TTC UPGRADE PLANS

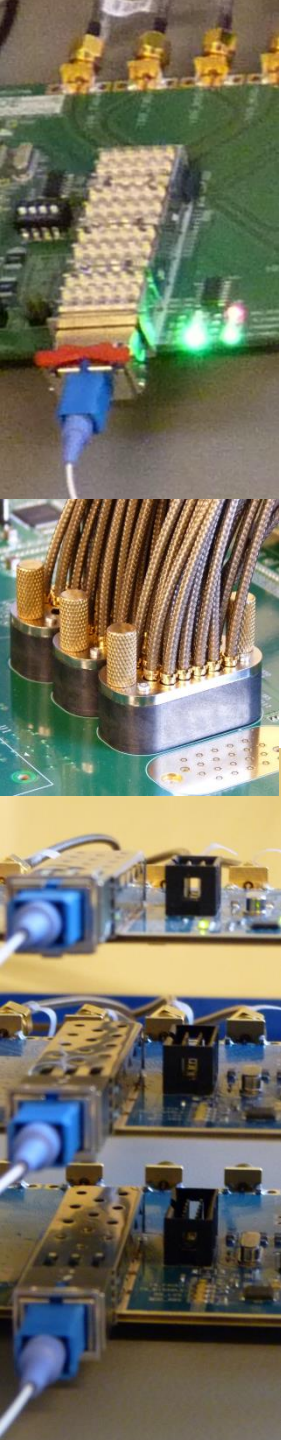
THE TTC-PON PROJECT

sophie.baron@cern.ch – ACES 2014

TTC UPGRADE PLANS

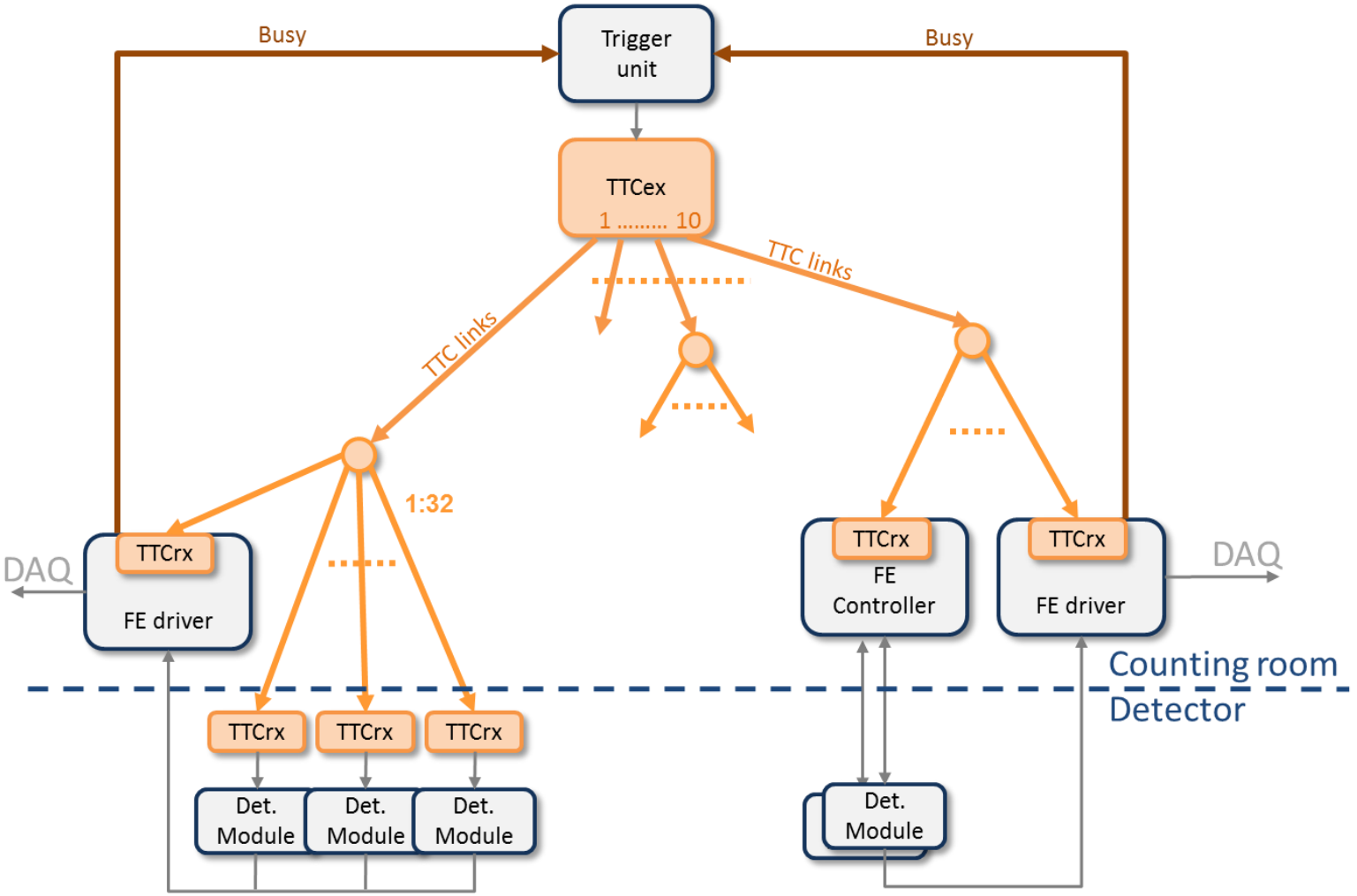
THE TTC-PON PROJECT

1. The plan in 2 slides
2. The TTC-PON demonstrator
3. Summary & Perspectives



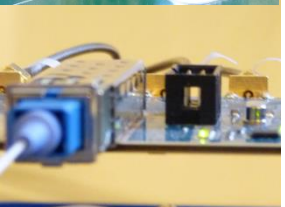
THE PLAN (in 2 slides)

- From the TTC legacy system…

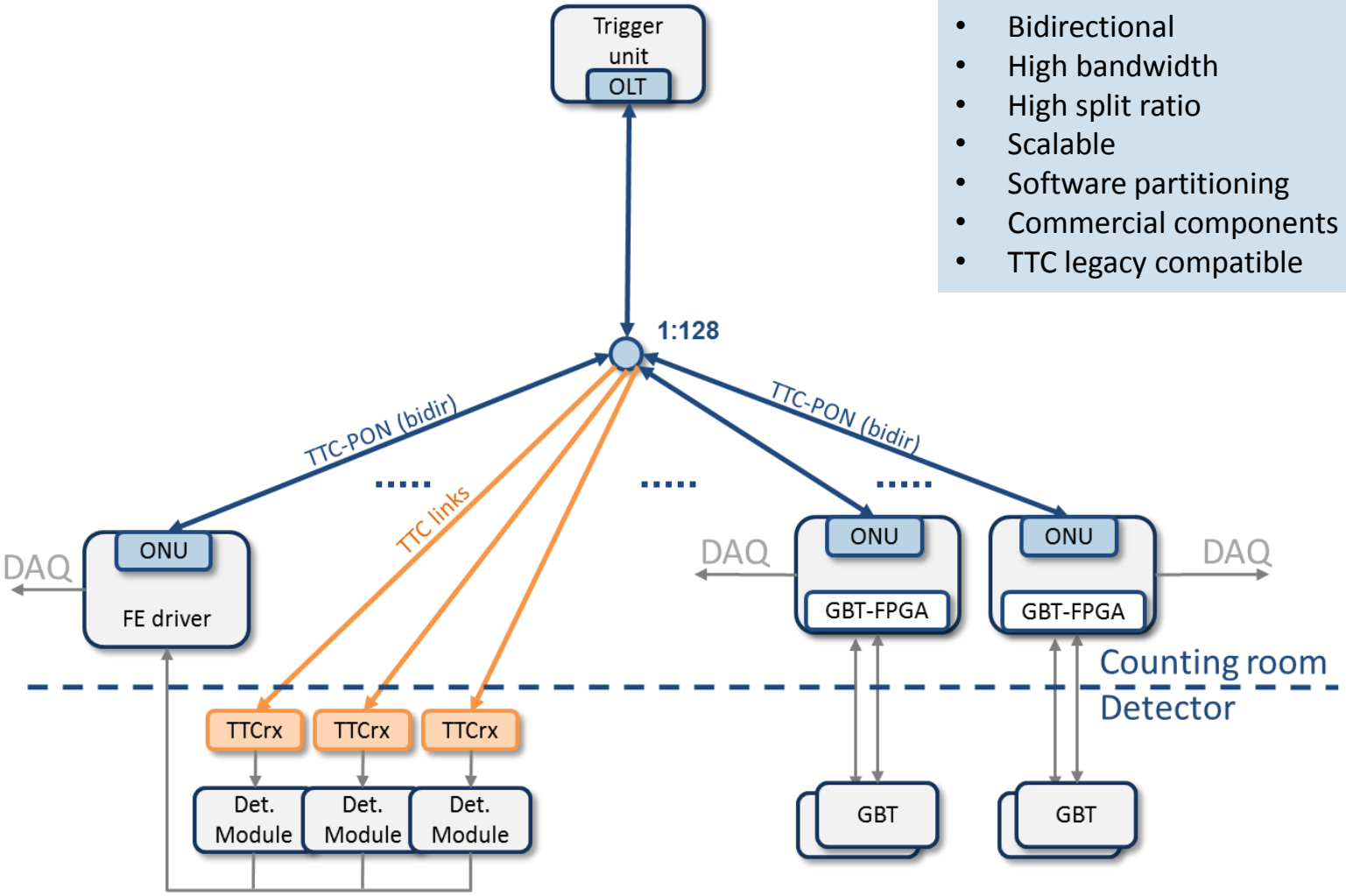


THE PLAN (in 2 slides)






- ...to the TTC-PON:



- Bidirectional
- High bandwidth
- High split ratio
- Scalable
- Software partitioning
- Commercial components
- TTC legacy compatible

