Progress and Issues Concerning the Power Budget Discussions in the Power Budget Ad Hoc

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Power Budget Considerations

Suggests 10GE-PON optical PHY structures, which
co-exists with 1G system and
achieves ClassB++, 29dB channel insertion loss.

Channel insertion loss (CH IL) :
PX10(20dB), PX20(24dB), ClassB++(29dB)

Optical wavelength (under study) :
1G U/S : 1.31um D/S : 1.49um
10G U/S : 1.31um (TDMA overlay), 1.59um (WDM overlay)
D/S : 1.57um

Figures in the discussion are assumed to be product specs.,
considering the worst case,
not the world top data, nor those under the typical condition.

Under ITU-T specs., 10G optical transceiver figures are discussed,
which includes all the component-oriented penalties
and excludes only Path Penalty.

Additional penalties for OLTs and/or ONUs are not yet discussed,
e.g. WDM filter insertion loss, Burst mode penalty, and ONU wide temp. range.

Optical Component Assumptions

		Conditions	Vendor suggestion range		
			worst	best	Prospects
Receiver Sensitivity [dBm]	PIN	ER>8.2 (EML)	-16	-17	
	APD	ER>8.2 (EML)	-24	-25	
		ER >6 (DFB)	-20	-23	
Transmitter Output Power [dBm]	DFB	Uncooled	-1	-0.5	
		Cooled	+3	+4	+5.5
	EML		0		+3
	SOA		+6	+8	+12?
FEC Improvement [dB]	RS	PIN Receiver	3		
		APD Receiver	3	4.5	
	E-FEC		4	5.5	

Cost Assumptions

	Lee	Gokhale	A	B	C	D
PIN ROSA	1	1	1	1	1	1
APD ROSA	3	3	7	10	3.5	3
DML TOSA	2		2	2.5 – 8	2	2 (Single Lens) 4 (Double Lens) 6 (TEC)
EML TOSA	10	10	8	10	6	10
SOA	20	20	30	30	20	20
EDFA	40	50	50	40	50	50
EML+SOA (int.)		20	35		25	
DFB+SOA+EA (C-band)		15				

Assumptions are based on the component cost available today.

APD ROSA cost differs among vendors.

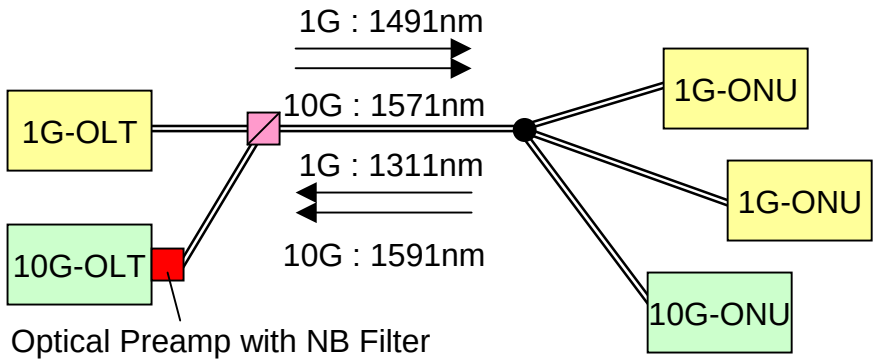
Upstream

Two options : 1G/10G WDM ovrelay or TDMA overlay

- Optical preamplifier in 10G OLT is required to achieve ClassB++ using 10G optical transceiver products available today --- WDM overlay
- Output power and performance improvements of optical signal source lead to a more cost-effective transceiver configuration --- TDMA overlay

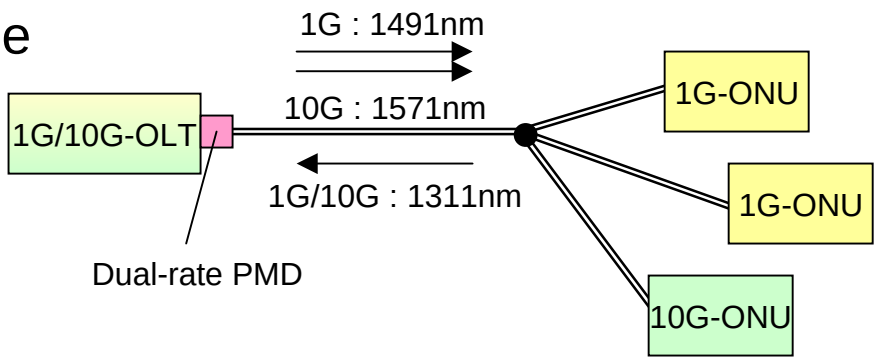
WDM overlay

- Optical preamplifier with narrow-band noise-rejection filter in 10G OLT
- 1G/10G independent structure
- More λ needed for 10G U/S



