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PHOTONICS DAYS Berlin Brandenburg innovationconference

Tektronix

Accelerating Transceiver Characterization and Verification

Presenter: Dr. Ali Emsia

Tektronix MASSTART

Tektronix High-End Solutions Overview

- Tektronix is a leading T&M company serving engineering and technical professionals
- Founded in 1946, acquired by Danaher in 2007, 2016 a Fortive company
- Headquartered in Beaverton, Oregon
- Leadership positions in key products and markets
- Highly-respected brand based on high quality innovative products, engineering excellence and global service and support
- Award winning:
  - Oscilloscopes
  - Signal Sources
  - Spectrum Analyzers

KEITHLEY
A Tektronix Company

- Keithley is a leader in precision electrical test
- Founded in 1946, acquired by Tektronix in 2010
- Headquartered in Solon, OH
- Offering instruments and systems to meet any measurement requirement from nanovolts to gigahertz
- 21 R&D 100 awards as well as honors from Semiconductor International, Solid State Technology, Electronic Products, Test & Measurement World magazines

Tektronix High-End Solutions Overview

- Tektronix simplifies serial standards testing complexity with measurement expertise and tools that provide accurate test results for high-speed computer and communications system designs

Sampling Oscilloscopes and Clock recovery

Characterizes the electrical and optical signal performance of components, boards & systems.

DPO70000SX ATI Performance Oscilloscopes

Performs pass/fail compliance test and debugging of high speed electrical components, boards & systems.

OMA Lightwave Signal Analyzers for coherent application

Analyzes optical modulation formats used in next generation long-haul networks.

RF Recorder & Playback /Signal Analyzers

Analyzes RF up to 26.5GHz at Real Time with 800MHz acquisition bandwidth

Keithley Waver-Testing

Characterization of semiconductor at device, wafer or cassette level. Configurable at customer needs.