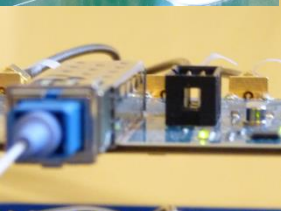
TTC UPGRADE PLANS

THE TTC-PON PROJECT

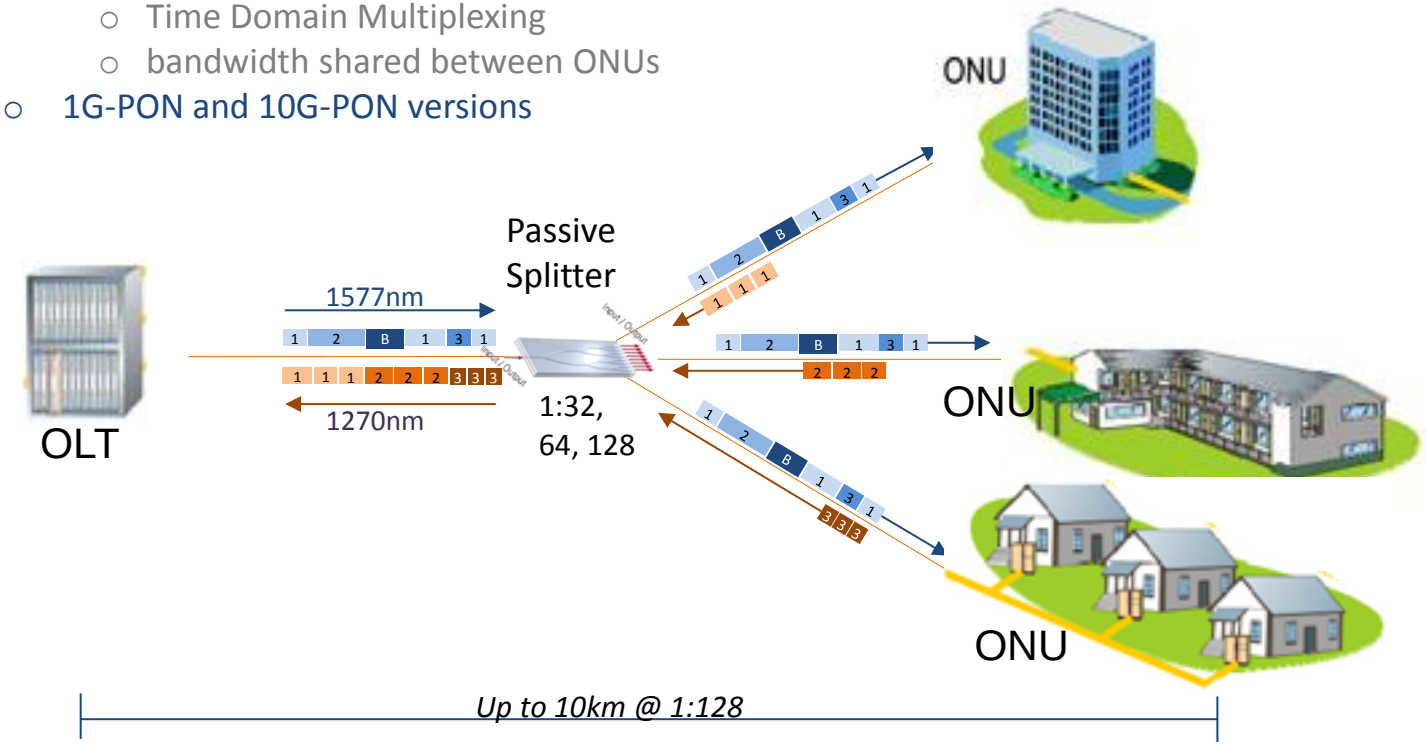
1. The plan in 2 slides
2. The TTC-PON demonstrator
   - The PON principle
   - TTC-PON General Overview
   - The Downstream Path
   - The Upstream Path
3. Summary & Perspectives

THE PON PRINCIPLE





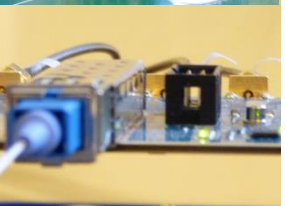

- PON=Passive Optical Network
  - Fiber To The Home (FTTH) technology
  - 1 single fiber, 2 directions
  - 2 wavelengths (one up, one down)
  - Downstream (OLT -> ONUs) :
    - high bandwidth broadcast
  - Upstream (ONUs -> OLT) :
    - Time Domain Multiplexing
    - bandwidth shared between ONUs
  - 1G-PON and 10G-PON versions



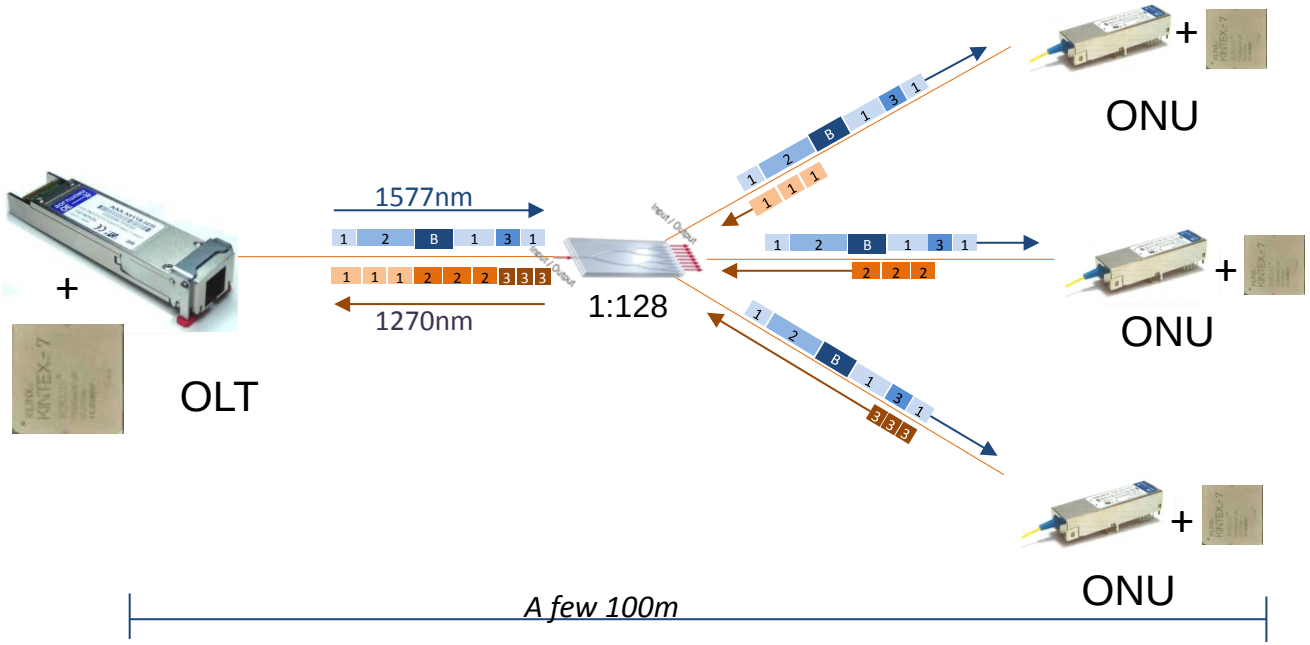
OLT: Optical Line Terminal
ONU: Optical Network Unit

THE TTC-PON DEMONSTRATOR (2014)



