Innovative R&D by NTT

Improving the Performance of Advanced Modulation Scheme

Yoshiaki Sone NTT

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Overview

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Background

Many studies in .3bs TF have investigated the technical and economic feasibility of 2km and 10km SMF PMDs. Next step required for consensus building would be investigations of system margin and market expansion possibility.

Overview of this presentation

Shows the potential of loss budget improvement in advanced modulation transmission (PAM4 and DMT) using the example experiment results.

Confirmation of performance improvement capability

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Performance improvement is a key factor for application expansion. Confirming this capability will increase the 400GE market going forward and enable cost reductions.

For example, increasing loss budget offers

- Flexibility in module implementation (Tx output power, mux/demux)
- Transmission reach expansion
- Delay reduction by FEC-OH reduction

Approach of loss budget improvement			Issues
1	Optical amplification (e.g. SOA)	Relaxation of receiving optical power requirement.	Downsizing. Power consumptions. Support of higher-order modulation.
2	APD	Improvement in receiver sensitivity	Support of higher-order modulation.
3	Use of 1500nm	Transmission loss reduction	TOSA/ROSA development
4	Increase of number of lanes	Baud rate reduction	Integration of optics, WDM Grid

Shown in this presentation

APD: Avalanche Photo-diode

Evaluation viewpoint and modulation formats examined

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Evaluation viewpoint

Investigate the potential of loss-budget improvement of higher-order modulation transmission. As an example, the approach using APD is investigated by using our lab-prototype. (But main purpose is not an evaluation of our APD itself.)

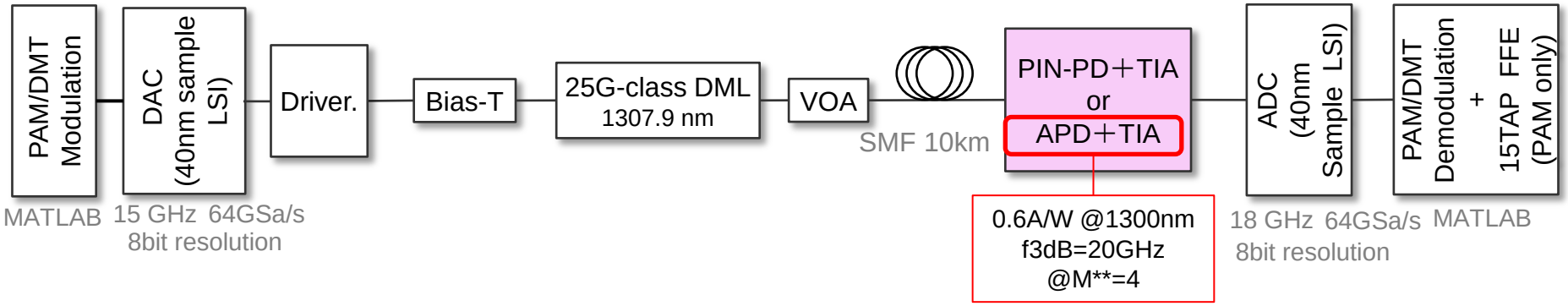
BER performances with PIN-PD and with APD are evaluated for 8λ-PAM4 and 8λ-DMT. (4λ solution has not been evaluated in this evaluation but we have no intension to preclude 4λ as a solution)

Target modulation schemes and presenting results

Scheme	PIN-PD receiver	APD receiver
4λ DMT	Already reported	Under investigation
8λ DMT	This presentation	This presentation
8λ PAM4	This presentation	This presentation

Evaluation conditions

・Transmission setup is common other than signal generation.
・Commercially available evaluation board LSI (40nm) is used.
・PIN-PD receiver and APD receiver*



*APD receiver does not have the functionalities sufficient to allow to be used as a commercial product. It was packaged in NTT-lab for experimental purposes.

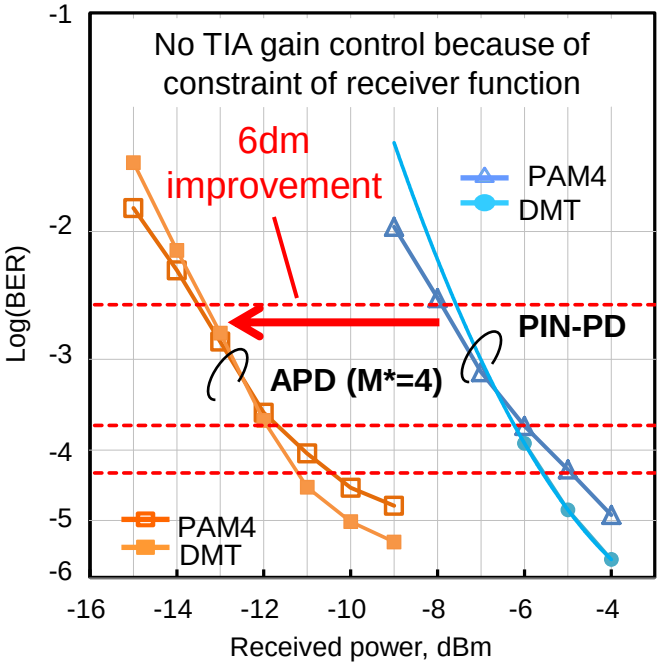
⇒This experiment was conducted in very restricted conditions(M=4) such that the receiver's output was passed to the ADC without TIA gain control.

