Multi-rate receiver Survey and analysis

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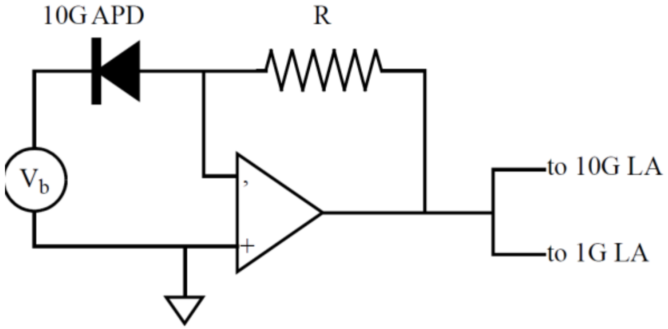
Background

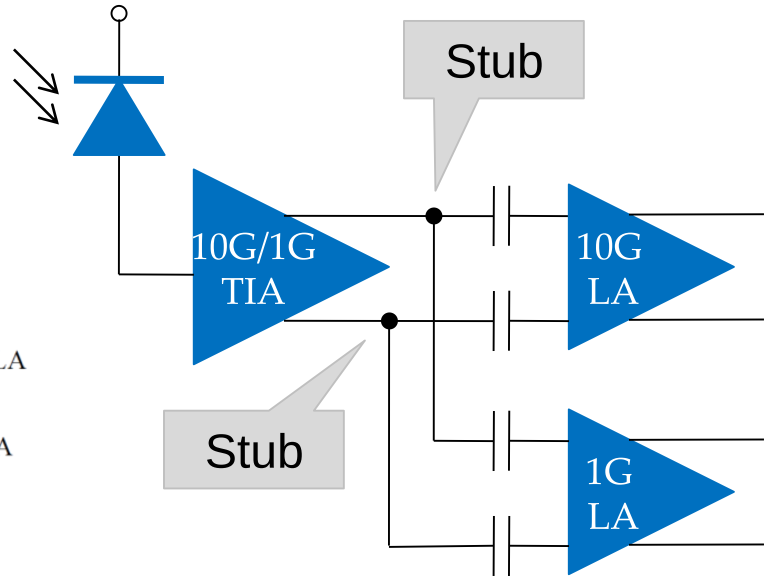
- TDMA is one of key methods in PLAN B, i.e. one dual-rate receiver in OLT to handle 10G and 25G US signals (both in 1260nm-1280nm)
- Specifically in CTC's scenario, triple-rate receiver is necessary to handle 1G, 10G and 25G US signals
  - 1G US signal in 10/1 ONU has been requested to be narrowed into 1260nm~1280nm in CTC's scenario
  - 10/1 ONU may still be deployed when 100G EPON sails
  - To save the cost, coexistence and smoothly migration are required
- The joint contribution provides information and analysis from partners in the survey, target to call for more analysis on the topic and get final estimation result to serve the wavelength decision
  - Multi-rate receiver design with necessary key components
  - Impact on requirement to PHY parameters
  - Impact on requirement to MAC control
  - Viewpoints for related Industry support

Multi-rate receiver examples (1)

- **Dual-rate receiver （10G and 1G）**
  - Popular design in PON system for coexistence, e.g. 10G EPON/1G-EPON, XG-PON/XGS-PON
  - Quite mature industry as it has been commercialized in PON product

10/1G OLT dual rate Receiver sensitivity requirement (dBm)	
10/1GBASE–PRX–D3 (1G)	-29.78@1E-12
10GBASE–PR–D3 (10G)	-28 @1E-3





- Evaluating capability of existing components, enough sensitivity margin observed for 1G signal, so burst mode TIA is always optimized and operated for 10G signal

Multi-rate receiver examples (2)

- **Dual-rate receiver (25G and 10G),** required in PLAN B, for 25/x ONU and 10/10 ONU coexistence

