{(R_e + 1)}{(R_e - 1)}$$

(注) 上式はmW単位を仮定 (mW)=10<sup>[(dBm)/10]</sup>

# 100GBASE-LR4/ER4の光周りの仕様(引用元IEEE802.3ba)

Table 88-7—100GBASE-LR4 and 100GBASE-ER4 transmit characteristics

| Description                                                              | 100GBASE-LR4                                                                         | 100GBASE-ER4 | Unit  |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------|-------|
| Signaling rate, each lane (range)                                        | 25.78125 ± 100 ppm                                                                   |              | GBd   |
| Lane wavelengths (range)                                                 | 1294.53 to 1296.59<br>1299.02 to 1301.09<br>1303.54 to 1305.63<br>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 <sup>a</sup> (min)                       | -4.3                                                                                 | -2.9         | dBm   |
| Optical Modulation Amplitude (OMA), each lane (max)                      | 4.5                                                                                  |              | dBm   |
| Optical Modulation Amplitude (OMA), each lane (min)                      | -1.3 <sup>b</sup>                                                                    | 0.1          | dBm   |
| Difference in launch power between any two lanes (OMA) (max)             | 5                                                                                    | —            | dB    |
| Difference in launch power between any two lanes (Average and OMA) (max) | —                                                                                    | 3.6          |       |
| 平均パワー -1.7 (dBm) (R <sub>e</sub> =4)                                     |                                                                                      |              |       |
| Launch power in OMA minus TDP, each lane (min)                           | -2.3                                                                                 | —            | dBm   |
| Transmitter and dispersion penalty (TDP), each lane (max)                | 2.2                                                                                  | 2.5          | dB    |
| Average launch power of OFF transmitter, each lane (max)                 | -30                                                                                  |              | dBm   |
| Extinction ratio (min)                                                   | 4                                                                                    | 8            | dB    |
| RIN <sub>20</sub> OMA (max)                                              | -130                                                                                 |              | dB/Hz |
| Optical return loss tolerance (max)                                      | 20                                                                                   |              | dB    |
| Transmitter reflectance <sup>c</sup> (max)                               | -12                                                                                  |              | dB    |
| Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}                 | {0.25, 0.4, 0.45, 0.25, 0.28, 0.4}                                                   |              |       |

<sup>a</sup>Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.

<sup>b</sup>Even if the TDP < 1 dB, the OMA (min) must exceed this value.

<sup>c</sup>Transmitter reflectance is defined looking into the transmitter.

Table 88-8—100GBASE-LR4 and 100GBASE-ER4 receive characteristics

| Description                                                                           | 100GBASE-LR4                                                                         | 100GBASE-ER4 | Unit |
|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------|------|
| Signaling rate, each lane (range)                                                     | 25.78125 ± 100 ppm                                                                   |              | GBd  |
| Lane wavelengths (range)                                                              | 1294.53 to 1296.59<br>1299.02 to 1301.09<br>1303.54 to 1305.63<br>1308.09 to 1310.19 |              | nm   |
| Damage threshold <sup>a</sup>                                                         | 5.5                                                                                  |              | dBm  |
| Average receive power, each lane (max)                                                | 4.5 <sup>b</sup>                                                                     |              | dBm  |
| Average receive power, each lane <sup>c</sup> (min)                                   | -10.6                                                                                | -20.9        | dBm  |
| Receive power, each lane (OMA) (max)                                                  | 4.5                                                                                  |              | dBm  |
| Difference in receive power between any two lanes (OMA) (max)                         | 5.5                                                                                  | —            | dB   |
| Difference in receive power between any two lanes (Average and OMA) (max)             | —                                                                                    | 4.5          |      |
| Receiver reflectance (max)                                                            | -26                                                                                  |              | dB   |
| Receiver sensitivity (OMA), each lane <sup>d</sup> (max)                              | -8.6                                                                                 | -21.4        | dBm  |
| Receiver 3 dB electrical upper cutoff frequency, each lane (max)                      | 31                                                                                   |              | GHz  |
| Stressed receiver sensitivity (OMA), each lane <sup>e</sup> (max)                     | -6.8                                                                                 | -17.9        | dBm  |
| Conditions of stressed receiver sensitivity test 平均パワー -6.2 (dBm) (R <sub>e</sub> =4) |                                                                                      |              |      |
| Vertical eye closure penalty, <sup>f</sup> each lane                                  | 1.8                                                                                  | 3.5          | dB   |
| Stressed eye J2 Jitter, <sup>f</sup> each lane                                        | 0.3                                                                                  |              | UI   |
| Stressed eye J9 Jitter, <sup>f</sup> each lane                                        | 0.47                                                                                 |              | UI   |

<sup>a</sup>The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.

