APD@ONU for 10GE-PON (2)

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Discussion

1. High-Power EML
2. Wide-Temp. Range APD
3. OLT Size
4. Upgrade
5. Cost

High-Power EML Availability (Supplier A)

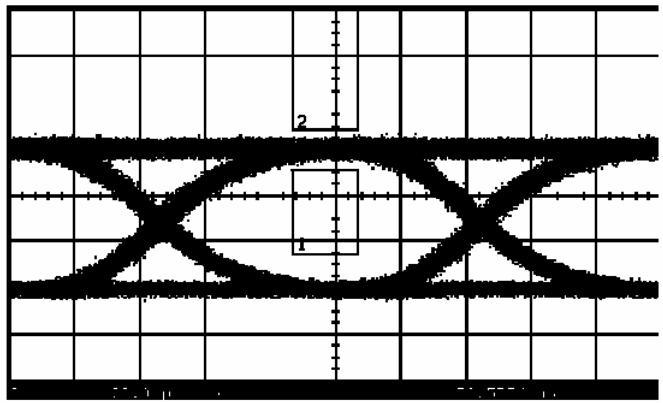
- High-power EML already available in the telecom market
- +3dBm (End of Life) output power guaranteed
- 0.5-1.0dB more power, with no dispersion care, covers WDM filter loss

Output Power	+4.0 dBm min., +5.0 dBm typ. +3.0 dBm min. (EOL)
Wavelength (CWDM grids also now available)	1530-1560 nm (1511, 1531, 1551, 1571nm)
Transmission Distance (Dispersion) Transmitter Penalty due to Dispersion	80 km min. (1600 ps/nm min.) 2.0 dB max.
RF Extinction Ratio	10.0 dB min.
Operating Current	150 mA max.
TEC Power Dissipation	1.4 W max.
Operating Case Temperature	-5-+75 degC

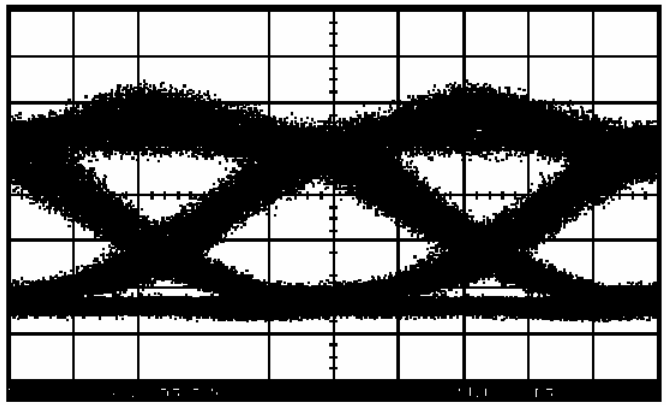
High-Power EML Sample (Supplier A)