- **Triple-rate receiver (25G, 10G and 1G), requires in PLAN B used in CTC scenario**
  - Receiver sensitivity for 10G and 1G signals should still meet the specification in 802.3, as shown in below table, to ensure those deployed ONUs working well when upgrading OLT from 10G to 100G capability
  - Receiver sensitivity for 25G signal should be capable for PR20 and PR30 in the upstream direction

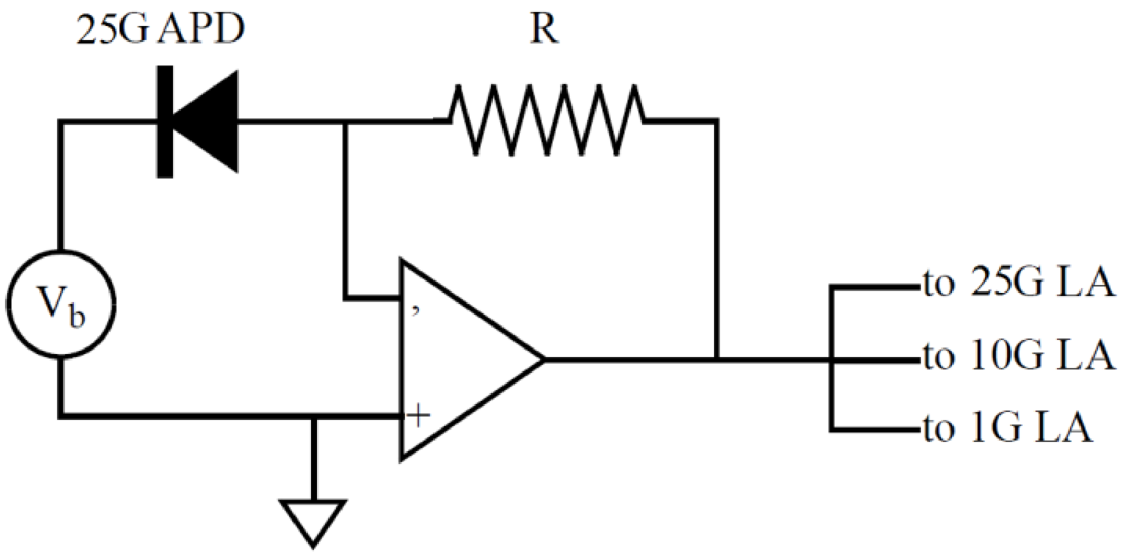
10/1G OLT dual rate Receiver sensitivity requirement (dBm)	
10/1GBASE–PRX–D3 (1G)	-29.78@1E-12
10GBASE–PR–D3 (10G)	-28 @1E-3

Survey result: example, Simulation results or estimation (1)

- Static TIA mode, due to same trans-impedance for 25G and 10G, so there will be a serious sensitivity degeneration on 10G and 1G signal.

Static trans-impedance,
Static reverse bias voltage

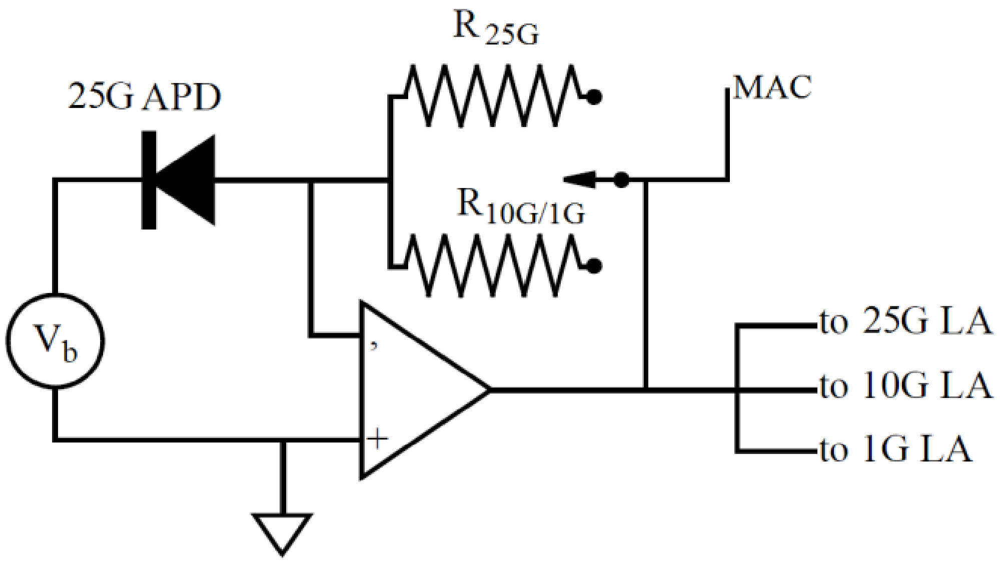
Item	10G single rate	25G dual rate		
	10G	1.25G	10G	25G
ER （dB)	6	10	6	6
Response (A/W)	0.85	0.7	0.7	0.7
Multiplication Gain	10	8	8	8
Excess Noise Factor at M	4.4	3.7	3.7	3.7
Bandwidth(GHz)	7.5	18	18	18
Sensitivity (dBm@1E-3)	-31.35	-29 (@1e-12)	-27	-26