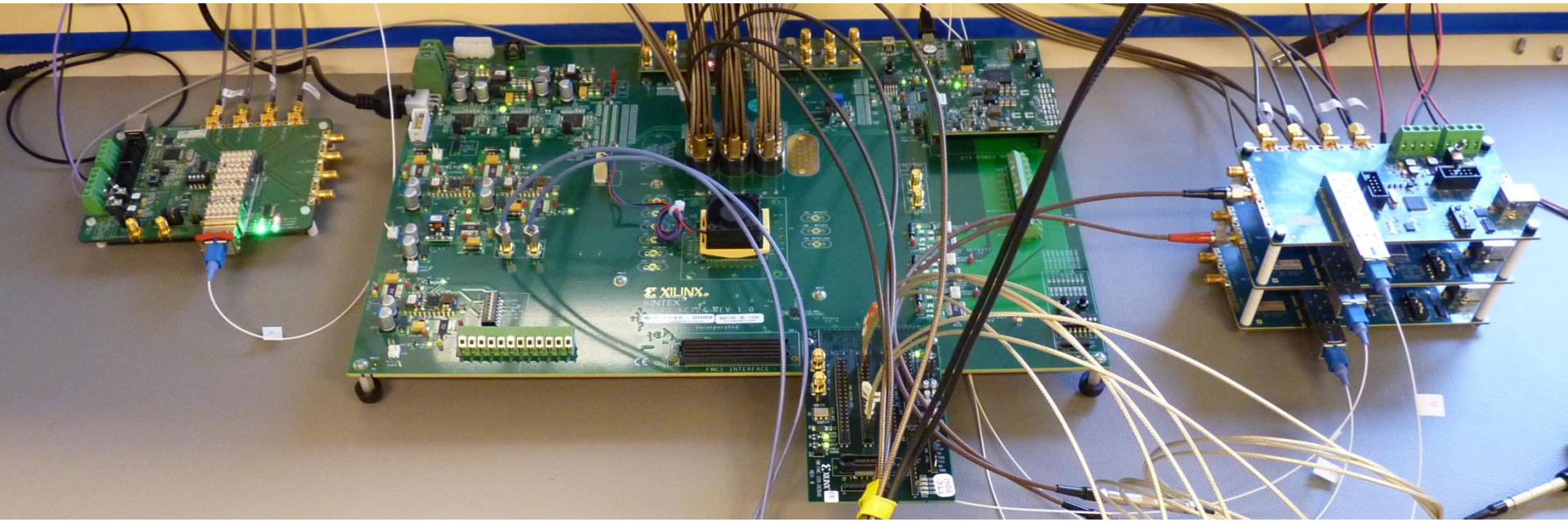


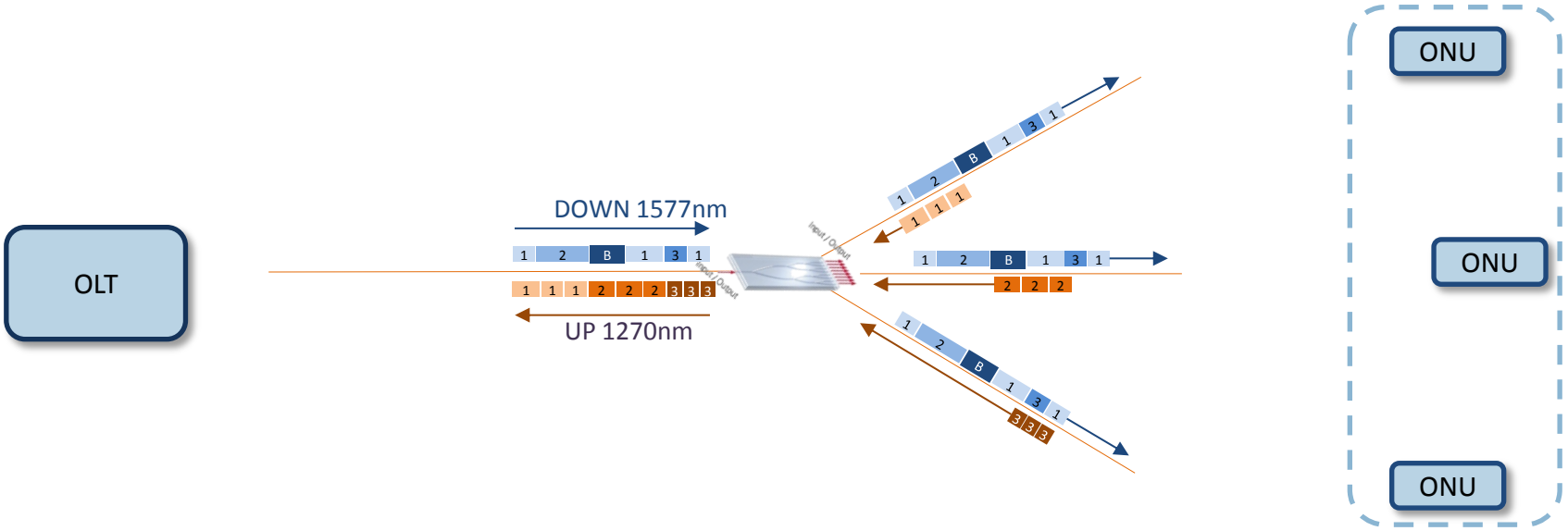

- 10G-EPON devices + Kintex7 KC724 evaluation board
- Tuned to TTC needs:
  - 10-300m
  - 11.2Gbps downstream/2.8Gbps upstream (shared between ONUs)
  - Fully synchronous with Bunch Clock recovery at ONUs
  - Custom protocol



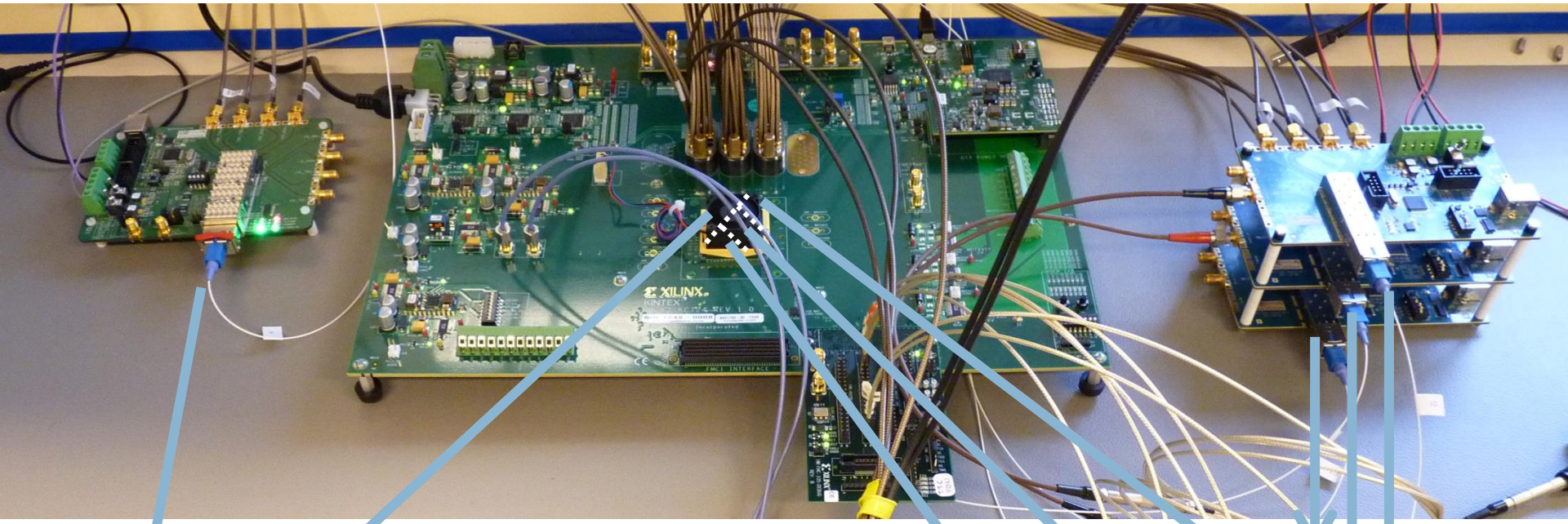
OLT: Optical Line Terminal
ONU: Optical Network Unit

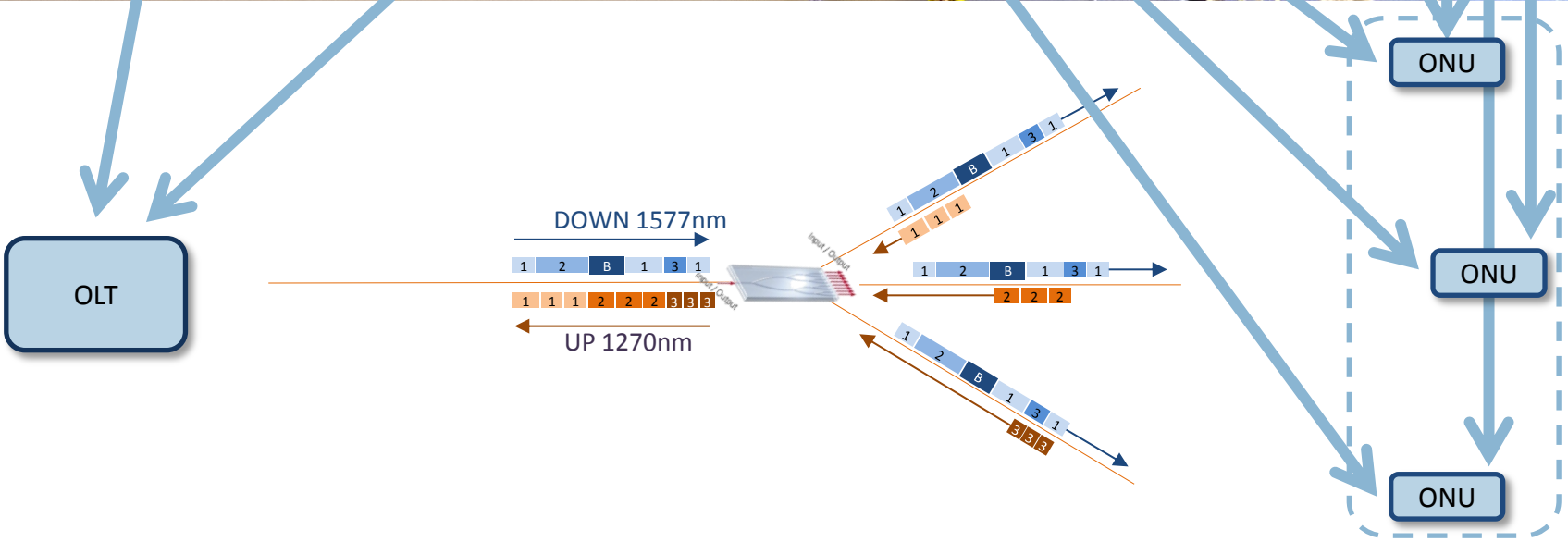
THE TTC-PON DEMONSTRATOR





THE TTC-PON DEMONSTRATOR





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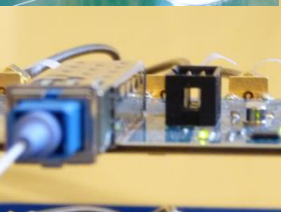
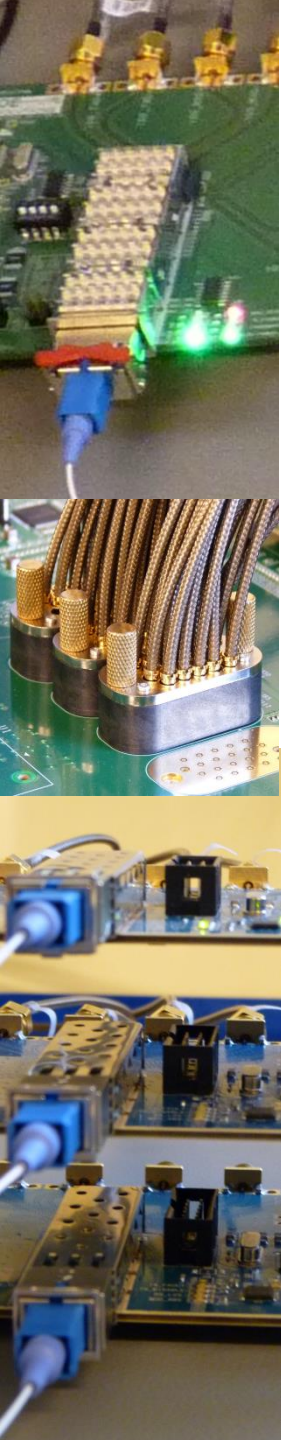



