•Slides 1-13:
Industry Buzz

•Slides 14-47:
eSeminar - Analyzing High-speed Optical Waveforms

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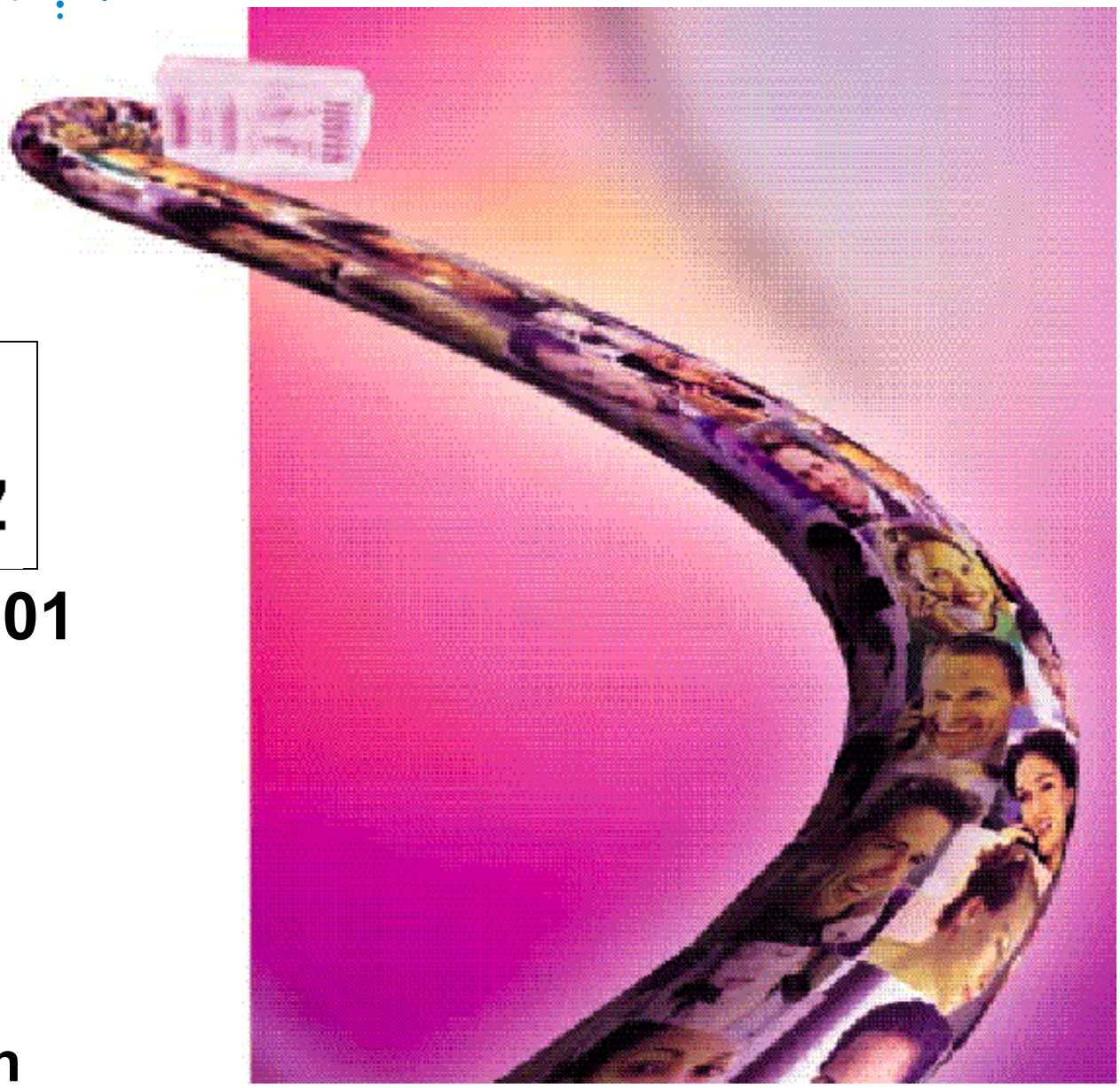


THE 40G INDUSTRY BUZZ

December 4, 2001

presented by:

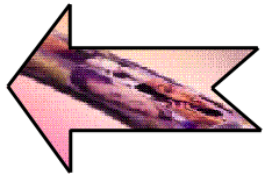
Larry DesJardin

THE 40G Industry Buzz

- Industry Update & Commentary
- “Late Breaking News” from Agilent
- Viewer Poll & Feedback

THE 40G Industry Buzz

- *Industry Update & Commentary*



- "Late Breaking News" from Agilent
- Viewer Poll & Feedback

40G Standards

- G.709 (Optical Transport Network)
- SFI-5 (SERDES Framer Interface 5)
- VSR-5 (Very Short Reach 5)

40G Standards

G.709

- Interface for the optical transport network (OTN)
- SONET-like, but can carry any protocol
- Standardized FEC

www.agilent.com/about/newsroom/01oct2001_ecoc/anote_ITU-TG709.pdf

40G Standards

SFI-5 SERDES Framer Interface 5

- Standardized Transponder Module Interface
- Data Bus= 16x2.5Gb/s + Parity = 17
- Built-in Skew Compensation
- Optical Transmit & Receive
- Can be any optics!

www.oiforum.com/

http://sunj.0catch.com/docs/SFI-5-Draft.pdf

40G Standards

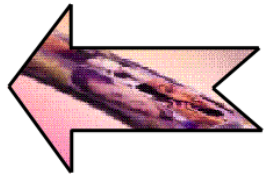
OIF VSR-5

- Very Short Reach interfaces for interconnecting office equipment
- 40G Serial
- 12 x 3.3G 850nm Parallel
- 4 x 10G 1310nm CWDM

www.oiforum.com/

THE 40G Industry Buzz

- **Industry Update & Commentary**
- ***"Late Breaking News" from Agilent***
- **Viewer Poll & Feedback**



Late Breaking Agilent News

New Optical Test Products:

- **Agilent 815xA Variable Attenuation Modules**
  - **Bench and System Apps**
  - **Atten. Or Atten. + Power Meter**
  - **Low PMD for 40Gb/s**

- **Agilent Optical Heads**
  - **Up to +40dbm for Raman**
  - **Low PDL for 40Gb/s**

See Resource Page for more info.

Late Breaking Agilent News

2 New Tributary Test Products:

- **Agilent ParBERT 81250 10.8G**
  - **9.5 to 10.8Gb/s Generator and Analyzer**
  - **Used singular or 4x10G for 40G apps.**

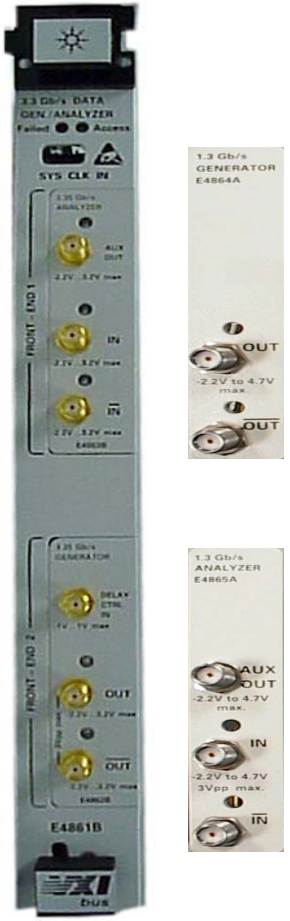
- **Agilent OmniBER OTN**
  - **SONET/SDH/OTN (G.709)**
  - **All rates: DS1 to OC-192/STM64 & 10.71Gb/s (OTU2 at G.709)**

See Resource Page for more info.

Late Breaking Agilent News

Orderable starting in January...

- **Agilent ParBERT 3.35G**
  - **21Mhz- 3.35Gb/s BER Generator and Analyzer**
  - **2 Front Ends / Module**
  - **Built-in SFI-5 Patterns**
  - **Will work as tributaries in ParBERT 43G system**
  - **12x3.3G Configuration addresses VSR-5**



Contact your Agilent Field Rep. for more info.

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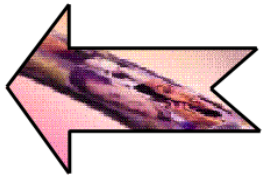
THE 40G Industry Buzz

- Industry Update & Commentary
- "Late Breaking News" from Agilent
- *Viewer Poll & Feedback*

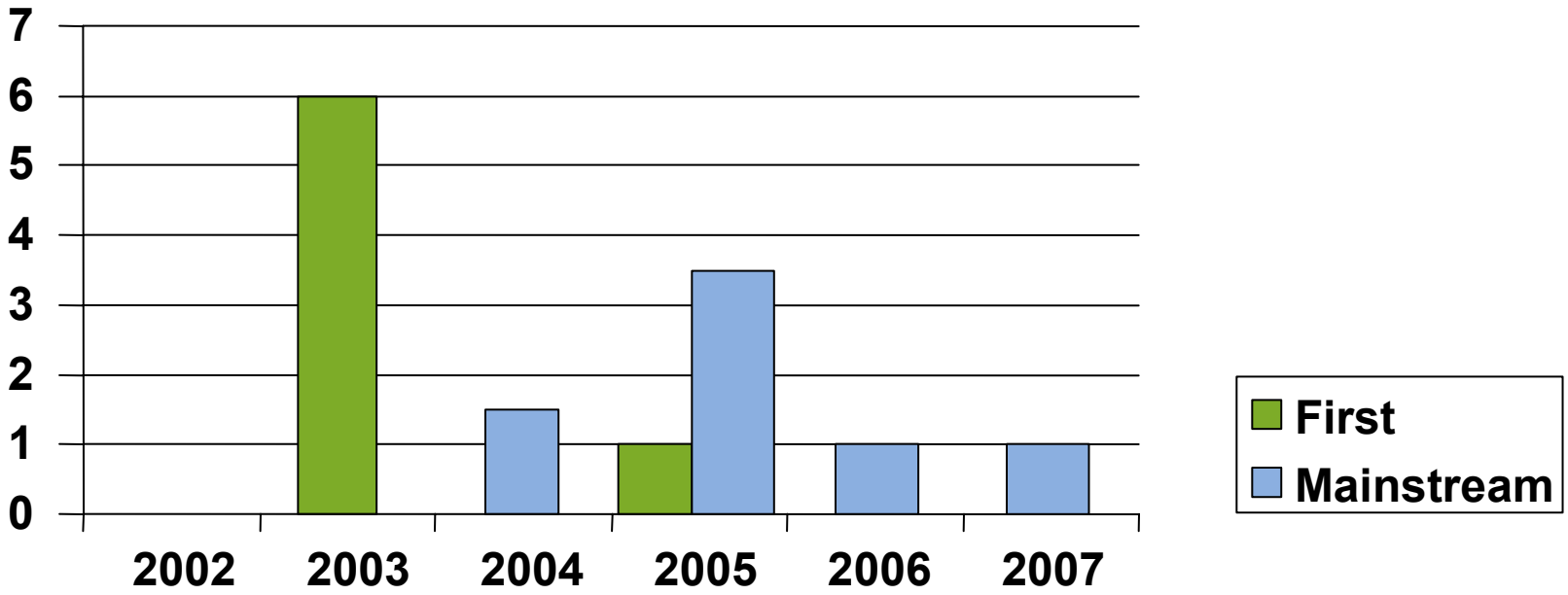


Viewer Poll and Feedback

From Last Month: In what year

***a)* will the first 40G Equipment be deployed?**

b) when will 40G become mainstream?