Survey result: example, Simulation results or estimation (2)

Dynamic trans-impedance
, Static reverse bias voltage

- bandwidth is optimized for both 25G and 10G signal accordingly, 0.2dB penalty observed for 10G
- Rate switch signal for TIA from MAC



Item	10G single rate	25G dual rate		
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Multiplication Gain	10	8	8	8
Excess Noise Factor at M	4.4	3.7	3.7	3.7
Bandwidth(GHz)	7.5	7.5	7.5	18
Sensitivity (dBm@1E-3)	-31.35	-34.8 (1e-10)	-31.15	-26

Survey result: example, Simulation results or estimation (3)

- Trans-impedance and V_{APD} can be switched by rate control signal
- Due to function M , Excess Noise Factor and bandwidth of V_{APD} , there is very limited extra benefit compared with previous one
- Rate switch signal for TIA from MAC

Item	10G single rate	25G dual rate		
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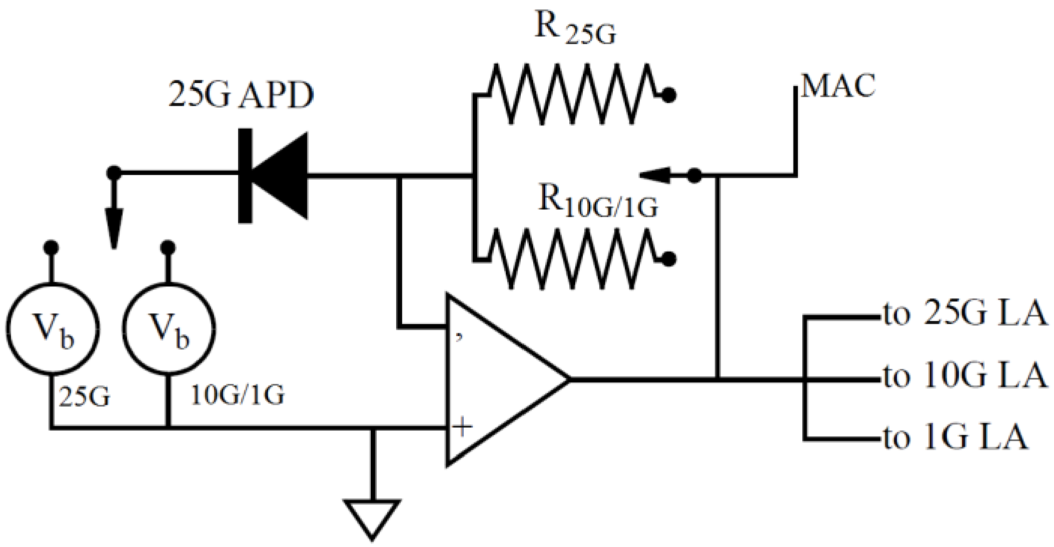
Dynamic trans-impedance
Dynamic reverse bias voltage