<sup>b</sup>The average receive power, each lane (max) for 100GBASE-ER4 is larger than the 100GBASE-ER4 transmitter value to allow compatibility with 100GBASE-LR4 units at short distances.

<sup>c</sup>Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

<sup>d</sup>Receiver sensitivity (OMA), each lane (max) is informative.

<sup>e</sup>Measured with conformance test signal at TP3 (see 88.8.10) for BER = 10<sup>-12</sup>.

<sup>f</sup>Vertical eye closure penalty, stressed eye J2 Jitter, and stressed eye J9 Jitter are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

# 100GBASE-LR4/ER4の光周りの仕様 (引用元IEEE802.3ba)

Table 88–9—100GBASE-LR4 and 100GBASE-ER4 illustrative link power budgets

| Parameter                                               | 100GBASE-LR4     | 100GBASE-ER4 |                 | Unit |
|---------------------------------------------------------|------------------|--------------|-----------------|------|
| Power budget (for maximum TDP)                          | 8.5              | —            |                 | dB   |
| Power budget                                            | —                | 21.5         |                 | dB   |
| Operating distance                                      | 10               | 30           | 40 <sup>a</sup> | km   |
| Channel insertion loss                                  | 6.3 <sup>b</sup> | 15           | 18              | dB   |
| Maximum discrete reflectance                            | –26              | –26          |                 | dB   |
| Allocation for penalties <sup>c</sup> (for maximum TDP) | 2.2              | —            |                 | dB   |
| Allocation for penalties <sup>c</sup>                   | —                | 3.5          |                 |      |
| Additional insertion loss allowed                       | 0                | 3            | 0               | dB   |

<sup>a</sup>Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than the worst case for B1.1, B1.3, or B6\_A single-mode cabled optical fiber

<sup>b</sup>The channel insertion loss is calculated using the maximum distance specified in Table 88–6 for 100GBASE-LR4 and fiber attenuation of 0.43 dB/km at 1295 nm plus an allocation for connection and splice loss given in 88.11.2.1.

<sup>c</sup>Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

# 40GBASE-LR4の光周りの仕様(引用元 IEEE802.3ba)

Table 87-7—40GBASE-LR4 transmit characteristics

平均パワー -3.6(dBm) (R<sub>e</sub>=3.5)

| Description                                                      | Value                                                                        | Unit  |
|------------------------------------------------------------------|------------------------------------------------------------------------------|-------|
| Signaling rate, each lane (range)                                | 10.3125 ± 100 ppm                                                            | GBd   |
| Lane wavelengths (range)                                         | 1264.5 to 1277.5<br>1284.5 to 1297.5<br>1304.5 to 1317.5<br>1324.5 to 1337.5 | nm    |
| Side-mode suppression ratio (SMSR), (min)                        | 30                                                                           | dB    |
| Total average launch power (max)                                 | 8.3                                                                          | dBm   |
| Average launch power, each lane (max)                            | 2.3                                                                          | dBm   |
| Average launch power, each lane <sup>a</sup> (min)               | -7                                                                           | dBm   |
| Optical Modulation Amplitude (OMA), each lane (max)              | 3.5                                                                          | dBm   |
| Optical Modulation Amplitude (OMA), each lane (min) <sup>b</sup> | -4                                                                           | dBm   |
| Difference in launch power between any two lanes (OMA) (max)     | 6.5                                                                          | dB    |
| Launch power in OMA minus TDP, each lane (min)                   | -4.8                                                                         | dBm   |
| Transmitter and dispersion penalty (TDP), each lane (max)        | 2.6                                                                          | dB    |
| Average launch power of OFF transmitter, each lane (max)         | -30                                                                          | dBm   |
| Extinction ratio (min)                                           | 3.5                                                                          | dB    |
| RIN <sub>20</sub> OMA (max)                                      | -128                                                                         | dB/Hz |
| Optical return loss tolerance (max)                              | 20                                                                           | dB    |
| Transmitter reflectance <sup>c</sup> (max)                       | -12                                                                          | dB    |
| Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}         | {0.25, 0.4, 0.45, 0.25, 0.28, 0.4}                                           |       |

<sup>a</sup>Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.

<sup>b</sup>Even if the TDP < 0.8dB, the OMA (min) must exceed this value.

<sup>c</sup>Transmitter reflectance is defined looking into the transmitter.

