Measurements of time variation in DMD-challenged multimode fiber at 1310nm for 10GE equalizer applications.

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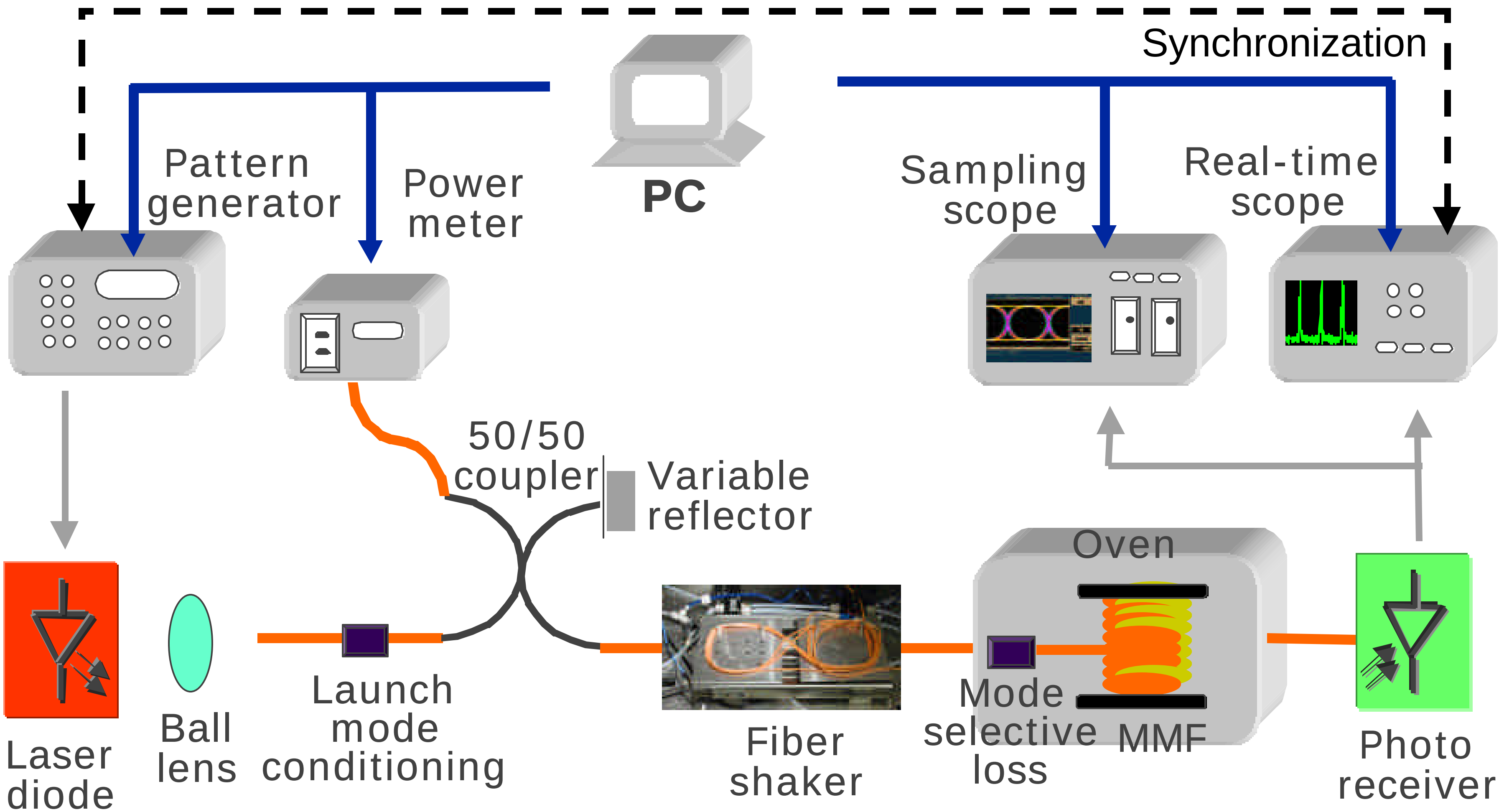
Outline

- Measure linearity & time variance on DMD-challenged MMF
- Measurements at 1310 nm with FP & DFB lasers at 2.5, 5 & 10 Gb/s.
- Used Agazzi & Lenosky methodology[1] to compute SNR.