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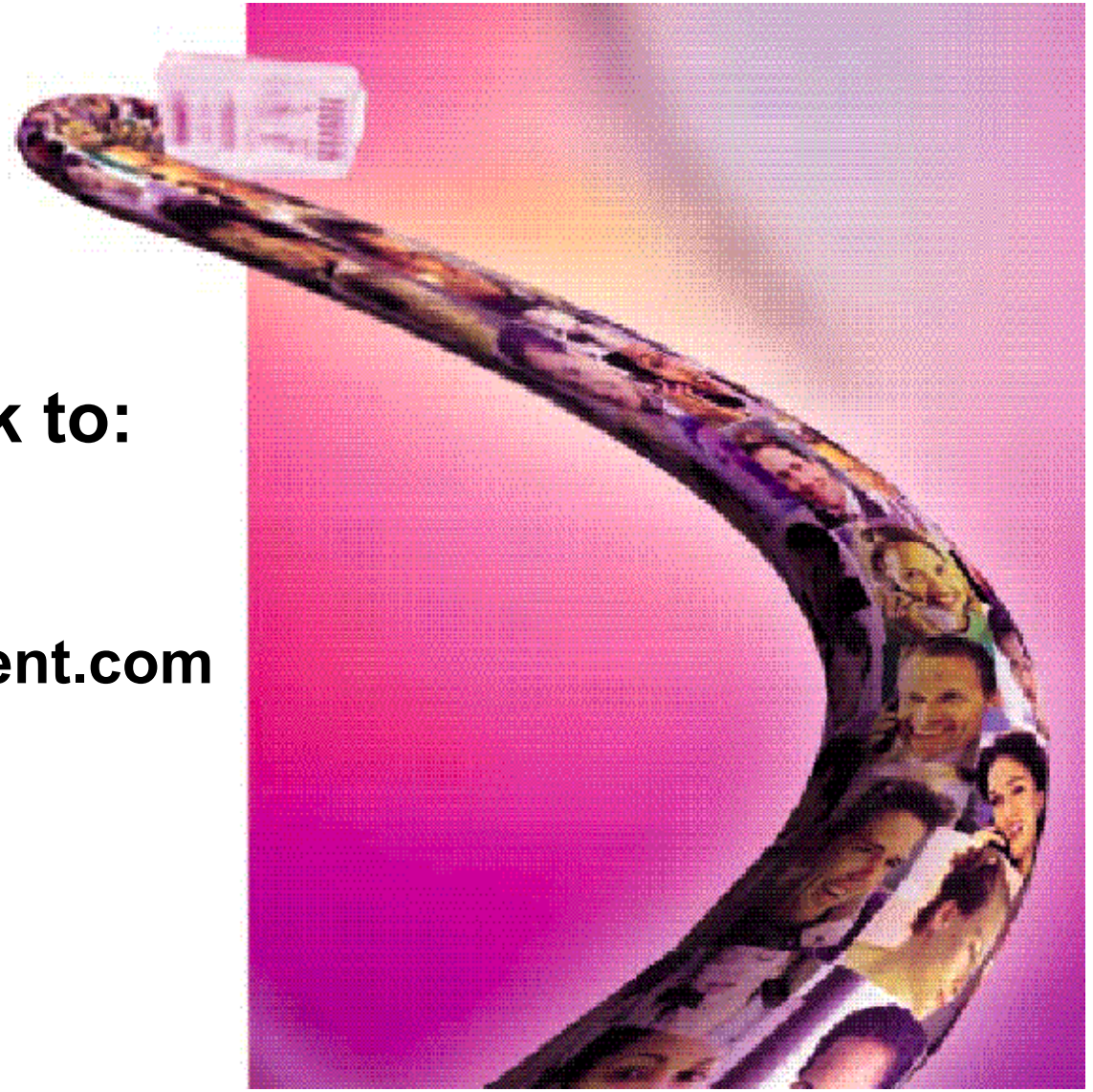
THE 40G INDUSTRY BUZZ



Send any feedback to:

larry_desjardin@agilent.com

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40 Gb/s Measurement Challenges: Analyzing High-speed Optical Waveforms

December 4, 2001

presented by:

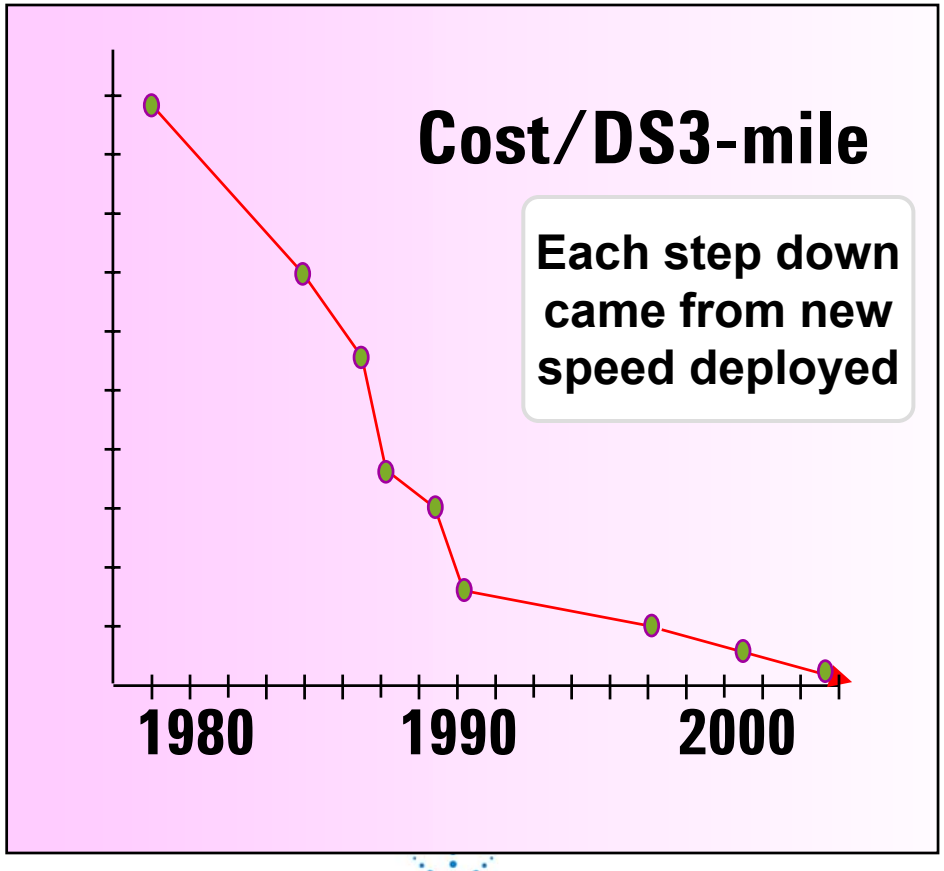
Greg LeCheminant

The road to 40 Gbit/s

Since 1982 the transmission speed of optical networks has roughly doubled every two years

- Mid 90's: 2.5 Gbit/s
- Late 90's: 10 Gbit/s
- ???: 40 Gbit/s

- (Ethernet jumps by factors of 10)



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The road to 40 Gbit/s

Along the way numerous performance barriers have been encountered and conquered

- Attenuation
  - Costly regenerators
- Capacity of a single fiber
- Device/component performance
- Optical amplification
- Increased signaling speeds and multiple wavelengths
- Wide BW modulators and receivers

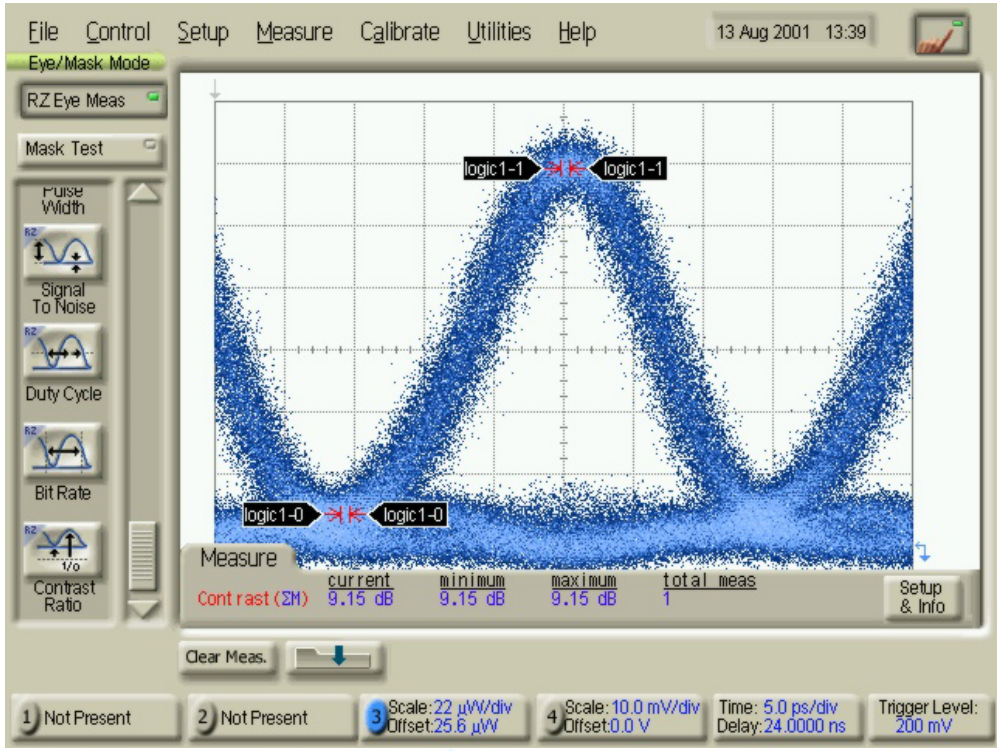
Everything gets worse at 40 Gbit/s

- Many openly question whether 40 Gbit/s transmission is viable given the effects of chromatic and polarization mode dispersion
  - Bit periods are only 25 picoseconds
- Components are extremely difficult to design and produce
  - Complex microwave design challenges