TDMA overlay

- Optical preamplifier not feasible because of 1G-signal rejection by NB filter
- 3 dB output power increase required for signal sources to achieve ClassB++



Power Budget Proposals (U/S) --- TDMA Overlay

1G/10G : 1.31um

(*1)PB: Power Budget (/CH IL+PP), (*2) PP: Path Penalty

#	RX --- TX Pair	PB (*1)	PP(*2)	Tx	Rx	FEC RS	Cost 1:32	Data Range	
1	APD----------DFB	23 / 22+1 27 / 25+2	2 1	-1 -0.5	-20 -23	3 4.5	1	worst best	Uncooled DFB
		30 / 29+1		+4- 5.5			1.2- 2.9	Pros-pect	Cooled DFB
2	APD----------EML	27.5 / 25.5+2 28 / 27+1	2 1	0	-24	3 4	4.8 2.9	worst best	
		30 / 29+1		+2				Pros-pect	High power EML

EML can be replaced by other signal sources, such as, MZ modulator with CW-LD.

Power Budget Proposals (U/S) --- WDM Overlay

1G : 1.31um, 10G : 1.59um

(*1)PB: Power Budget (/CH IL+PP), (*2) PP: Path Penalty

#	RX --- TX Pair	PB (*1)	PP(*2)	Tx	Rx	FEC RS	Cost 1:32	
1	PD/Pre------EML	>31 / 29+2	2	0	<-27	3- 4.5	4- 5	

EML can be replaced by other signal sources, such as, MZ modulator with CW-LD.

Note: Each column shows its own data range individually.
Sum of the figures along lines is NOT indicating 'Power Budget'.

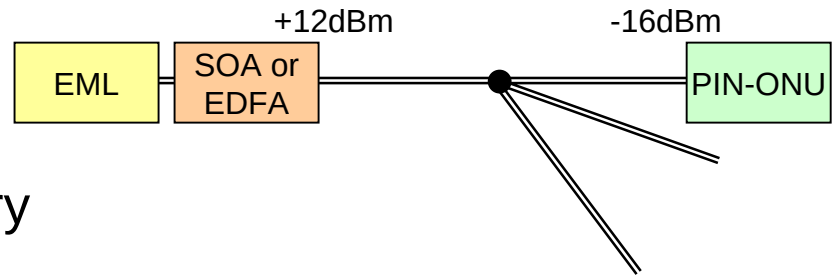
Downstream

Two options : PIN or APD@ONU

- Optical power level shifts drastically depending on the PD choice
- Vendor opinions are divided for ClassB++; PIN:APD = 3:3

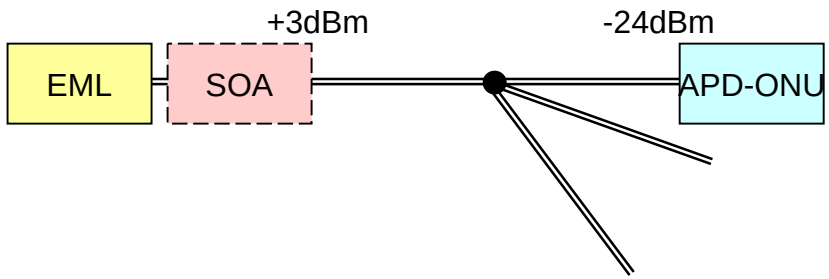
PIN@ONU

- Cost minimum
- Optical amplifier for all the classes
- High-power SOA reliability issue
  - +12dBm@ClassB++ may be necessary
  - EDFA another choice
- Fiber non-linearity issue
- Single ONU for all the classes



APD@ONU

- Depends on APD cost reduction scope
- High-power EML may eliminate SOAs
- Single APD-ONU or mixed for classes
  - PIN for PX10,20 and APD for ClassB++



Power Budget Proposals (D/S) --- PIN@ONU

1G : 1.49um, 10G : 1.57um

(*1)PB: Power Budget (/CH IL+PP), (*2) PP: Path Penalty

#	TX --- RX pair	PB (*1)	PP(*2)	Tx	Rx	FEC RS	Cost 1:32	Data Range	
1	EML/SOA-----PIN	25 / 23+2 28 / 26+2	2	+6 +8	-16 -17	3	2 1.5	worst best	
		31 / 29+2		+12?				Pros-pect	High Power SOA
2	EML/EDFA----PIN	>31 / 29+2	2	+11 +12	-16 -17	3	2.3 2	worst best	only for ClassB++

EML can be replaced by other signal sources, such as, MZ modulator with CW-LD.

