10GBASE-LRM over 300m of FDDI-grade Fiber

Experimental & Simulation Results

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Outline

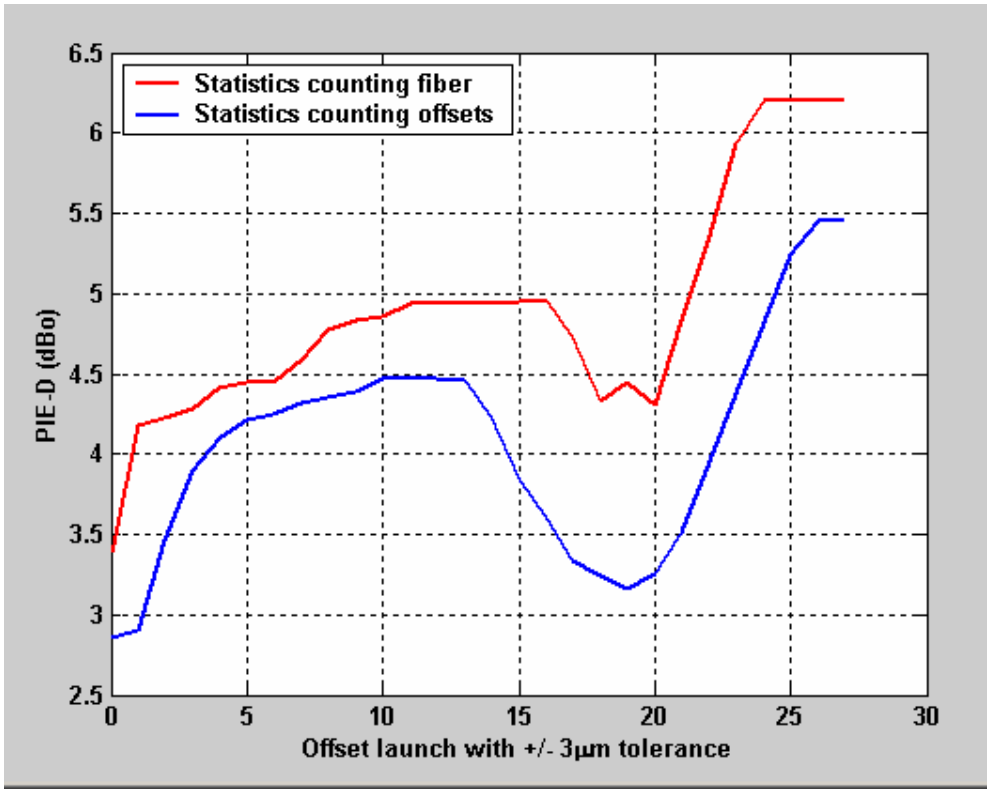
- System Simulations
  - Description of Model
  - Results (CL & OSL)
- System Experiments on TIA 12-96 Round Robin Fiber Set
  - Test set-up
  - PIE Metrics
  - Lab BER Results (CL & OSL)
- Discussion & Next Steps

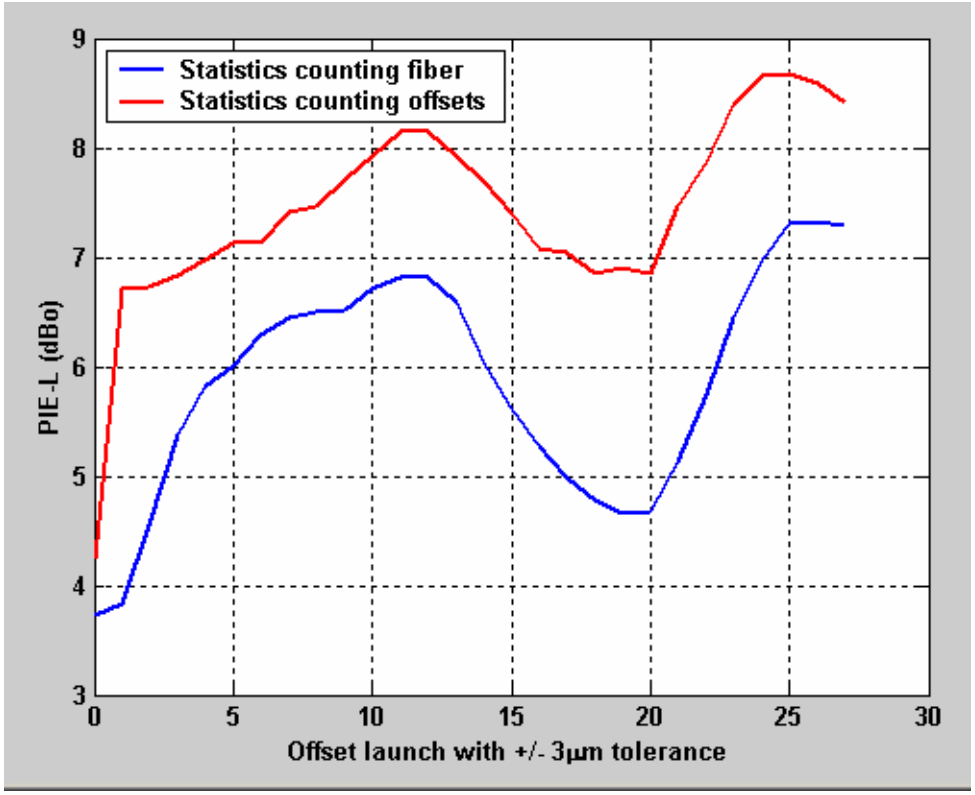
Simulation Model

- Cambridge v1.1 81 fiber mode delays
- Cambridge 2.0 Mode Power Distribution
  - MPD for OSL at 1um steps
- 18 mode-groups were used in calculations

