
PIN-PD based ONU for 10GE-PON (3)

Naoki Suzuki and Yoshifumi Hotta
Mitsubishi Electric Corporation

Supporters

Toshiaki Mukojima, OKI

Shinji Tsuji, Sumitomo

Yoshifumi Hotta, Mitsubishi

Naoki Suzuki, Mitsubishi

San Francisco meeting summary

- Cost [1] , productivity, technology, and scalability advantages [1-2] for PIN-PD at ONU have been proposed

[1] 3av_0707_lee_1, [2] 3av_0707_suzuki_1

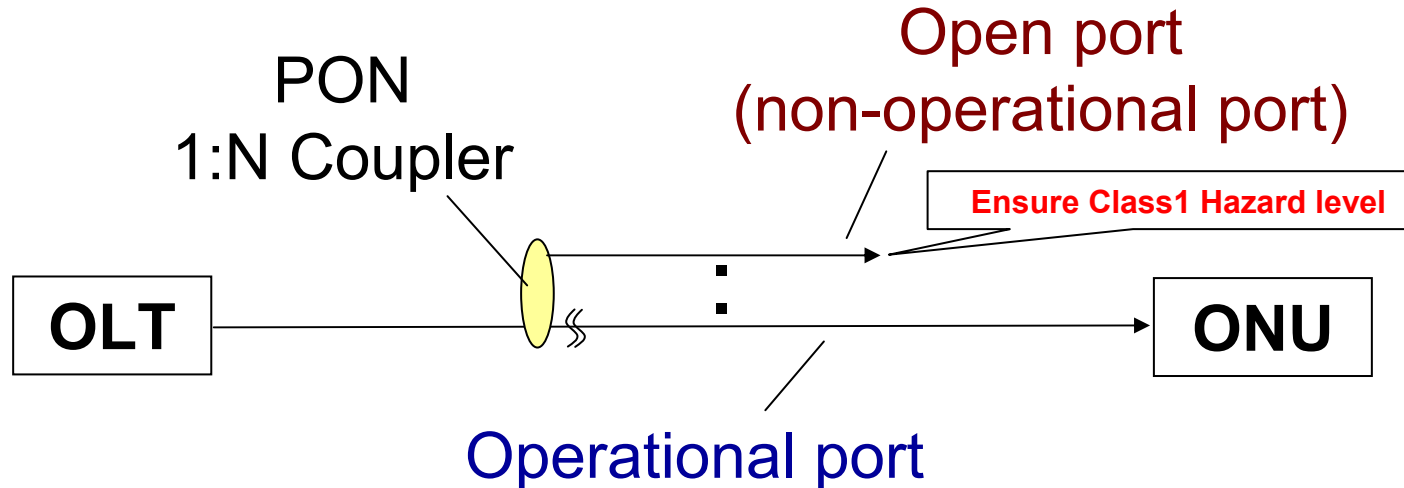
- According to the straw poll #11, PIN-PD supporters claim that the primary reason of concern for the APD at ONU is **the cost impact**
- On the other hand, the straw poll #12 result shows that APD supporters concern that the PIN-PD at ONU has **potential problems associated with high power (mainly eye-safety issue)**

In this presentation, we propose a new downstream power budget to meet eye-safety requirements. In Addition, PIN-PD based ONU's advantages are updated.

Safety requirements for 10G-EPON(1/3)