Eye Diagram

B to B with filter



After 80 km (1600 ps/nm) with filter



TLD = 35 degC

ILD = 125 mA

Vo = 0.2 V

Vmod = 2.0 Vpp

Pave = 4.11 dBm

Rext = 10.6 dB

9.95328 Gb/s

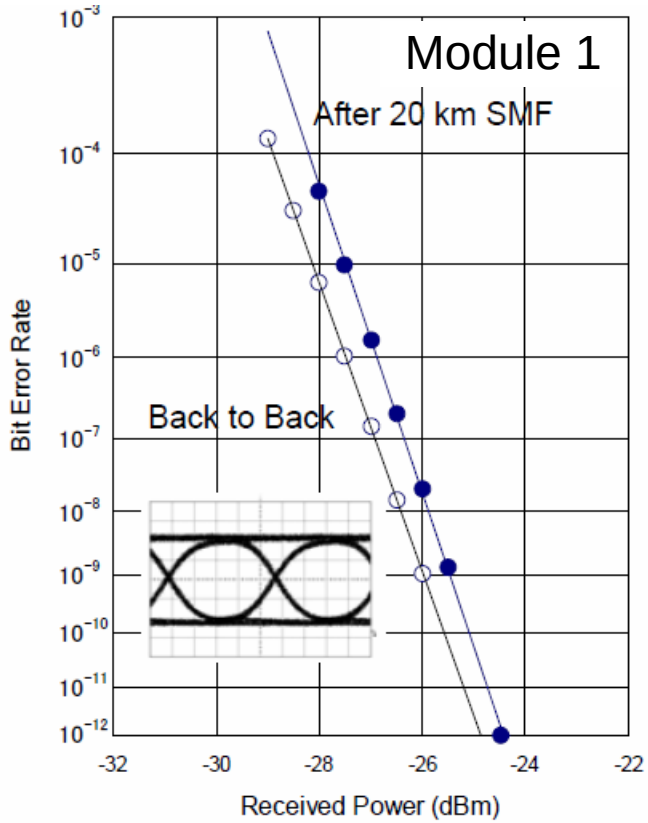
PRBS = 2^{23}-1

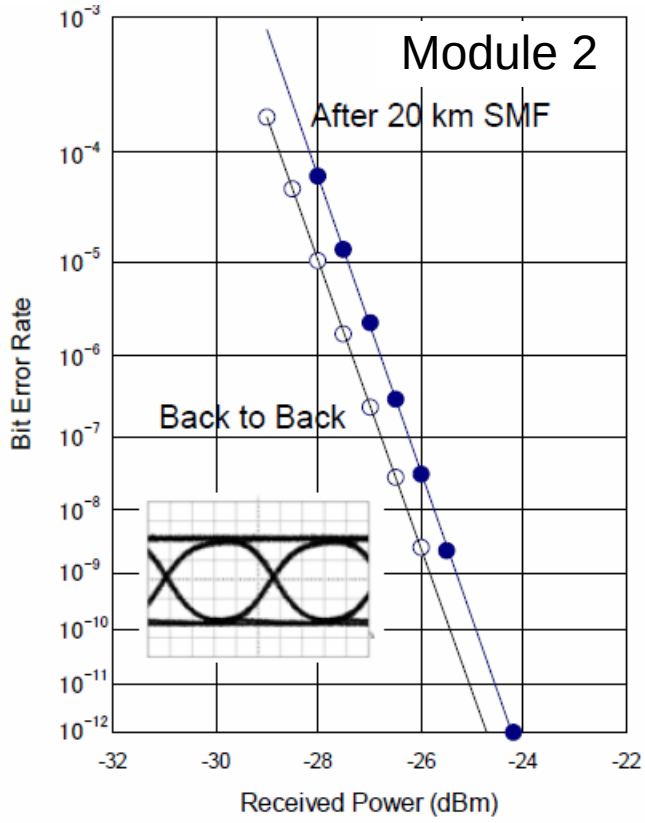
Power penalty = 1.6 dB@10^{-10}

It is TODAY, not tomorrow!!

High-Power EML Samples (Supplier B)

	Module 1	Module 2
Power (dBm)	5.2	5.7
Extinction Ratio (dB)	9.4	8.9
Path Penalty (dB)	0.6	0.7
Wavelength (nm)	1549.6	1552.7





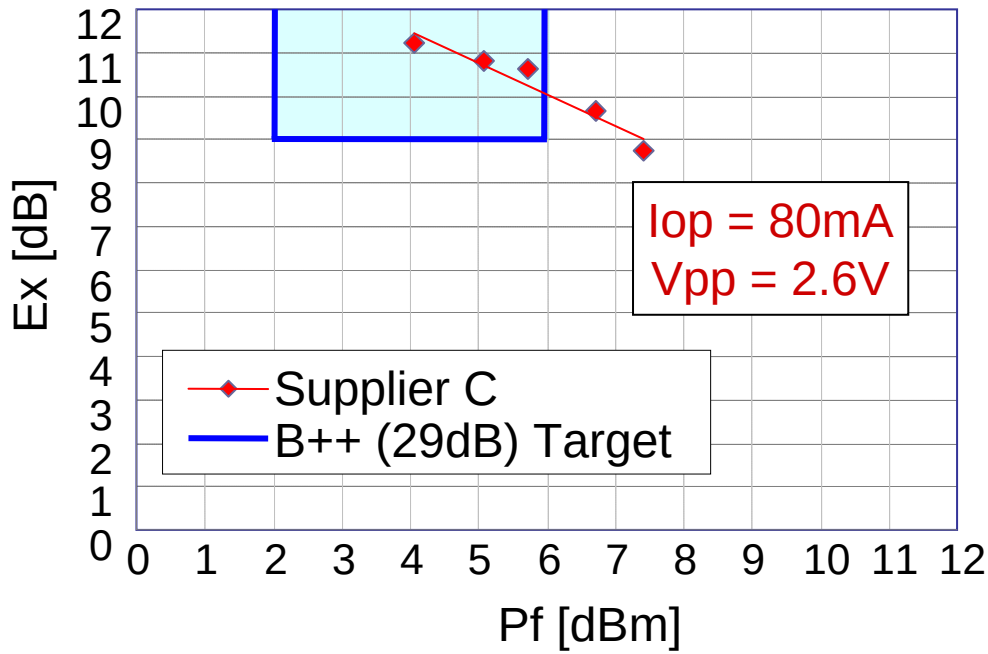
Vpp= 2.0 V,
10.3 Gb/s,
PRBS 2^{31}-1,
SMF 20 km

