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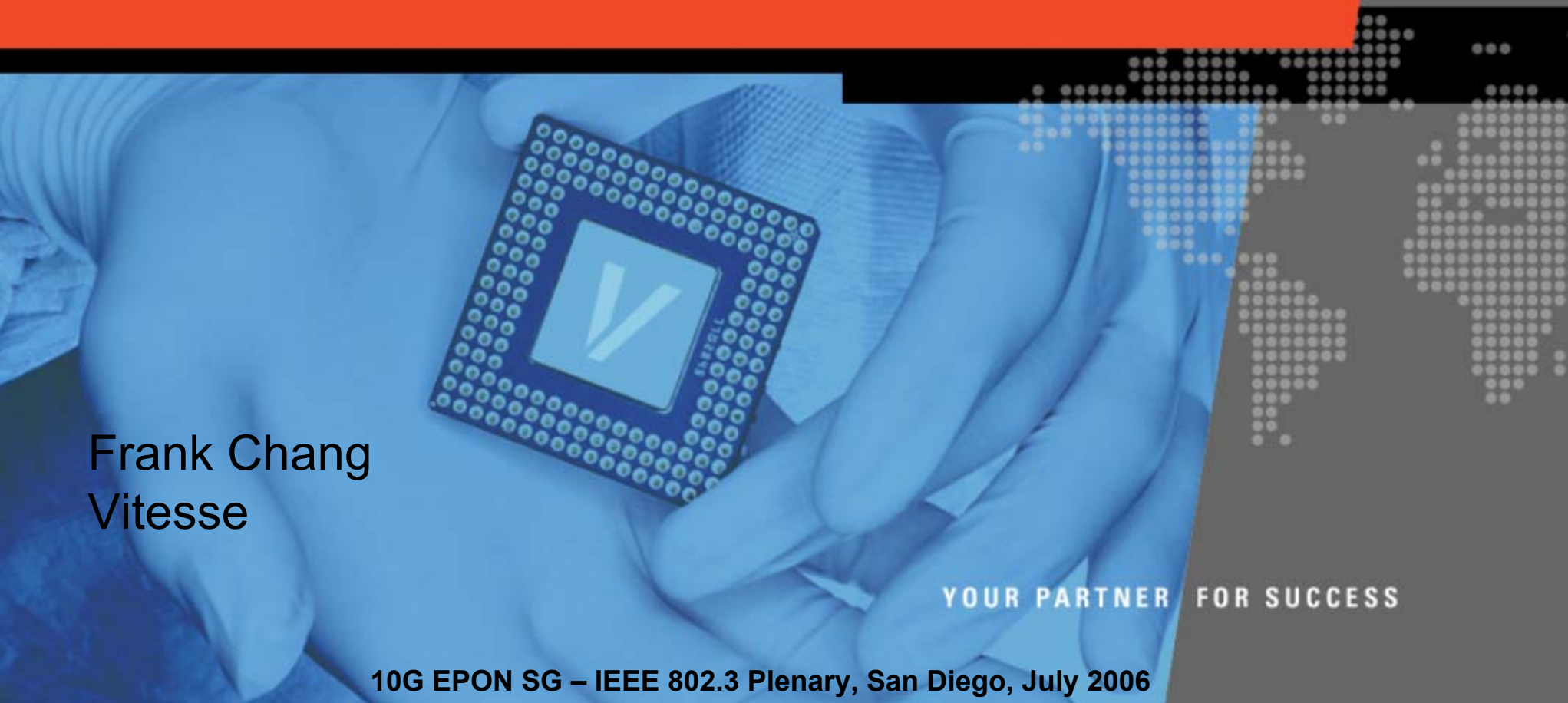
10G EPON Optical Budget Considerations



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10G EPON SG – IEEE 802.3 Plenary, San Diego, July 2006

Outline

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- Technical and Cost Assumptions
- Technology Choices Review
- Link Budget Choices
- Downstream Consideration
- Upstream Consideration
- Summary

Technical and Cost Assumptions

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- 10G EPON will re-use the fiber plant compatible with 1G EPON.
  - 1G EPON currently deploy PX10 and PX20, limit fiber distance up to 20km.
- Consider high split ratios to share OLT cost among more users.
  - ONU is more cost sensitive than OLT, but has volume advantages.
- Reduce 10G system cost and simplify network architecture
  - Current cost still high, leverage with the use of cheaper transmitters; eliminate the use of EDFA or SOA+VOA, or optical pre-amplified Rx.
  - PMD selection of low cost packaged PIN or APD, together with advanced Rx post-detection equalization techniques.
  - Promote advanced PHY, and FEC integrated electronics, where mass production possible.
  - Parallel vs. Serial approach: 4x2.5G approach is an option but DON'T have to use if 10G serial works.
- Serial 10G burst-mode uplink is considered challenging
  - Bit rates could be limited up to 2.5Gb/s, leverage with existing 1-2G PON BM ICs in laser driver, TIA, PostAmp, CPA, CDR and SerDes with FPGA BM controller.
  - Lack of serial 10G BM transmit and receive characteristics, the group need to develop that.