Class1 (+10dBm) *at open ports of PON 1:N coupler* IEC60825-1

→ **Maximum OLT output power < + 13dBm**

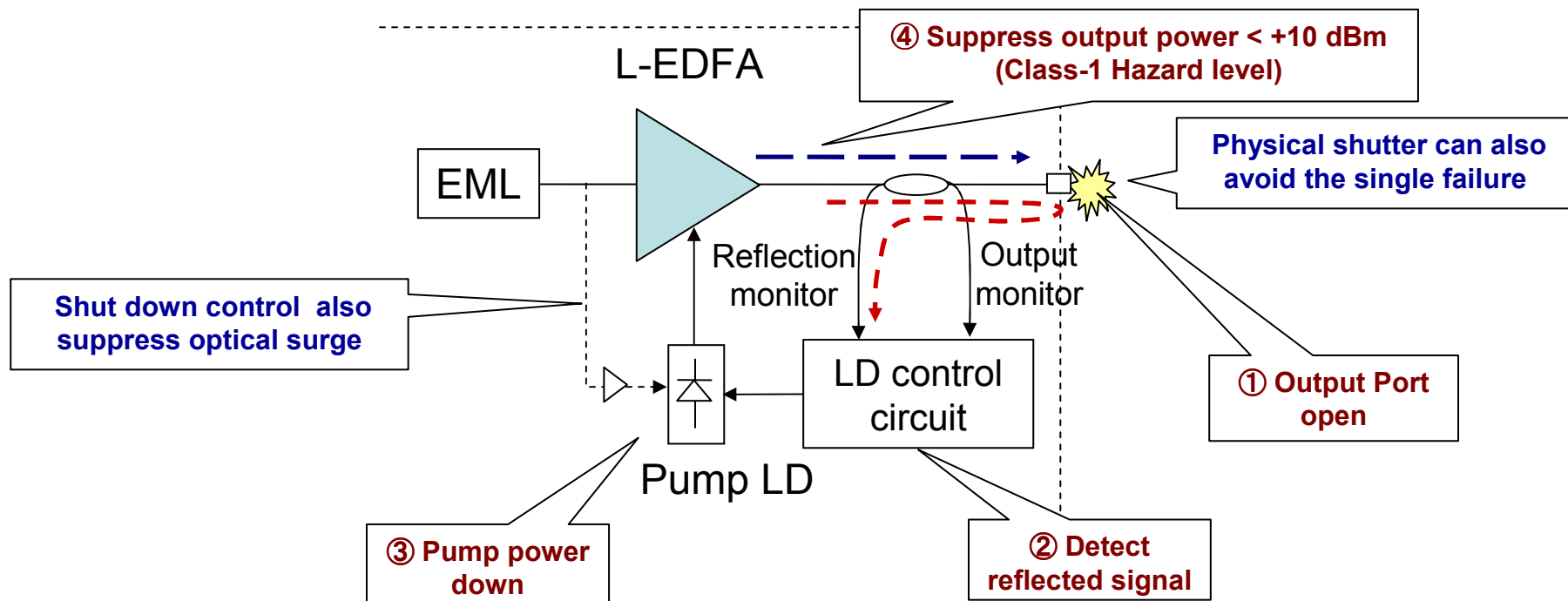


1 : N Splits	Maximum output power from open port of PON coupler
2	+10dBm
4	+7dBm
8	+4dBm
16	+1dBm

Safety requirements for 10G-EPON(2/3)

Class1 (+10dBm) at OLT PON-interface output port

- ➔ **Eye-safety control + Physical shutter**
- ➔ **Employ a physical shutter to avoid single failure accident of the eye-safety control**

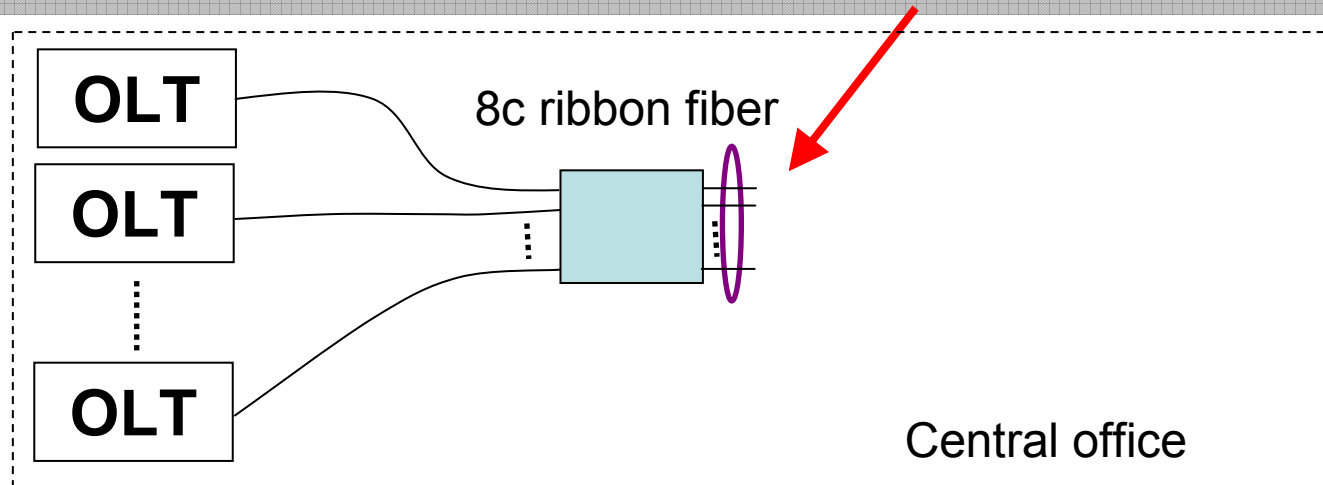


Safety requirements for 10G-EPON(3/3)

Class1M (+21.3dBm)* with 8c ribbon fiber (worst case) in the central office

*IEC60825-2

Normal case : When 8c fiber port is open, each OLT output power is suppressed by eye-safety control, and the total output power is kept Class1M.
Single OLT failure case : Total output power is less than +13dBm.