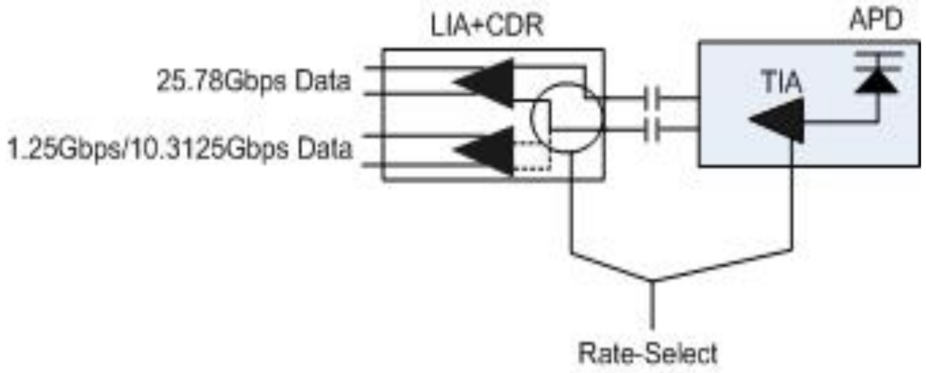


Survey result: example, Simulation results or estimation (4)

- 25G/10G dual-rate would simplify the system design (10G tunnel to handle both 10G and 1G)
- Rate-Select function is required
- Based on the test result (10G/1G dual-rate), using TIA/LA under 10G mode to receive 1G signal, there is some penalty on receiver sensitivity but still within the spec definition
- Based on experienced data when developing dual mode GPON and XG-PON module, it is estimated that >=3dB penalty on 1G signal's receiver sensitivity using 10G TIA/LA, compared to 1.25G TIA/LA

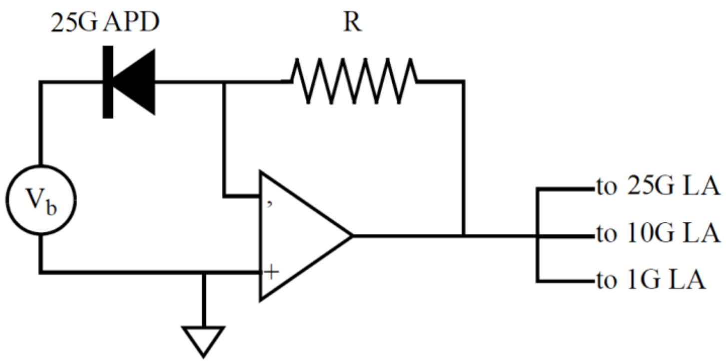
Rate_select

Group	Rate	Receiver Sensitivity requirement
Group 1	25.78 Gbps	-24 dBm-TDP @ONU Tx Min = 5dBm
Group 2	10.3125 Gbps	-28 dBm
Group 2	1.25 Gbps	-29.78 dBm



Survey result: example, Simulation results or estimation (5)