High-Power EML TOSA Feasibility (1) (Supplier C)

Class B++ Power Target Feasible with Current Technology

- Both >+4.0 dBm output power and >9 dB ER achievable at the operation current Iop= 80 mA
- No problem for pertier cooler reliability and heat sink design at the supposed operation current

High-Power EA Pf and Ex Test Results



High-Power EML TOSA Feasibility (2) (Supplier C)

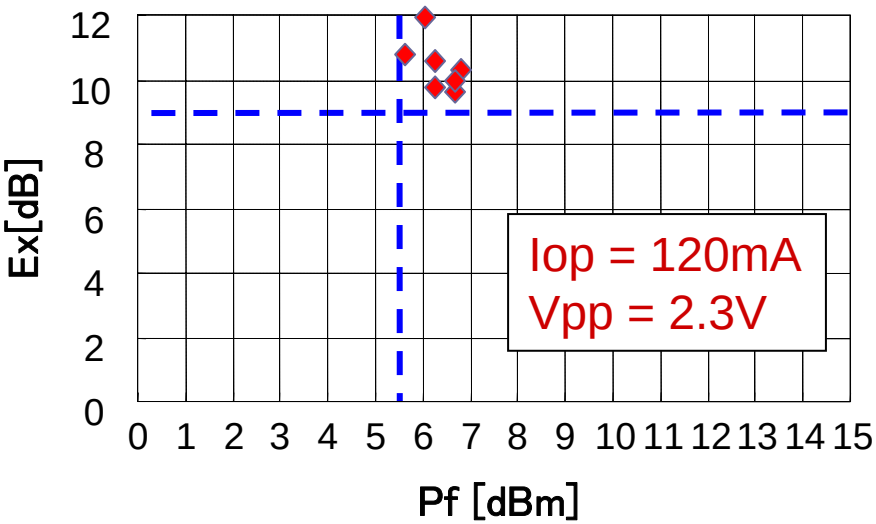
Sample Deviation

- 7 samples tested
- +5.5 dBm with >9 dB ER feasible at Iop= 120 mA
- Cooler reliability and heat design possible at high bias current

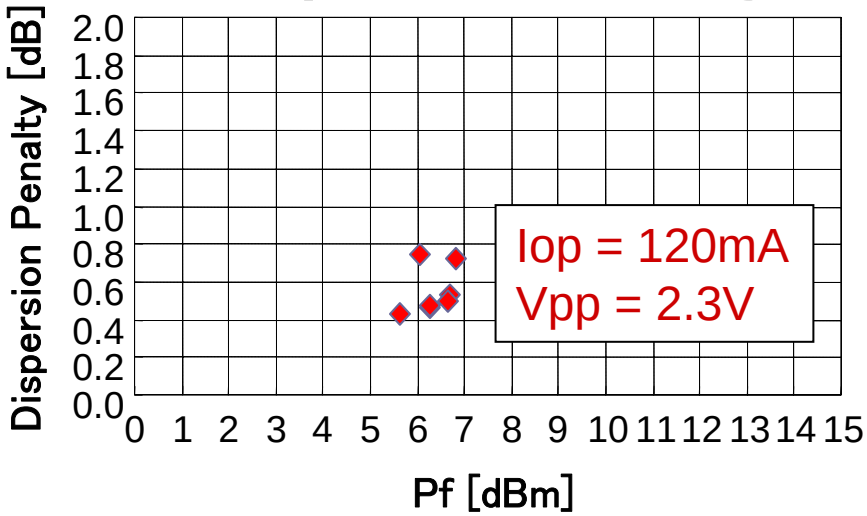
Dispersion Penalty

- <1 dB penalty feasible at 495 ps/nm dispersion

Sample Deviation (Pf, Ex)