- PIE-L & PIE-D
  - 47.1ps rise-time Gaussian Tx filter
  - 7.5GHz, 4^{th}-order Bessel-Thompson Rx filter

Simulation 81 Fiber Delay Set – PIE Metrics



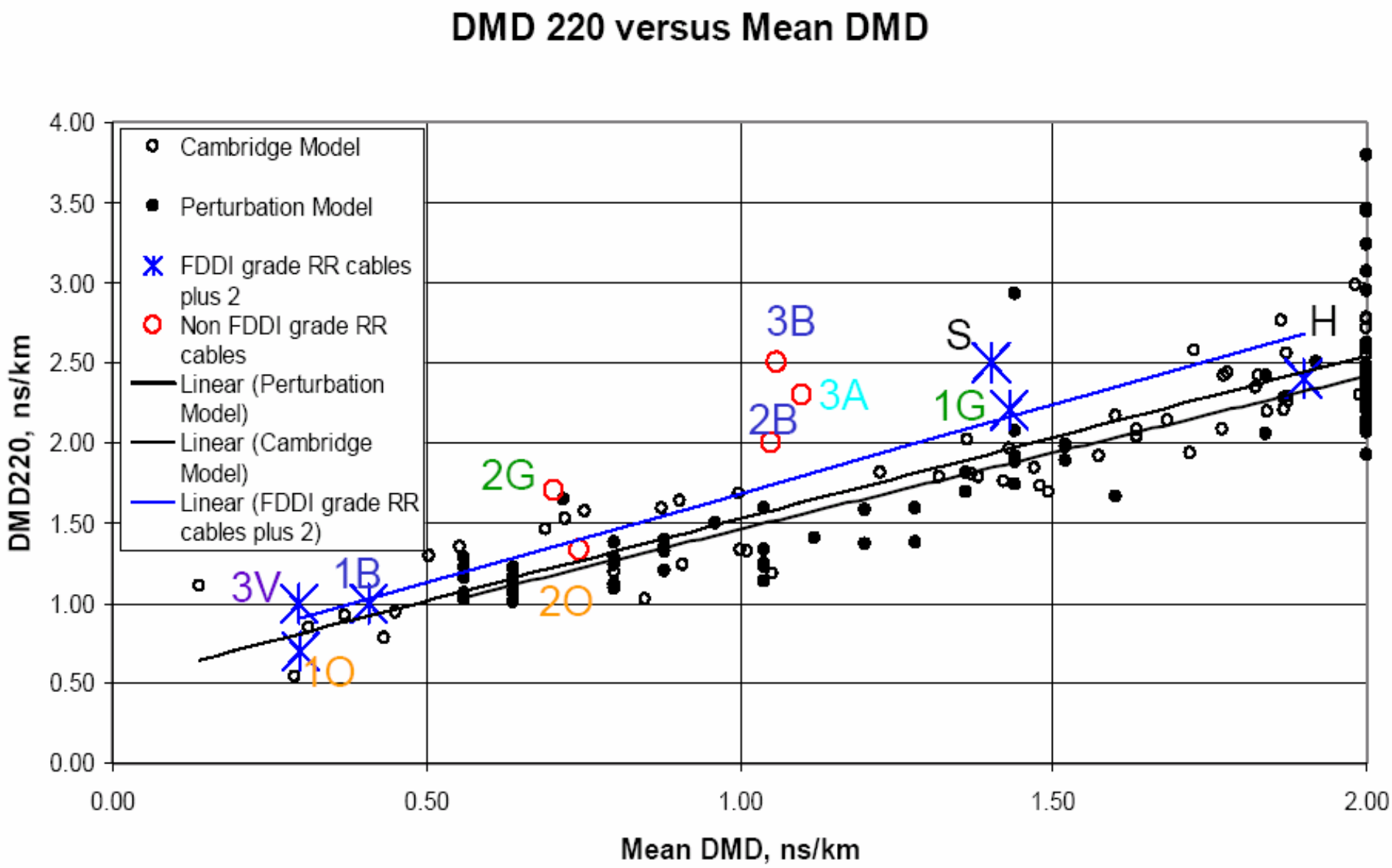


- DFE required to meet 300m distance requirements
  - Center Launch
  - 802.3z OSL (20 +/- 3um)
- LE unlikely to meet 300m distance requirements
- Connectors are not included – likely to degrade performance

Experimental Comparison to TIA Round Robins

- "FO2-2 12/96 BW Modal Launch Test Cable"
  - Originally used for 1 Gigabit Ethernet round robin testing
  - E.g. 2orange, 4orange, …
- 15 fibers - nine 62.5um & six 50um fibers
  - Nine 62.5um fiber results presented here
- All fibers 300m in length
- Recently used in measurement validation of the simulation model for Cambridge 81 fibre set (see cam_1_0504)
  - 4 fibres worse than 500MHz·km
  - Selection of causal, anti-causal and 'symmetric' impulse responses for OSL

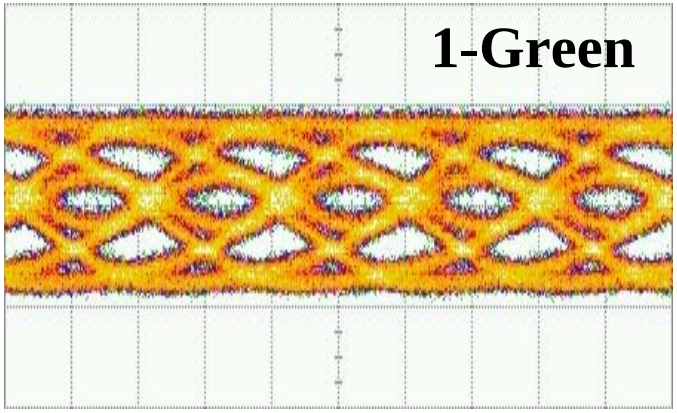
Comparison of Cambridge model, an independently implemented Perturbation model and measured fibers