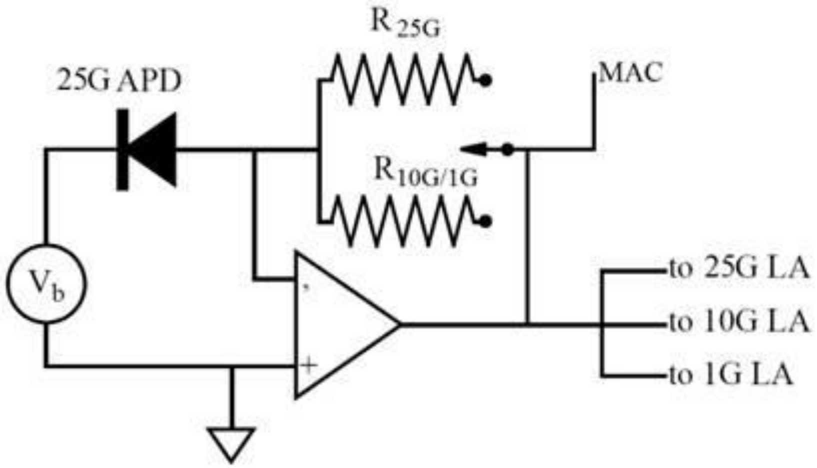
3 Rates by one static Load Resistance



Parameters	Single 10G Rx	25G Rx		
	10G	1.25G	10G	25G
ER (dB)	6	6	6	6
Bandwidth (Hz)	7.5G	1G	7.5G	18G
Responsivity (A/W)	0.85	0.7	0.7	0.7
AvalancheMult Gain	10	8	8	8
Excess Noise Factor	4.4 (k=0.3)	3	3	3*
Thermal Noise	5.25pA/Hz^(1/2)	10pA/Hz^(1/2)	10pA/Hz^(1/2)	10pA/Hz^(1/2)
Rx Sensitivity	-33dBm@1e-3	-31.7dBm@1e-10	-30.4dBm@1e-3	-28dBm@1e-3

Survey result: example, Simulation results or estimation (6)

3 Rates by two dynamic Load Resistance



- Comments:
  - If switch time is OK, then there is very small penalty to use multi-rate APD-TIA with dynamic Resistor switch;
  - Even with the worse case (static Resistor), one can always reduce the penalty by increasing the load Resistor, or use low Ionization coefficient ratio APD, like Si based APD;

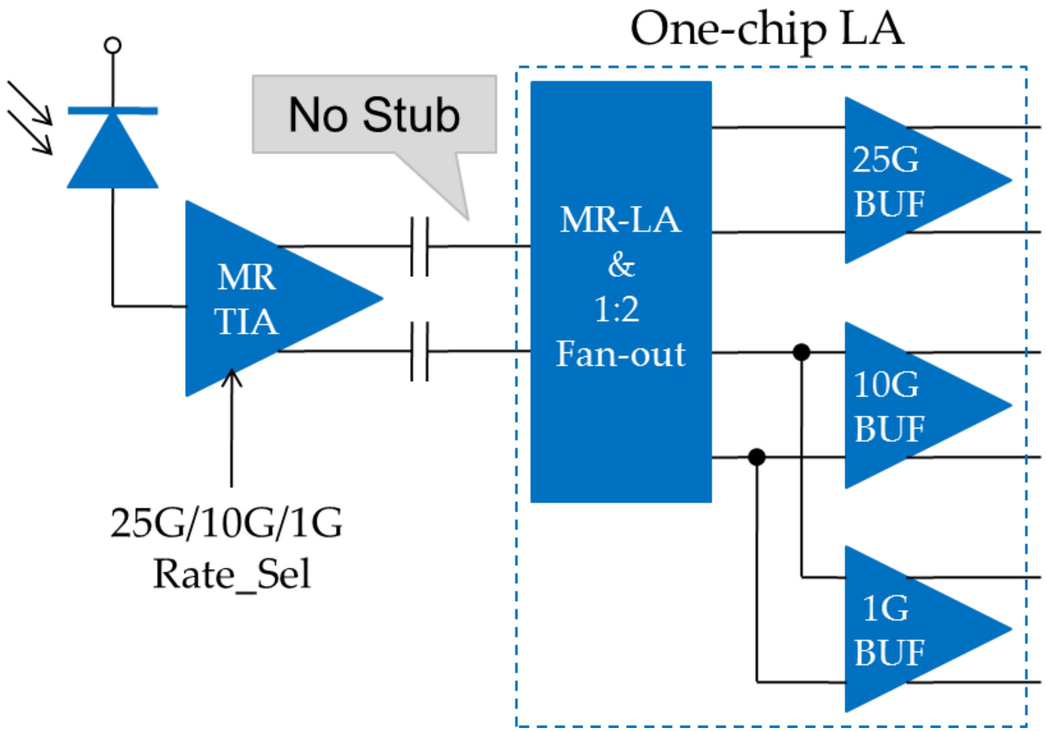
Parameters	**Single 10G Rx**	**10G Rx**		**25G Rx**
	10G	1.25G	10G	25G
ER (dB)	6	6	6	6
Bandwidth (Hz)	7.5G	1G	7.5G	18G
Responsivity (A/W)	0.85	0.7	0.7	0.7
AvalancheMult Gain	10	8	8	8
Excess Noise Factor	4.4 (k=0.3)	3	3	3*
Thermal Noise	5.25pA/Hz^(1/2)	5.25pA/Hz^(1/2) (4x load Resistor)	5.25pA/Hz^(1/2) (4x load Resistor)	10pA/Hz^(1/2)
Rx Sensitivity	-33dBm@1e-3	-34dBm@1e-10	-32.5dBm@1e-3	-28dBm@1e-3