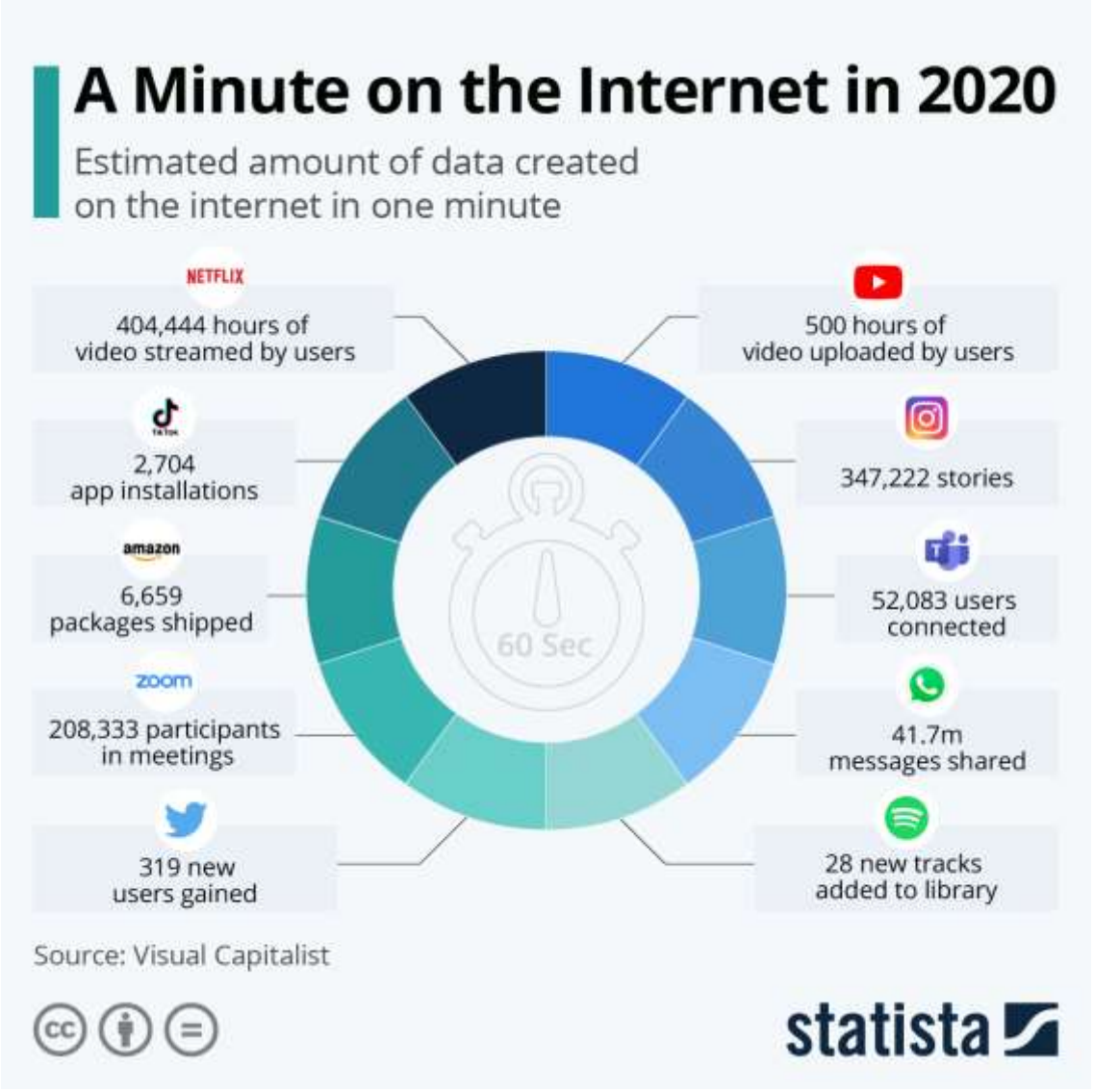
AWG Arbitrary Waveform Generators

Aids research efforts by generating complex signal patterns that help evaluate communications system designs.