10Gb/s PHY Performance

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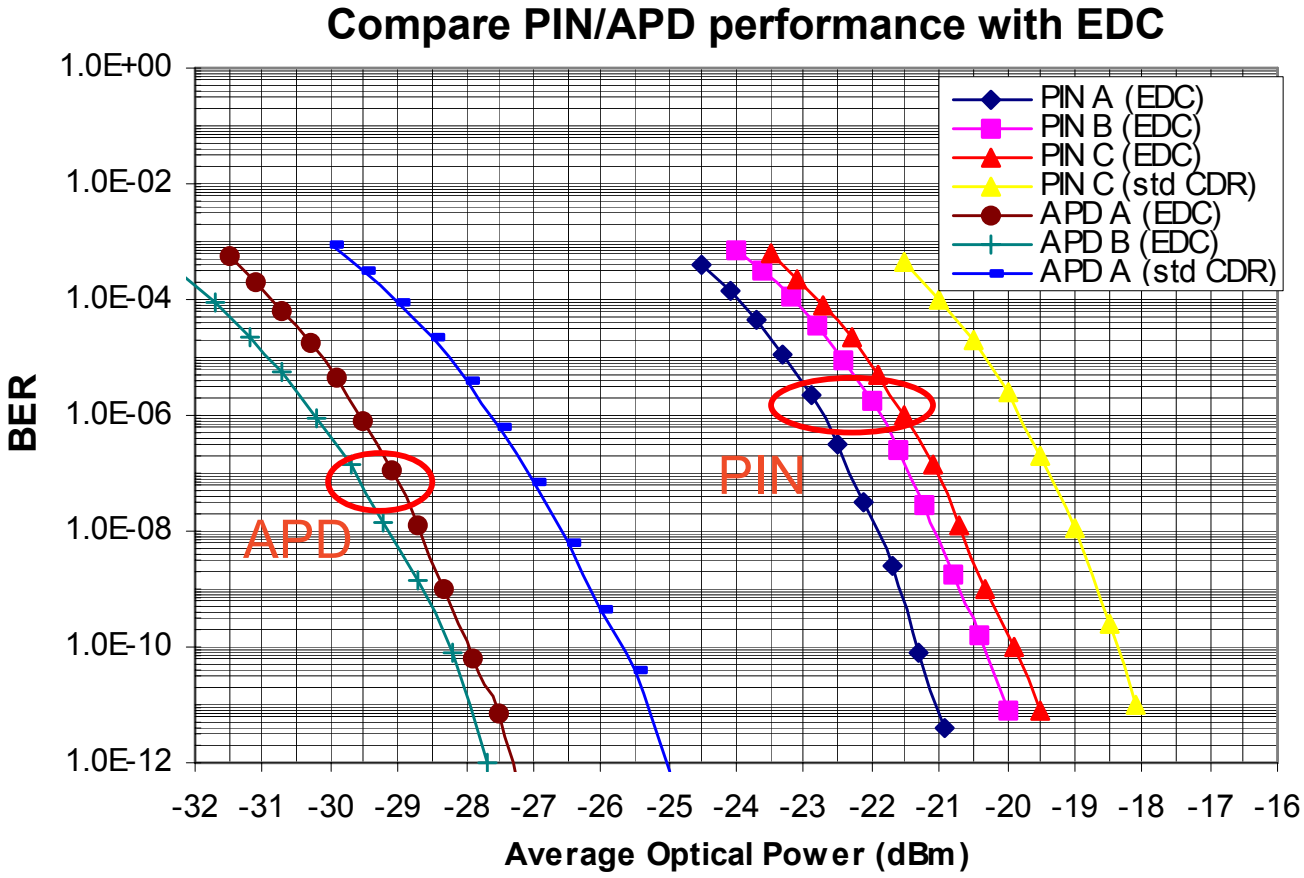
Current PMD/PHY improve Rx sens. up to 2dB with the following

- Low noise TIA with high responsivity PD at 1550nm
- Various post-detection equalization techniques (EDC)
- Sens. for PIN typically at over -20dBm, while for APD at -27.5dBm.