Power Budget Proposals (D/S) --- APD@ONU

1G : 1.49um, 10G : 1.57um

(*1)PB: Power Budget (/CH IL+PP), (*2) PP: Path Penalty

#	TX --- RX pair	PB (*1)	PP(*2)	Tx	Rx	FEC RS	Cost 1:32	Data Range	
3	EML----------APD	26 / 24+2 29 / 27+2	2	-1.5 0	-24 -25	3.5 4	8 2.5	worst best	
		31 / 29 +2		+3				Pros-pect	High Power EML
4	EML/SOA----APD	>31 / 29+2	2	>+3 >+5	-24 -25	3 4	9 3	worst best	only for ClassB++

EML can be replaced by other signal sources, such as, MZ modulator with CW-LD.

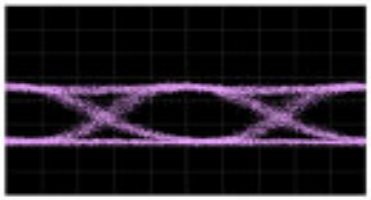
Note: Each column shows its own data range individually.
Sum of the figures along lines is NOT indicating 'Power Budget'.

Mitsubishi Sample Data

MITSUBISHI ELECTRIC

Experiment Results of the 10Gb/s EPON

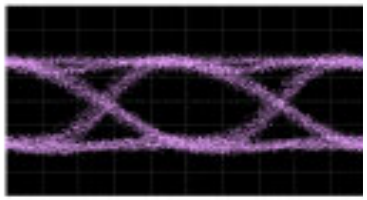
- Optical output waveforms -



OLT output waveform

Output power: +7.8dBm

Extinction ratio: 11.0dB



ONU output waveform

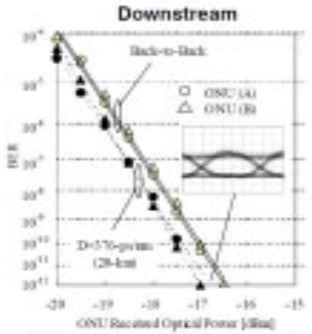
Output power: +2.0dBm

Extinction ratio: 6.3dB

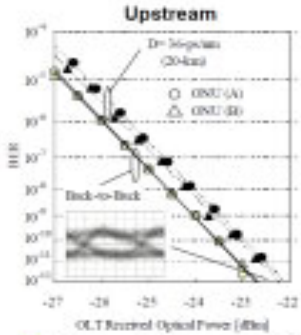
MITSUBISHI ELECTRIC

Experiment Results of the 10Gb/s EPON

- Bit error rate -



- Minimum Receive sensitivity: -16.5dBm(@1E-12, FEC OFF) -19.7dBm(@1E-12, FEC ON)
- Penalty: -0.5dB



- Minimum Receive sensitivity: -22.7dBm(@1E-12, FEC OFF) -27.3dBm(@1E-12, FEC ON)
- Penalty: 0.6dB

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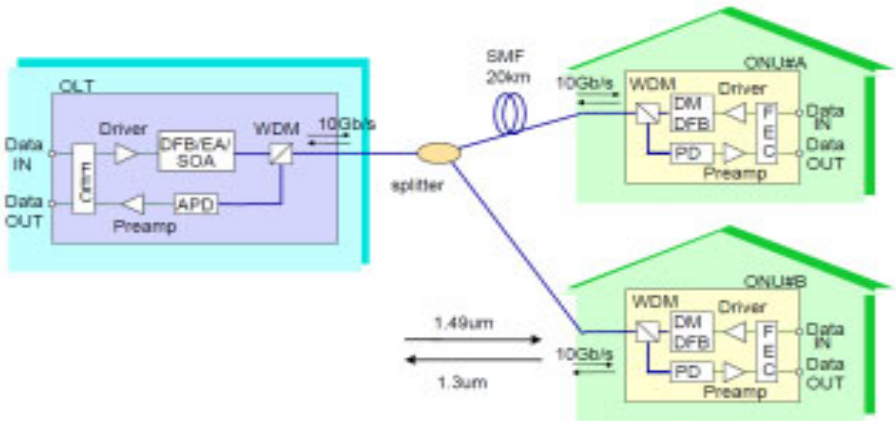