Measuring 40 Gbit/s waveforms

Seeing the waveform is an essential part of the design and verification of 40 Gbit/s components and systems

- **A quick and intuitive way to verify the quality of a signal**



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Measuring 40 Gbit/s waveforms

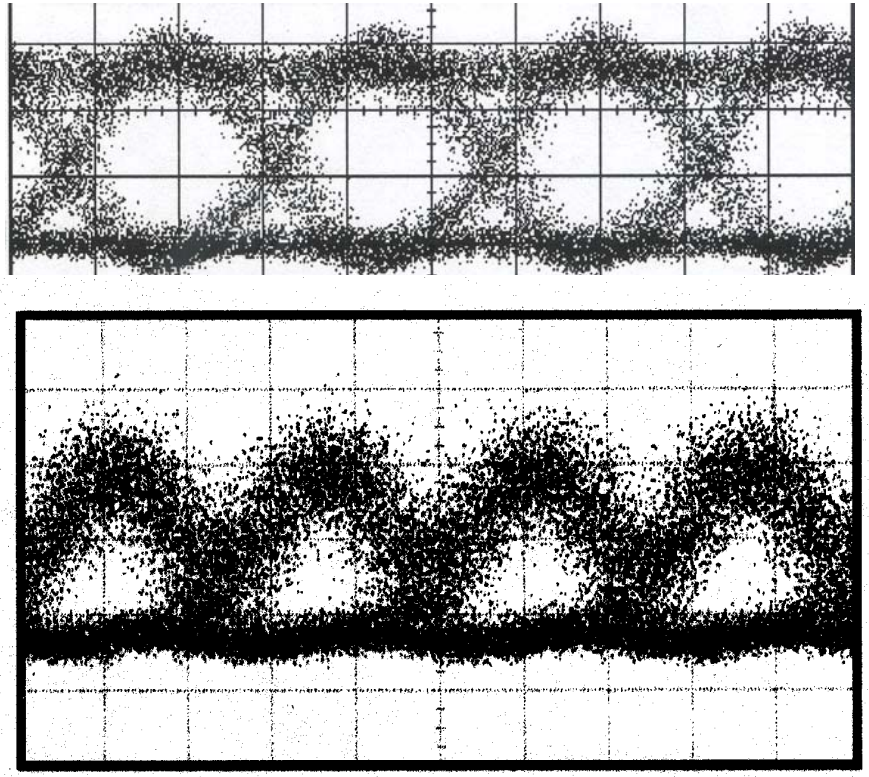
While data rates have jumped by factors of four and ten, waveform measurement capabilities have been stable

- **Performance standards for the past 10 years:**
  - **50 GHz bandwidth**
  - **1 ps timing precision (jitter)**

Measuring 40 Gbit/s waveforms

While adequate for 10 Gbit/s, is it viable for 40 Gbit/s?

- **The bottom line: Is what I see on the scope an accurate representation of the true signal performance?**
  - **Some views of 40 Gbit/s waveforms**



•Kawanishi et al; OKI Electric Industry; OFC 2001

•Otani and Suzuki; KDD Labs; OFC 2001

Measuring 40 Gbit/s waveforms

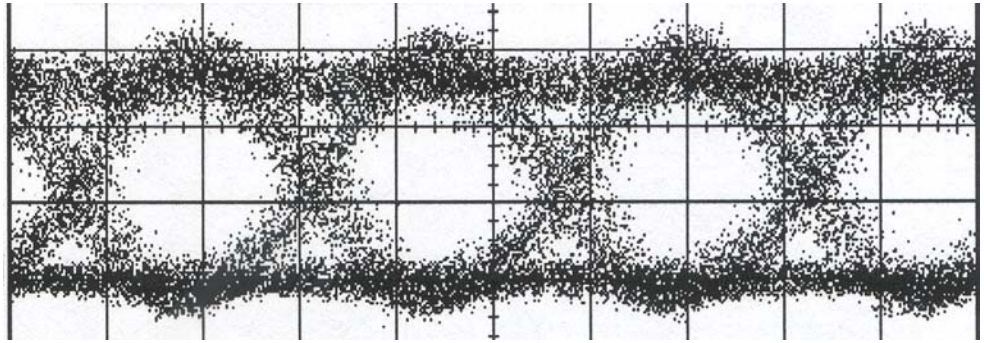
What determines the precision of a waveform measurement system?

- **The parameter usually found at the top of the list is bandwidth**
  - **The best indication of the speed of the measurement system**
  - **If bandwidth is low, waveform edges will appear to be slow**

Is there more to it than just bandwidth?

Precision effected by several parameters

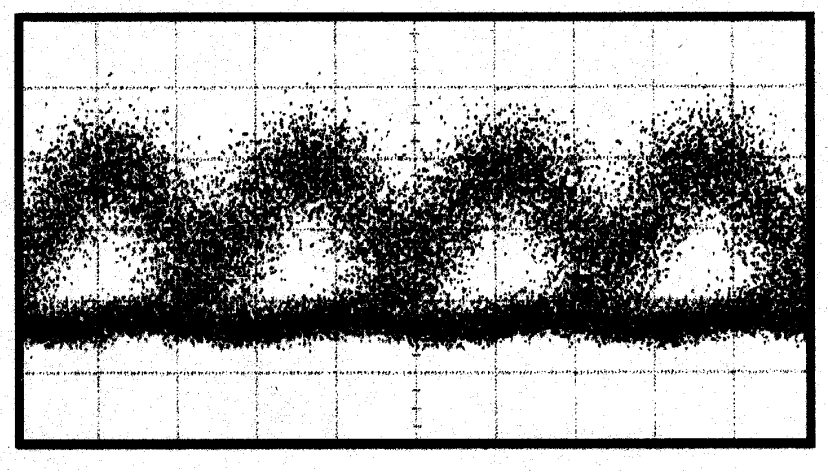
- Is this what the waveform really looks like?
- What are some of the telltale signs of measurement inaccuracy?
- Is there any way to know for sure?



Is there more to it than just bandwidth?

What are the other critical issues?

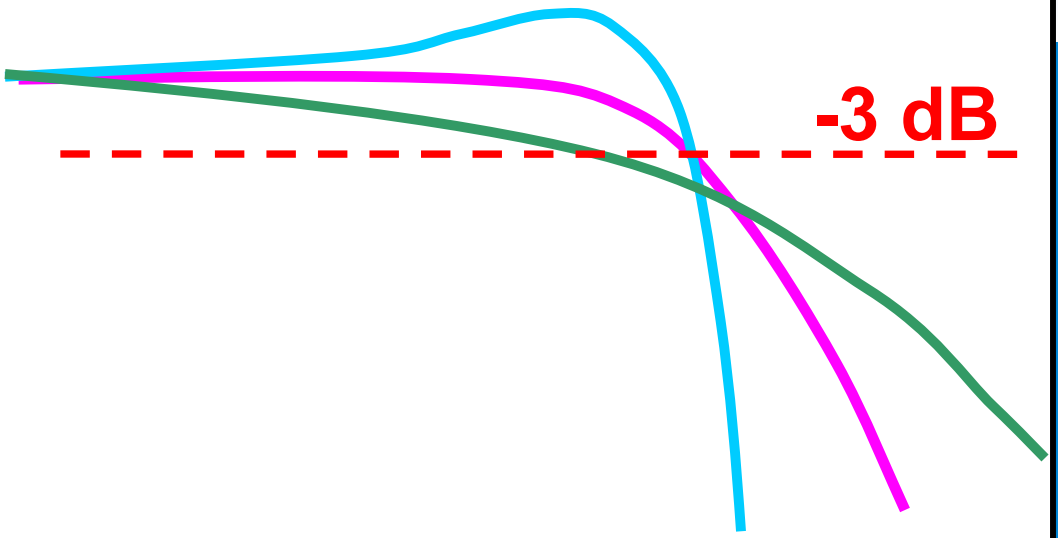
- Overall frequency response
  - Bandwidth is just one component
- Jitter
- Noise



Oscilloscope frequency response

Directly effects the shape of the waveform

- Bandwidth is a useful parameter to describe frequency response
- But…there can be several possible frequency responses with similar bandwidths