10Gb/s FEC Performance

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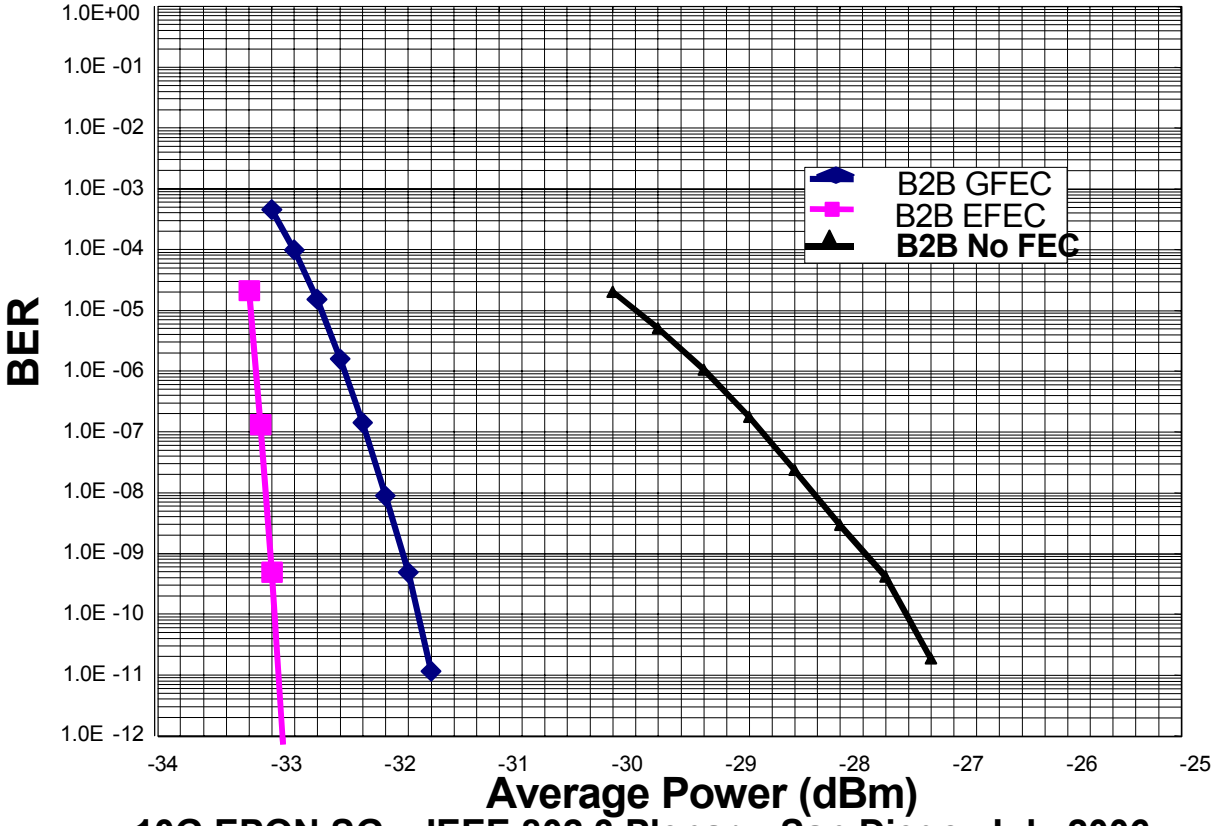
G.709 FEC Enhanced Link Budgets:

- Support Ethernet apps with 64B/66B PCS encoded data at 10.3125Gb/s.
- GFEC : RS(255, 239) codes, add overhead ~7% , correct input BER of 10^{-5} (NECG ~ 6.5dB).
- EFEC: Optional Proprietary enhanced codes, correct input BER of 10^{-3} (NECG~8.5dB).
- APD based: typically <-31dB for GFEC, <-32.5dB for EFEC, enough margin for -29dBm.