- Key Features

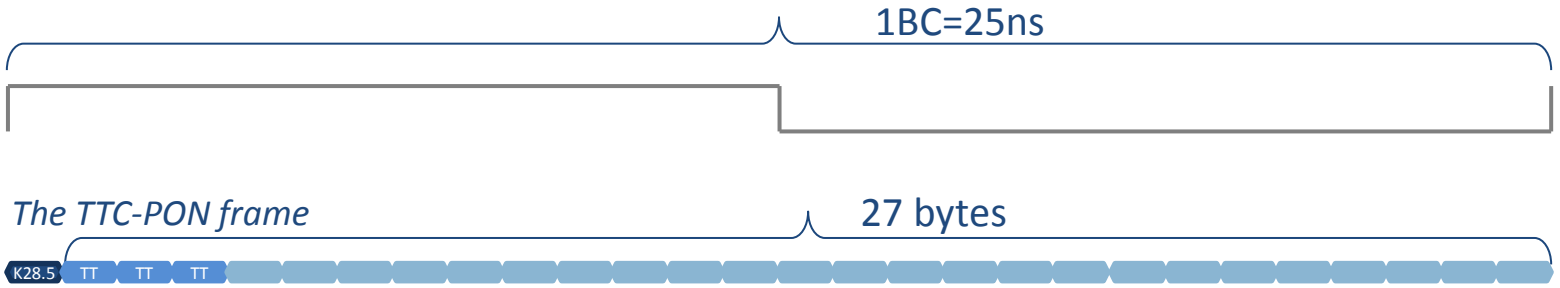
GENERAL FEATURES			
	TTC-PON (2014)	TTC-PON (2011)	TTC system
Technology	10G-EPON	1G-EPON	SONET/SDH OC-3
Line Rate (D/U)	11.2/2.8Gbps	1.6/0.8Gbps	80Mbps
Bidirectional	**YES**	**YES**	**NO**
Fiber length	10-1000m	10-1000m	10-300m
Split Ratio	**1:128**	1:64	1:32
BC synchronous	YES	YES	YES
Error detection	YES	YES	CH. B ONLY

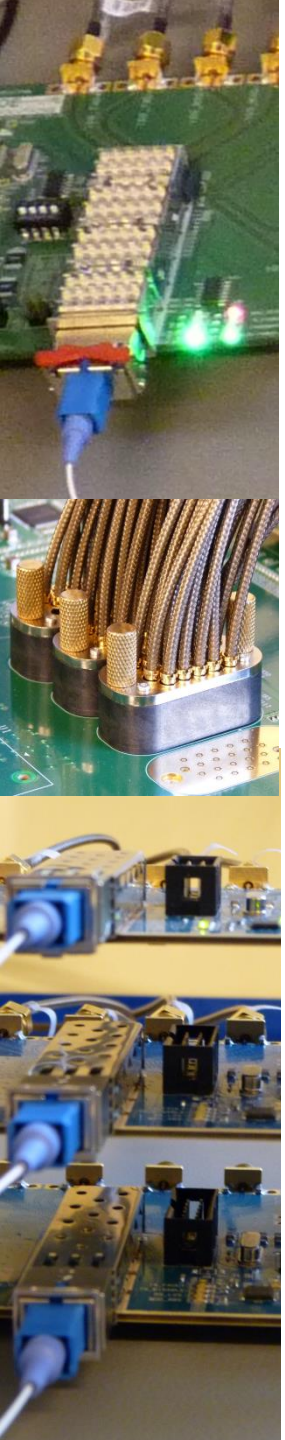


THE TTC-PON DEMONSTRATOR

DOWNSTREAM PATH

- Framing
  - Broadcast
  - LHC BC synchronous
  - 11.2Gbps serial link
  - 8b/10b encoded, K28.5 comma
  - Payload:
    - 216bits @ 40MHz
    - 27 bytes per BC





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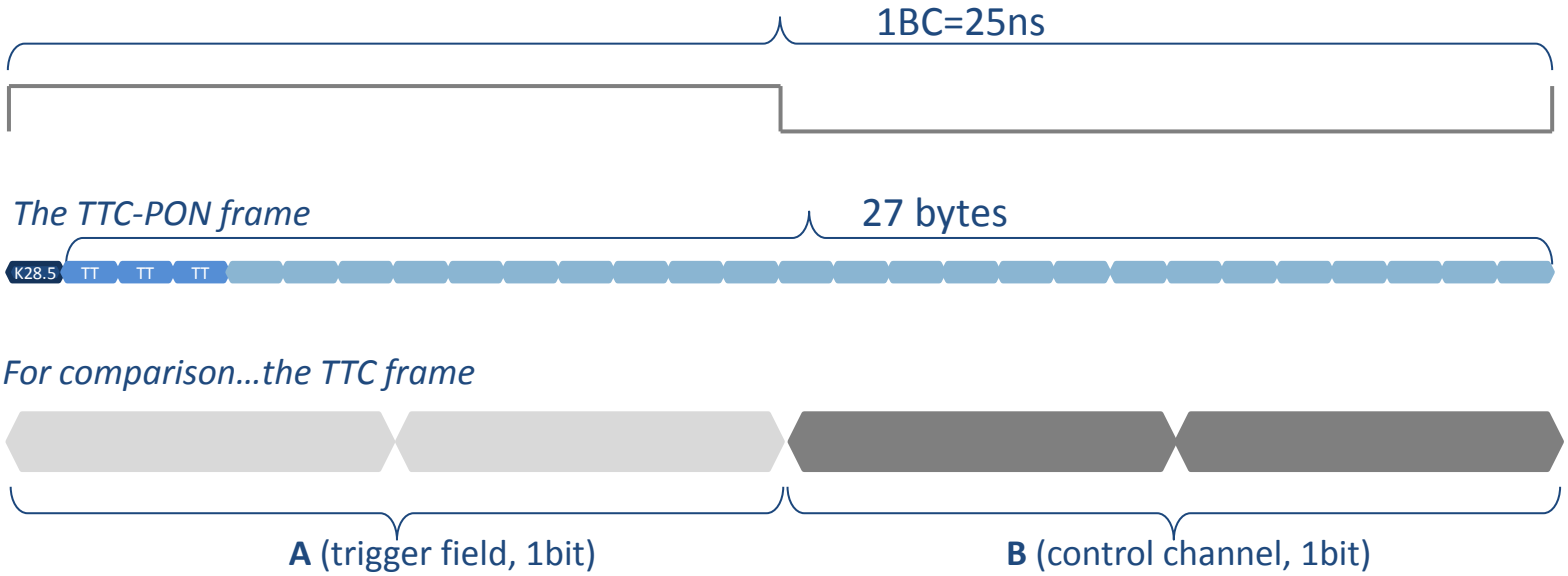
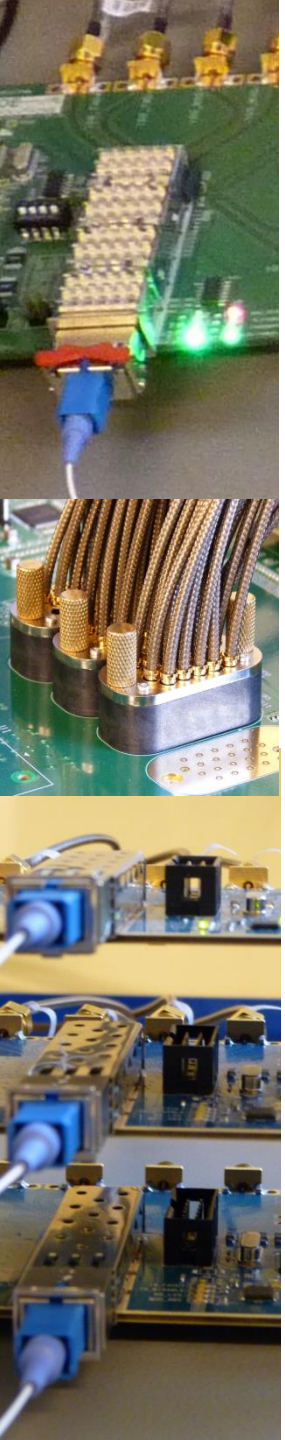




THE TTC-PON DEMONSTRATOR

DOWNSTREAM PATH

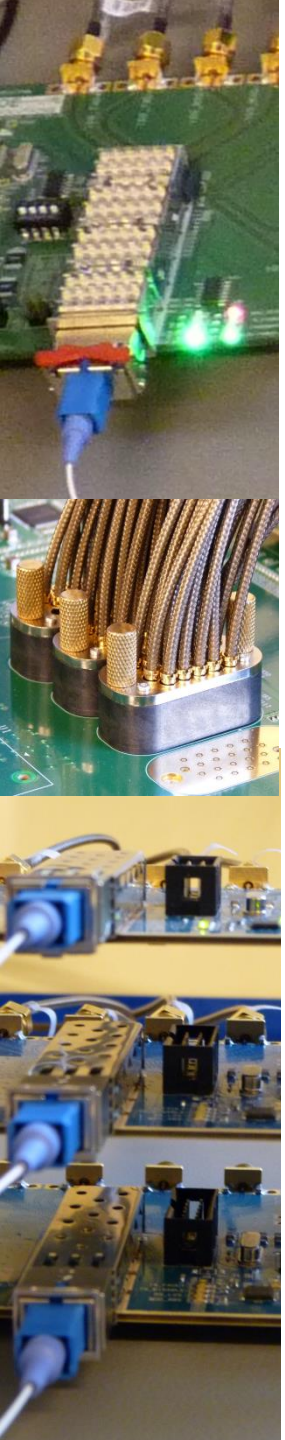
- Key features

DOWNSTREAM FEATURES			
	TTC-PON (2014)	TTC-PON (2011)	TTC system
Technology	10G-EPON	1G-EPON	SONET/SDH OC-3
Line Rate	11.2Gbps	1.6Gbps	80Mbps
Wavelength	1577nm	1490nm	1310nm
Encoding	8b/10b	8b/10b	BPM, Hamming
Payload	~8.64Gbps	~590Mbps	~80Mbps(1)
Payload/BC	**216 bits/BC**	**32 bits/BC**	**2 bits(1)/BC**
Trigger Rate	40MHz	40MHz	**<40MHz**
Synchronous Trigger Type	**YES (>32bits)**	YES (16 bits)	**NO**
Trigger latency	**~80ns(2)**	~250ns(2)	~100ns(2)
	Fixed & deterministic		