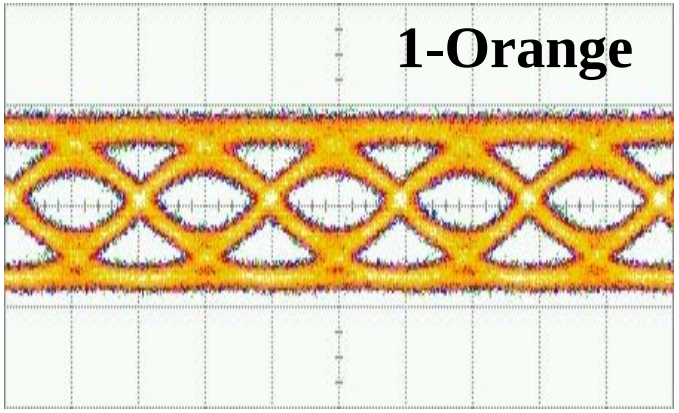


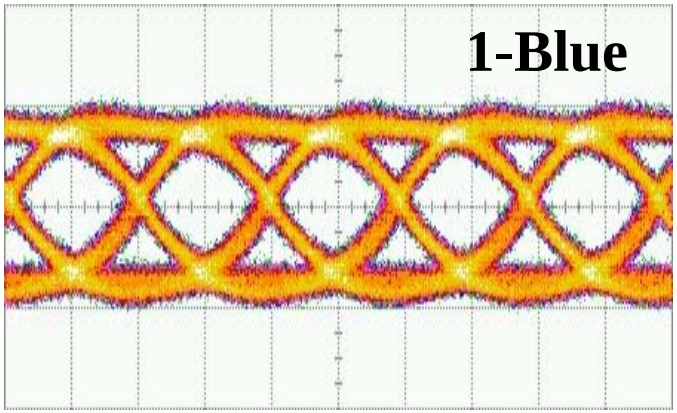
Strong correlation between measurements and theory

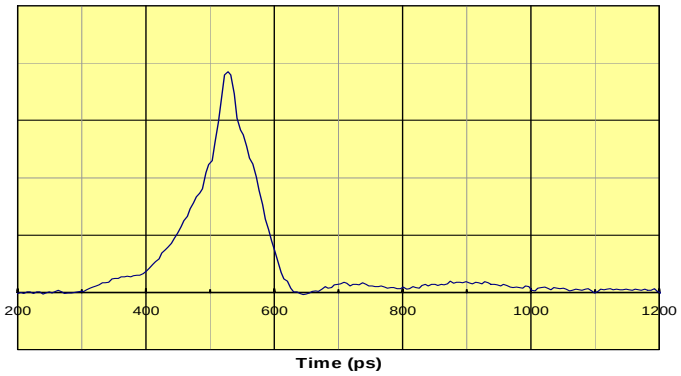
Source: Cambridge (cam_1_0504)