Even in the case of single OLT failure accident, optical output level of 8c ribbon fiber remains under Class 1M.

New Power Budget Proposal

- Ensure the 10GE-PON required eye-safety level
- Available Tx power range (3dB) and Rx sensitivity

Downstream Power Budget : PIN-PD ONU B++

	Takizawa ^(*3)	Proposal	Remarks
CHIL (dB)	29	←	
Path Penalty (dB)	1	←	
OLT launch (min)	+10 (+11)	+10	Optical amplified OLT Eye-safety control
OLT launch (max)	+13 (+14)	+13	
ONU Sensitivity	-20 (-19)	-20	E-FEC : e.g. RS(255,223) BER=10 ⁻³
ONU Overload	-2 (-1)	-2	

[3] 3av_0707_takizawa_1

San Francisco

Plenary Meeting Material

PIN-PD advantages

(3av_0707_suzuki_1)

PIN-PD System

Basic Concept :

By use of **experienced-technologies** (e.g. EDFA, low-power EML, pin-PD ONU), we can simply realize all 10Gbps PMD classes with advantages of **cost-effective, high-reliable PON systems and stable supply**.

PIN-PD System D/S (e.g.)

	Device	Specifications	Target (Difficulty)
OLT	Low-EML	-1 dBm, ER 9 dB	10GBASE-ER
	EDFA*	+10 dBm - +12 dBm	MSA w/ power control (APC)
ONU	PIN-PD	-16 dBm @ 10^{-12}	10GBASE-LR+ α

*** Hi-power SOA is a prospective choice in future**

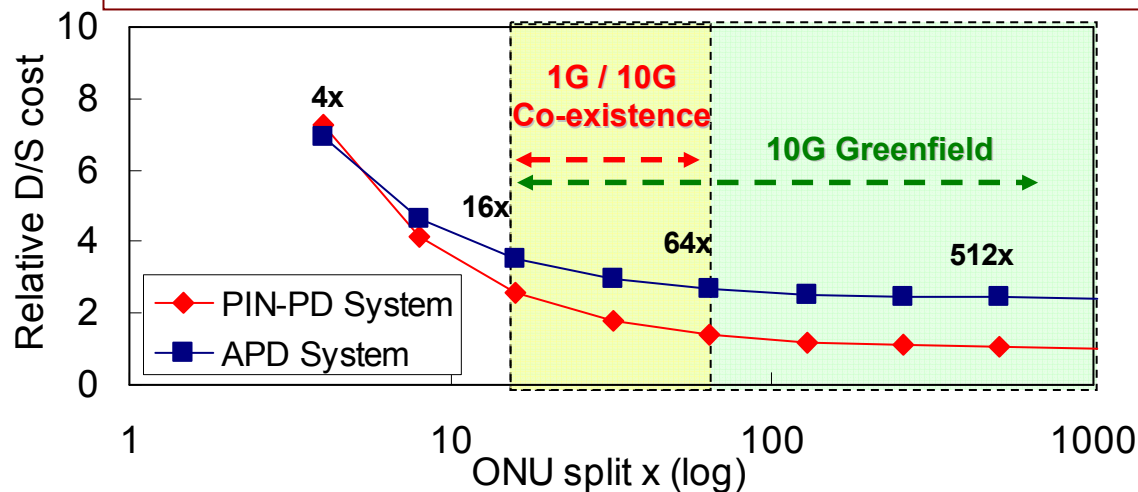
Cost (1/2)

- Relative cost figures based on current market price of XFP and EDFA

Relative cost figures

Device		Lee	Proposal	Remarks
OLT Tx	L-band EML TOSA	10	6	ER (40 km)
	L-band Hi power EML TOSA	-	18	Screening
	L-band EDFA Gain block	40	19	MSA (Multi-source-agreement)
ONU Rx	APD ROSA	3	2.4	
	PIN-PD ROSA	1	1	

Relative D/S cost = ONU Rx + OLT Tx / Subscribers



Cost reduction :