Dispersion Penalty



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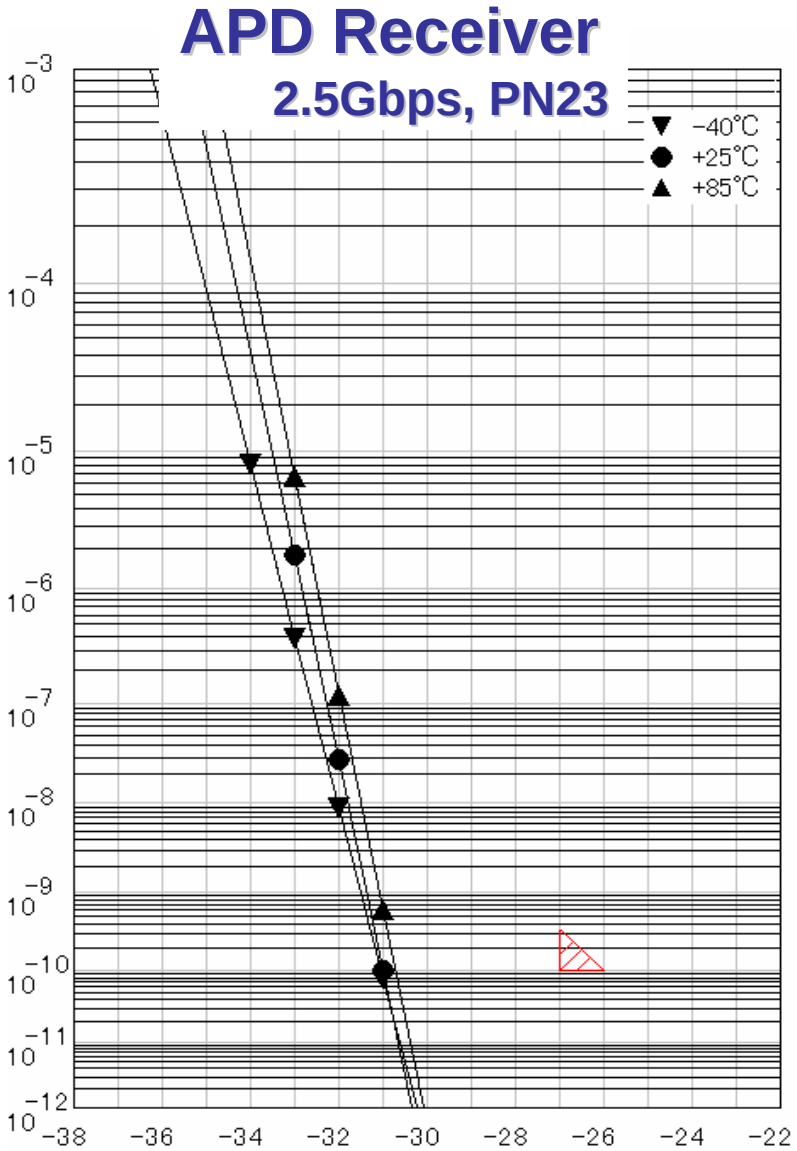
GPON ONT Class B+ (Supplier D)



- GPON ONT reality in the crucial outdoor application
- Stable operation under wide temperature range

APD Receivers

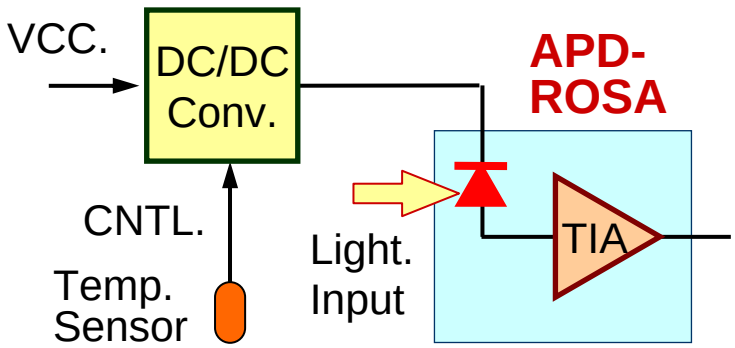
- 1G : GEPON OLT
  2.5G: GPON OLT, ONT
  (incl. outdoor)
- 10G : XFP, 300pin
  (APD >10 km)
  10GEPON OLT
  (incl. outdoor in case of GPON migration)