(1) Actually much less, due to heavy TTC protocol on channel B
(2) Active components only (no fiber, no cable). Delay between flags on K28.5 right before 8b10b encoder at the OLT and after the 8b10b decoder at the ONU

THE TTC-PON DEMONSTRATOR

UPSTREAM PATH



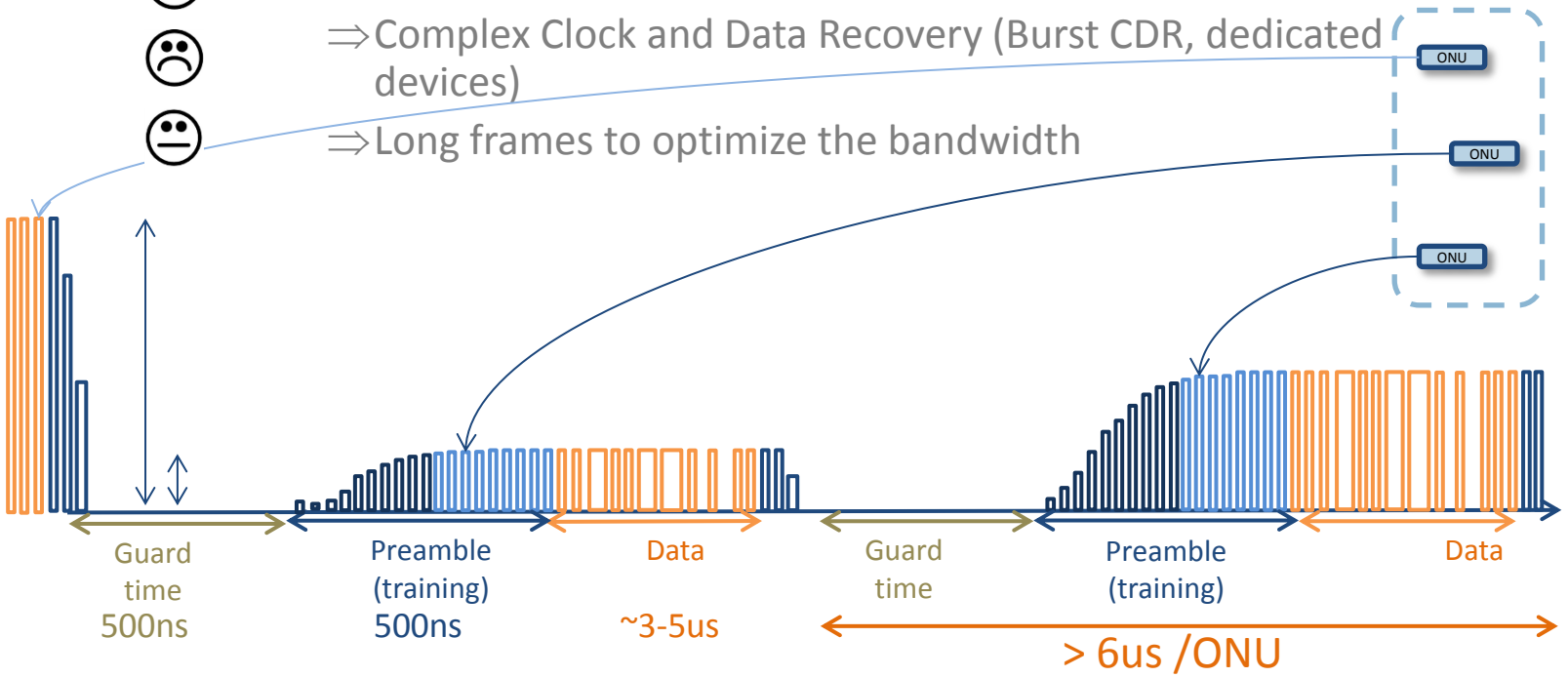
- The FTTH framing
  - 10.31Gbps line rate, TDMA
  - Wide dynamic range (>25dB!)
  - Asynchronous system
  - Transmission arbitration by OLT

Long waiting time for the token, high payload per burst, complex CDR

☹ ⇒Long guard time & preamble

☹ ⇒Complex Clock and Data Recovery (Burst CDR, dedicated devices)

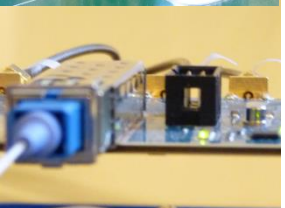
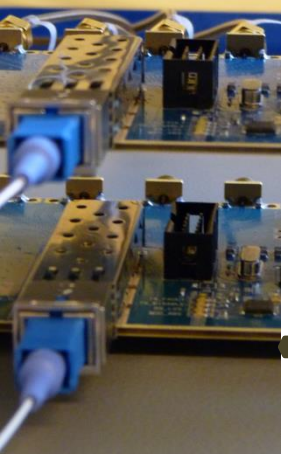
😐 ⇒Long frames to optimize the bandwidth



THE TTC-PON DEMONSTRATOR

UPSTREAM PATH



- The TTC-PON framing: taking advantage of our specificity
  - 2.8 Gbps, TDMA
  - Similar OLT/ONU distances

    => reduced dynamic range
  - FULLY synchronous system

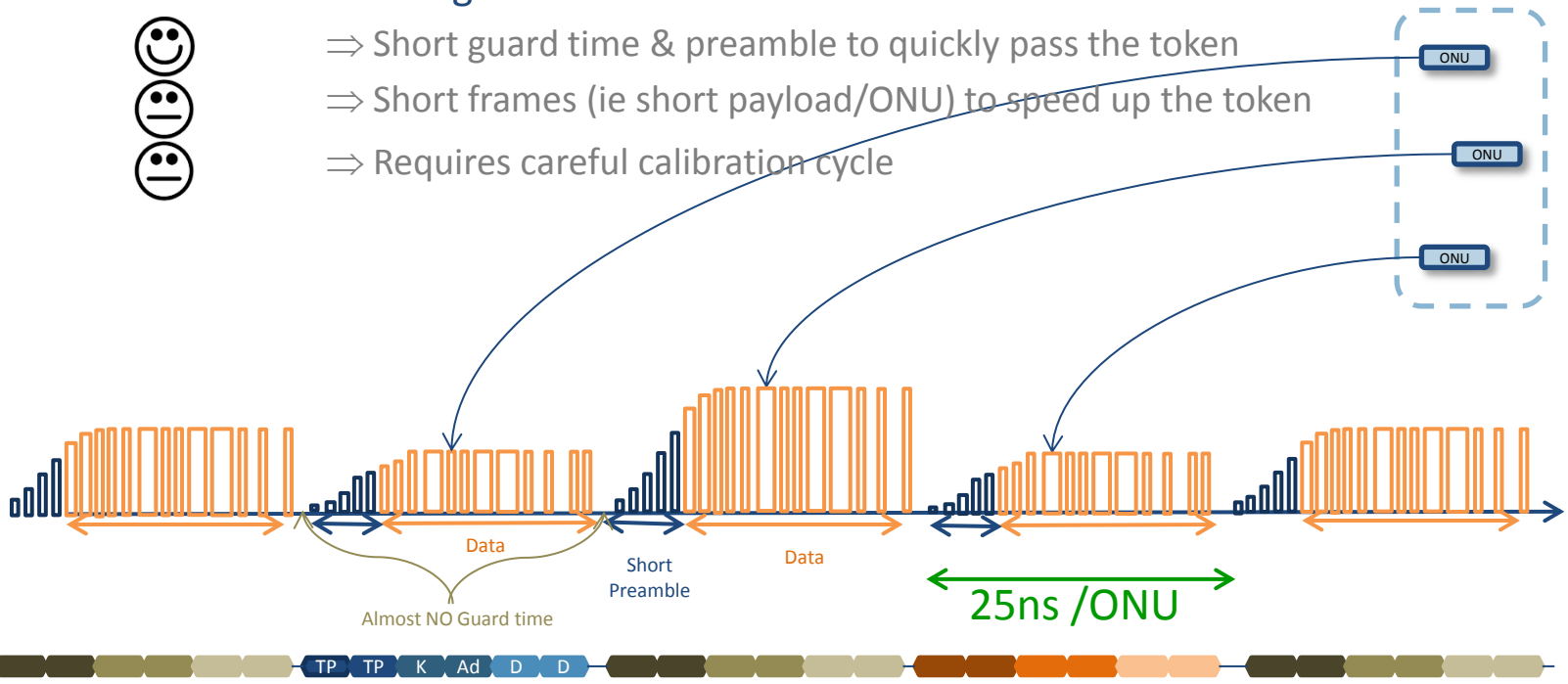
    => No Clock Recovery (simple oversampling & phase alignment in FPGA)
  - Token Ring Arbitration

