100GE 40km SMF PMD
SOA-Receiver Performance

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Outline

■ 100GE 40km SMF PMD power budget and receiver specifications
■ SOA-receiver Sensitivity model
■ SOA Optical Crosstalk experiments
■ Chromatic Dispersion Penalty model and experiments
■ Polarization Mode Dispersion Penalty experiments
■ Conclusions
100GE 40km SMF PMD baseline

Key specifications reviewed in this presentation:

Receiver Sensitivity:  -22.4dBm  OMA
                        -24dBm  Pave  (Tx ER=8.0dB min)

Allocation for penalties:  3.2dB

1.5dB CD Penalty,  1.7dB PMD and Other Penalties
SOA-Receiver Model

1. Parameters used in SOA-receiver model

SOA (similar SOA used in experiments)
- External Gain: 20dB
- NF: 7dB

DEMUX
- Insertion loss: 2.5dB, passband: 2.3nm

PIN-Rx
- $R \sim 0.8\text{A/W}$, $S21\text{ BW} \sim 21\text{GHz}$
- TIA input-referred noise current density $\sim 15\text{pA/sqrt(Hz)}$
  $\Rightarrow 2.1\mu\text{A rms noise current} \Rightarrow$ sensitivity estimate $-15.8\text{dBm (Pave, ER}\sim8\text{dB)}$

2. SOA-receiver model for sensitivity calculation

- calculate signal and noise terms (incl. SOA ASE noise)
  $\Rightarrow$ calculate input optical power required for $\text{BER}=10^{-12}$

The model was verified in 10Gb/s and 40Gb/s experiments.
SOA-Receiver Sensitivity: modeling results

Model predicts that SOA-receiver can meet sensitivity requirement

-24dBm (Pave)
-22.4dBm (OMA)

Note: -23dBm (Pave), -21.4dBm (OMA) sensitivity target can be met with additional margin
SOA-Receiver impairments: optical crosstalk

SOA gain saturation at high input power can lead to
- waveform distortion (1-channel)
- cross-gain modulation – XGM – (multi-channel WDM environment).

**Objective**

experimentally evaluate the effect of optical crosstalk on SOA-Receiver sensitivity

**Finisar feasibility experiments**

conducted in 1550nm spectral band at 40Gb/s and 10Gb/s
used commercially available SOA
SOA-Receiver: optical crosstalk experiments

2 channels: Chn1 = SIGNAL, Chn2 = AGGRESSOR
independent PRBS31 streams into Chn1 and Chn2
Tx ER ~ 10dB (Chn1 and Chn2)
channel spacing: 10nm/1250GHz (40Gb/s), 6.4nm/800GHz (10Gb/s)
SOA gain ~ 20dB
TP3: test point for sensitivity measurement
Tested at aggressor channel power up to Psig + 8dB
(3 channels, 3dB channel power window)
SOA-Receiver: optical crosstalk experimental results

SOA-receiver sensitivity measurements with and without aggressor

P(agggressor)=P(signal)+8dB

XTALK penalty at sensitivity

< 0.5dB (40G)
< 0.2dB (10G)
SOA-Receiver: optical crosstalk experimental results

Optical Crosstalk at Sensitivity
40G and 10G experiments indicate small sensitivity penalty due to crosstalk:
<0.5dB worst case

Explanation
SOA input power (Sig and Agg) at sensitivity is significantly below saturation
⇒ eye closure due to gain saturation and XGM is small/negligible

Optical Eye-diagrams at ~sensitivity
PIN-PD input 10Gb/s

without aggressor

TP3 Chn1=-32dBm, Chn2=OFF

with aggressor

TP3 Chn1=-32dBm, Chn2=-24dBm
100GE 40km path penalties: Chromatic Dispersion

- **Power Penalty due to Chromatic Dispersion (EML transmitter)**
  
  estimated via 40Gb/s experiments and 28Gb/s computer modeling

- **Experiments – 40Gb/s**
  
  EML transmitter, 1554nm, ER~10dB
  
  Path Dispersion adjusted using SMF+DCF combination
  
  SOA-PIN-Rx (SOA Gain~20dB)
  
  Extrapolate B=40Gb/s results to B=28Gb/s using “B^2-scaling”
  
  CD in 100GE 40km link (LAN-WDM baseline grid 1295 -1305nm)
  
  40km: from -114ps/nm to +36ps/nm
  
  which corresponds to -55.9ps/nm to 17.6ps/nm at 40Gb/s

- **Modeling - 28Gb/s**
  
  Optsim fiber link simulator
  
  EML transmitter
  
  SOA-PIN-Rx (SOA Gain~20dB)
100GE 40km path penalties: Chromatic Dispersion

Power Penalty vs. Chromatic Dispersion, 28Gb/s, SOA-Rx

EXP Tx1 and Tx2:
40Gb/s test data with dispersion scaled for 28Gb/s
100GE 40km path penalties: Chromatic Dispersion

- Experimental results using commercial 40Gb/s EML transmitters support proposed 1.5dB CD penalty allocation.
- Modeling results using 28Gb/s EML transmitters support proposed 1.5dB CD penalty allocation.
100GE 40km path penalties: PMD

Sensitivity Measurements for DGD = 0 to 9.5ps

- PMD/DGD test at Finisar
- 40Gb/s, 1554nm
- EML transmitter, ER~10dB
- SOA-PIN Rx (SOA gain ~ 20dB)
- DGD emulator

BER vs Power [dBm] = signal average power at TP3
100GE 40km path penalties: PMD

PMD/DGD experimental results (40G)

Measured DGD penalty values do not exceed values predicted in Refs. 1, 2

1 U.I. = 1/25.78125G
PMD penalty allocation = 1.0dB
max DGD = 0.3 U.I. = 11.64ps
⇒ max PMD = 3.1ps
(used safety factor of 3.75 for 2.6 sec/year outage)
⇒ 240km on 0.2ps/√km fiber
40km objective met for G.652.B&D fiber

⇒ 38km on 0.5ps/√km fiber
30km objective met for G.652.A&C fiber
40km requires an engineered link

Ref. 1: ITU-T Rec. G.691, Figure I.3
(receiver with signal-dependent noise)
Ref. 2: “Polarization Mode Dispersion in 100GbE links” P. Anslow, anslow_01_0308
(10G measured values)
Conclusions

- Experiments and modeling demonstrate technical feasibility of the 100GE 40km SMF PMD adopted baseline as per cole_02_0508
  - receiver sensitivity -22.4dBm (OMA), -24dBm (Pave)
  - CD penalty ≤ 1.5dB
  - PMD and other penalty allocations ≤ 1.7dB

- Recommendation for additional margin
  - Change receiver sensitivity to -21.4dBm (OMA), -23dBm (Pave) for additional 1 dB of margin
  - Change PMD and other penalty allocations to 2.0dB for additional 0.3 dB of margin
  - Proposed in cole_02_0708
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