Table 87-8—40GBASE-LR4 receive characteristics

平均パワー -8.4(dBm) (R<sub>e</sub>=3.5)

| Description                                                       | Value                                                                        | Unit |
|-------------------------------------------------------------------|------------------------------------------------------------------------------|------|
| Signaling rate, each lane (range)                                 | 10.3125 ± 100 ppm                                                            | GBd  |
| Lane wavelengths (range)                                          | 1264.5 to 1277.5<br>1284.5 to 1297.5<br>1304.5 to 1317.5<br>1324.5 to 1337.5 | nm   |
| Damage threshold <sup>a</sup> (min)                               | 3.3                                                                          | dBm  |
| Average receive power, each lane (max)                            | 2.3                                                                          | dBm  |
| Average receive power, each lane <sup>b</sup> (min)               | -13.7                                                                        | dBm  |
| Receive power, each lane (OMA) (max)                              | 3.5                                                                          | dBm  |
| Difference in receive power between any two lanes (OMA) (max)     | 7.5                                                                          | dB   |
| Receiver reflectance (max)                                        | -26                                                                          | dB   |
| Receiver sensitivity (OMA), each lane <sup>c</sup> (max)          | -11.5                                                                        | dBm  |
| Receiver 3 dB electrical upper cutoff frequency, each lane (max)  | 12.3                                                                         | GHz  |
| Stressed receiver sensitivity (OMA), each lane <sup>d</sup> (max) | -9.6                                                                         | dBm  |
| Conditions of stressed receiver sensitivity test:                 |                                                                              |      |
| Vertical eye closure penalty, <sup>e</sup> each lane              | 1.9                                                                          | dB   |
| Stressed eye J2 Jitter, <sup>e</sup> each lane                    | 0.3                                                                          | UI   |
| Stressed eye J9 Jitter, <sup>e</sup> each lane                    | 0.47                                                                         | UI   |

<sup>a</sup>The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level

<sup>b</sup>Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

<sup>c</sup>Receiver sensitivity (OMA), each lane (max) is informative.

<sup>d</sup>Measured with conformance test signal at TP3 (see 87.8.11) for BER = 10<sup>-12</sup>.

<sup>e</sup>Vertical eye closure penalty, stressed eye J2 Jitter, and stressed eye J9 Jitter are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

# 40GBASE-LR4の光周りの仕様 (引用元 IEEE802.3ba)

Table 87–9—40GBASE-LR4 illustrative link power budget

| Parameter                                           | Value | Unit |
|-----------------------------------------------------|-------|------|
| Power budget (for max TDP)                          | 9.3   | dB   |
| Operating distance                                  | 10    | km   |
| Channel insertion loss <sup>a</sup>                 | 6.7   | dB   |
| Maximum discrete reflectance                        | –26   | dB   |
| Allocation for penalties <sup>b</sup> (for max TDP) | 2.6   | dB   |
| Additional insertion loss allowed                   | 0     | dB   |

<sup>a</sup>The channel insertion loss is calculated using the maximum distance specified in Table 87–6 and cabled optical fiber attenuation of 0.47 dB/km at 1264.5 nm plus an allocation for connection and splice loss given in 87.11.2.1.

<sup>b</sup>Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

# 10GBASE-Lの光周りの仕様(引用元 IEEE 802.3ae)

Table 52-12—10GBASE-L transmit characteristics  
平均パワー -5.0(dBm) (R<sub>e</sub>=3.5)

| Description                                                | 10GBASE-LW                           | 10GBASE-LR | Unit  |
|------------------------------------------------------------|--------------------------------------|------------|-------|
| Signaling speed (nominal)                                  | 9.95328                              | 10.3125    | GBd   |
| Signaling speed variation from nominal (max)               | ± 20                                 | ± 100      | ppm   |
| Center wavelength (range)                                  | 1260 to 1355                         |            | nm    |
| Side Mode Suppression Ratio (min)                          | 30                                   |            | dB    |
| Average launch power (max)                                 | 0.5                                  |            | dBm   |
| Average launch power <sup>a</sup> (min)                    | -8.2                                 |            | dBm   |
| Launch power (min) in OMA minus TDP <sup>b</sup>           | -6.2                                 |            | dBm   |
| Optical Modulation Amplitude <sup>c</sup> (min)            | -5.2                                 |            | dBm   |
| Transmitter and dispersion penalty (max)                   | 3.2                                  |            | dB    |
| Average launch power of OFF transmitter <sup>d</sup> (max) | -30                                  |            | dBm   |
| Extinction ratio (min)                                     | 3.5                                  |            | dB    |
| RIN <sub>OMA</sub> (max)                                   | -128                                 |            | dB/Hz |
| Optical Return Loss Tolerance (max)                        | 12                                   |            | dB    |
| Transmitter Reflectance <sup>e</sup> (max)                 | -12                                  |            | dB    |
| Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}   | {0.25, 0.40, 0.45, 0.25, 0.28, 0.40} |            |       |

<sup>a</sup>Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.

<sup>b</sup>TDP is transmitter and dispersion penalty.