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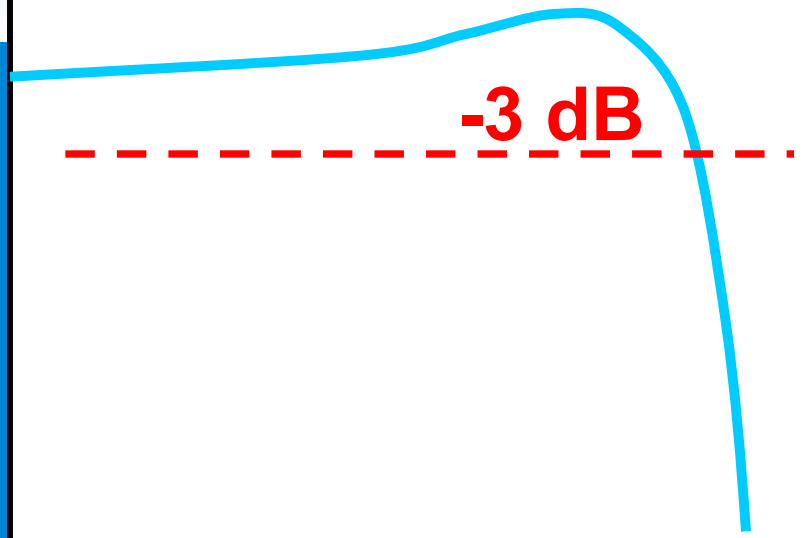
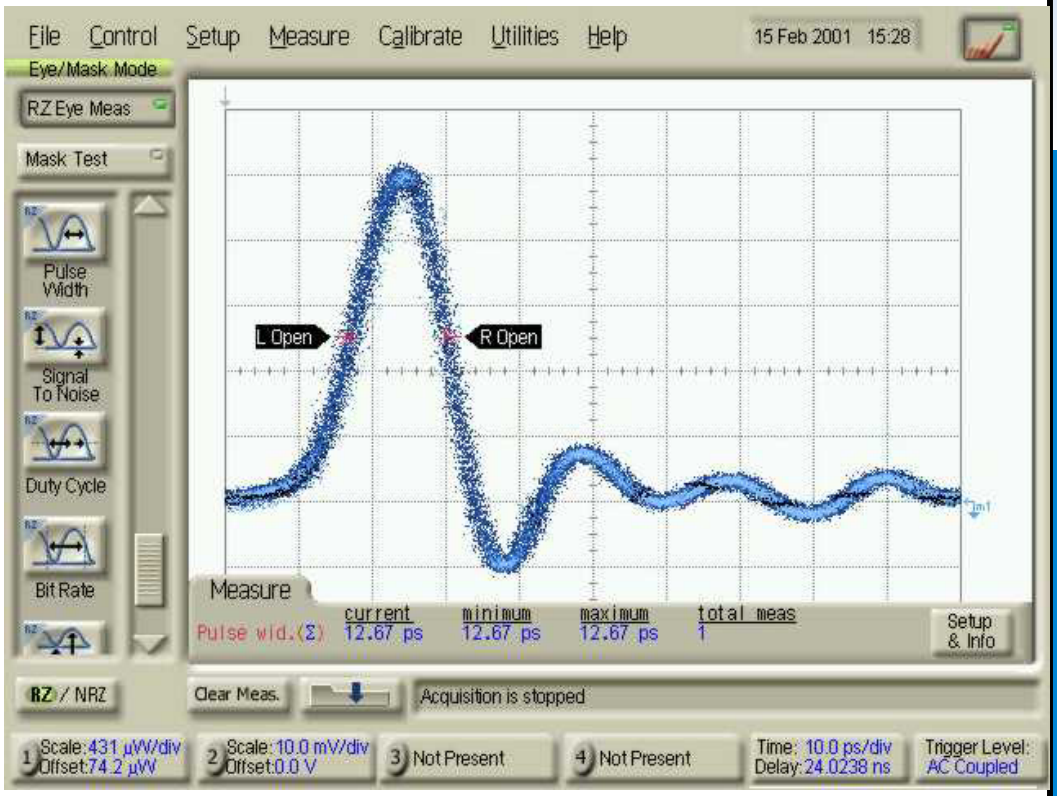
The effects of frequency response

Not all bandwidths are created equal





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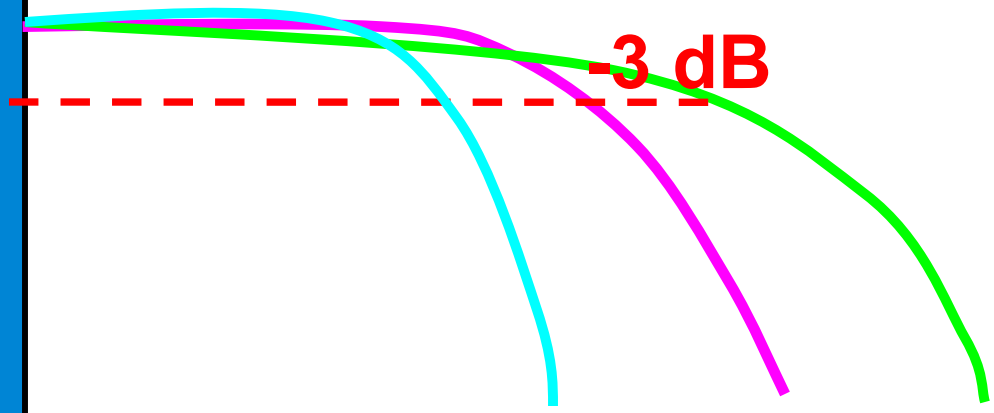
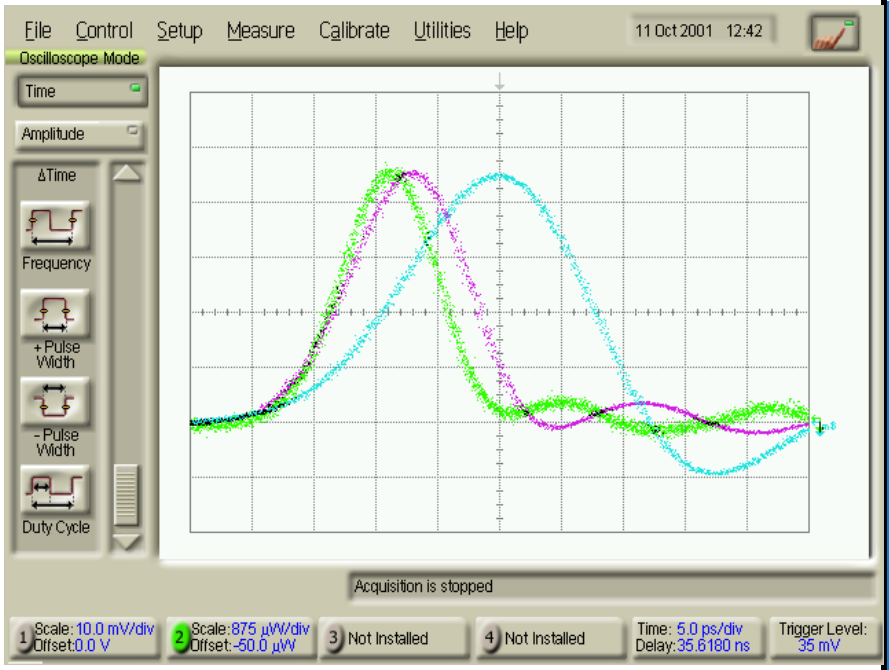
The effects of frequency response

Bandwidth and well-behaved frequency responses yield fast, well-behaved time responses





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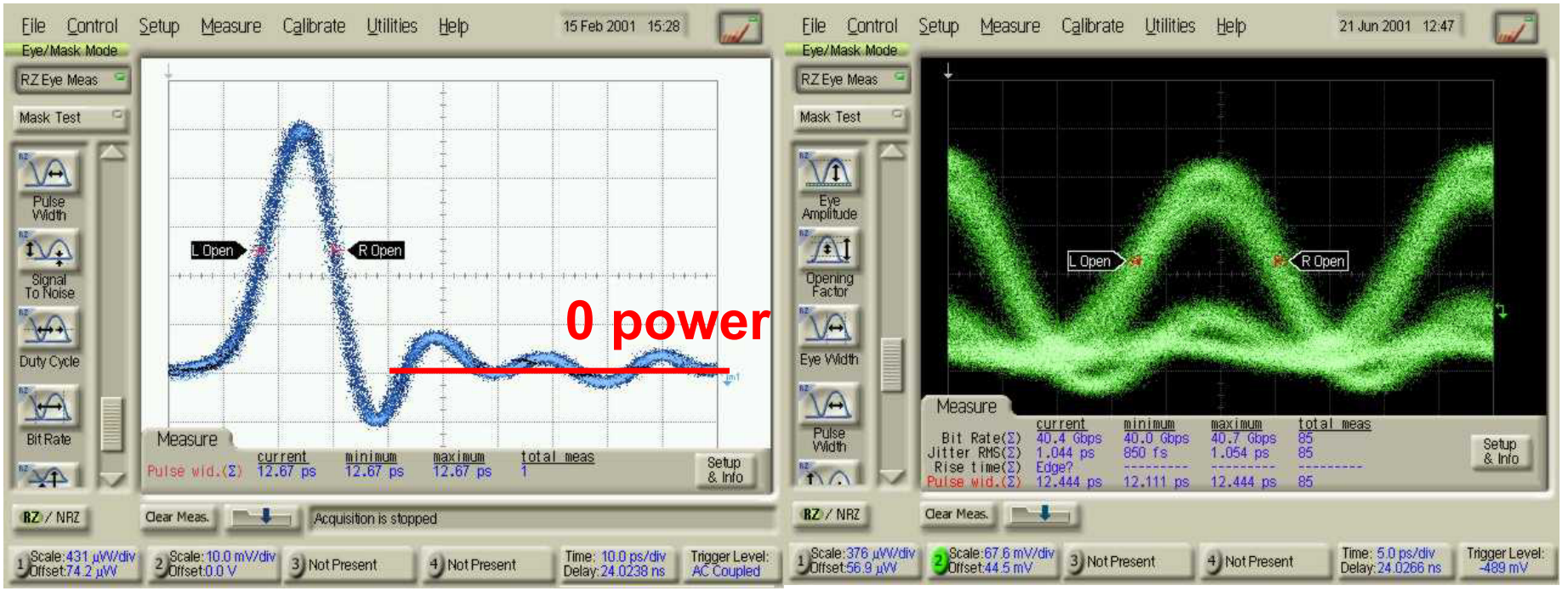
The effects of frequency response