*SiFhotonics, Si based APD Ionization coefficient ratio k<2 (here k=0.13) (pan_3ca_1_0916.pdf)

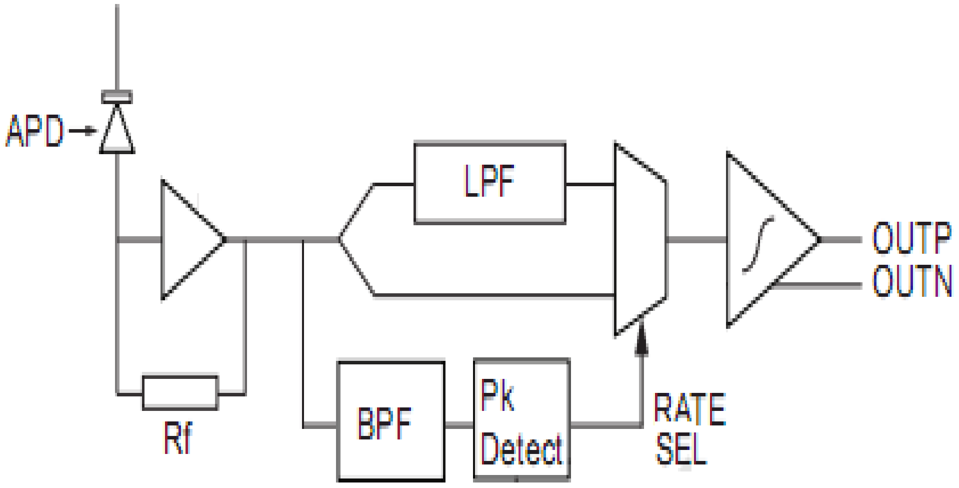
Survey result: example, Simulation results or estimation (7)

Comments: Stubs should be avoided between TIA and LA. One-chip Multi-rate LA may be good choice, but it is different with single 25G rate LA.

MR-TIA and MR-LA



Survey result: example, Simulation results or estimation (8)



- Using automatically rate detecting technology to control
  - By spectrum detect or Peak detect, which is already inused in 10G EPON
  - Detect signal rate, and adapt filter accordingly in chip to remove noise spectrum and improve sensitivity
- Complex multi-rate TIA/LA design, with simplified MAC interface and control
- Extra time needed in guard time period for signal rate-detecting, about 100ns including detecting and instruct switching
- Reduced discovery quiet window types compared to the way which getting rate-Select signal from MAC

Viewpoints from optical module vendor in the Survey

Technical feasibility

- Generally, Triple-rate burst mode receiver design would be doable but challenging
- The margin of 1G sensitivity SPEC would be very tighter than dual-rate 10G/1G receiver, as usually 25G photo detector has smaller active region size, lower responsibility, larger dark current, less max. overload current, which results in worse RX performance than 10G photo detector under lower data rate
- Additional Rate_Sel input will be helpful to realize the Multi-rate TIA as Data rate variation ratio of 25G/10G/1G Multi-rate receiver is up to 25X