Parameter Analyzer / Curve Tracer

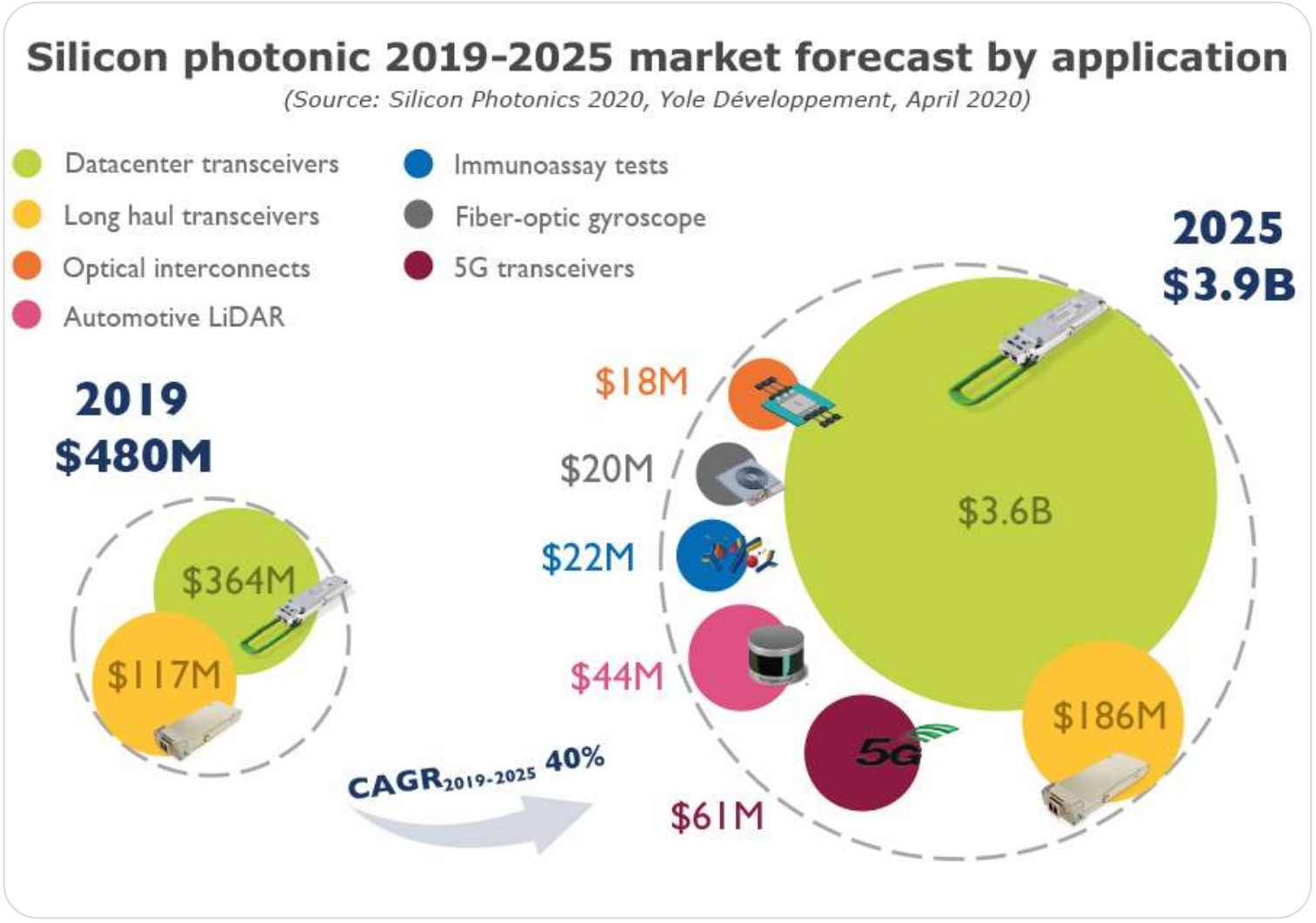
Synchronized I-V and C-V characteristic

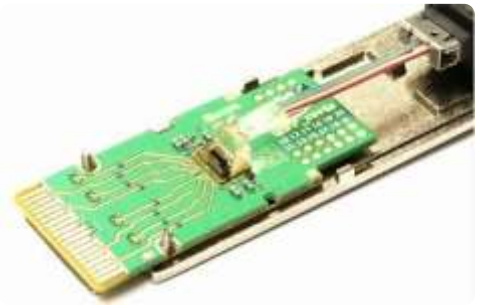
Key bandwidth drivers



Key bandwidth drivers

Market Growth

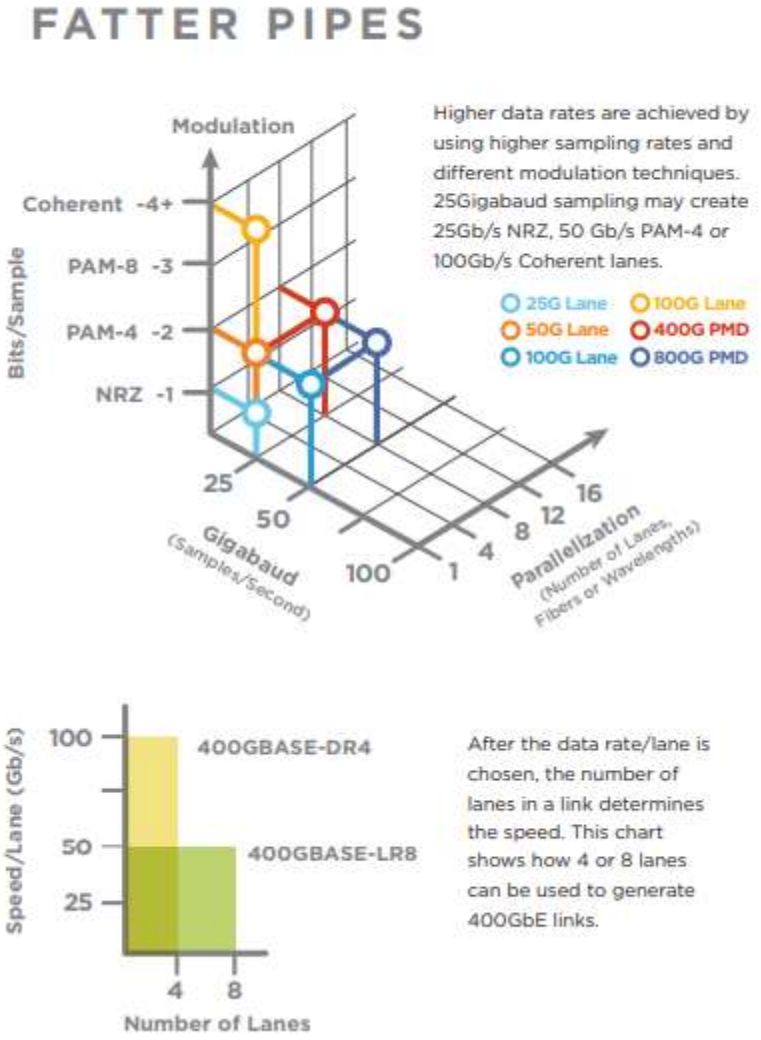




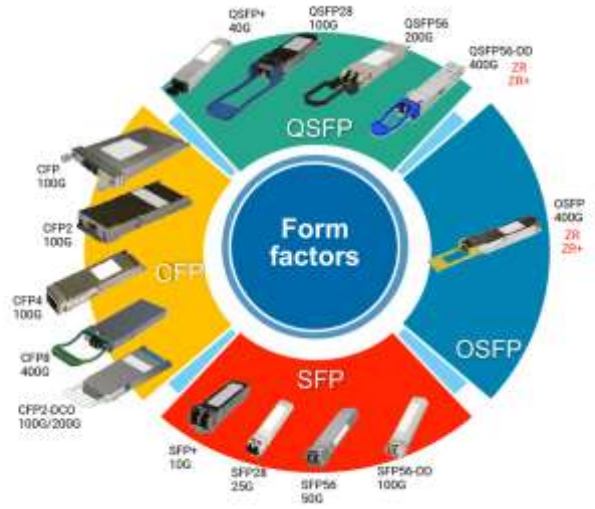
Keeping up with bandwidth demand

How to overcome increasing bandwidth demand

- ✓ More complex modulations
  - ✓ NRZ - PAM4 – QAM
- ✓ More channels
- ✓ Higher baud rates



What's new in Ethernet standards?



electrical — optical

	Electrical Interface	Backplane	Twinax Cable	Twisted Pairs	MMF	Parallel SMF	2km SMF	10km SMF	40km SMF
1983 10BASE-				T					
1995 100BASE-				TX	FX			LX	
1998 1000BASE-		KX	CX	T	SX			LX	
2.5GBASE-		KX		T					
5GBASE-		KR		T					
2002 10GBASE-	SFI, XFI XSBI, XAUI	KX4, KR	CX4 SFP+DAC	T	SR			LR	ER
25GBASE-	25GAUI	KR	CR	T	SR			LR	ER
2010 40GBASE-	XLAUI	KR4	CR4	T	SR4		FR	LR4	ER4
2017 50GBASE-	50GAUI 50GAUI -2	KR, KR2	CR, CR2		SR		FR	LR	
2019 100GBASE-	CAUI10 CAUI4 100GAUI-2	KR4, KR2	CR10, CR4, CR2		SR10 SR4 SR2	PSM4 DR	10X10 CWDM4 CLR4	LR4 10X10	ER4 10X10
200GBASE-	200GAUI-4 200GAUI-8	KR4	CR4		SR4	DR4	FR4	LR4	
400GBASE-	400GAUI-16 400GAUI-8				SR16	DR4	FR8	LR8	
2023 800GBASE / 1.6TbE									