Overshoot degrades the eye-diagram



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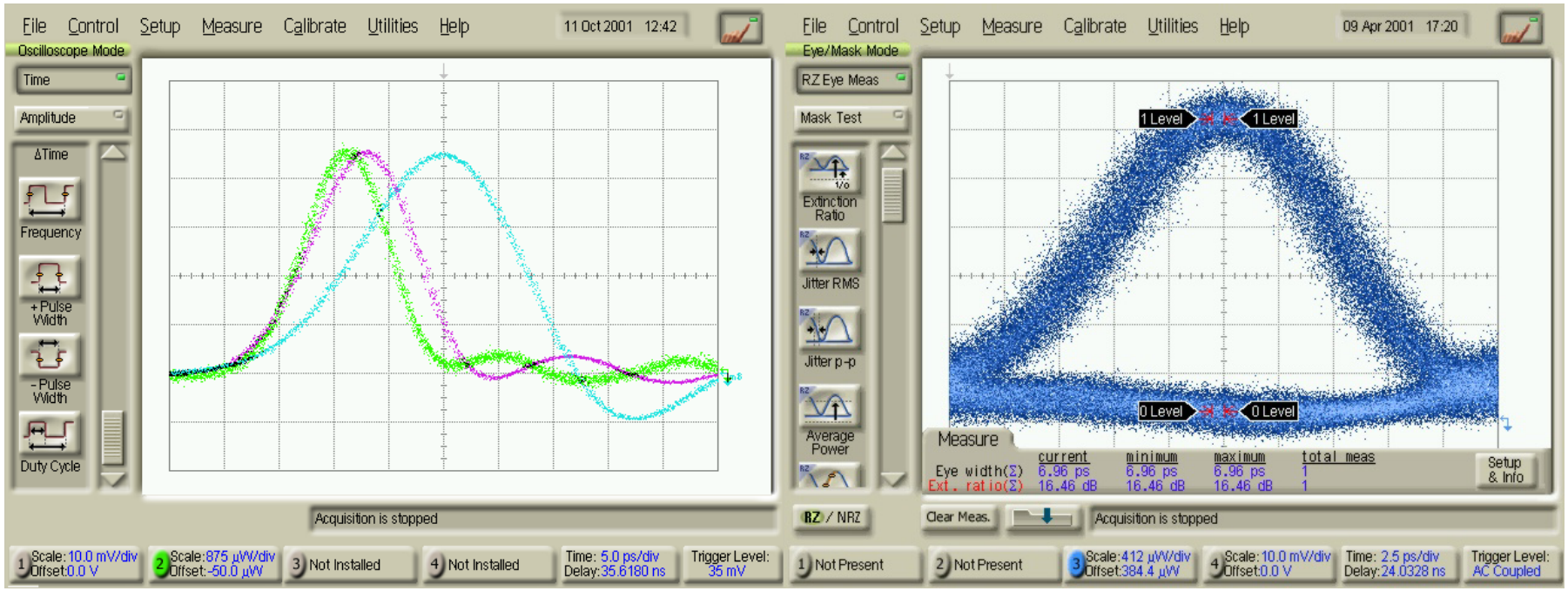
The effects of frequency response

Well-behaved impulse response yields a high-fidelity eye



- 55, 40 and 30 GHz BW

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Measuring 40 Gbit/s waveforms

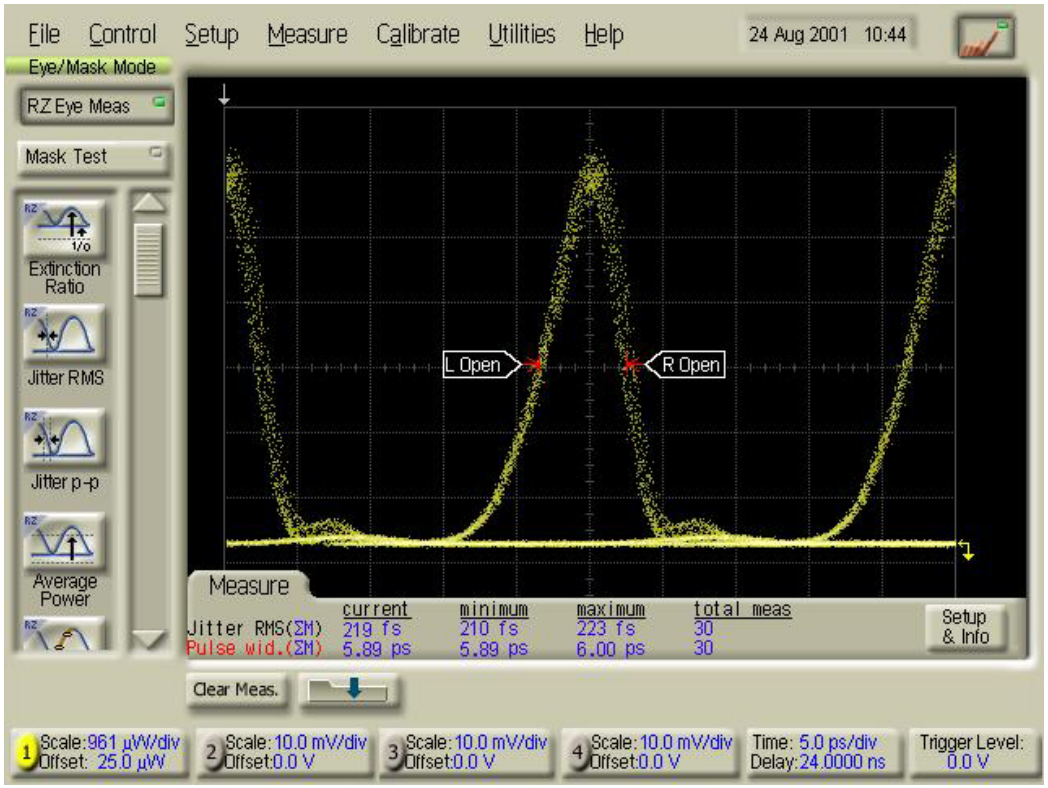
How much bandwidth is enough?

- ***Anytime you bandlimit a signal, the resulting waveform is incorrect. Error magnitude depends on frequency content of the signal and scope response***
- **Signal speeds are increasing much faster than instrument bandwidths**
  - **How much farther can electrical sampling techniques be extended?**
  - **For the most precise view of 40 and 80 Gbit/s waveforms, bandwidths well in excess of 100 GHz are required**

Measuring 40 Gbit/s waveforms

Optically based sampling techniques offer dramatic improvements in bandwidth

- Not based upon converting a signal to electrical domain
- Order of magnitude improvements in bandwidth without O/E frequency response issues
- C or L band



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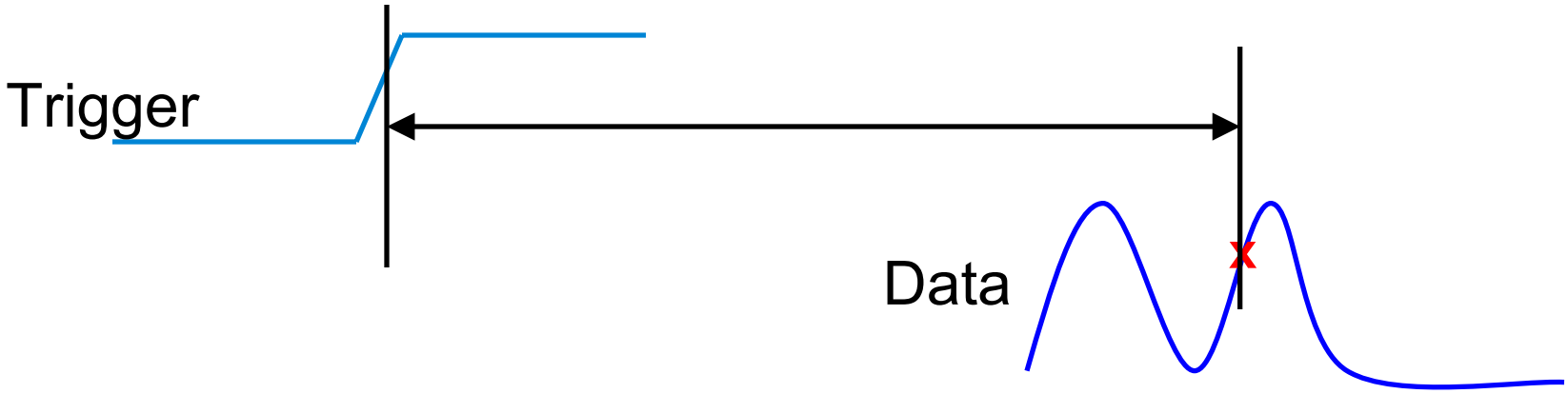
Timing issues also present problems

How much uncertainty exists in determining where in time a sample is taken?

- **For sampling oscilloscopes this is referred to as jitter**
- **Typical performance level has been “1 picosecond RMS”**



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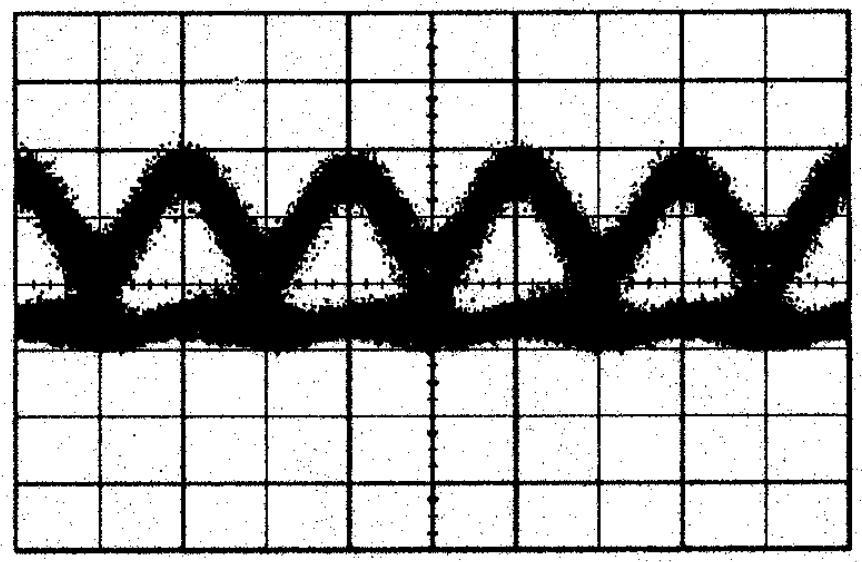
Timing issues present problems

The effects of oscilloscope jitter

- When viewing eye diagrams, peak-to-peak jitter is critical
- 1 ps RMS yields roughly 5 to 9 ps peak-to-peak
- Significant eye closure for a 40 Gb/s signal (25 ps bit period)