Vendors are all quite familiar with APD bias control

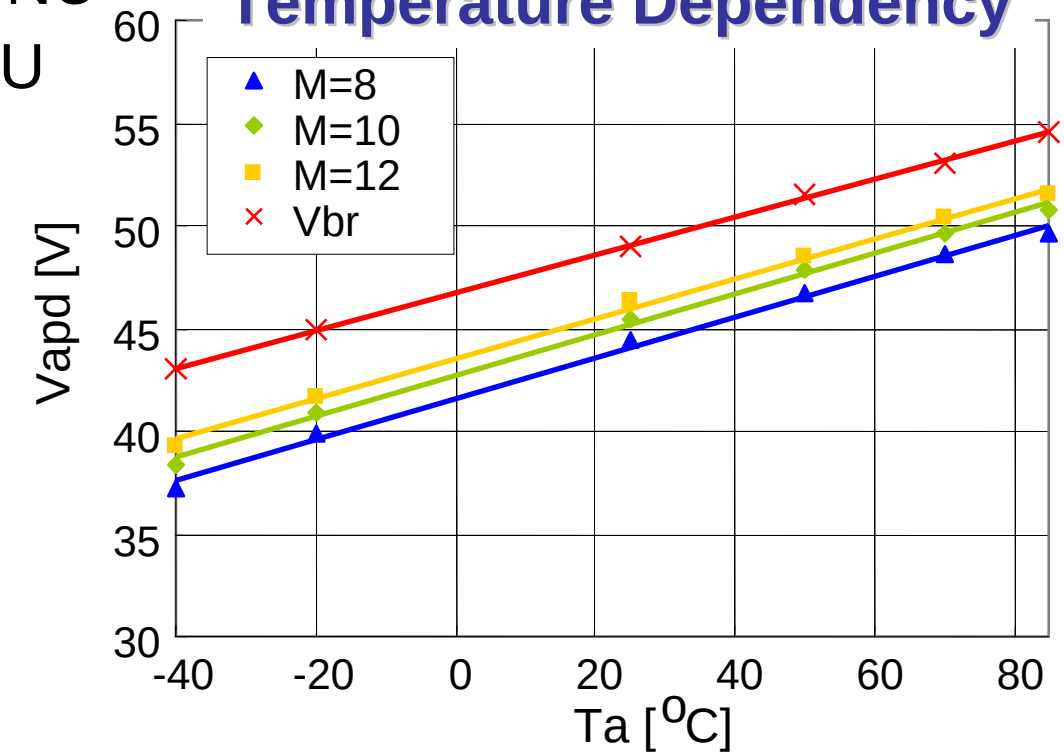
Simple APD Bias Control (Supplier D)

- Linear temperature dependency and M-insensitive APD bias
  Simple straight bias control over the temp. works perfect
- Negligible small circuitry, everything mountable in XFP
- Only loading the attached bias data into RX controller
  Manually few sec./ONU
  Digitally milisec./ONU