Industry support

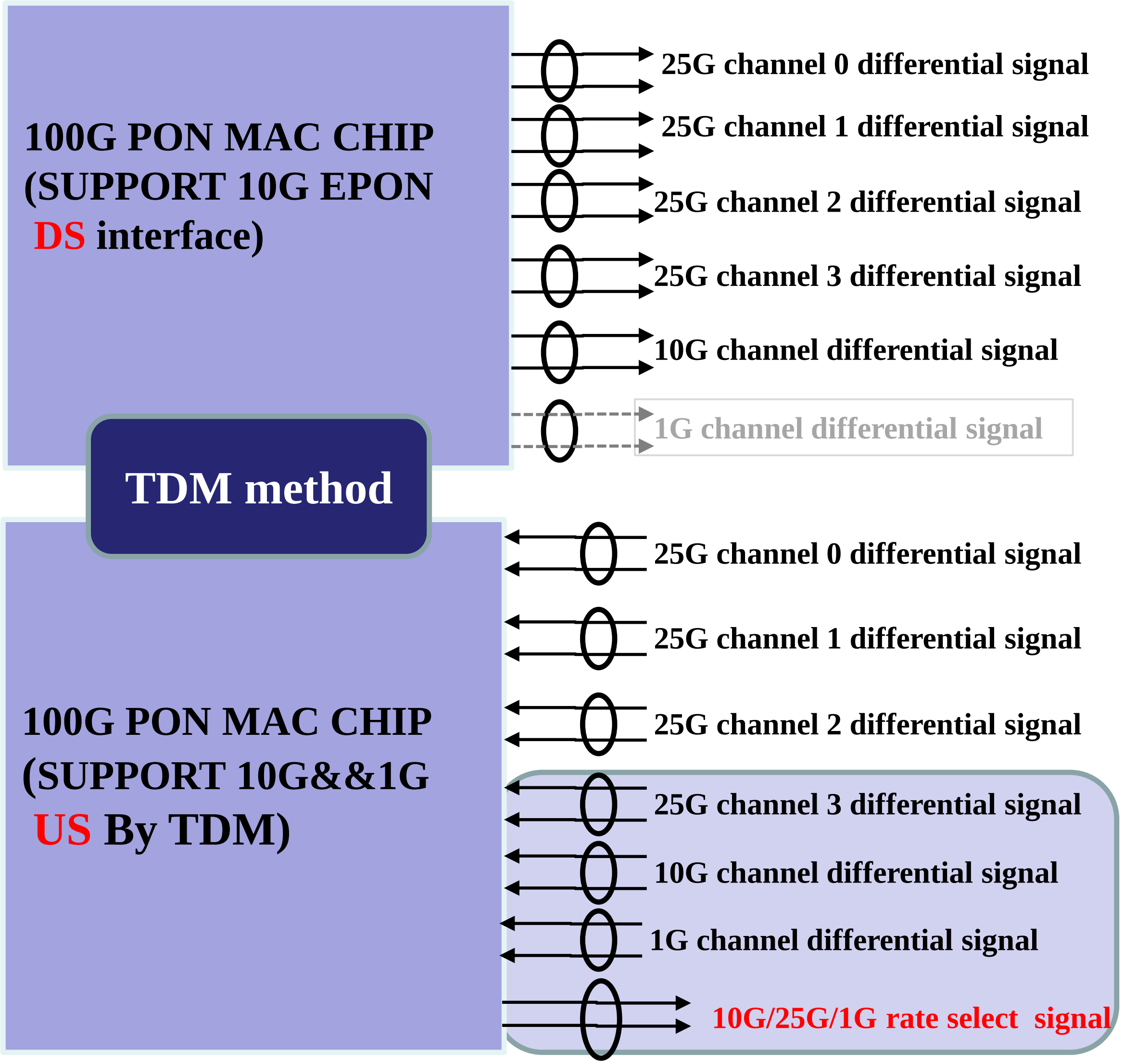
- No 25G burst mode TIA/LA in the market yet
- Triple-rate test on same receiver means more test items, it would result in low yield
- 25G IC semiconductor process may be more expensive than 10G/1G due to different semiconductor processes and test platforms between 25G and 10G IC fabrication
- Two kinds of burst mode receivers existed in 100G EPON OLT (multi-rate, and pure 25G), which leads to scattered Burst mode RX ICs demand