[1] agazzi_1_0101, IEEE P802.3ae interim meeting, Irvine, CA, January 2001

Measurement set-up



Transmitter

- 10 Gb/s FP and DFB lasers at 1310 nm tested over temperature and under reflections
  - FP laser at 25^{o}C and 75^{o}C
  - DFB laser at 25^{o}C and with 26 dB return loss
- Launch mode conditioning
  - Single mode fiber
  - Multimode fiber (CPR > 30 dB)
  - Newport mode scrambler (CPR = 26 dB)

Fiber

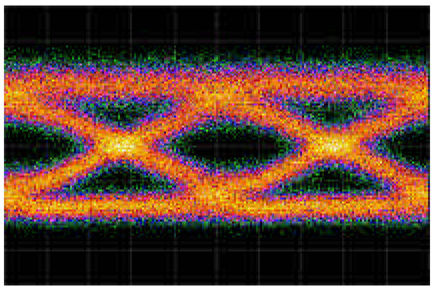
- Fiber shaker
  - according to FOTP-142
- Mode selective loss generator
  - 2 mode selective loss connections at 2 m and 6 m from input
- Multimode fiber
  - 6 spools of DMD-challenged fiber provided by TIA 300 m long
- Oven temperature
  - 25^{o}C, 75^{o}C and ramped between 15^{o}C and 35^{o}C

Receiver

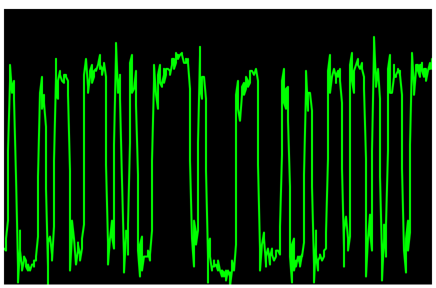
- 10 Gb/s receiver with TIA and post-amplification stage
- 8 GHz bandwidth
- Responsivity

Launch mode conditioning	CPR	Responsivity
Single mode	NA	0.60
LED	18 dB	0.55
LED + Mode filter	15 dB	0.58
Mode scrambler	22 dB	0.59

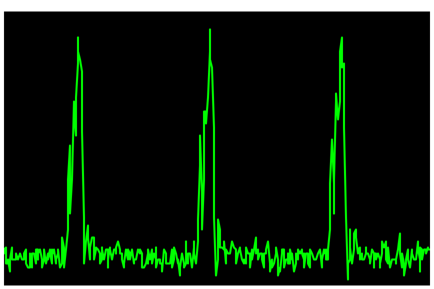
Measurements



Filtered eye diagram for
2^{23}-1 PRBS sequence
at ER = 6.5 dB and bit rates
2.5, 5, and 10 Gb/s



Received sequence for
2^{23}-1 PRBS sequence
at ER = 6.5 dB and bit rates
2.5, 5, and 10 Gb/s



Impulse response for
40 ps pulses generated by
gain switching the laser
with repetition period of 6.4 ns

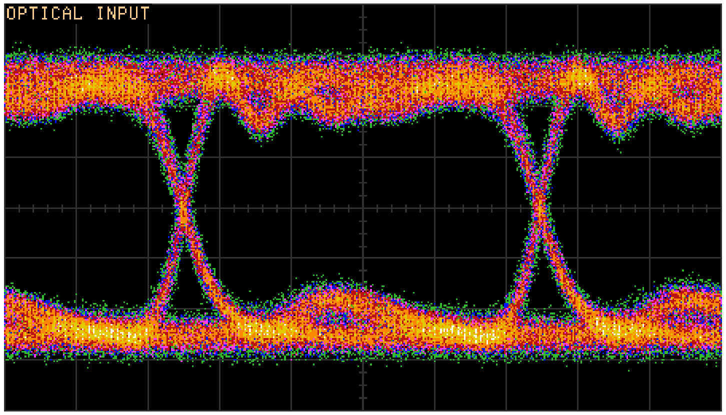
Sampling scope

Real-time scope

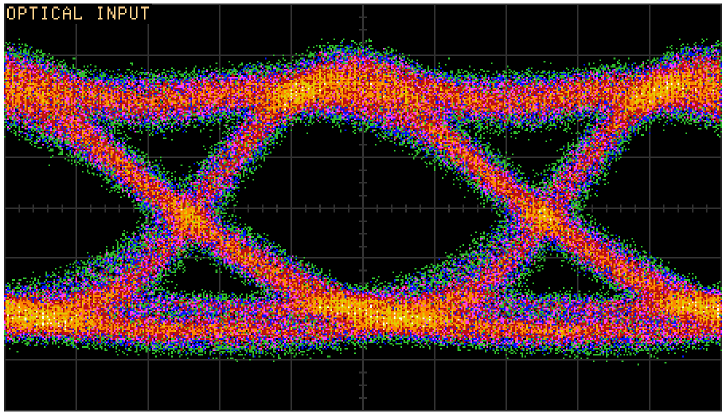
Tektronix TDS 7040
20 GHz sampling rate
4 GHz bandwidth (-3dB)
32 MSamples record length
⇨1.6 ms windows
8-bit resolution