Bias Circuit Example



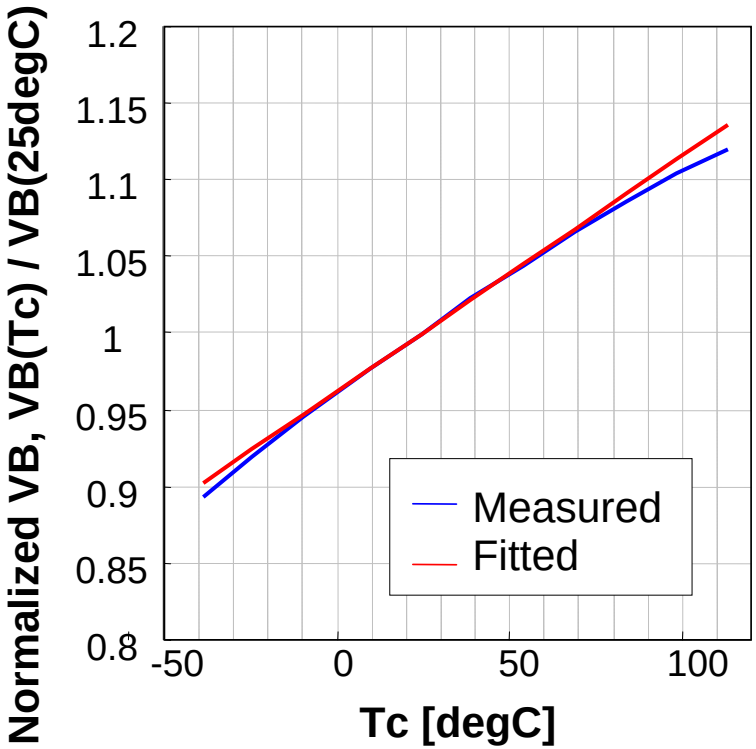
Temperature Dependency



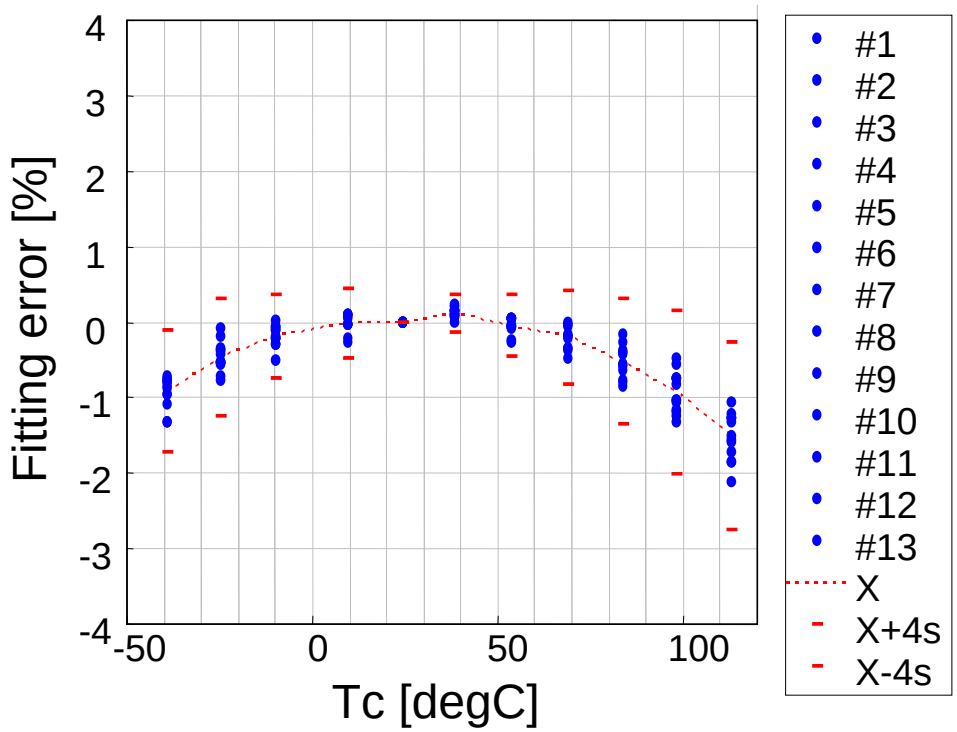
10G APD Bias Control (Supplier A)

- Negligible error with simple straight bias control
  1.74% error at -40 degC (4δ assumption)
- 10G volume chip supply ready

10G APD Temp. Dependency



Control Error



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10G OLT Size

1G and 10G OLT Size Uniformity

- Reuse of equipment footprint in the central office
- Minimal OPEX for OLT replacements and fiber rearrangements

Small size optics indispensable

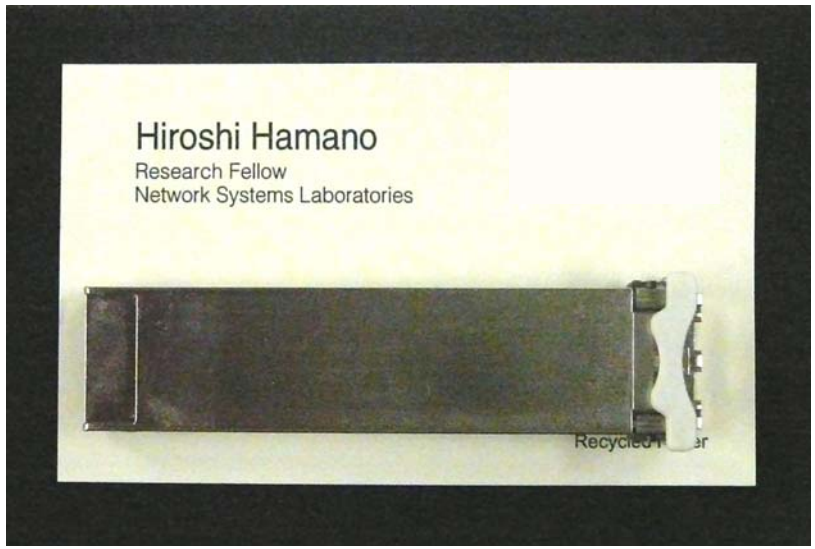
Extreme in case of GPON
double or quad OLT migration

APD@ONU Reduces OLT Size

Simple EML TX enables
all the optics to be assembled
into a small transceiver package;

- BIDI style, or
- pluggable XFP type

10G TRX Example (XFP)



78 x 18.4 x 8.5 (12 cc)

Uncooled L-band EDFA ??

- BIDI- or XFP-style integrated transceiver impossible
  At least double the size of current 1G OLT
- Messy time-consuming handwork for ;
  fiber splicing, forming and bundling
  10s of minutes more for each OLT assembly
- Wider temp. range in case of GPON migration
  EDFA pump temperature stabilization necessary
- Concern for L-band EDFA volume supply
- Concern for sudden-death free,
  reliable 980nm uncooled pump supply