<sup>c</sup>Even if the TDP < 1 dB, the OMA(min) must exceed this value.

<sup>d</sup>Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD\_global\_transmit\_disable or other optional transmitter shut down conditions.

<sup>e</sup>Transmitter reflectance is defined looking into the transmitter.

Table 52-13—10GBASE-L receive characteristics  
平均パワー -9.1(dBm) (R<sub>e</sub>=3.5)

| Description                                                | 10GBASE-L          | Unit     |
|------------------------------------------------------------|--------------------|----------|
| Signaling speed (nominal)                                  | 10.3125<br>9.95328 | GBd      |
| Signaling speed variation from nominal (max)               | ± 100              | ppm      |
| Center wavelength (range)                                  | 1260 to 1355       | nm       |
| Average receive power <sup>a</sup> (max)                   | 0.5                | dBm      |
| Average receive power <sup>b</sup> (min)                   | -14.4              | dBm      |
| Receiver sensitivity (max) in OMA <sup>c</sup>             | 0.055 (-12.6)      | mW (dBm) |
| Receiver Reflectance (max)                                 | -12                | dB       |
| Stressed receiver sensitivity (max) in OMA <sup>d, e</sup> | 0.093 (-10.3)      | mW (dBm) |
| Vertical eye closure penalty <sup>f</sup> (min)            | 2.2                | dB       |
| Stressed eye jitter <sup>g</sup> (min)                     | 0.3                | UI pk-pk |
| Receive electrical 3 dB upper cutoff frequency (max)       | 12.3               | GHz      |

<sup>a</sup>The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average receive power (max) plus at least 1 dB.

<sup>b</sup>Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

<sup>c</sup>Receiver sensitivity is informative.

<sup>d</sup>Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10<sup>-12</sup>.

<sup>e</sup>The stressed sensitivity values in the table are for system level BER measurements, which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effect of CDR circuits.

<sup>f</sup>Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

<sup>g</sup>Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

# BIP詳細(引用元 IEEE802.3ba)

- 仮想レーン単位でのビットエラー発生の有無の確認が出来る機能
- 仮想レーン単位で16384ブロックのパリティを計算し、AMのBIP3/BIP7に値を入れ込む
- 受信側で計算したBIP3とAMのBIP3の値を比較し、違う場合はBIPカウンターが増える

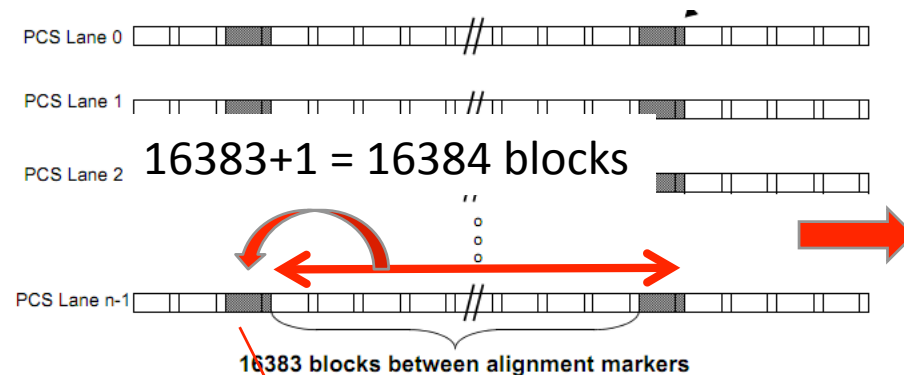


Figure 82-8—Alignment marker insertion period

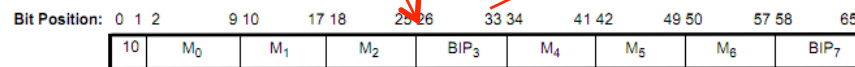


Figure 82-9—Alignment marker format

Table 82-4—BIP<sub>3</sub> bit assignments

| BIP <sub>3</sub> bit number | Assigned 66-bit word bits        |
|-----------------------------|----------------------------------|
| 0                           | 2, 10, 18, 26, 34, 42, 50, 58    |
| 1                           | 3, 11, 19, 27, 35, 43, 51, 59    |
| 2                           | 4, 12, 20, 28, 36, 44, 52, 60    |
| 3                           | 0, 5, 13, 21, 29, 37, 45, 53, 61 |
| 4                           | 1, 6, 14, 22, 30, 38, 46, 54, 62 |
| 5                           | 7, 15, 23, 31, 39, 47, 55, 63    |
| 6                           | 8, 16, 24, 32, 40, 48, 56, 64    |
| 7                           | 9, 17, 25, 33, 41, 49, 57, 65    |

BIPの計算対象フィールド  
対象ビットのXORをとっている