FP laser at 25°C + 10 m MMF jumper

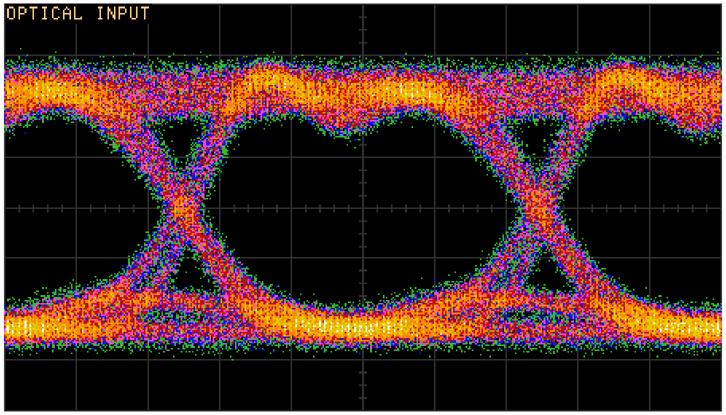
2.5 Gb/s



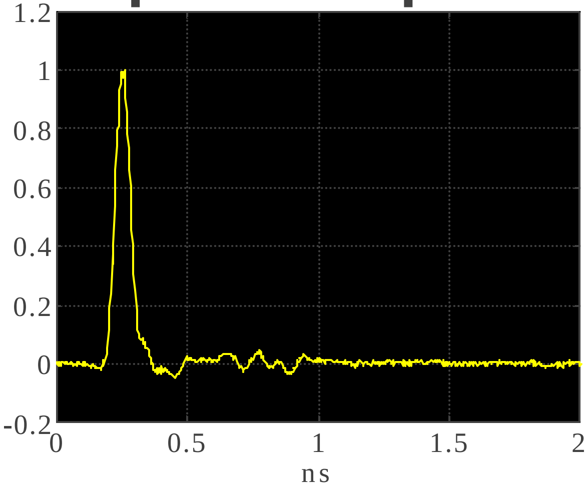
10 Gb/s



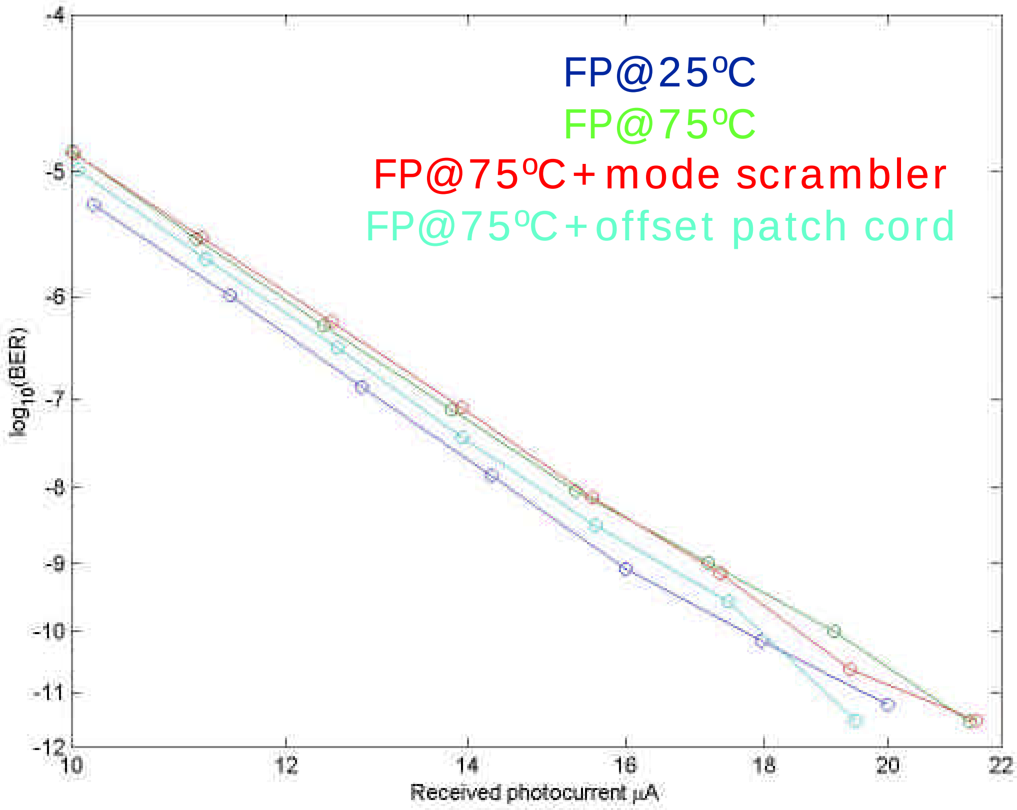
5 Gb/s



Impulse response