**M : APD Multiplication factor

Loss-budget improvement shown by experiment

Loss budget of 8λ DMT and 8λ PAM4 can be improved by using APD as an example. Large margin brings flexibility in module implementation and possibility of reach extension or FEC-OH reduction.

BER Measurement result



*M : APD Multiplication factor

Loss budget(Rough estimation)

	0%-OH FEC KR4 Operating BER 5e-5		3%OH FEC KP4 Operating BER = 2e-4		12% OH FEC BCH Operating BER =3e-3	
	8λ-DMT (58G)	8λ-PAM4 (56G)	8λ-DMT (58G)	8λ-PAM4 (56G)	8λ-DMT (58G)	8λ-PAM4 (56G)
Tx output (dBm)	**9.5**					
8λ Mux loss (dB)	3					
8λ Demux loss (dB)	3					
Min. receiver sensitivity (dBm)	-11	-10.5	-12	-12	-13	-13
Loss budget(dB)	14.5	13	15.5	15.5	16.5	16.5

Enough larger than 10km SMF PMD requirement (6.3dB)

Further improvement would be possible as shown in slide #9 and #10.

Conclusion

- Loss budget of higher-order modulation transmission can be improved. This offers flexibility in module implementation. Further performance improvements would be expected in future with commercial implementation.

- Extending the reach of 400GE 10km PMD is not so difficult. Over10km reach will soon be possible with higher-order modulation.

- For the market expansion, we should select a 10km SMF PMD solution that has the reach extension capability.

Backup slides

Reference spec of APD

APD characteristic parameters for 1300nm @M=10

M: Multiplication Factor

GB product=235GHz

item	value
Sensitivity（@M=10）	9.0 A/W
3dB bandwidth(@M=10)	18.0 GHz

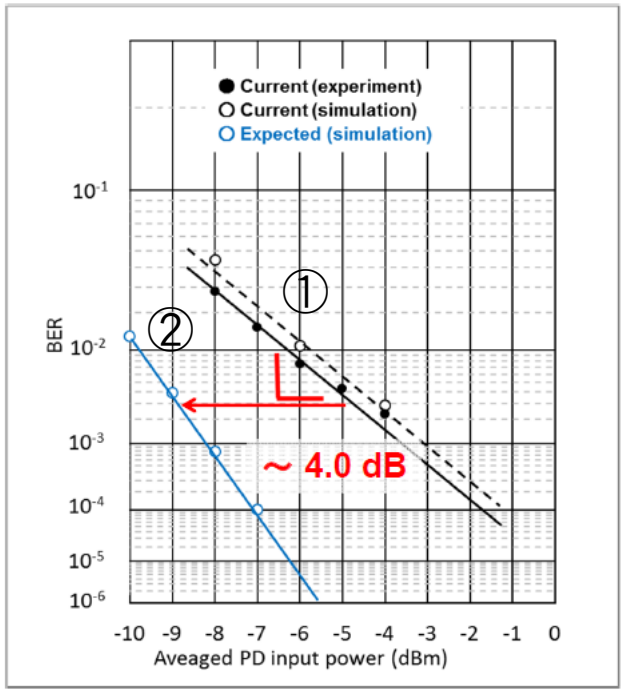
REF. M. Nada, et.al. ELECTRONICS LETTERS 21st June 2012 Vol. 48 No. 13

Expected performance improvement in DMT

Receiver sensitivity will improve by 4.0 dB according to bandwidth improvement of TX/RX component

takahara_3bs_01a_0914.pdf

Expected improvement of receiver sensitivity FUJITSU



116 Gbps

SC: 256

Target BER 3.3E-3

BCH(9193,8192)

	①	②
TX bandwidth [GHz]	12	18
RX bandwidth [GHz]	16	21
Optical Modulation index	0.42	0.45
Input referred noise [pA/√Hz]	20	12

① current performance

② expected improved performance

Expected performance improvement in PAM4

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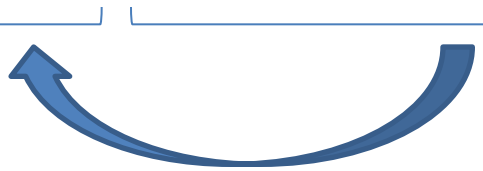
Future technology progressions for Rx bandwidth will enable better BER performance of PAM4

	56G-PAM4			
TX optics	EML (40G-Class)		DML (25G-Class)	
RX optics	PIN-PD			APD
RX bandwidth	32GHz DSO	18GHz CMOS ADC		
Min. receiver sensitivity	-12 dBm	-8 dBm	-8 dBm	-13 dBm
Ref.	sone_3bs_01_0714.pdf	sone_3bs_01_0914.pdf	sone_3bs_01_0914.pdf	sone_3bs_01_1114.pdf



4dB improvement