Impact on requirement to PHY parameters

- **Some observations are summarized based on simulation results**
  - Sensitivity penalties on 1G signal might be negligible (enough margin regarding spec)
  - Different Sensitivity penalties on 10G signal, depend on specific triple-rate receive design
  - For 25G signal, receiver sensitivity result is better than implementation (might be caused by the difference between simulation tool and real component)
- **Generally, dual-rate or triple-rate receiver will cause differential degradation of receiver sensitivities for each signal (1G, 10G, 25G)**
- **Simulation results may be optimistic, compared to achievable values in real yield**
- **Reasonable values for degradation of receiver sensitivities are important for further wavelength discussion and feasibility evaluation**

MAC interface

- Rate_select signal should be generated by MAC, which is not challenging to achieve it
- Several viewpoints on the switch time of trans-impedance:
  - Vendor 1: can be several nanoseconds by the control signal. the impact on guard time requirement is small
  - Vendor 2: stabilization time for TIA and LA would be up to several tens of nanoseconds, which heavily depends on dedicate TIA design

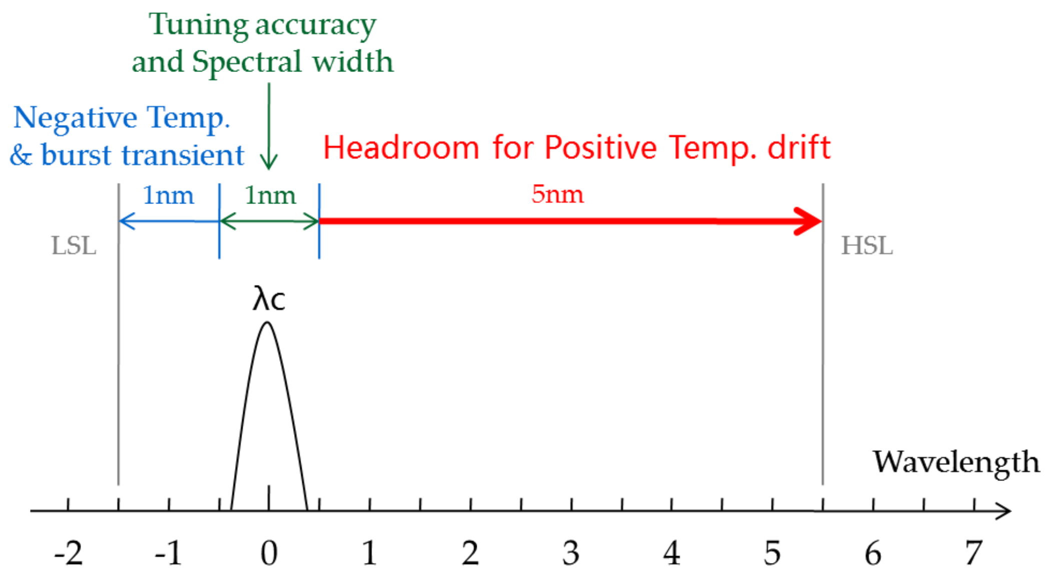


Summary of survey

- **Technically triple-rate receiver design is feasible as many designs feedback in the survey**
- **Suggest more efforts on analysis of degradation of receiver sensitivities, to get recognized impact (estimation) and serve the wavelength discussion and PHY parameter calculation**
- **Some Triple-rate receiver designs need a rate_select signal from MAC to dynamically control the appropriate TIA/LA, doable but brings extra complexity in the OLT receiver**
- **The switch time of dynamic TIA trans-impedance seems not be a problem**

Extra points on wavelength plan in the survey

- **7nm Pass band for US0, instead of 3nm (PLAN A),** to balance performance and cost
  - Lower power dissipation of TEC may be used
  - Under C-Temp condition, TEC might be avoid as low cost heating-only technique might be enough for temperature control
  - Relative cost comparison of “Collimated lens” V.S. “TEC device&controller” : 1x V.S. 2.2x



Thanks！