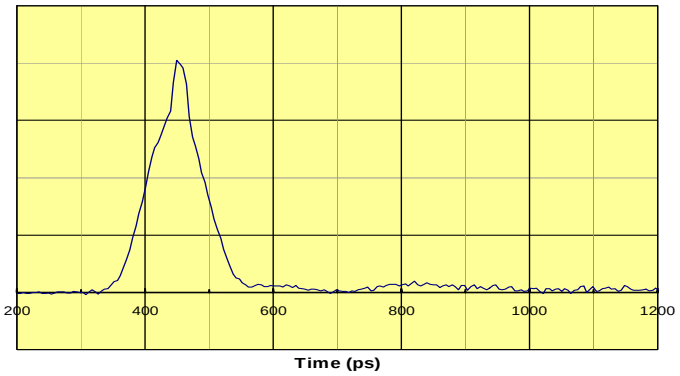
TIA 12-96 Fiber Set With OSL: 62.5um

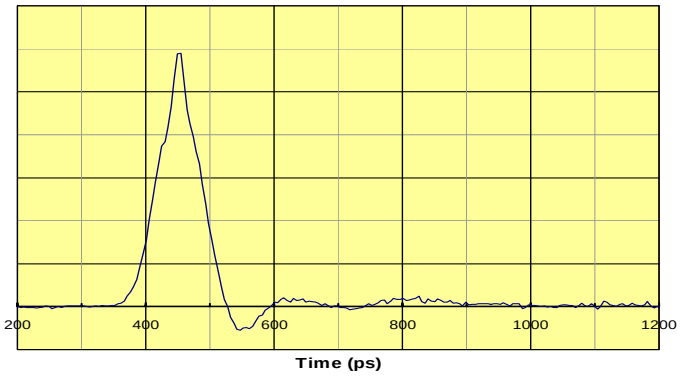


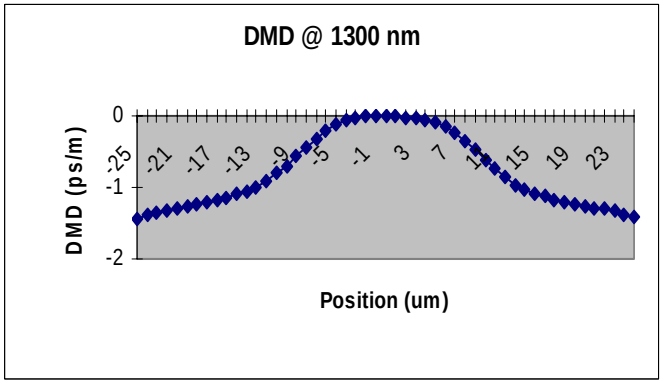


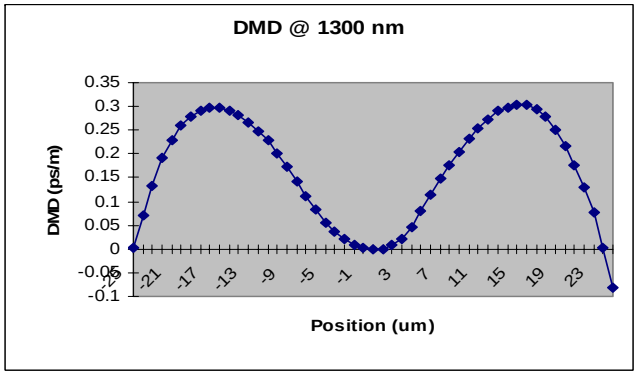


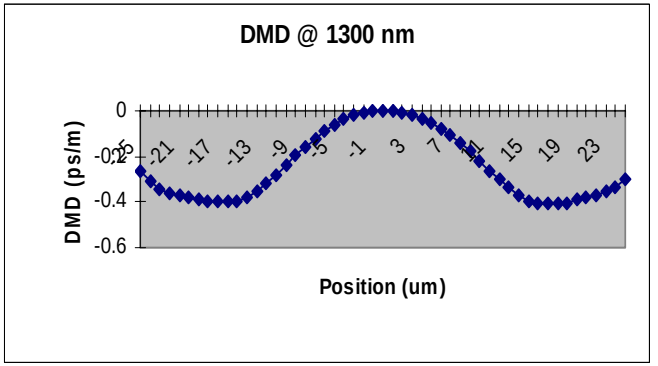




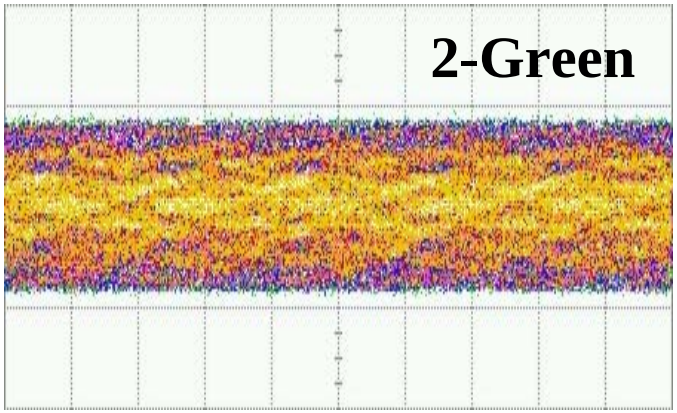


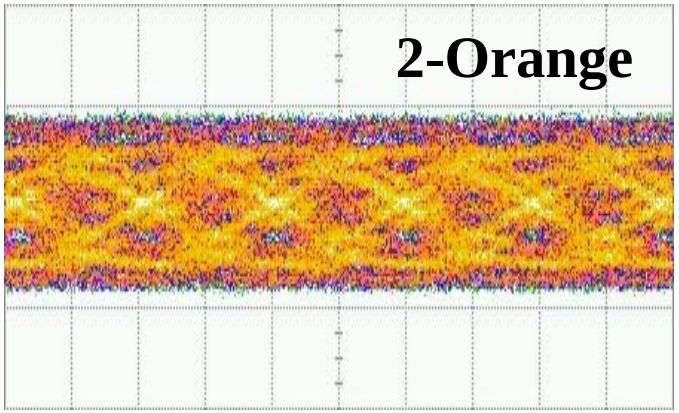


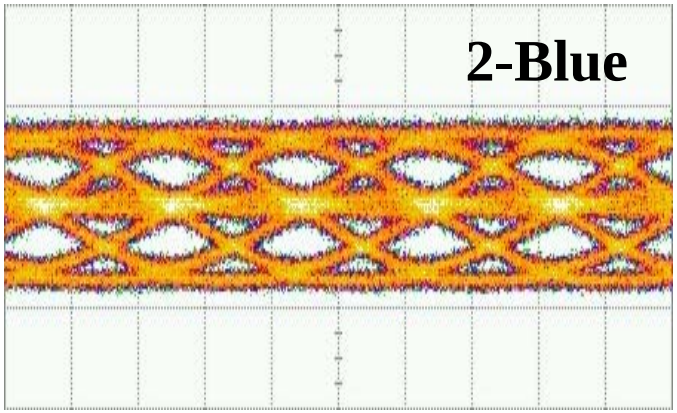


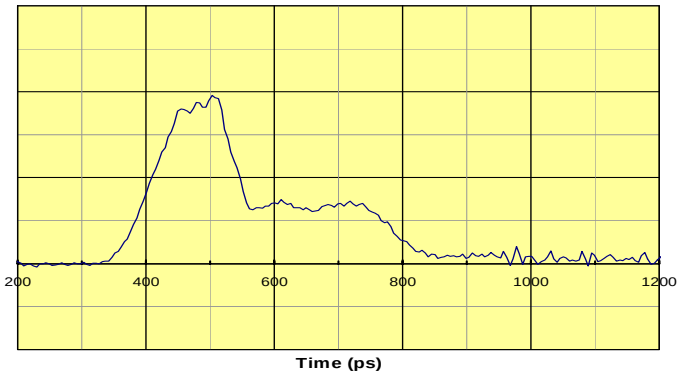