Improving jitter performance

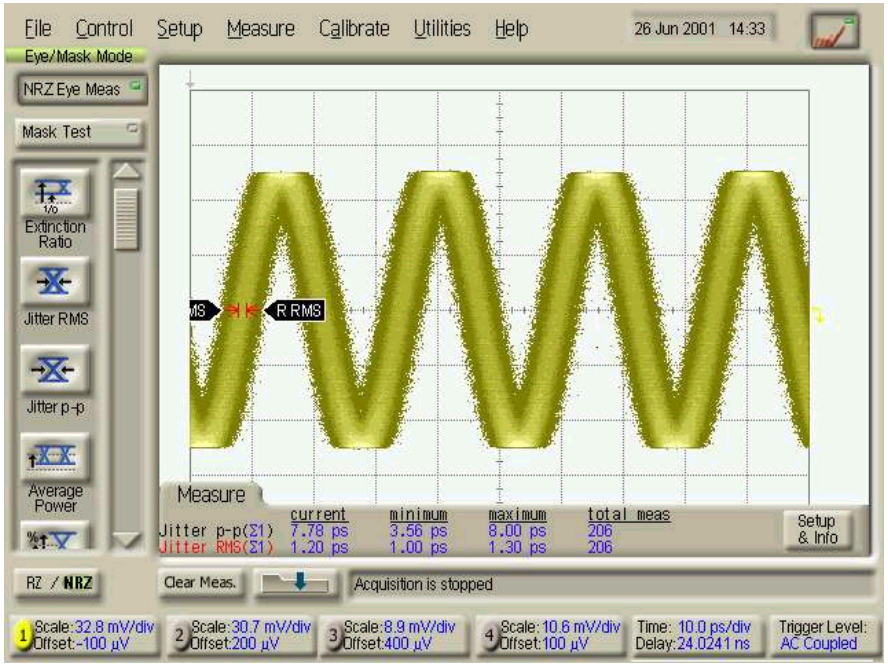
A new approach to timing precision

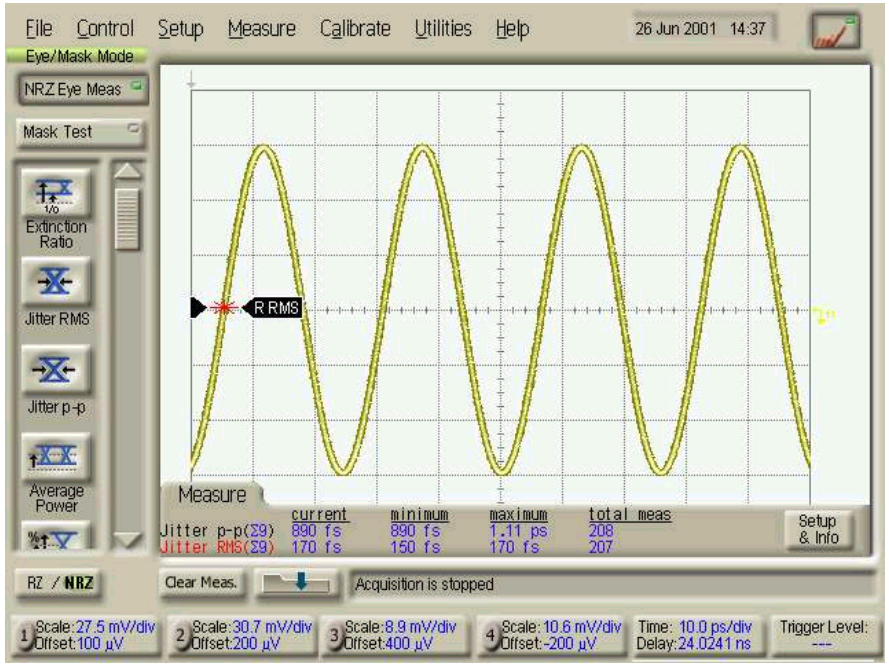
- Rather than knowing *absolute time* from the trigger event, determine the *phase*
- With precision of one or two degrees, RMS jitter is well below 200 fs
- Peak-to-peak jitter is below 1 ps

Measuring 40 Gbit/s waveforms

Oscilloscope jitter is virtually eliminated

- Basic architecture yielded 1.2 ps
- New timing scheme reduces jitter to 170 fs





Test signal: 165 mV synthesized sinewave

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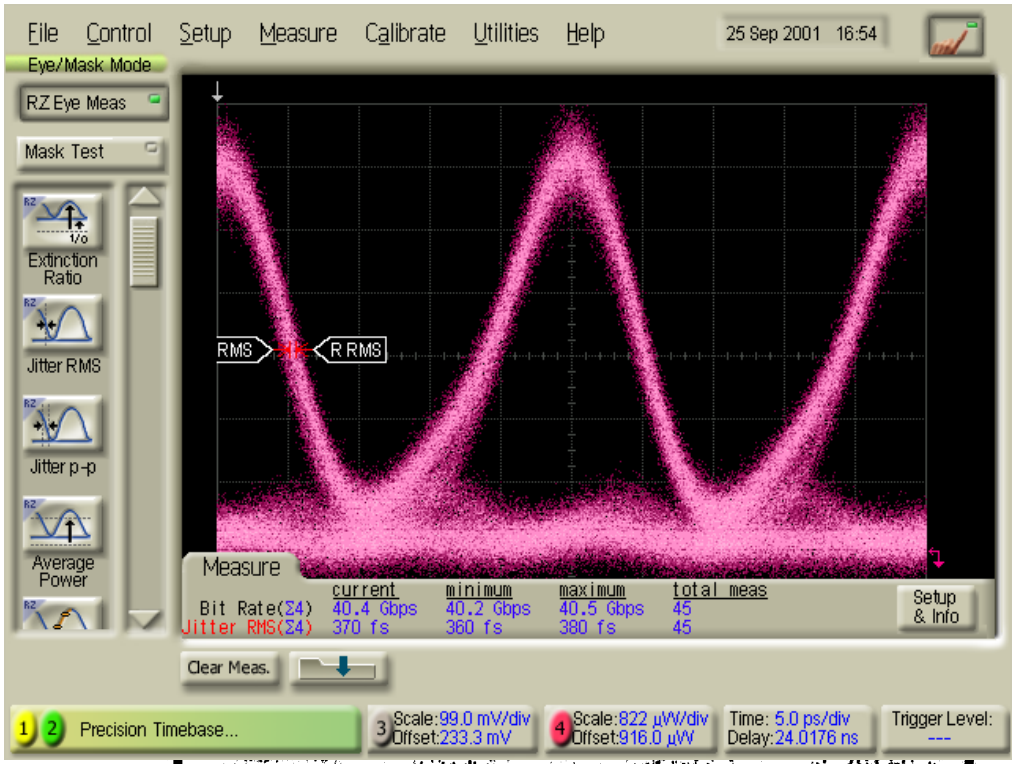
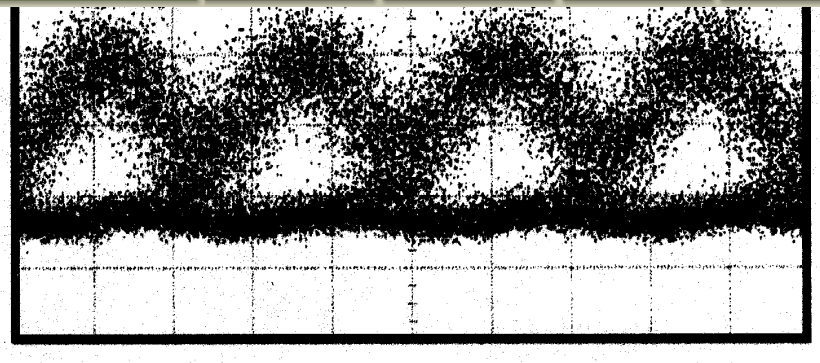
Top performance available today

- Viewing real 40 Gb/s waveforms with improved bandwidth (55 GHz) and jitter measurement capabilities
- Where we are now compared to where we've been





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Measuring 40 Gbit/s waveforms

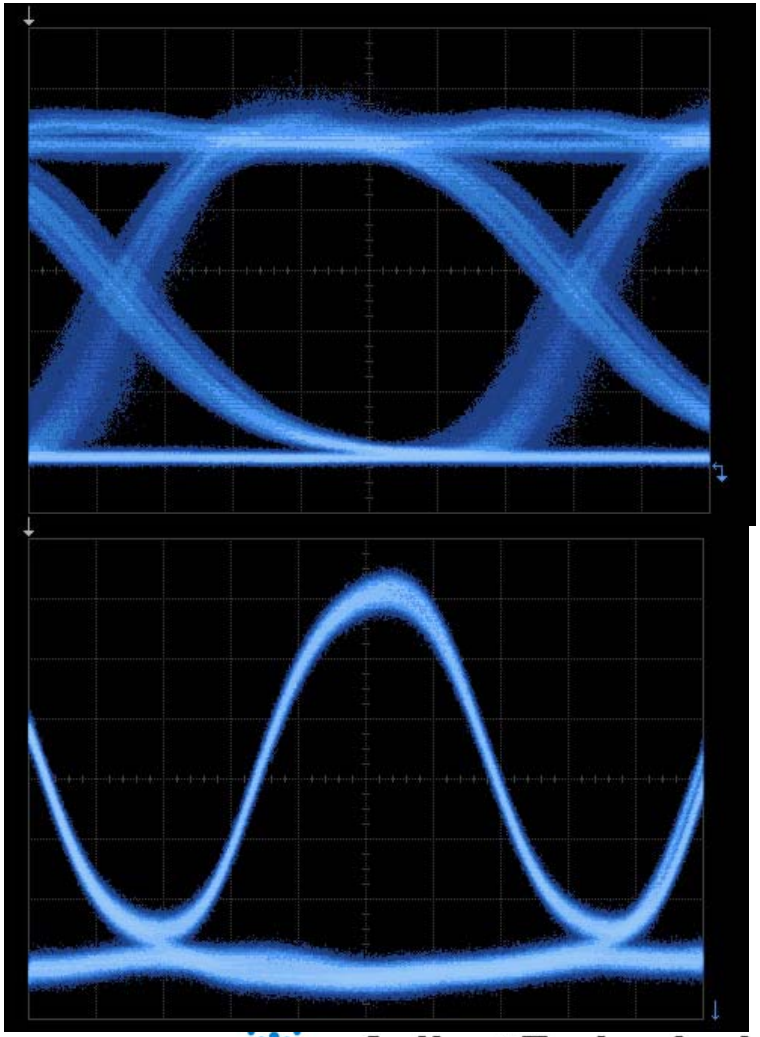
Dealing with return-to-zero (RZ) signals