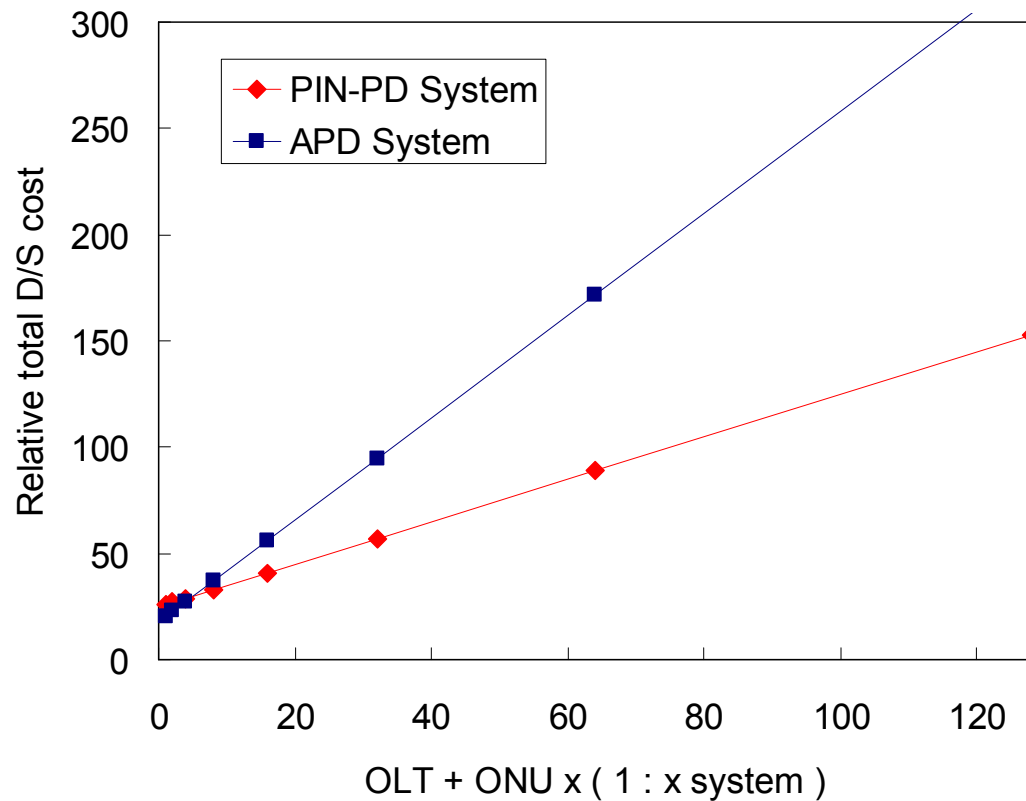
1G/10G co-ex - 45 %

10G Greenfield - 60 %

Cost (2/2)

- Comparison results of **Relative total D/S cost**

$$\text{Relative total D/S cost} = \text{ONU Rx} \times \text{Subscribers} + \text{OLT Tx}$$



Technology (1/5)

1. EDFA Advantages (PIN-PD System)

- Excellent optical gain can afford to support hi-class power budgets of over PX20 and B++, and mitigate TOSA (Tx source) specifications
- Very small and low power consumption (L-band) gain block superior to MSA, which can not impact on OLT-card size, is available

Very small EDFA (Vender A)

72 x 50 x 9 mm (Business Card)

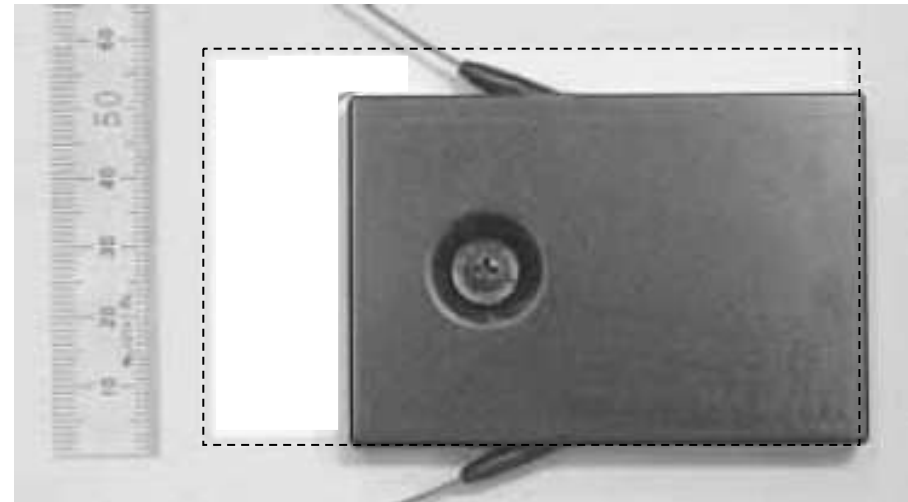
(* MSA: 90 x 70 x 15 mm)

Output power : +11 dBm

Gain bandwidrh : 1560 nm – 1600 nm

Power consumption : 1 W (typ.)