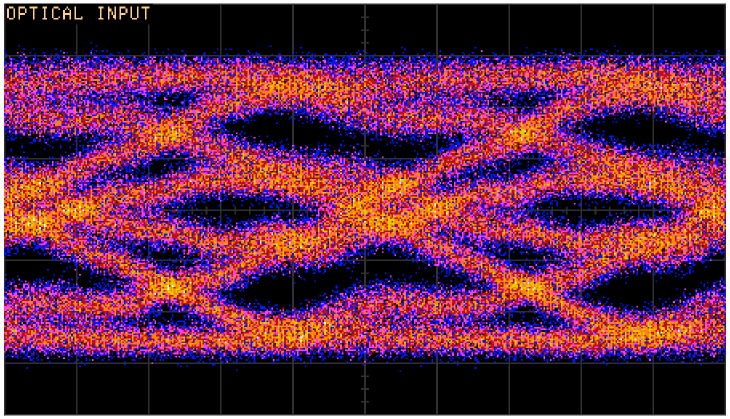


Bit error rate without fiber

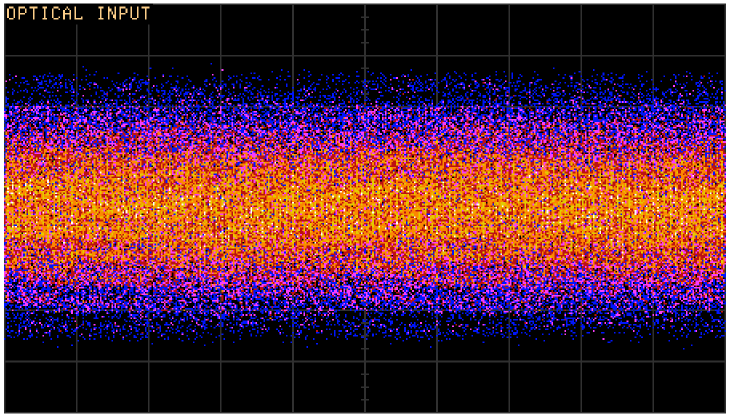


FP laser at 25C + 10m MMF jumper + Mode filter+ 300m TIA MMF (F2) at 25C

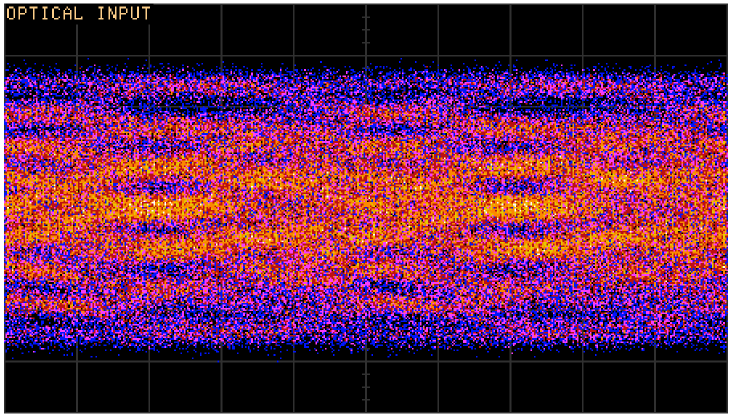
2.5 Gb/s