- Most long-haul 40 Gbit/s signals will be sent in an RZ format
  - Short-haul 40 Gbit/s can still be NRZ
- RZ signals can increase dispersion tolerance
- RZ signals require roughly double the bandwidth as an NRZ signal at the same bit-rate

Automated Eye Measurements

NRZ measurement algorithms often do not function with RZ signals

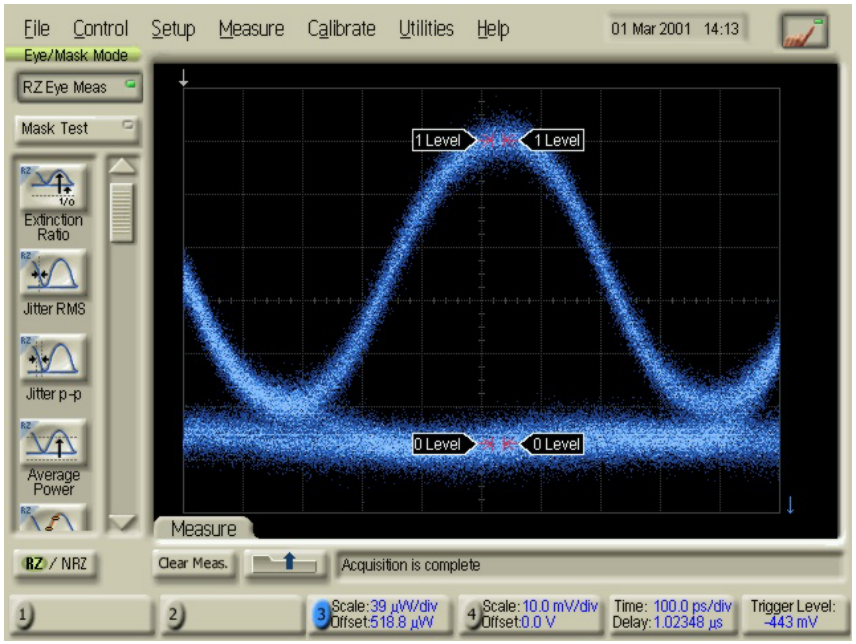
- Oscilloscope looks for crossing points to “anchor” the measurements
- Some NRZ definitions may not apply to RZ signals
- Many NRZ measurements require a reference receiver



Measurements for RZ waveforms

A measurement set specific to RZ

- Extinction ratio definition
- Contrast ratio
- RZ reference receivers
- RZ Eye mask



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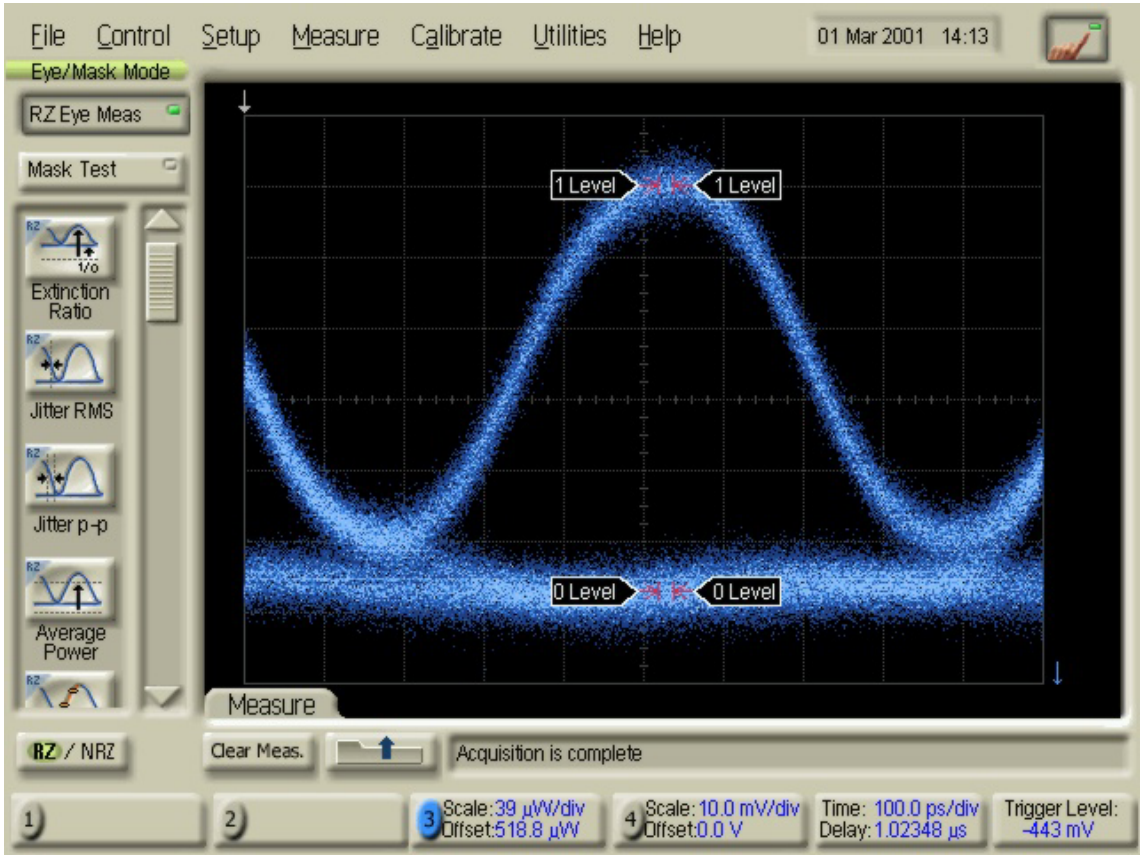
Measurements for RZ waveforms

Extinction ratio

- **NRZ: Mean power in a 1 divided by mean power in a 0**
- **RZ: Mean power in the 1 or peak power in the 1?**



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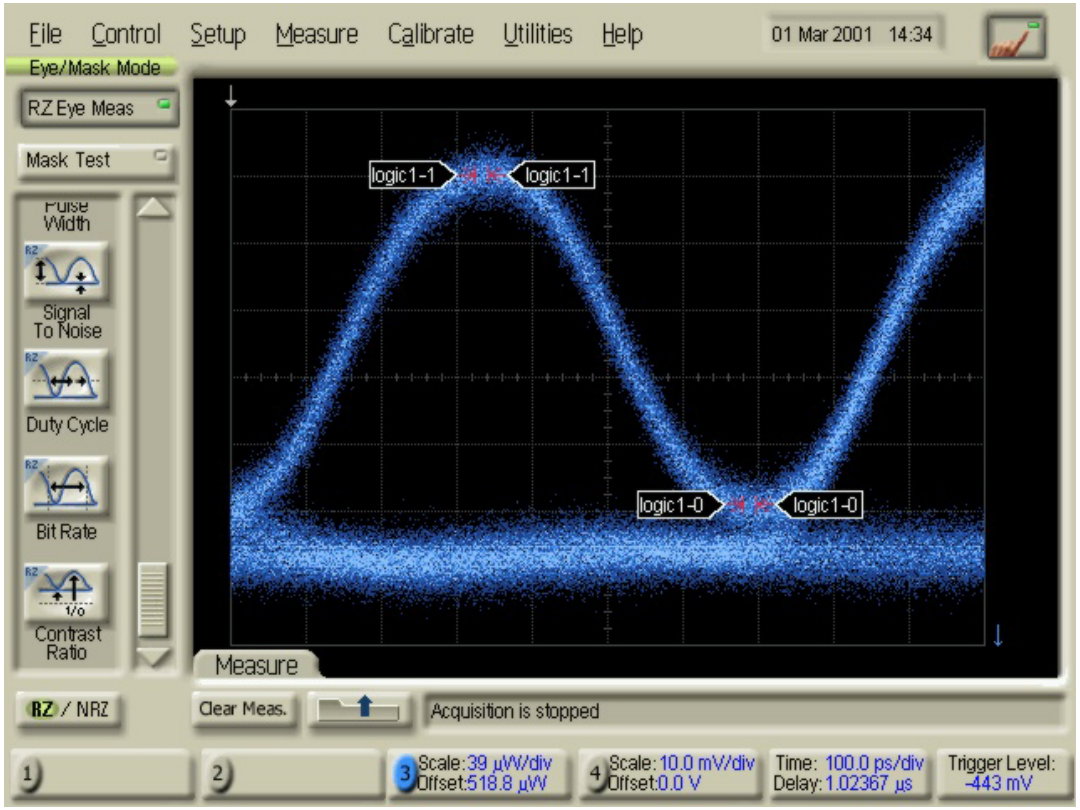
Measurements for RZ waveforms

Contrast ratio

- Ratio of the 1 at the peak to the 1 at the trough
- How well does the signal return to 0?