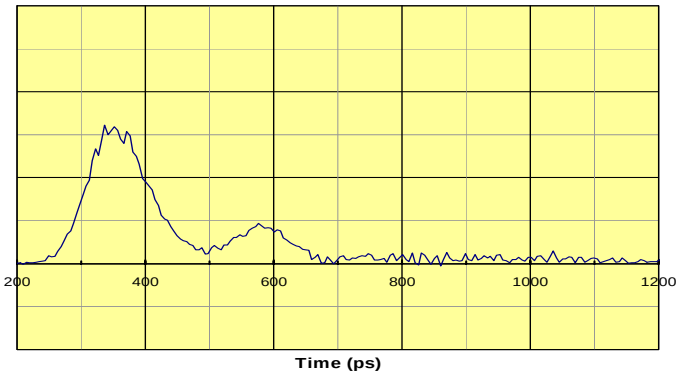
TIA 12-96 Fiber Set With OSL: 62.5um

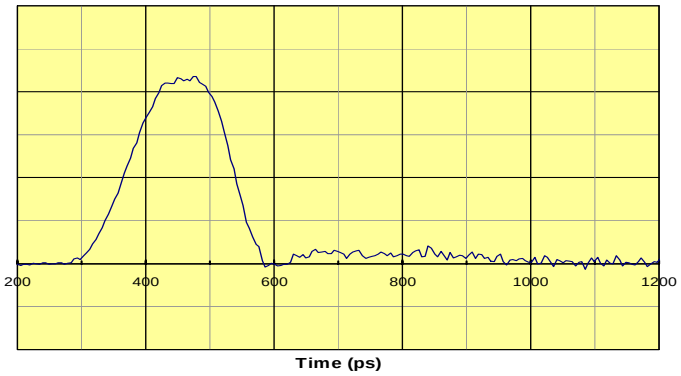


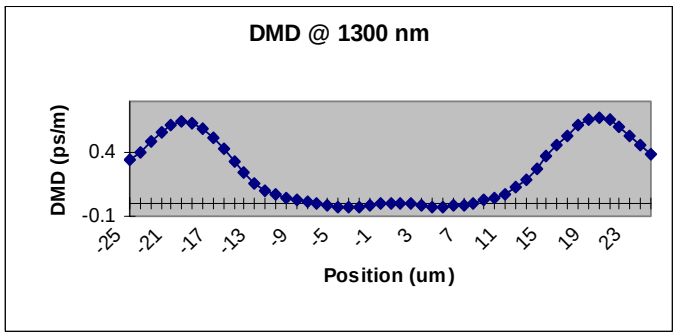


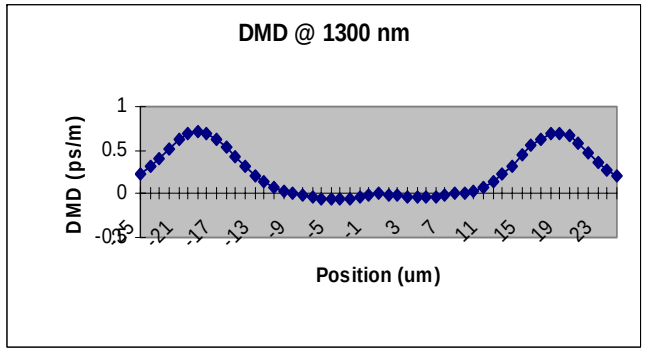


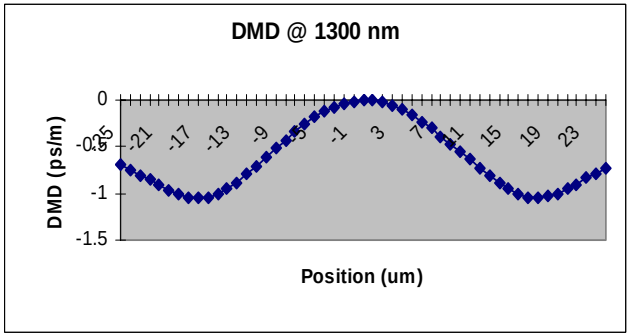




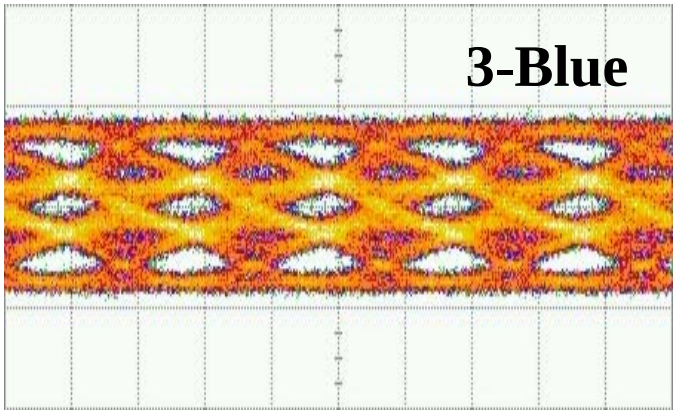


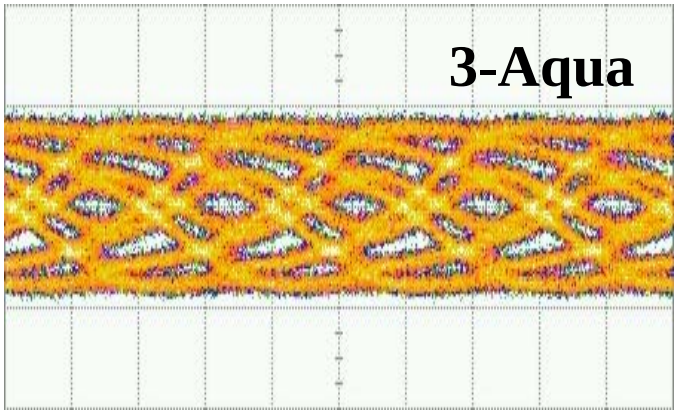


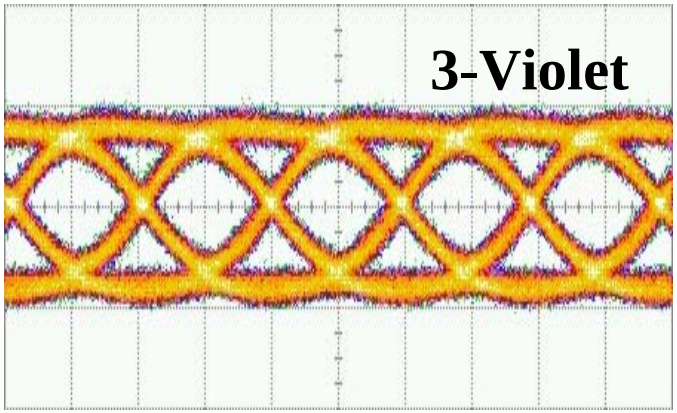


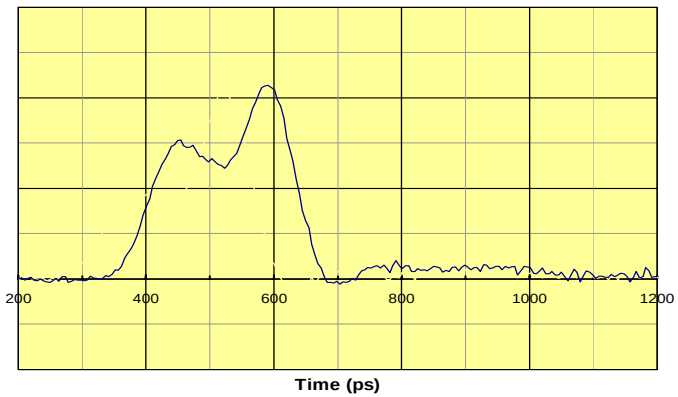