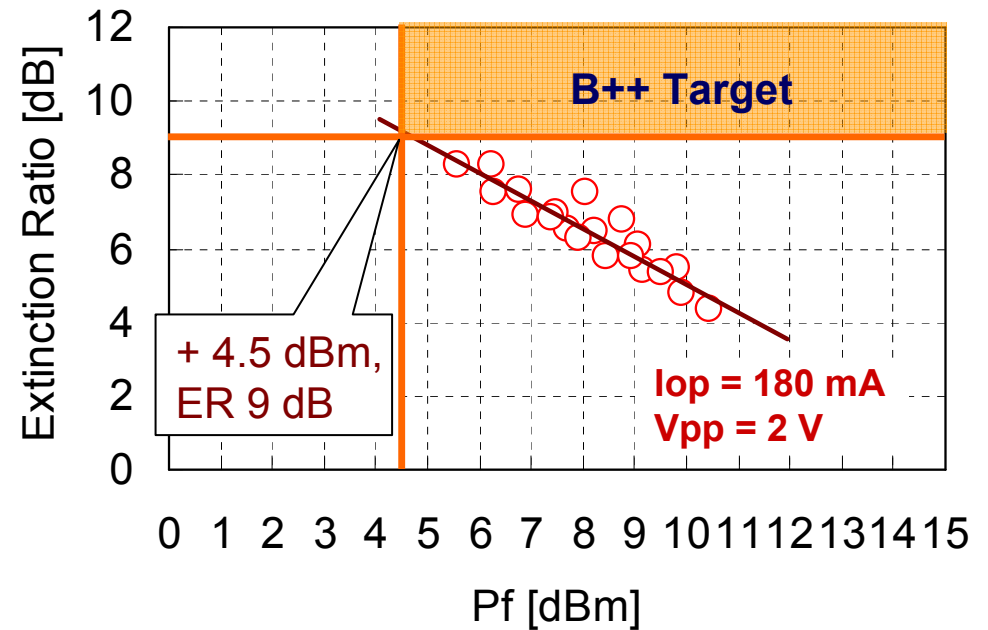
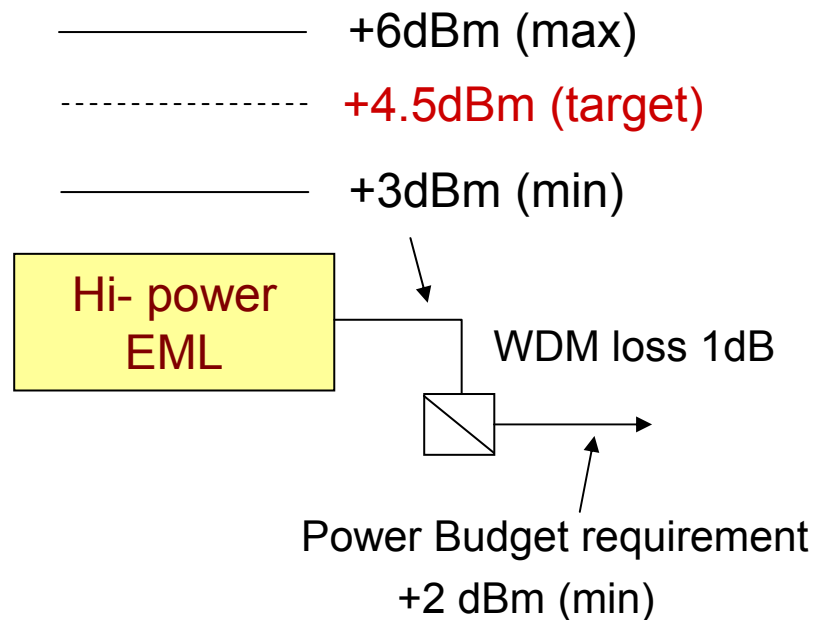
(uncooled 1.48 um pump, control circuits)



Technology (2/5)

2. Hi-power EML Problem (APD System)

- Very large LD injection current of more than **180 mA - 200 mA (reach the maximum rating of standard LD)** can cause reliability degradation
- Required target power of more than **+4.5 dBm** indicates that we need “Screening” in mass production and it yields negative impact on cost



Technology (3/5)

3. Hi-power 10Gbps Transmission

item	Permitted fiber input power of 10Gbps signal	remarks
SBS	+ 15 dBm (w/ frequency modulation)	Figure 1
XPM	+ 17 dBm	Dr. Piehler, <i>XPM.pdf</i> , May 30
SRS	+ 16 dBm	Figure 2