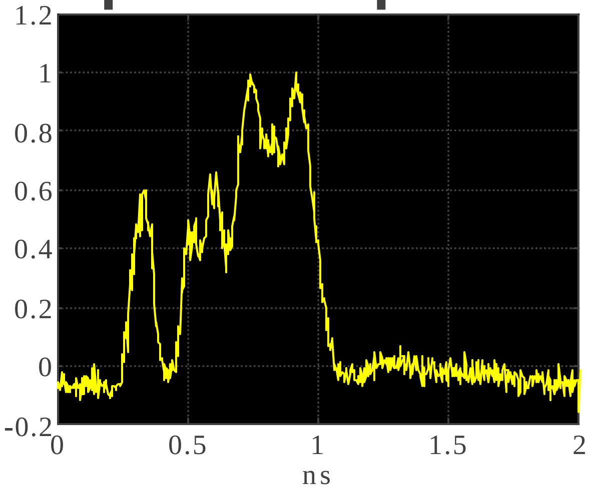
10 Gb/s



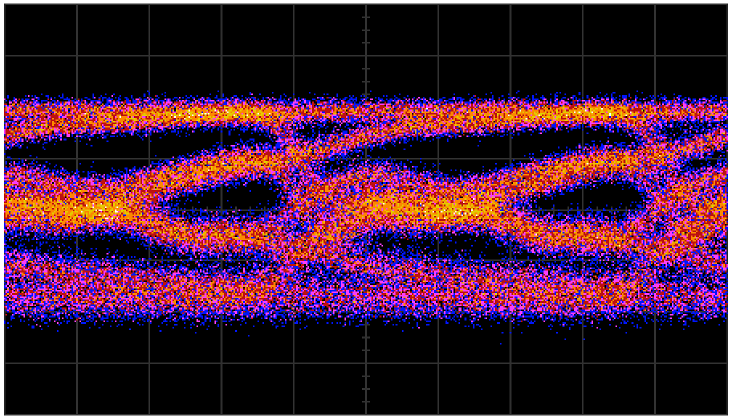
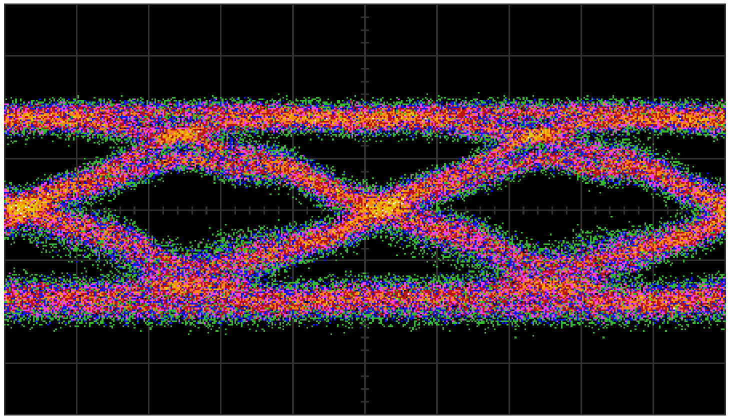
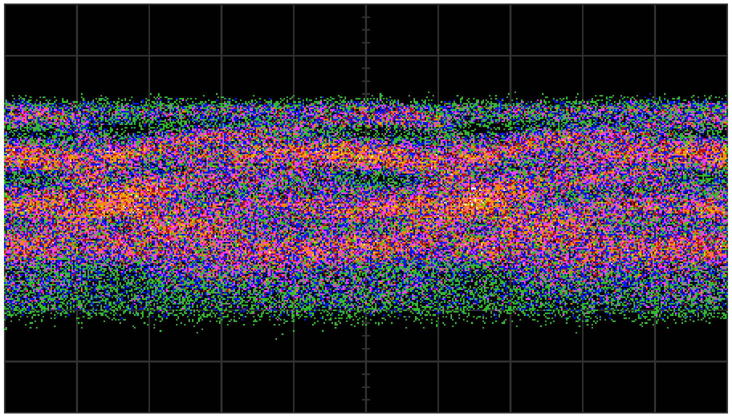
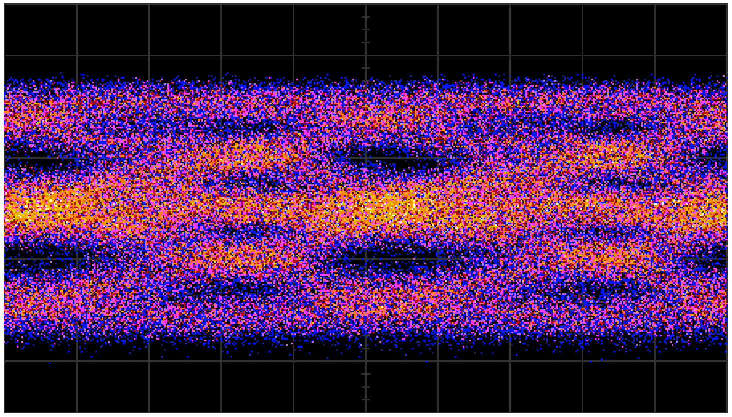
5 Gb/s