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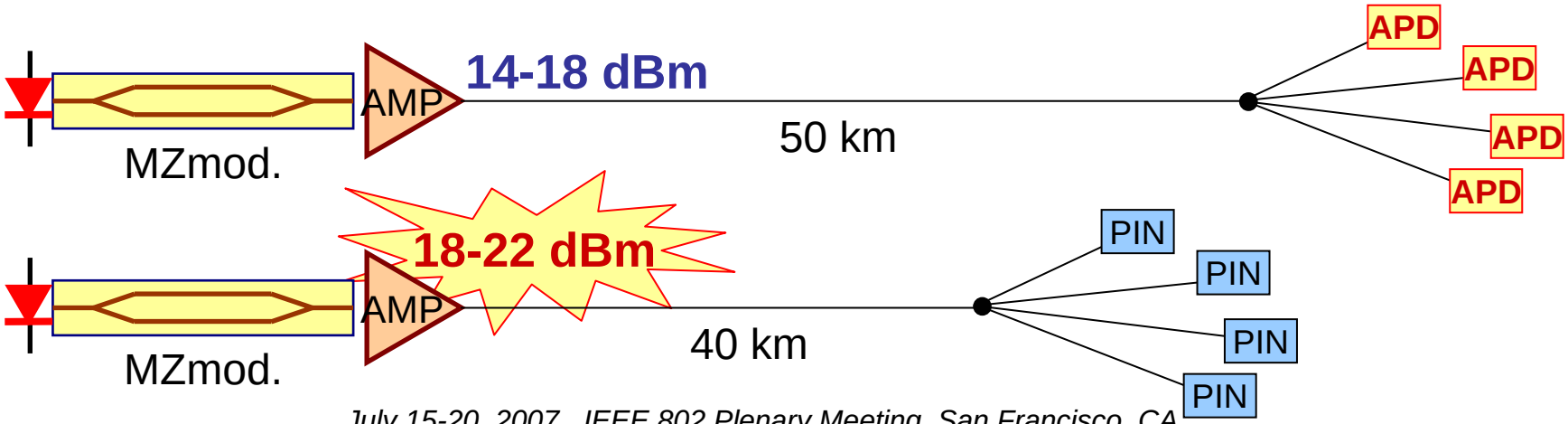
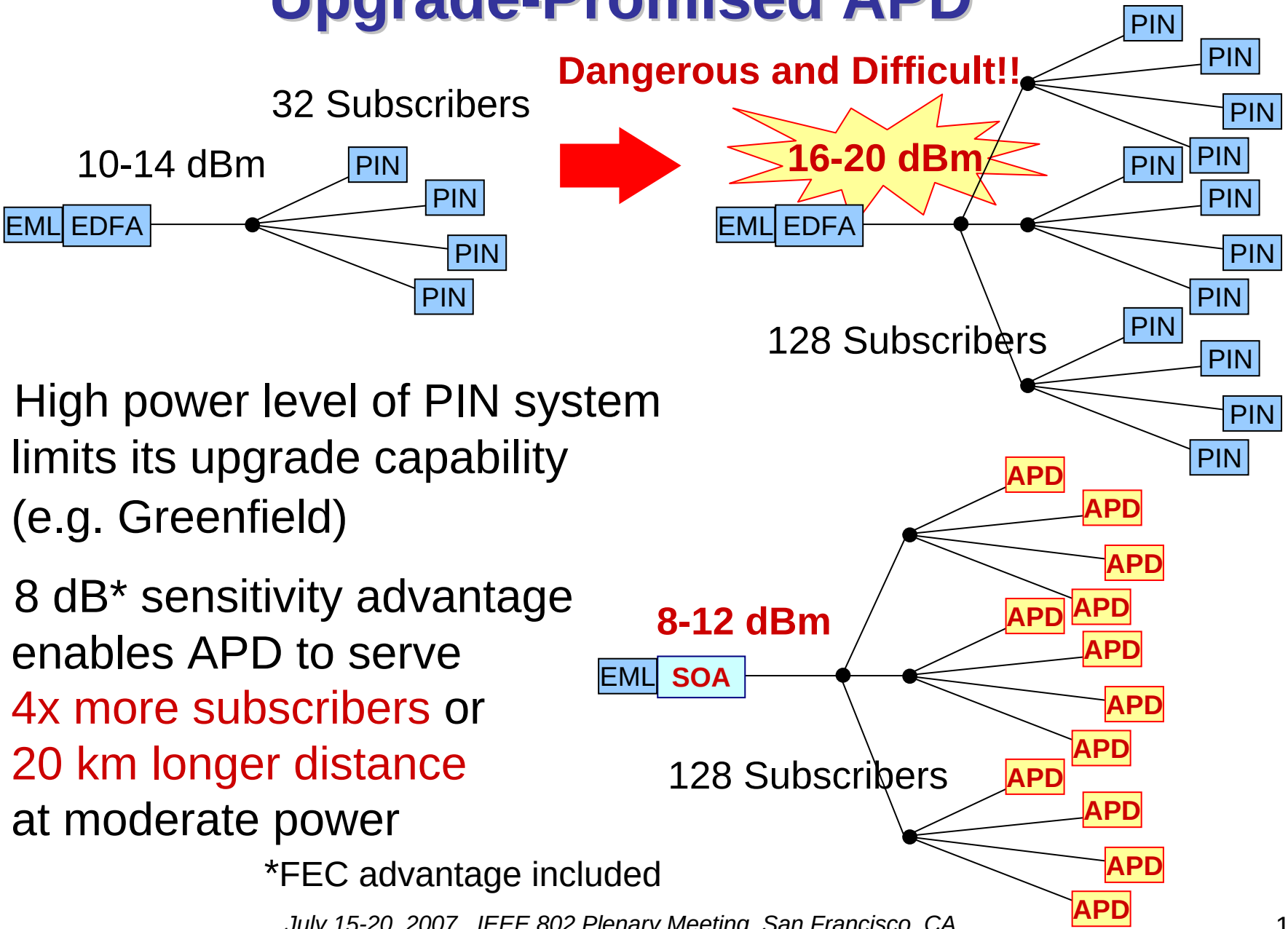
OLT Optical Source Options