    ⇒ Short guard time & preamble to quickly pass the token

    ⇒ Short frames (ie short payload/ONU) to speed up the token

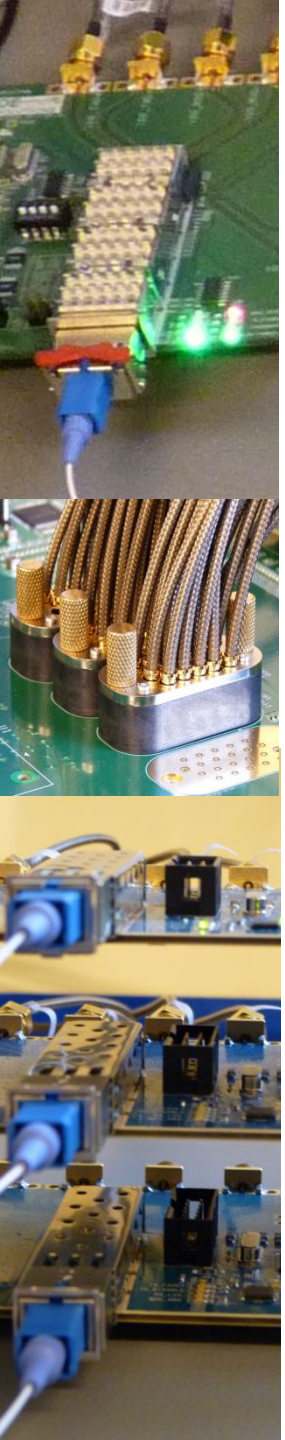
    ⇒ Requires careful calibration cycle

Token passes quickly, low payload per burst, simple implementation

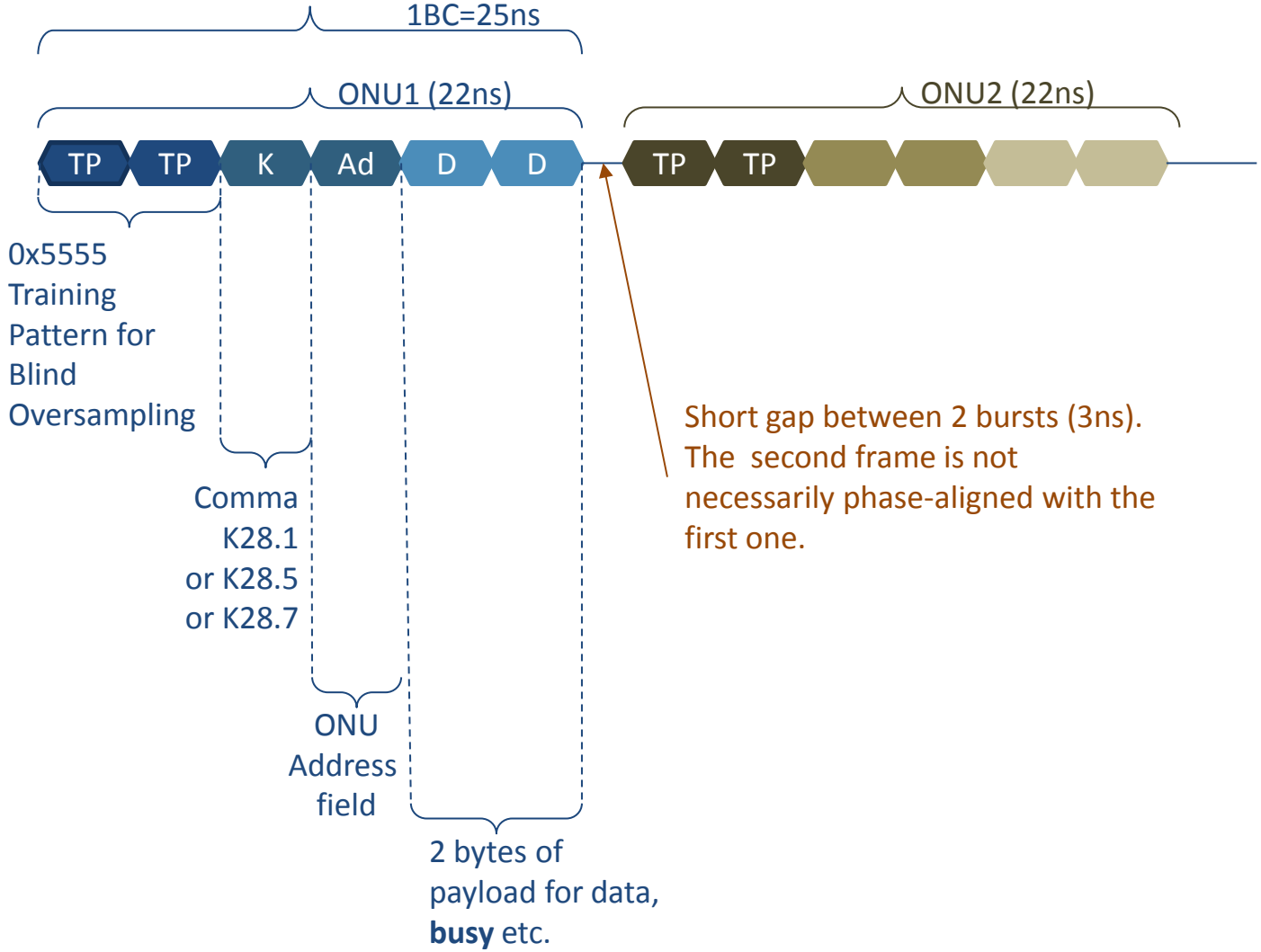


THE TTC-PON DEMONSTRATOR

UPSTREAM PATH



- Framing details



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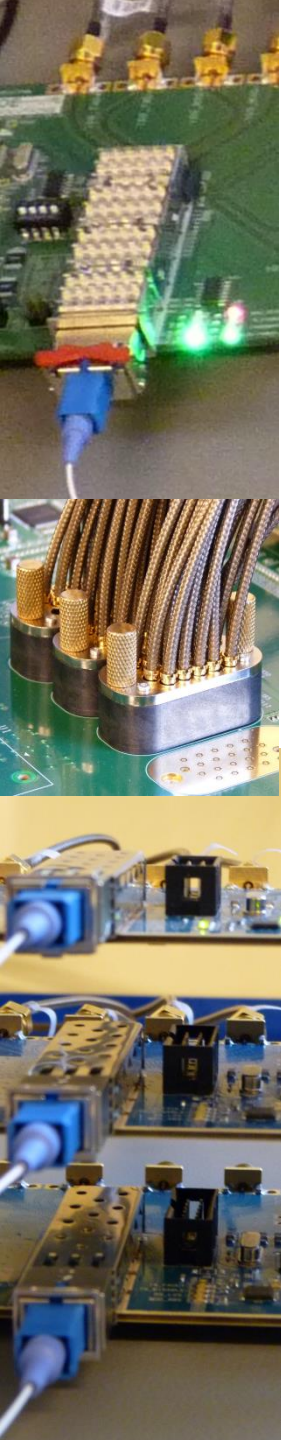
UPSTREAM PATH



- Key Features

UPSTREAM FEATURES			
	TTC-PON (2014)	TTC-PON (2011)	TTC system
Technology	10G-EPON	1G-EPON	x
Line Rate	2.8Gbps	0.8Gbps	x
Wavelength	1270nm	1310nm	x
Encoding	8b/10b	8b/10b	x
Total Payload (All ONUs)	640Mbps(1)	2.2Mbps(2)	x
Total Payload/BC	~16bits/BC(1)	3.5bits/BC(2)	x
ONU Burst length	**25ns (3)(16 bits)**	~1.6us(2)	x
Max Latency for 1:64	**1.6us**	**14us**	x
Max Latency for 1:128	**3.2us**	x	x

BUSY

(1) Pure Data: Doesn't include 8 bits of ONU address field + the possibility of having 3 commas
(2) Split ratio related – these values are for 1:64
(3) 22ns + 3ns of gap

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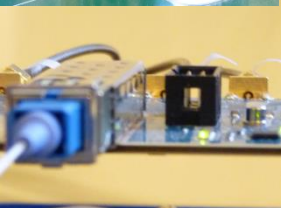
SUMMARY






GENERAL FEATURES			
	TTC-PON (2014)	TTC-PON (2011)	TTC system
Technology	10G-EPON	1G-EPON	SONET/SDH OC-3
Typical Line Rate	10.31Gbps	1.25Gbps	80Mbps
Bidirectional	**YES**	**YES**	**NO**
Fiber length	10-1000m	10-1000m	10-300m
Split Ratio	**1:128**	1:64	1:32
BC synchronous	YES	YES	YES
Error detection	YES	YES	CH. B ONLY

DOWNSTREAM FEATURES			
	TTC-PON (2014)	TTC-PON (2011)	TTC system
Line Rate	11.2Gbps	1.6Gbps	80Mbps
Wavelength	1577nm	1490nm	1310nm
Encoding	8b/10b	8b/10b	BPM
Payload	~8.64Gbps	~590Mbps	~80Mbps
Payload/BC	**216 bits/BC**	**32 bits/BC**	**2 bits/BC**
Trigger Rate	40MHz	40MHz	<40MHz
Synchronous Trigger Type	YES (>32bits)	YES (16 bits)	NO
Trigger latency	**~80ns**	~250ns	~100ns
	Fixed & deterministic		