Impulse response



Mode conditioning offset patch cord improves eye

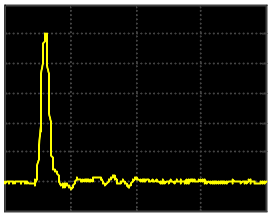
	Without patch cord	With patch cord
2.5 Gb/s		
5 Gb/s		

Signal processing on MMF data

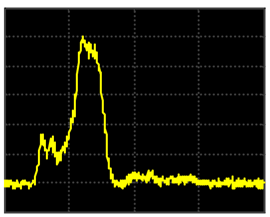
- A linear adaptive LMS canceller is used to estimate the measured data
- (8, 4, 2) Interleaved cancellers each operating at the symbol rate were used for (2.5, 5, 10 Gb/s) respectively
- Any fast time variations, noise and some nonlinearity are not tracked by the LMS and result in untracked error
- Signal to Noise Ratio (SNR) is defined as the ratio to the measured signal power to the untracked error
- This SNR is the upper bound for any receiver and corresponds to the “matched filter bound”

FP laser at 25ºC + 10 m MMF jumper + Mode filter + 300 m TIA MMF at 25ºC

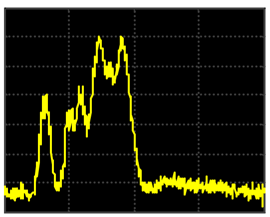
F0



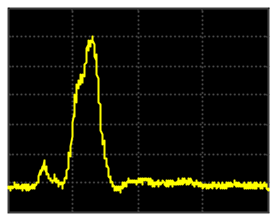
F1



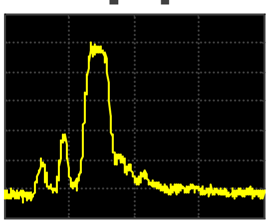
F2



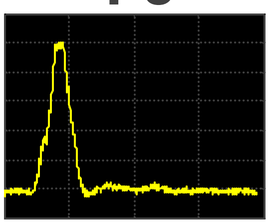
F3



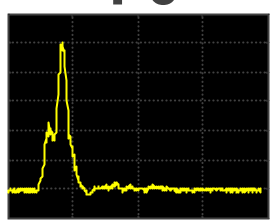
F4



F5

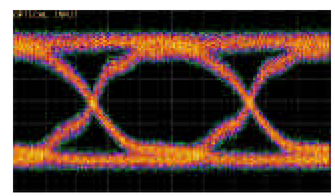


F6



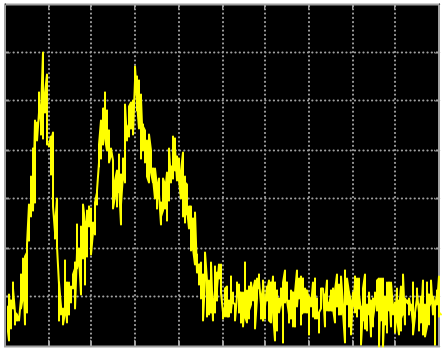
SNR

	2.5 Gb/s	5 Gb/s	10 Gb/s
F0	25.4	24.0	23.1
F1	23.5	22.1	19.2
F2	25.0	22.7	20.5
F3	25.9	24.5	22.5
F4	26.0	23.6	21.5
F5	26.3	24.6	23.2
F6	27.3	25.1	23.8

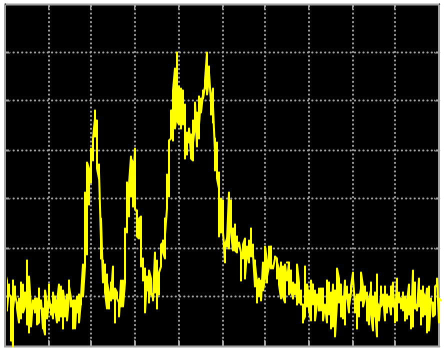


FP laser at 75ºC + 10 m MMF jumper + RL 22 dB + Fiber shaker + Mode selective loss + 300 m TIA MMF at 75ºC