Sophisticated future optical sources will make OLT more cost effective or longer reachable.

- Dispersion-tolerable DML
  - EML alternative for cost reduction
  - DFB high-power feature also eliminates optical booster
- $LiNbO_3$ Mach-Zender Modulator
  - Together with optical booster, long-reach application is easily achievable without extreme power



Upgrade-Promised APD



- High power level of PIN system limits its upgrade capability (e.g. Greenfield)
- 8 dB* sensitivity advantage enables APD to serve 4x more subscribers or 20 km longer distance at moderate power

*FEC advantage included

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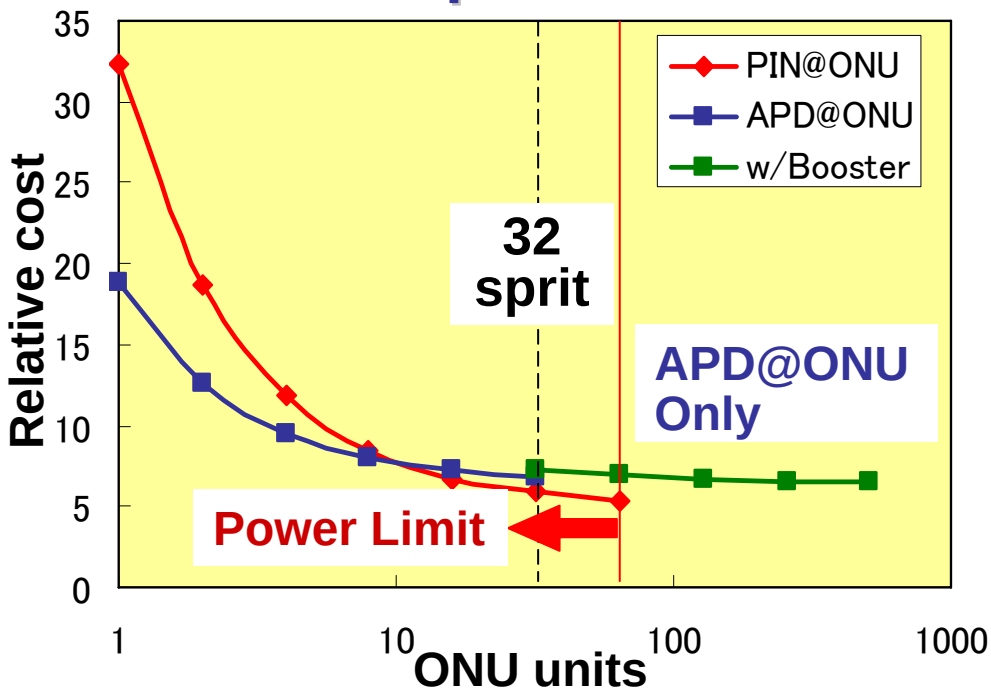
APD, the Cost-Effective Solution

- Only 15% difference even at 32 sprit
  RX contribute small in ONU total optics cost
- PIN@ONU initial CAPEX still doubled
- Simple and small 10G OLT also saves OPEX
  in central offices at replacement

Total Optics Cost



Components Cost

	Lee/ Schrans	Our Assumption
PIN ROSA	**1**	**1**
APD ROSA	**3**	**2.4**
EML TOSA	**10**	**6**
High-Power EML TOSA		**10**
EDFA	**40**	**19**
High-Power DFB TOSA	**4**	**4 Counted**

Summary

APD@ONU for 10GE-PON is

- **Feasible** with currently available high-power EML of Class B++ target output power
- **Simple and Stable** over the outdoor temperature with GPON-ready bias control
- **Small and Easy** with minimum size package integrated transceiver in OLT
- **Upgrade possible** with its low optical power feature for both distance and subscriber extension
- **Cost effective** with its simple OLT for both initial CAPEX and replacement OPEX

Advanced PON Device