Vitesse FEC Performance Curves



Burst-mode PMD/PHY Performance

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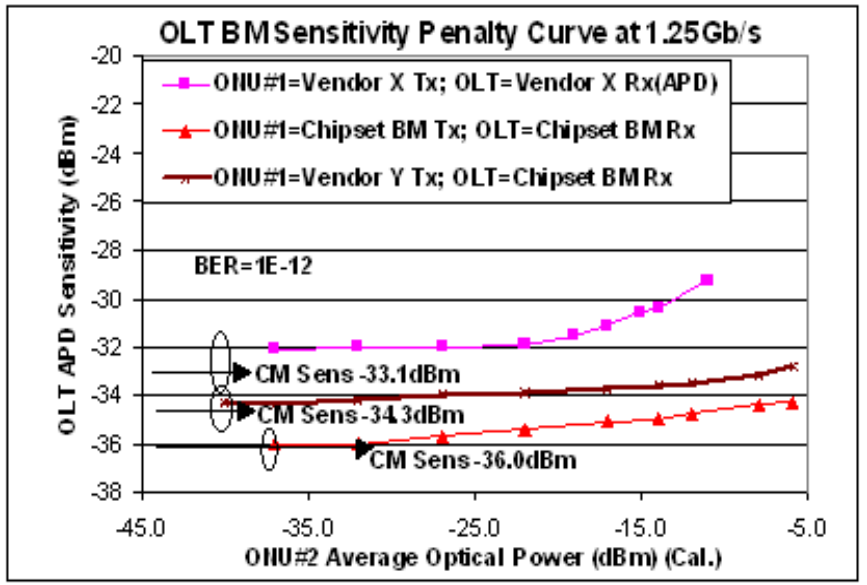
- Current BM PMD/PHY Chipset includes:
  - Burst Laser driver
  - Burst Transimpedance Amplifier (TIA), and Limiting Amplifier (LA)
  - Bust CDR and clock-phase alignment receiver
- Bit rates was limited to no more than 2.5Gb/s
- BM transmission has optical penalty when the weakest burst followed by a strongest burst.
  - BM Penalty is typically less than 1dB.
- 10Gb/s serial BM receiver design is challenging
  - Needs compromise between turn-on/ turn-off times and CID
- Verify parallel approach with 4x2.5Gb/s using CWDM 1310nm



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Link Budgets Under Consideration

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- EPON PX10 budget: 21dB
  - Min. 10km ODN: 5-20dB.
  - Allocate 1dB optical penalty.
- EPON PX20 budget: 26dB
  - Min 20km ODN: 10-24dB.
  - 1dB optical penalty.
  - Cover Class B loss budge.
- Class B+ budget: 29dB
  - 20km over G.652 fibre and class B+ loss budget
  - Higher split ratios: 1:64 @20km or 1:128 @10km.

Downstream Consideration

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Downstream System Overview

- We believe the Tx for DS link budget should be based on:
  - 1550nm DML: High power of over +4 to +5 dBm possible with no extra cost penalty.
  - 1550nm EAM: Small size integrated with cooled EAM available.
  - Low-cost TO-CAN packaged TOSA available for both DML and EAM.
- Three 10G Rx options:
  - PIN + EDC
  - APD + EDC
  - APD + EDC +FEC
- No dispersion penalty is required for DS at up to 20km for the specific Tx used, a 1dB system margin is allocated.
  - 20km dispersion as 340ps/nm for G.652 fiber at 17ps/nm/km.

Downstream Consideration

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Suggested DS 10G Budgets at 1550nm

	PX10	PX20	Class B+
Transmitter Max.	+7dBm	+5dBm	+5dBm
Transmitter Min	+3dBm	+1dBm	0dBm
ER	10dB	8.2dB	8.2dB
Tx Type	DML	EAM	EAM
Optical loss	20dB	25dB	28dB
Optical Penalty	1dB	1dB	1dB
Rx type	PIN (EDC)	APD (EDC)	APD+FEC
Receiver Sens.(avg)	-18dBm	-25dBm	-29dBm
Receiver overload	0dBm	-8dBm	-8dBm

Upstream Consideration

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Suggested US 4x2.5G Budgets at 1310nm CWDM

	PX10	PX20*	Class B+
Transmitter Max.	+5dBm	+5dBm	+5dBm
Transmitter Min	+0dBm	-2dBm	+1dBm
ER	6dB	6dB	6dB
Tx Type	DML	DML	DML
Optical loss	20dB	25dB	28
Optical/BM Penalty	1dB	1dB	1dB
Rx type	PIN	APD	APD
Receiver Sens.(avg.)	-21dBm	-28dBm	-28dBm
Receiver overload	-1dBm	-8dBm	-8dBm

*: PIN option will result in Tx max over +9dBm.

Summary

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- Should carefully consider the total cost of 10G EPON system upgrades for economical feasibility.
- We believe up to 29dB link budget is achievable with current advanced integrated circuits available today. EDC and/or FEC is mandatory in the DS to keep ONT cost down.
- 1550nm is used for DS as low cost optics available off-the-shelf and in volume production, eliminate the use of either EDFA or SOA+VOA by taking advantage of EDC and FEC enhancement to link budget.
- Parallel 4x2.5Gb/s approach probably the viable option so far for the 10G US by taking advantage of current IC developments for EPON and GPON.

Summary

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- Consider optical overlay of RF video?
  - One option is to use alternative C-band wavelengths or simply in L band where EDFA available, as optical overlay typically required amplified high powers.
  - Scalability: support co-existence of 1G DS at 1490nm, 10G DS at 1550nm and optical overlay at alternative C-band wavelength other than 1550nm or L band.