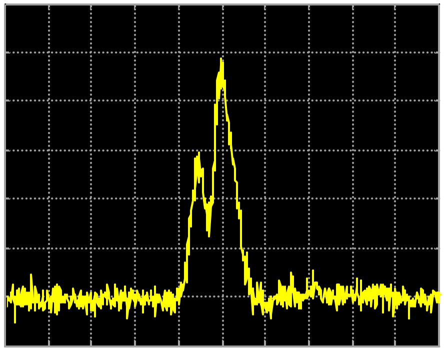
F2



F4



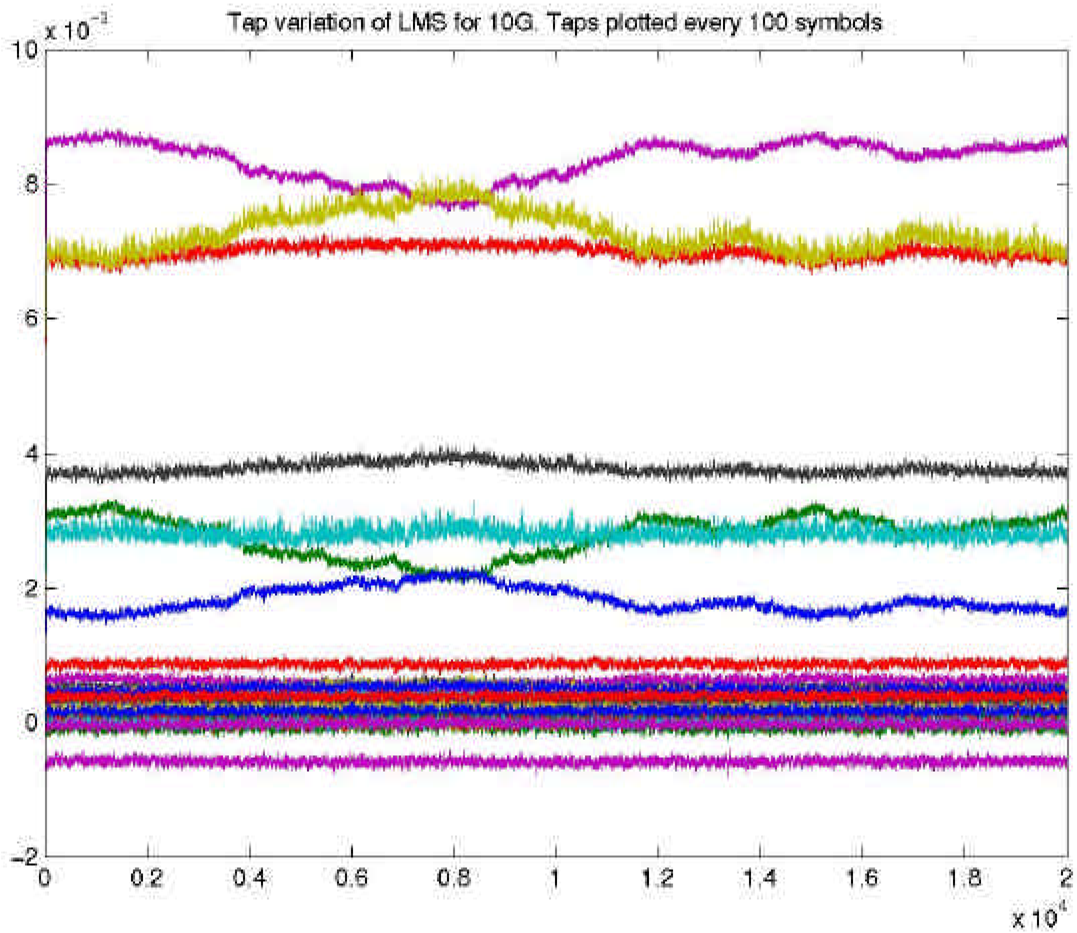
F6



SNR

	2.5 Gb/s	5 Gb/s	10 Gb/s
F1	23.1	21.1	18.5
F2	22.9	17.4	17.5
F3	20.4	20.4	16.9
F4	22.1	19.5	16.8
F5	21.8	20.8	20.3
F6	22.3	20.0	20.6

LMS canceller is tracking channel time variation



agere systems

300 m TIA MMF (F2)