Results of the 10Gb/s EPON experiment

	10Gb/s EPON experiment results		Further study issue
	Down	Up	
Power budget (FEC On)	27.5dB	29.3dB	Higher-power SOA
Dispersion penalty	-0.5dB	+0.6dB	
Extinction ratio	11.0dB	6.3dB	Fast burst modulation circuit at ONUs

takahashi_1_0706.pdf, IEEE 802.3av SG, SanDiego, July 2006

Hitachi Sample Data
- 10Gbps downstream -

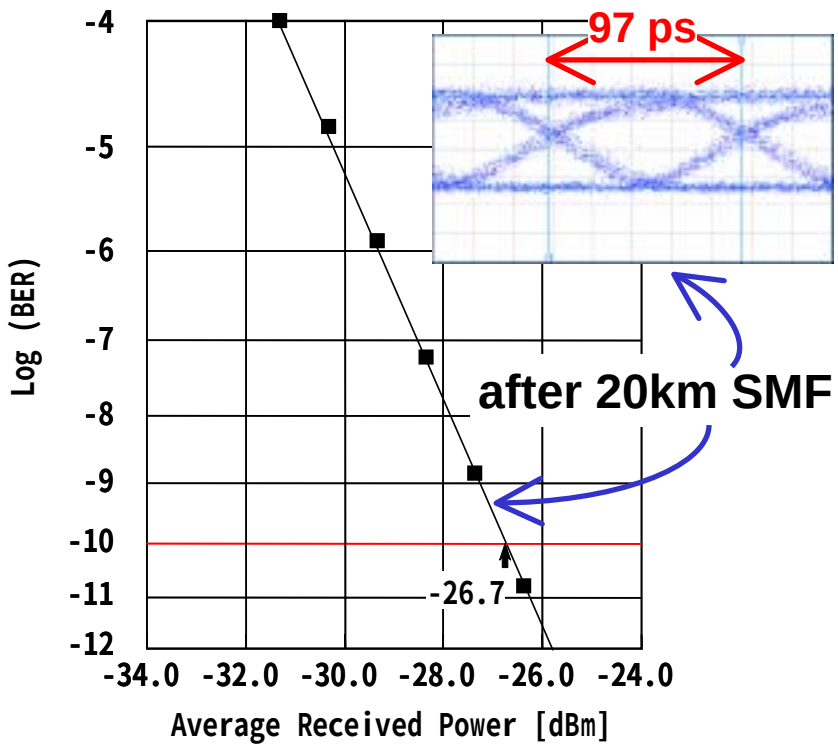
HITACHI
Inspire the Next

- Experimental Configuration

	Transmitter	Receiver	Remarks
D/S config.	EA-DFB	APD	20km SMF, λ=1539nm, 10.3Gbps, NRZ PRBS 2^{31}-1

- Error rate measurement
  - Output power:
    +5.6dBm
  - Receiver sensitivity
    after 20km SMF:
    -26.7dBm@BER10^{-10} (※)
  - Loss budget:
    32.3dB (※)

※ measured w/o FEC



Issues

FEC

- RS (255/239) Mandatory

  Sensitivity improvements depend on the optical components;

  RX : PIN, APD, or Optical preamp. (Noise source).

  TX : Direct-modulated DFB or EML (ER, ISI).

  Assumptions differ among vendors.

- In-band FEC Mandatory

  Rate-increase penalty may be fatal to ClassB++

- More Discussion needed for Enhanced-FEC

  Considering burst-mode CDR risks etc.

EDC

- U/S TDMA / D/S WDM overlay : no EDC necessary
- U/S, D/S WDM overlay : Some component options may need it

Issues (continued)

Developments for optical signal sources

- Higher power to achieve ClassB++
- Improvement of ER, relaxation oscillation freq., and eye opening
- ONU wide operational temperature range

Reduction of additional penalties is a must, esp. PON relations

- WDM filter insertion loss and crosstalk
- Burst-mode penalty
- Dual-mode PMD;
    - 10G best performance necessary
    - 1G/10G power level difference; overload, LOP (Loss of Power)

Discussions on ITU-T specs.

- Translation to IEEE specs. required for IEEE Drafts

Summary

Upstream :

TDMA overlay is supposed to be a suitable target for a practical ClassB++ transceiver configuration, expecting new higher-power optical signal sources, compared to WDM overlay with optical preamp. in OLT.

Downstream :

PIN@ONU seems so far the minimum cost approach,
but several vendors prefer APD and further discussions are needed.

Further Study :

- Developments for higher power optical signal sources
- Reduction of additional penalties, especially PON relations
- ITU-T specs. translation into IEEE Drafts
- Discussions among vendors;
  DFB or EML, Power targets for signal sources,
  PIN or APD, Assumptions for a variety of penalties

Next Step :

- Tentative figures for 10GE-PON PHY spec. sheets