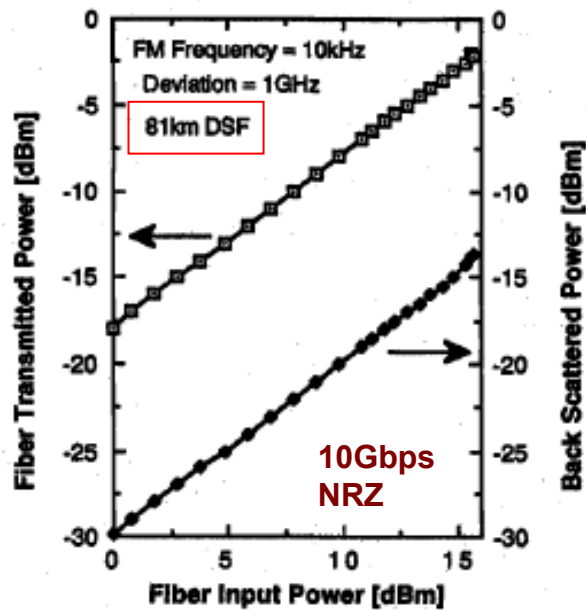


Fig.1 SBS experimental result

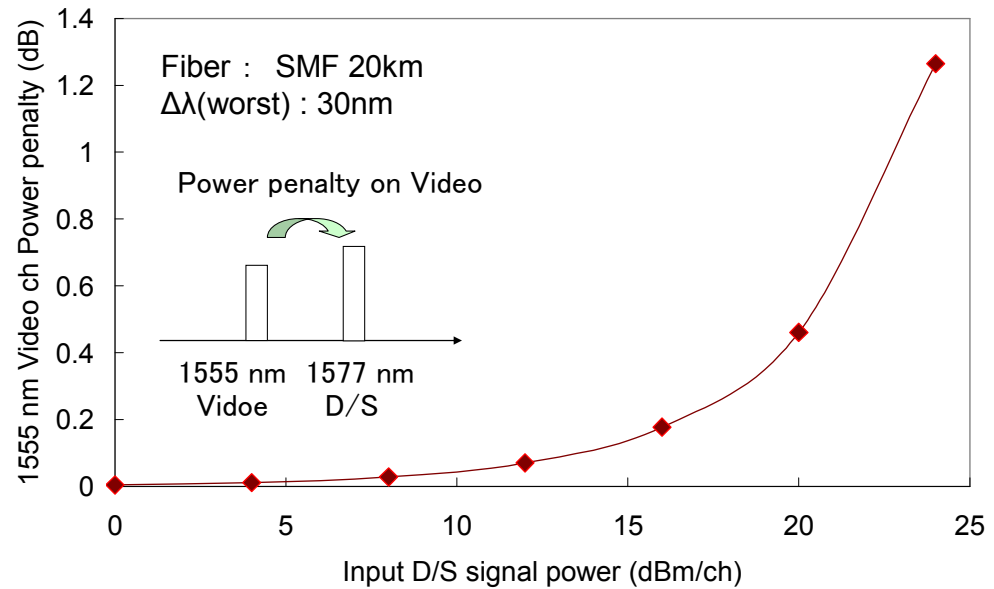
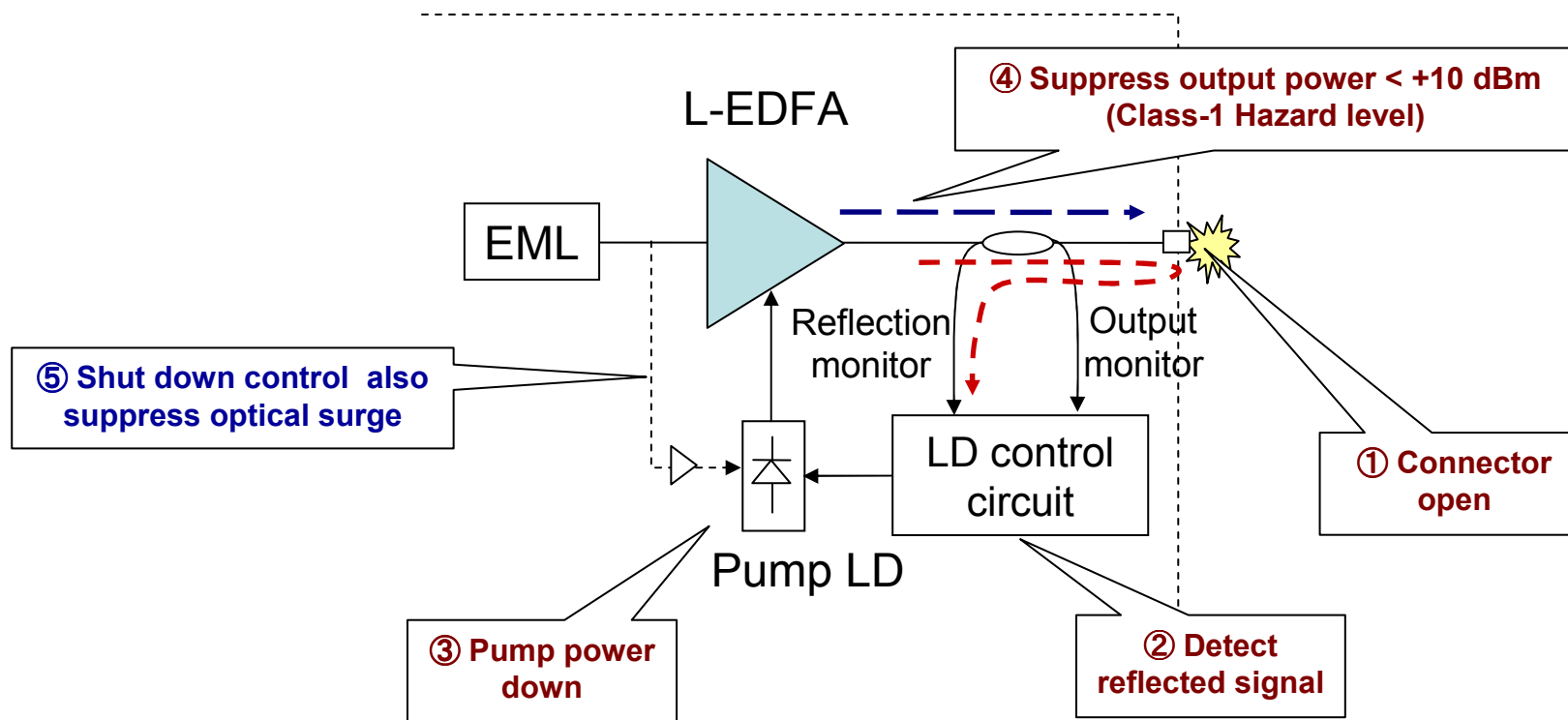