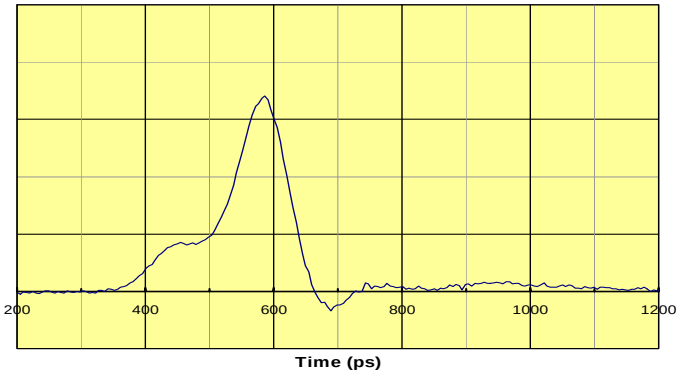
TIA 12-96 Fiber Set With OSL: 62.5um

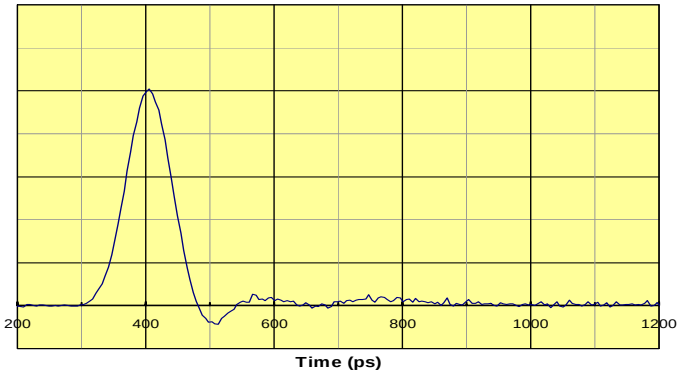


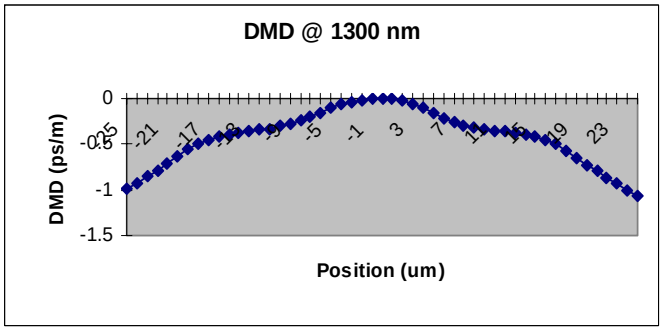


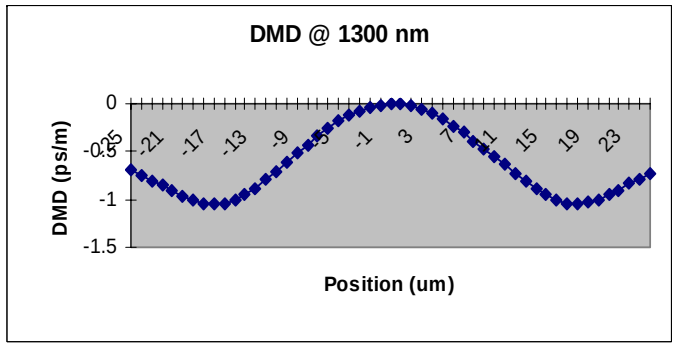


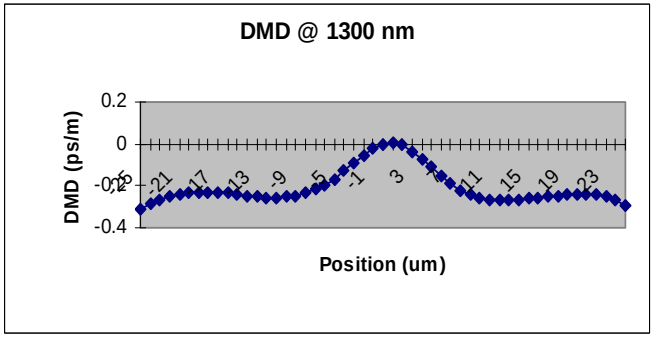






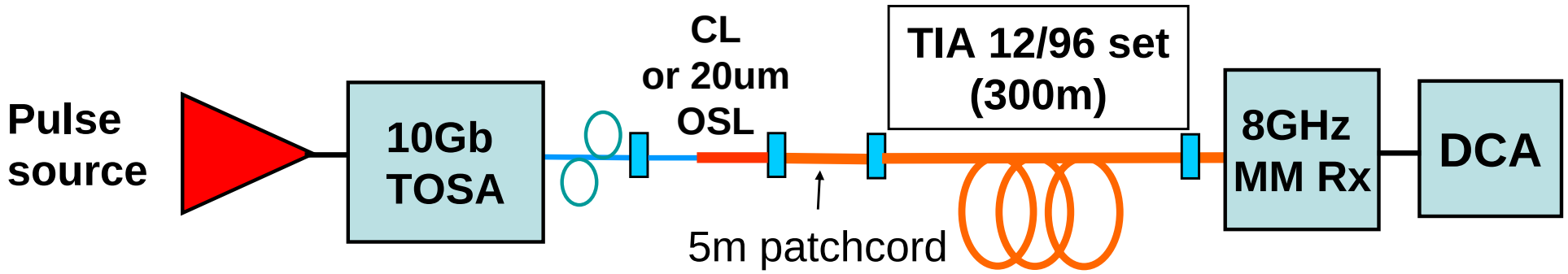






PIE Metrics: Test Set-up and Procedure

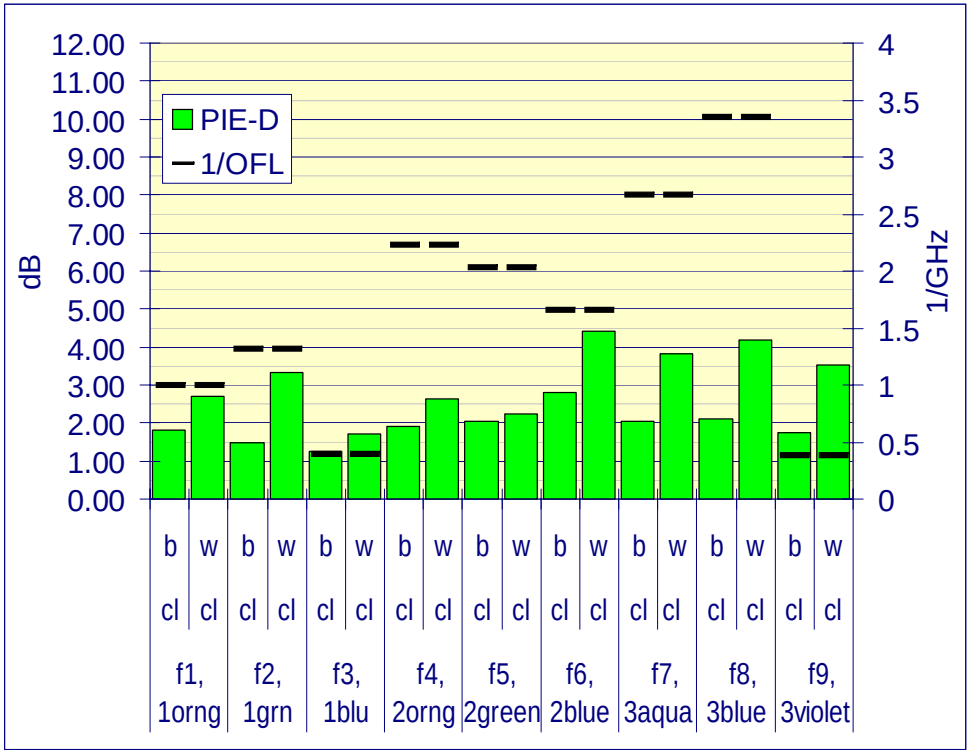
- Impulse response measured using gain switched DFB
  - CL, OSL (62.5um for all) launches, best and worst polarization / fibre configuration
- Integrate impulse to get step response
- Delay step by 97.7ps, invert & subtract from original to yield isolated '1' bit response
- FFT, normalize DC component, and fold spectrum around 5.1GHz
- Piece-wise integration from 0 to 5.1GHz, following equations for PIE-L & PIE D (Bhoja_01_0704)