Gray Text = IEEE Standard Red Text = In Standardization
Blue Text = Non-IEEE standard but complies to IEEE electrical interfaces

ethernet alliance

Pushing the envelope to higher baud rates

Impact on optical transceiver Testing

- Increase in complexity
- Steady uptick in test requirements
- Increase time device spends on the manufacturing floor

Contrast Between PAM-4 and NRZ

- PAM4 Measurements
  - Transmitter and dispersion eye closure quaternary (**TDECQ**)
  - Outer Optical Modulation Amplitude (OMA_{outer})
  - Outer Extinction Ratio (OER)
  - Level separation mismatch ratio (R_{LM})

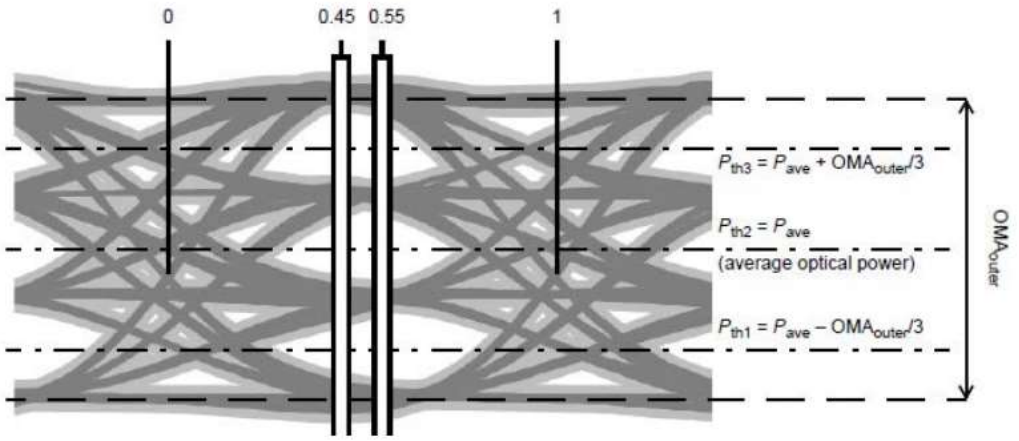
- NRZ Measurements
  - Tx Eye Mask
  - Optical Modulation Amplitude (OMA)
  - Extinction ratio (ER)

Contrast Between PAM-4 and NRZ

PAM4 TDECQ

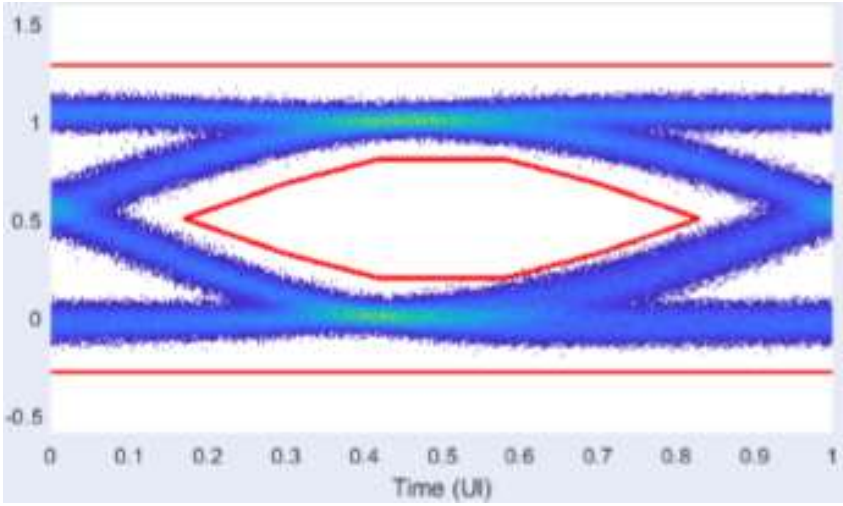
- Measures each of the optical transmitter's vertical eye closure as measured through and optical to electrical converter.

$$TDECQ = 10\log_{10}\left(\frac{OMA_{outer}}{6} \times \frac{1}{Q_t R}\right)$$



NRZ Eye Mask

- Measures the number of hits on a mask to characterize the BER of a transmitter.