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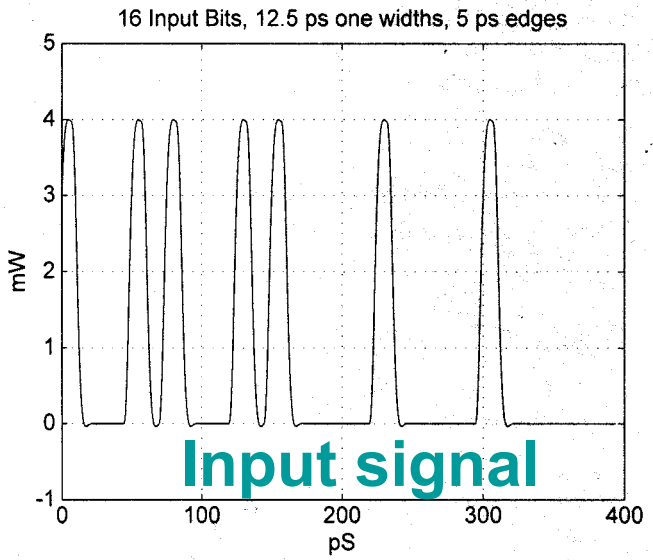
Measurements for RZ waveforms

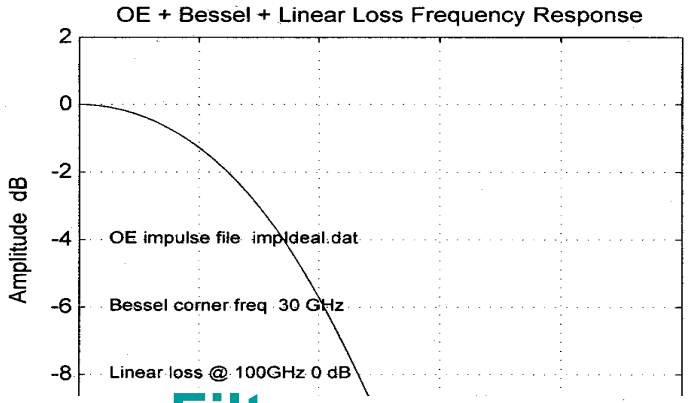
Using reference receivers

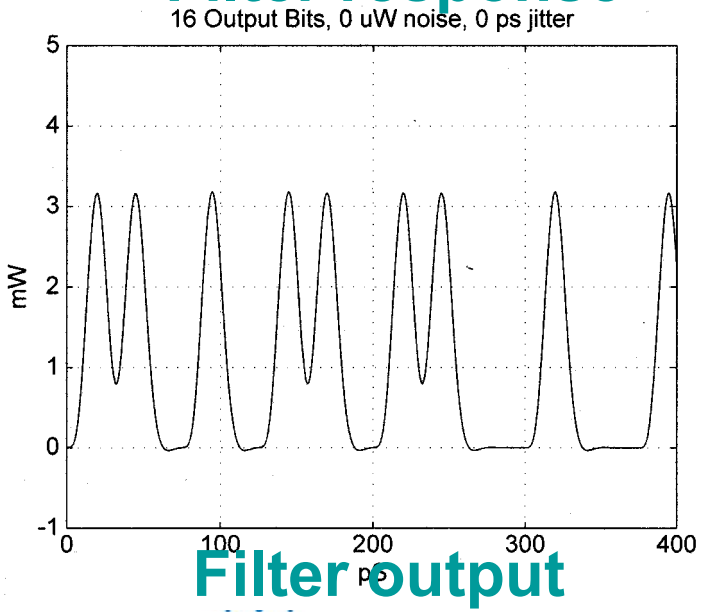
- Used to provide a consistent measurement methodology
  - Different BW's yield different results
- For NRZ waveforms reference receiver BW is typically set at 75% of the optical bit rate
- RZ pulsewidths typically require significantly more BW than NRZ signals

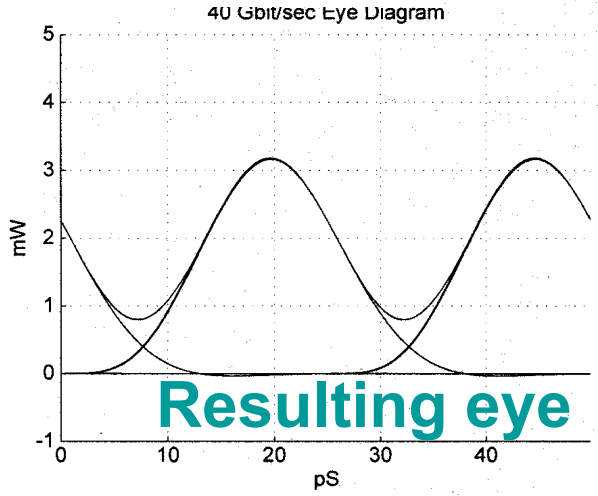
Measurements for RZ waveforms

Using a 75% of bit rate receiver









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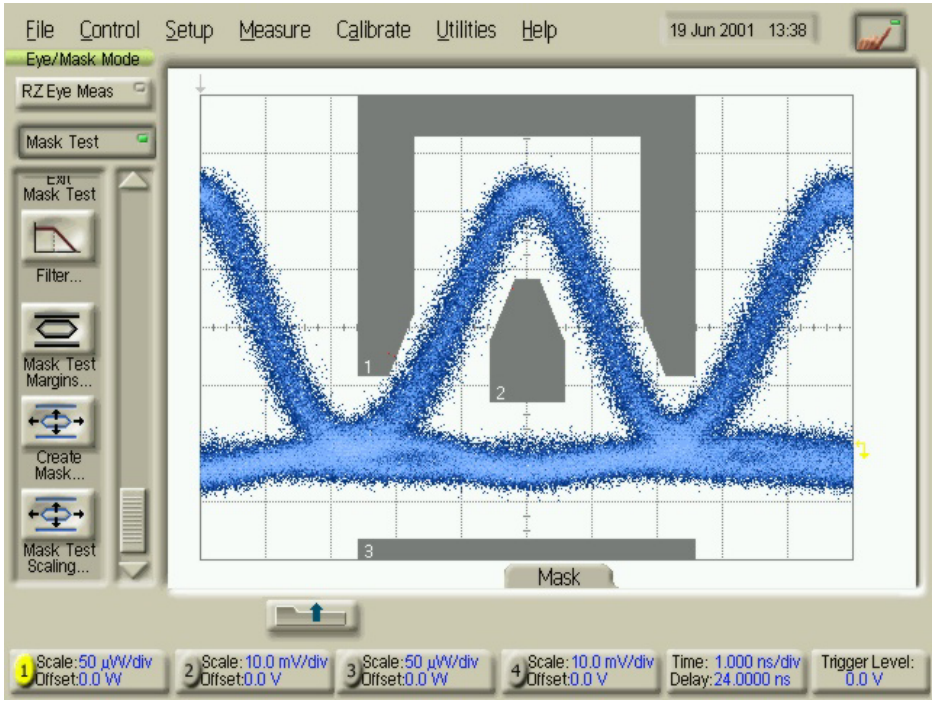
Measurements for RZ waveforms

An RZ reference receiver

- Has not been defined by the standards committees
- Receiver needs to be designed in parallel with key RZ waveform specifications
- “75% of bit rate” is likely to be insufficient
- Currently, most systems are proprietary diminishing the urgency for a reference receiver

Eye-mask for RZ waveforms

- No standard yet
- Needs to be coordinated with the design of a reference receiver
- For now, there is a generic RZ mask that is easily customized



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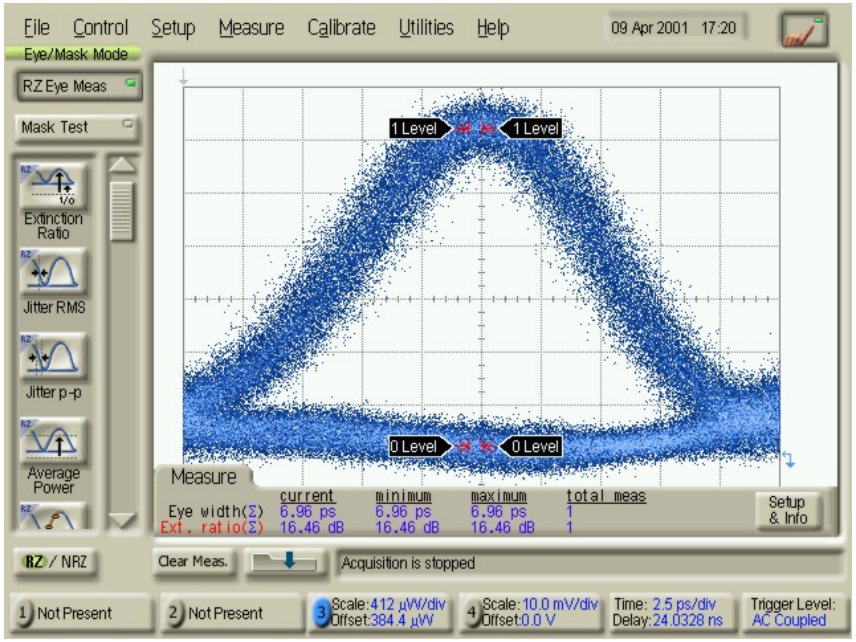
Analyzing high-speed optical waveforms

Conclusions

- **Frequency response, including bandwidth is essential to produce accurate waveform displays**
- **Jitter is a significant problem when measuring extremely high-speed signals**



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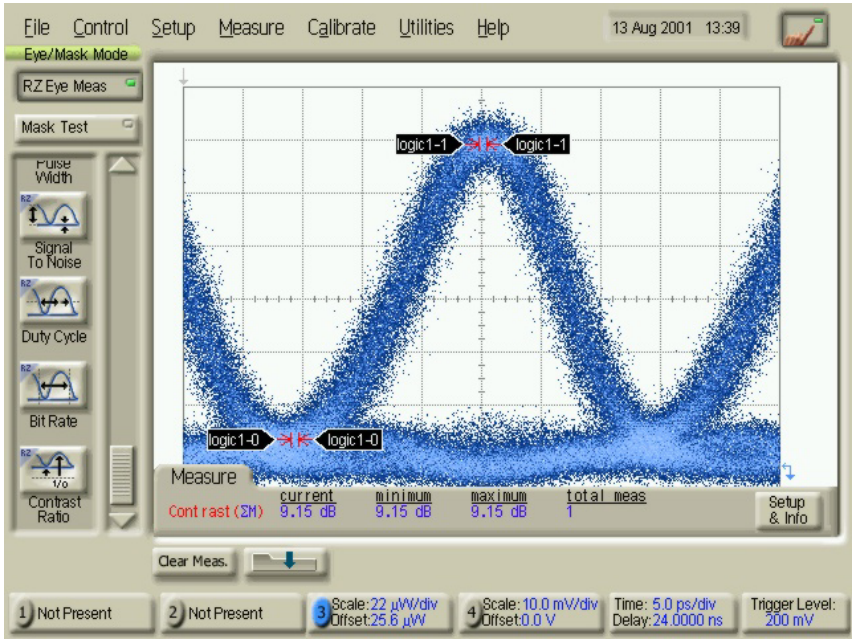
Analyzing high-speed optical waveforms

Conclusions

- **RZ specifications and methodologies are a work in progress**
- **Breakthroughs in measurement capabilities recently achieved**



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