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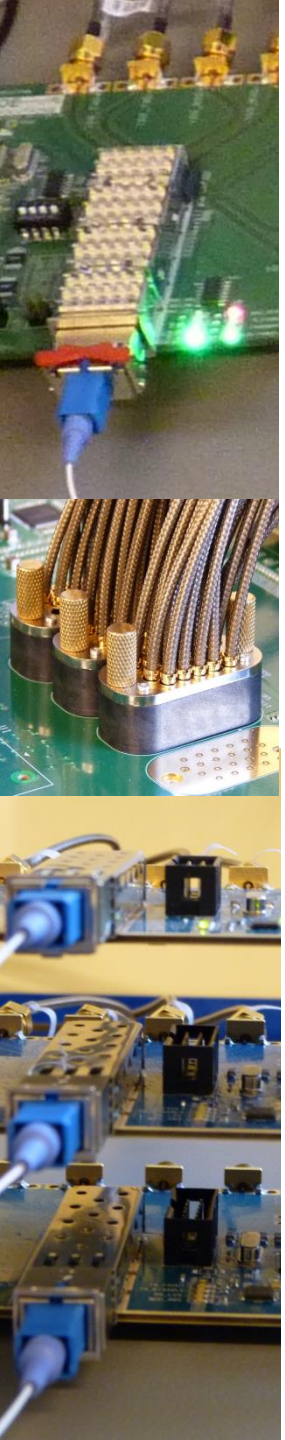
Line Rate	2.8Gbps	0.8Gbps	x
Wavelength	1270nm	1310nm	x
Encoding	8b/10b	8b/10b	x
Total Payload	640Mbps	2.2Mbps	x
Total Payload/BC	~16bits/BC	3.5bits/BC	x
ONU Burst length	**25ns (16 bits payload)**	~1.6us	x
Max Latency for 1:64	**1.6us** ?	**14us**	x
Max Latency for 1:128	**3.2us**	x	x

SUMMARY

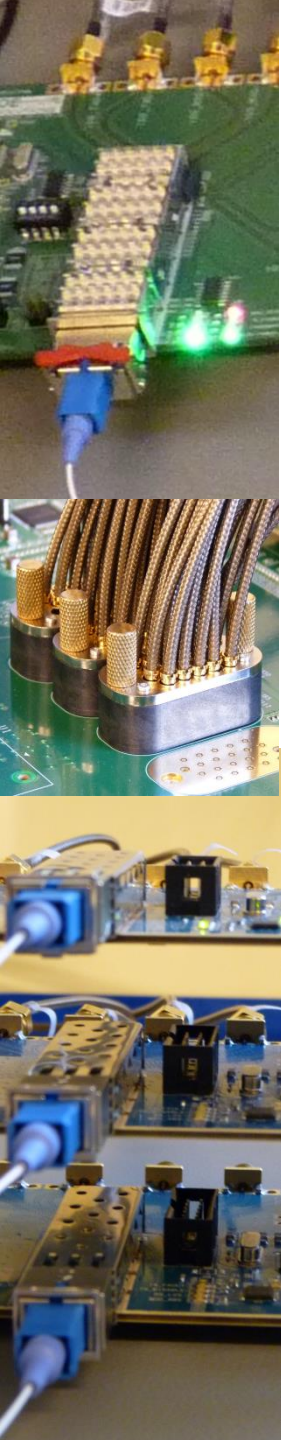


- A **flexible & scalable passive network**,
  - From 1 to 128 ONUs for one single OLT (no impact on hardware)
  - soft partitioning
- Downstream:
  - A **very high bandwidth** transmission link for clock, trigger data, synchronous commands, control …
- Upstream:
  - **25ns per ONU**, including
    - 3 possible commas
    - 1 address byte
    - 2 bytes of data
  - **Compromise** between max latency/ONU and # of ONUs

# of ONUs (N)	Max latency/ONU (N*25ns) (L)	Effective bandwidth /ONU (16 bits /L)
10	250 ns	64 Mbps
64	1.6 us	10 Mbps
100	2.5 us	6.4 Mbps
128	3.2 us	5 Mbps

Are these features meeting your expectations?

PERSPECTIVES



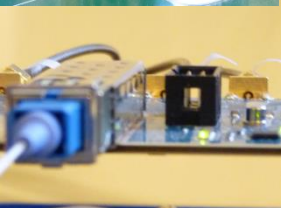
- Short term plans
  - Finish-off the implementation (calibration, etc..)
  - Fully characterize the system
  - Results @ TWEPP 2014
  - Get your feedback!
  - Improve the upstream path (if required):
    - Still reduce the busy latency by
      - Optimizing the oversampling and phase alignment
      - Increasing the line rate
      - Adapting the protocol to typical use cases
    - Increase the payload if necessary

- Longer term plans
  - On-site deployment & testing

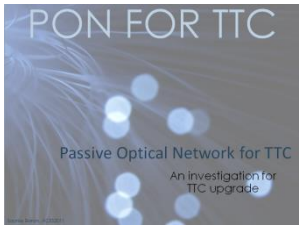
WE NEED YOUR INPUT !

REFERENCES






- The TTC-PON team:
  - Sophie Baron,
  - Dimitris Kolotouros,
  - Csaba Soos,
  - François Vasey
- Introduction to the TTC-PON concept @ACES 2011



- *TTC-PON, an upgrade proposal for off-detector TTC* @ DAQ@LHC 2013
- *Metrics and Methods for TTC-PON System Characterization* , D. Kolotouros, TWEPP 2013, Perugia
- *Passive Optical Networks in Particle Physics Experiments*, I. Papakonstantinou, 24th November 2009, PH-ESE Seminar
- *A Fully Bidirectional Optical Network with Latency Monitoring Capability for the Distribution of Timing-Trigger and Control Signals in High-Energy Physics Experiments*, I. Papakonstantinou et al., IEEE Transactions on Nuclear Science , 58 (4 PART 1) 1628 - 1640. 10.1109/**TNS.2011.2154364**.
- Sharepoint site for information
  - https://espace.cern.ch/Project-TTC-PON

THANK YOU !

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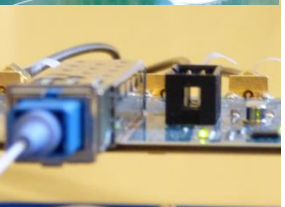
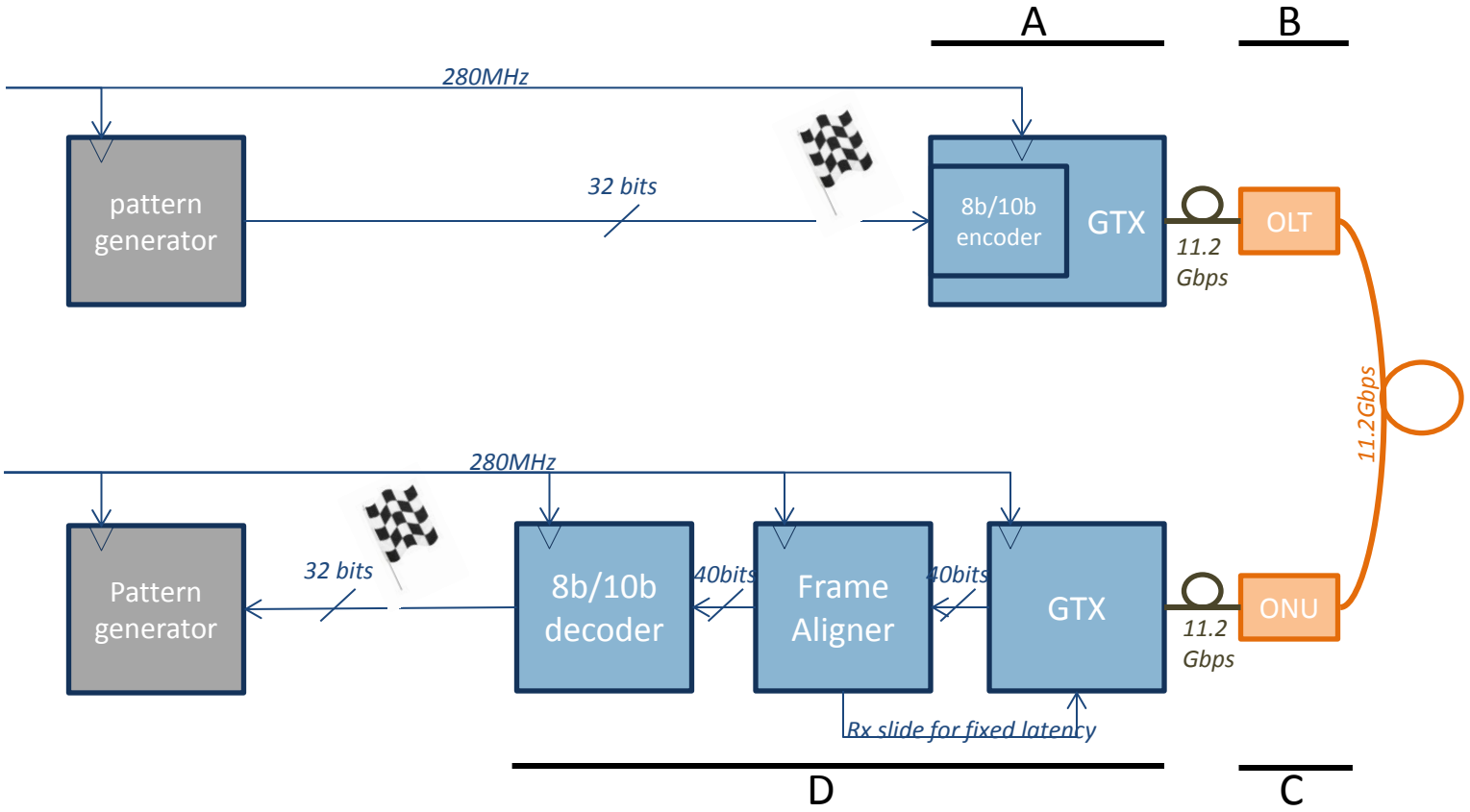
SPARE SLIDES