Fig.2 SRS calculated result

Technology (4/5)

4. Eye-safety

- Eye-safe control can keep **Class1(<+10 dBm)** output at “open” condition
- A connector with safety-shutter is also effective for safety design

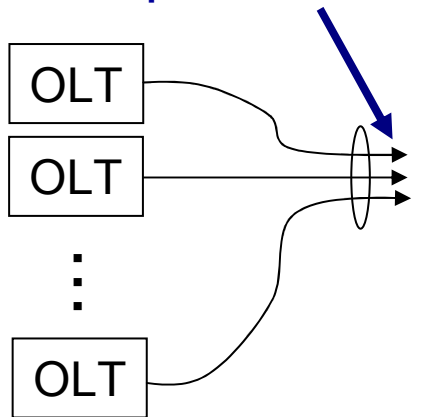


Technology (5/5)

5. Power Budget Proposal

- Assuming a worst case scenario of **8c ribbon fiber wiring in CO**
- Optical amplified OLT can successfully control the output power range of +10 dBm - +12 dBm with simple APC (Automatic Power Control)
- **+12 dBm x 8c (9dB) = +21 dBm : Class1M (< +21.3 dBm) HL**

8c ribbon fiber output :
OLT power + 9dB



	Takizawa ^(*1)	Proposal	Remarks
CHIL (dB)	29	←	
Path Penalty (dB)	1	←	
OLT launch (min)	+10 (+11)	+10	Optical amplified OLT with APC
OLT launch (max)	+13 (+14)	+12	
ONU Sensitivity	-20 (-19)	-20	E-FEC ^(*2) or RS(255,239) + -17 dBm@10 ⁻¹²
ONU Overload	-2 (-1)	-3	

(*1) 3av_0705_Takizawa_1, (*2) 3av_0705_Daido_1

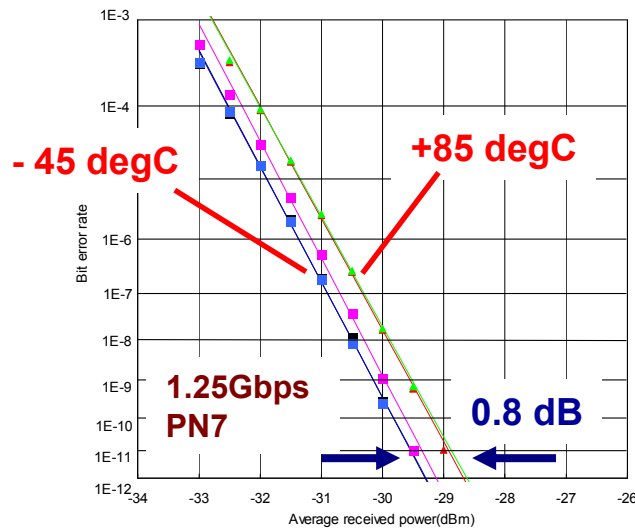
Scalability

PIN-PD ONU :