Cost of Test for optical transceivers

	Test station cost [$k]				
Test Time [min]	150	125	100	75	50
120					
90					
60					
30					
15					
	Cost of test per device				

Why is Test time so important?

Go to market faster

Significantly reduce cost of device

Increase throughput / reduce capital expenses

Meet customer demand

Impact of Machine Learning in optical communication

Machine learning has recently seen significant popularity in optical communication with respect to applications such as:

- Optical Performance Monitoring
- Failure and Fault Management

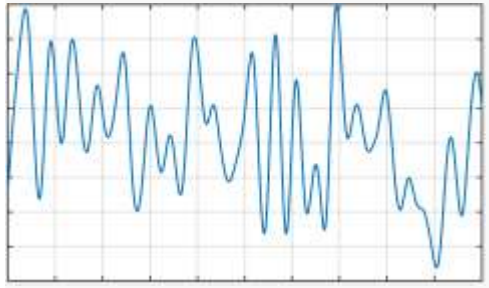
due to its ability to efficiently model systems using abstract inputs.

To cope with high cost and to address reliability concerns, Machine Learning must be explored in this environment to assist testing and provide additional device insight.

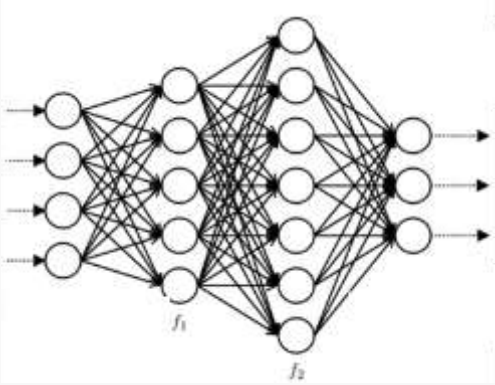
Machine Learning TDECQ

UTILIZING MACHINE LEARNING TO SPEED UP TDECQ MEASUREMENT

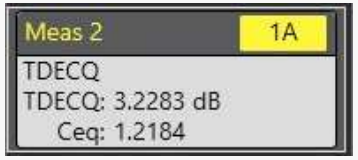
Input:
- Waveform data acquired from scope