DOWNSTREAM LATENCY MEASUREMENT



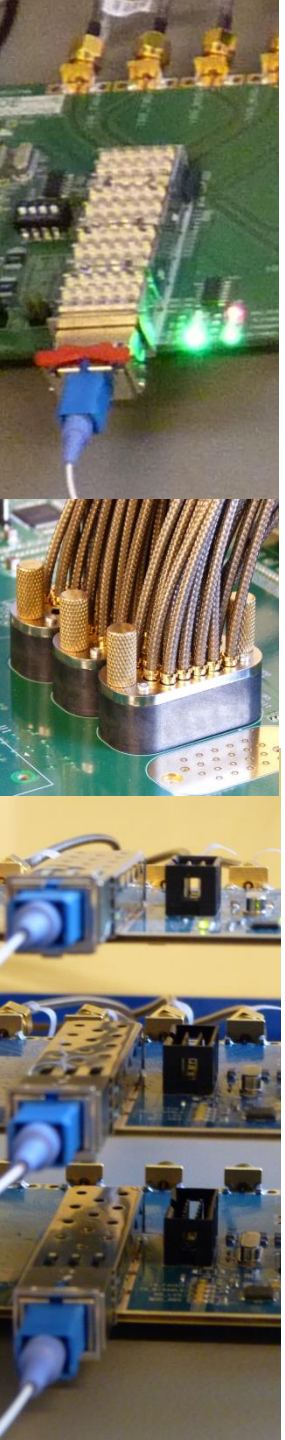


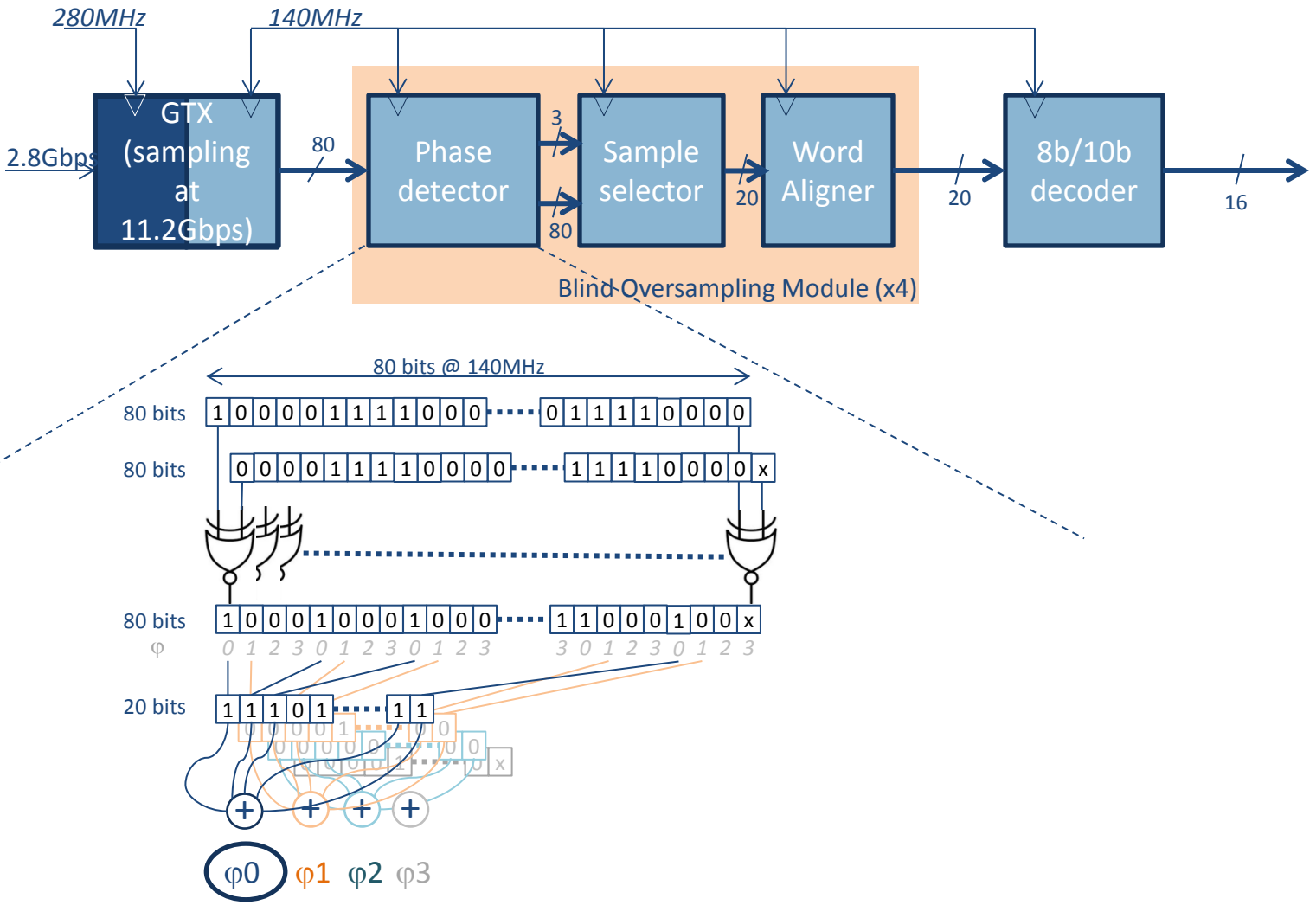

73ns (rounded to 80) = A + B + C + D



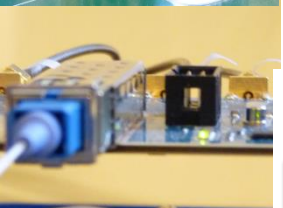
Blind Oversampling in the Kintex7

UPSTREAM PATH





10G-EPON Power Budget



Standards: EPON and 10G EPON

- The Rates of EPON and 10G EPON are shown below:

Classes "x" =	Application	Down-Stream	Up-Stream
PX	EPON	1G	1G
PRX	10GEPON Asymmetric	10G	1G
PR	10GEPON Symmetric	10G	10G

- The Link Classes of EPON and 10G EPON are shown below:

Classes	Application	Budget (dB) *
x10	10 km, 1:16	20
x20	20 km, 1:16 10km, 1:32	24
x30	20 km, 1:32	29
x40	20 km, 1:64 **10 km, 1:128**	33

EPON, 10G-EPON (Px10,20,30,40), GPON, NGPON2

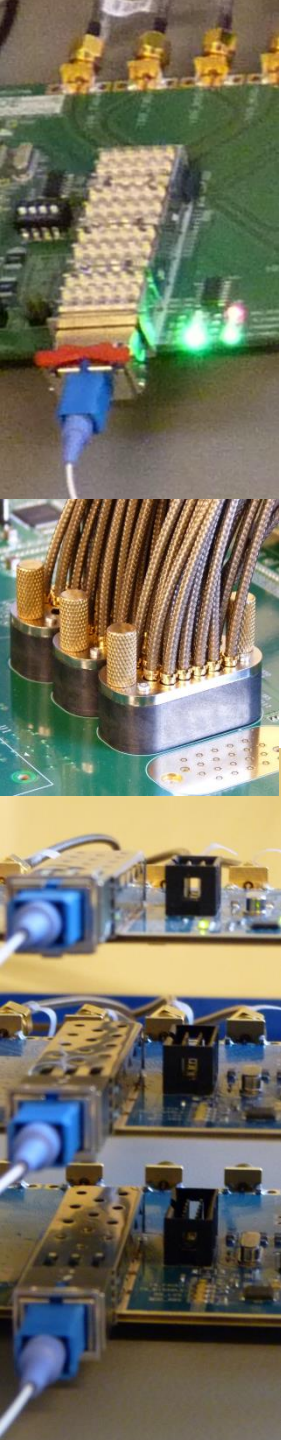
Link Budget (dB) *	System	Class
20	IEEE	Px10
24	IEEE	Px20
28	GPON	B+
29	IEEE / XG-PON1 / NG-PON2	Px30 / N1
31	XG-PON1 / NG-PON2	N2
32	GPON	C+
33	IEEE / XG-PON1 / NG-PON2	Px40 / E1
35	XG-PON1 / NG-PON2	E2

*at BER 10^{-3}.

Remove 6dB power budget for a BER 10^{-12}

Source: Alcatel-Lucent - Optical Wavelength Considerations for NG EPON IEEE 802.3 NG EPON Meeting, Indian Wells, CA – 21 January 2014

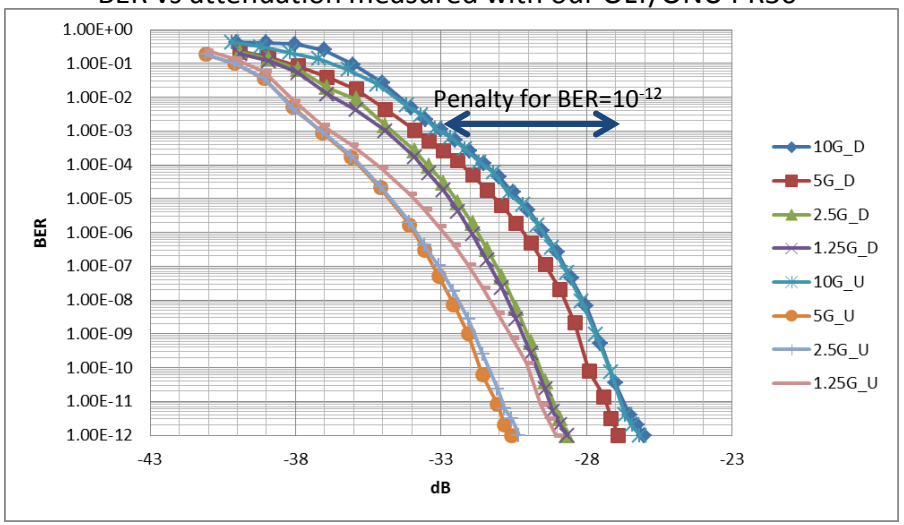
Split Ratio & Power Budget



PR30 Power Budget (@ BER =10^{-3})	29 dBm
Split 1:128	-21 dB
Fiber Losses	-2 dB
10^{-3} to 10^{-12} penalty	-6 dB
Margin	**2 dB**

PR40 Power Budget (@ BER =10^{-3})	33 dBm
Split 1:128	-21 dB
Fiber Losses	-2 dB
10^{-3} to 10^{-12} penalty	-6 dB
Margin	**6 dB**

BER vs attenuation measured with our OLT/ONU PR30



OLT: RSL8777X-GGA (OE solution)
ONU: RSN7877P-GGI (OE solution)