	2.5 Gb/s	5 Gb/s	10 Gb/s
FP@25°C+MMF+TIA F2@25°C	24.7	22.8	21.5 (23.2)
FP@25°C+MMF+Mode filter+TIA F2@25°C	25.0	22.7	20.5 (22.2)
FP@25°C+MMF+RL 22dB+Mode filter+TIA F2@25°C	24.1	21.4	19.4 (20.4)
FP@75°C+MMF+RL 22dB+TIA F2@25°C	23.3	21.0	18.6 (19.8)
FP@75°C+MMF+RL 22dB+Fiber shaker+TIA F2@25°C	22.8	19.9	17.0 (17.7)
FP@75°C+MMF+RL 22dB+Fiber shaker+Mode selective loss+TIA F2@25°C	22.1	19.7	17.9 (18.2)
FP@75°C+MMF+RL 22dB+ Mode selective loss+TIA F2@75°C	20.7	18.6	16.7 (17.8)
FP@75°C+MMF+RL 22dB+Fiber shaker+Mode selective loss+TIA F2@75°C	22.9	17.4	17.5 (18.1)
DFB@25°C+MMF+RL 22dB+ Mode selective loss+TIA F2@75°C	18.9	18.9	17.4
DFB@25°C+MMF+RL 22dB+ Fiber shaker+Mode selective loss+TIA F2@75°C	19.3	19.2	16.9
DFB@25°C+SMF+Mode selective loss+TIA F2@75°C	16.5	15.7	15.0
DFB@25°C+SMF+RL 26dB+Mode selective loss+TIA F2@75°C	16.3	14.0	13.5
DFB@25°C+SMF+Fiber shaker+Mode selective loss+TIA F2@75°C	15.7	13.3	14.3
DFB@25°C+SMF+RL 26dB+Fiber shaker+Mode selective loss+TIA F2@75°C	11.3	14.2	12.3

41 (256) canceller taps

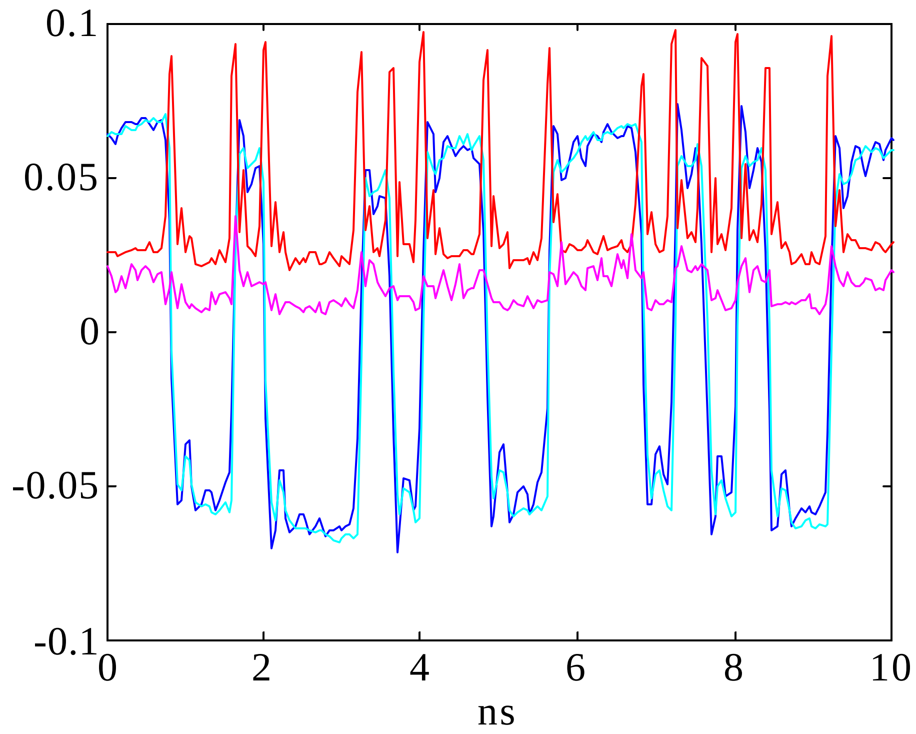
Measurements issues with real-time scope

Sampling scope signal

Real-time scope signal

Sampling scope noise (x10)

Real-time scope noise (x10)



Conclusions

- The results indicate that equalization is feasible even at 10 Gb/s. A completely closed eye could be opened to a low bit error rate.
- However, the SNR on the TIA DMD challenged fiber is marginal (just above the 17 dB required for 10^{-12} BER).
- Note that the SNR reported is the theoretical bound for the optimal receiver. Actual implementations will have degradation from this limit.

Conclusions (cont'd)

- Uncertainty in measurements made with real-time scope.
- The relaxation oscillation of the laser is non-linear, non-symmetric but has a strong deterministic component. The LMS canceller cannot completely cancel this component, resulting in SNR degradation. Other algorithms may improve performance.
- Possible remedies:
  - specs on launch conditions to obtain better SNR
  - Forward Error Correction can provide the required coding gain to obtain the specified BER.