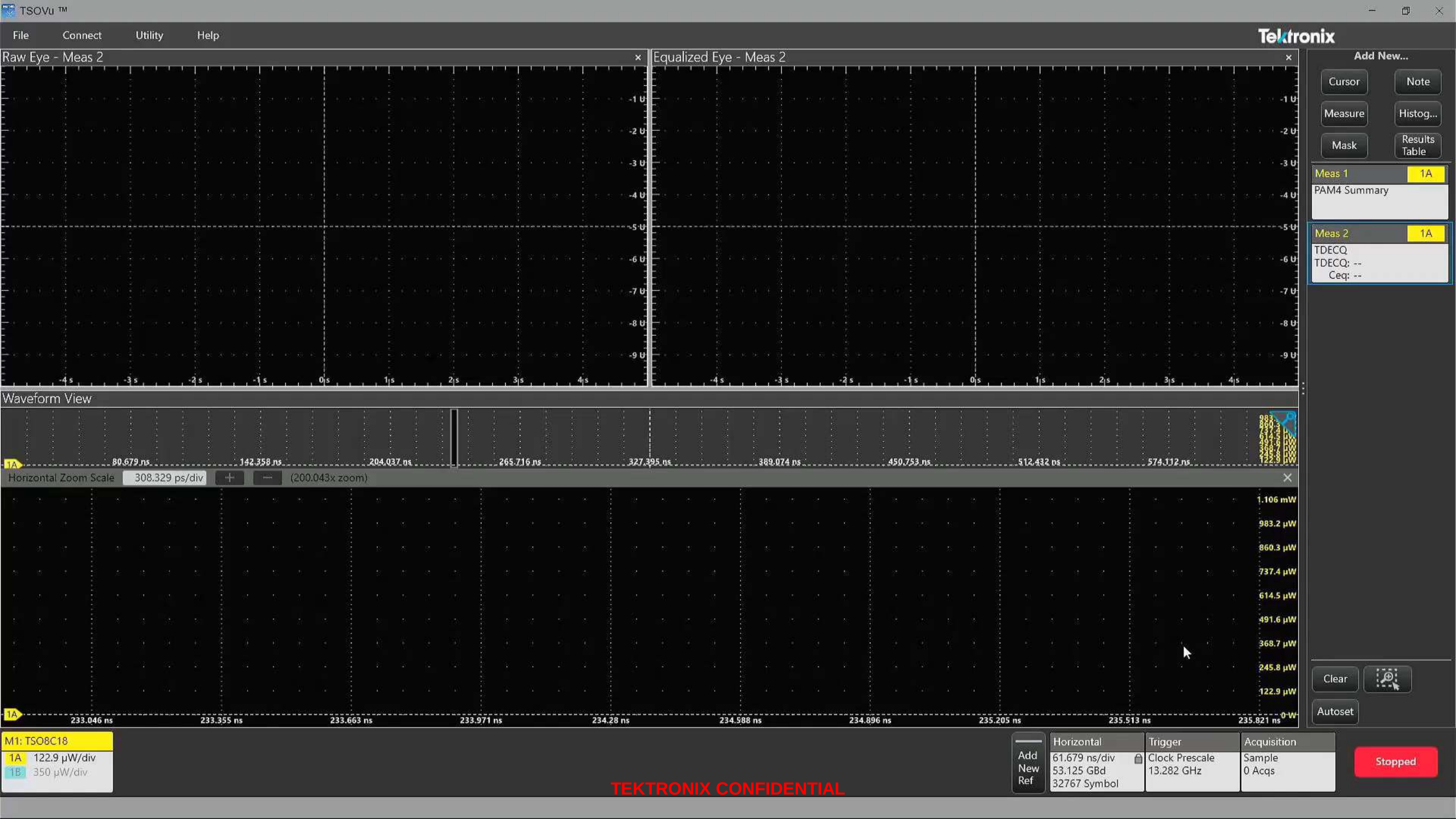
Analysis:
- Trained convolutional neural network (CNN)



Output:
- TDECQ measurement



TDECQ Computation speed improvement of 20X


TSOVu ™
File
Connect
Utility
Help
Tektronix
Raw Eye - Meas 2
Equalized Eye - Meas 2
Add New...
Cursor
Note
Measure
Histog...
Mask
Results Table
Meas 1
1A
PAM4 Summary
Meas 2
1A
TDECQ
TDECQ: --
Ceq: --
Waveform View
80.679 ns
142.358 ns
204.037 ns
265.716 ns
327.395 ns
389.074 ns
450.753 ns
512.432 ns
574.112 ns
Horizontal Zoom Scale
308.329 ps/div
(200.043x zoom)
1.106 mW
983.2 µW
860.3 µW
737.4 µW
614.5 µW
491.6 µW
368.7 µW
245.8 µW
122.9 µW
0 W
233.046 ns
233.355 ns
233.663 ns
233.971 ns
234.28 ns
234.588 ns
234.896 ns
235.205 ns
235.513 ns
235.821 ns
Clear
Autoset
M1: TSO8C18
1A 122.9 µW/div
1B 350 µW/div
Add New Ref
Horizontal
61.679 ns/div
53.125 GBd
32767 Symbol
Trigger
Clock Prescale
13.282 GHz
Acquisition
Sample
0 Acqs
Stopped
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