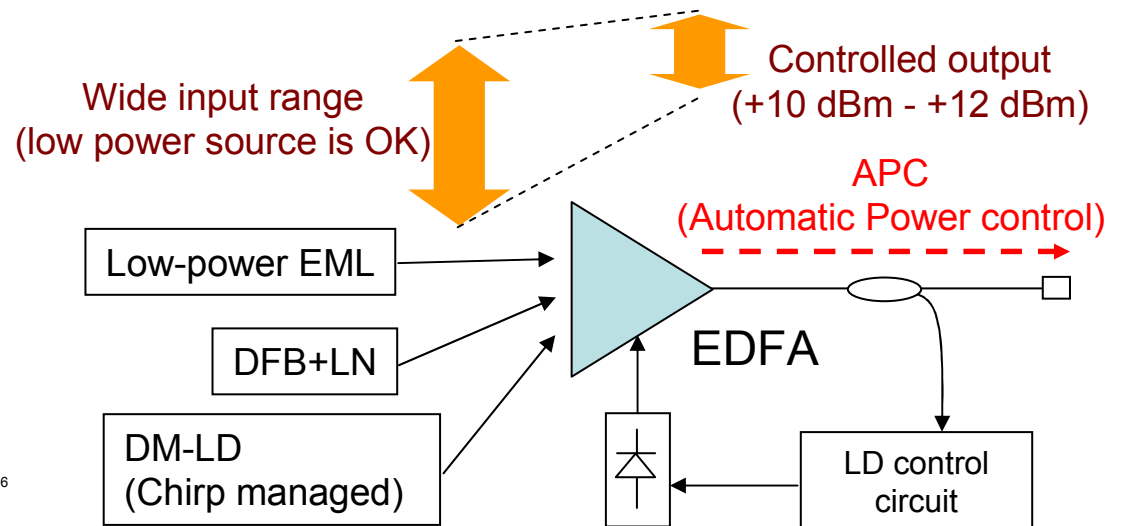
Temperature insensitive behavior of pin-PD based Rx can support “outdoor operation” of ONU (-45 degreeC - +85 degreeC) ”

Optical amplified OLT :

Optical amplifier’s wide input dynamic range (w/ APC) can support various types of “prospective” transmitter sources (EML, Chirp managed DM-LD, DFB+LN, etc..)



Experimental result of ONU Rx sensitivity



APC-EDFA based OLT (e.g.)

PIN-PD Advantages

Cost	PIN-PD system is the promising candidate for cost-effective 10GE-PON : cost reduction of -45 % to -60 % (compared to APD system)
Productivity / Stable supply	PIN-PD system is suitable for mass-production (proven by B / GE-PON). (Ref. 3av_0705_suzuki_1.pdf, Geneva)
Technology	Experienced-technologies (e.g. EDFA, low-power EML, pin-PD ONU) can provide higher reliable PON systems supporting hi class budgets of over PX20 and B++.
Scalability	PIN-PD system can provide the outdoor ONU and various types of OLT Tx sources for market demands.

Answers to Geneva

Downstream: PIN-PD at ONU with amplified EML at OLT

Pro	Con
Lowest cost solution (fully subscribed); system cost should comprehend replacement of ONUs during lifetime of OLT	More costly solution (fully subscribed and first costs)
Simple control electronics at ONU; does not require calibration (e.g. temperature)	Size of OLT too big, requires Tx and control electronics at OLT, power dissipation
Continuity with 1G EPON for easy/fast migration to 10G for existing suppliers	Questions of booster SOA reliability and availability for high power
Total volume of 10G PINs greater than that of 10G APDs; higher reliability of PIN over APD	Possible WDM crosstalk in OLT
All components commercially available today	Concern over optical surge from EDFA
	Concern for SRS penalty on analog video and XPM between 10G DS and video
	High power handling concerns

APD at ONU with high power (+2 or +3 dBm minimum output) EML at OLT

Pro	Con
Low development cost and short time-to-market	Expensive ONU (fully subscribed system)
OLT Tx in same footprint as 1G	Higher complexity in ROSA; multiple DC voltages required
FEC optical gain for APD > PIN	Twice power consumption at ONU (withdrawn)
Components available today	Target spec for Tx power (+2-3 dBm) is difficult and beyond current technology
Cost effective OLT	Complex adjustment process

- ① PIN-PD is lowest cost solution: Cost reduction of -45 % to -60 % at co-existence / fully subscribed systems
- ② Very small and low power dissipation EDFA is available
- ③ EDFA is one of the reliable choices for 10Gbps-OLT booster. Hi-power SOA is also good prospective choice because it has the potential to be small packaged (integrated) transmitter .
- ④ Hi-power (> + 15 dBm) 10Gbps transmission and eye-safe control/shut down control (< Class1 HL) have already been demonstrated.
- ⑤ Hi-power EML's required injection current of more than 180 mA – 200 mA (reach the maximum rating of standard LDs) can cause reliability (FIT) degradation. Also, a target power of more than +4.5 dBm is difficult in mass production.