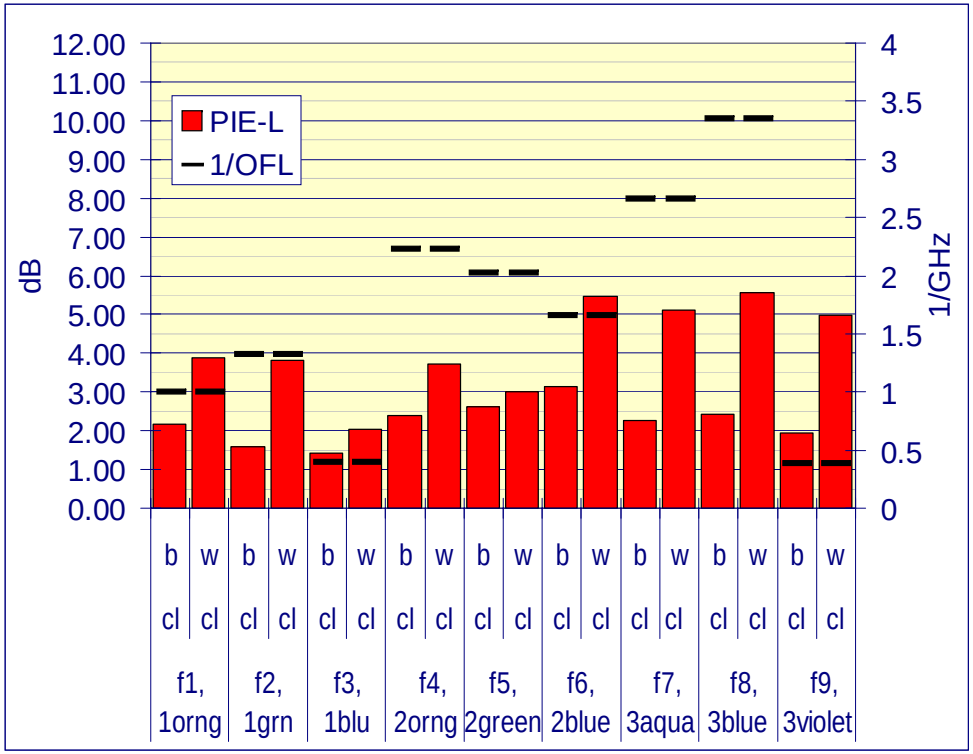


Summary Table: PIE-L & -D Metrics for 12-96 Set

Fibre	1 1orange	2 1green	3 1blu	4 2orange	5 2green	6 2blu	7 2aqua	8 3blu	9 3violet
OFL Bw MHz.km	998	756	2532	449	493	602	375	298	2582
CL Bw, MHz.km	2787	352	2785	2785	2785	2785	637	701	2783
CL b, PIE-L	2.16	1.57	1.43	2.4	2.62	3.12	2.27	2.41	1.95
CL w, PIE-L	3.88	3.83	2.04	3.73	3.02	5.45	5.1	5.57	4.98
CL b, PIE-D	1.82	1.47	1.26	1.9	2.05	2.82	2.04	2.12	1.76
CL w, PIE-D	2.7	3.33	1.7	2.62	2.26	4.42	3.82	4.18	3.52
OSL b, PIE-L	2.58	4.17	1.7	5.42	9.48	6.99	5.12	6.78	1.26
OSL w, PIE-L	2.58	4.77	1.7	5.95	10.41	8.39	5.53	7.3	1.34
OSL b, PIE-D	2.09	3.26	1.49	4.52	6.98	4.81	3.83	4.88	1.12
OSL w, PIE-D	2.09	3.63	1.49	4.87	7.46	4.98	4.0	5.02	1.34

12-96 Set PIE Metrics for CL

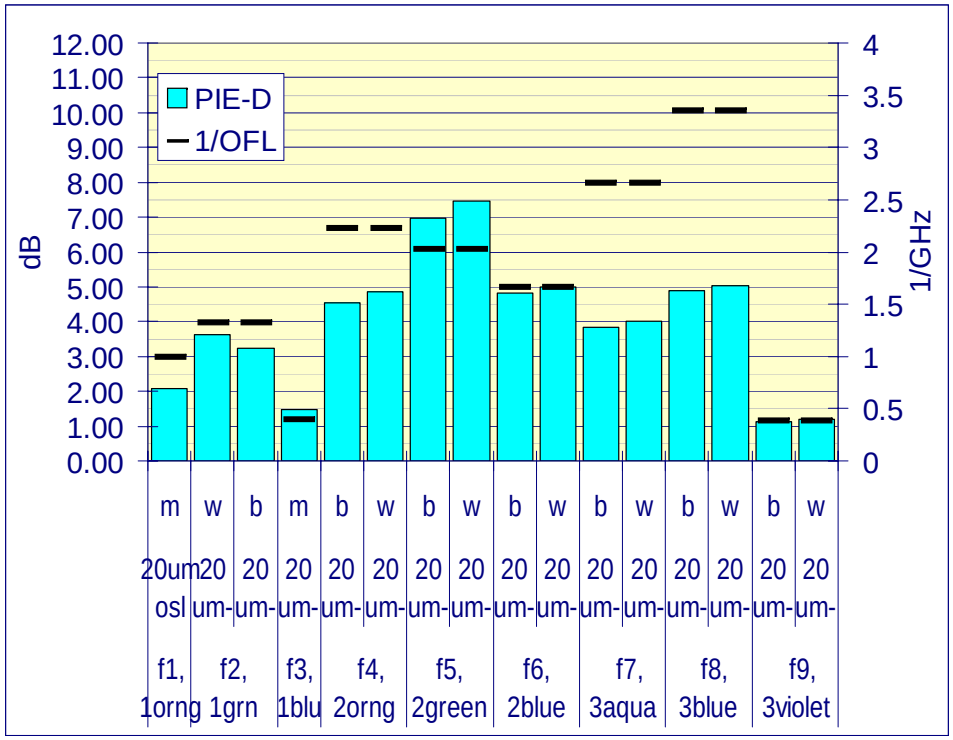


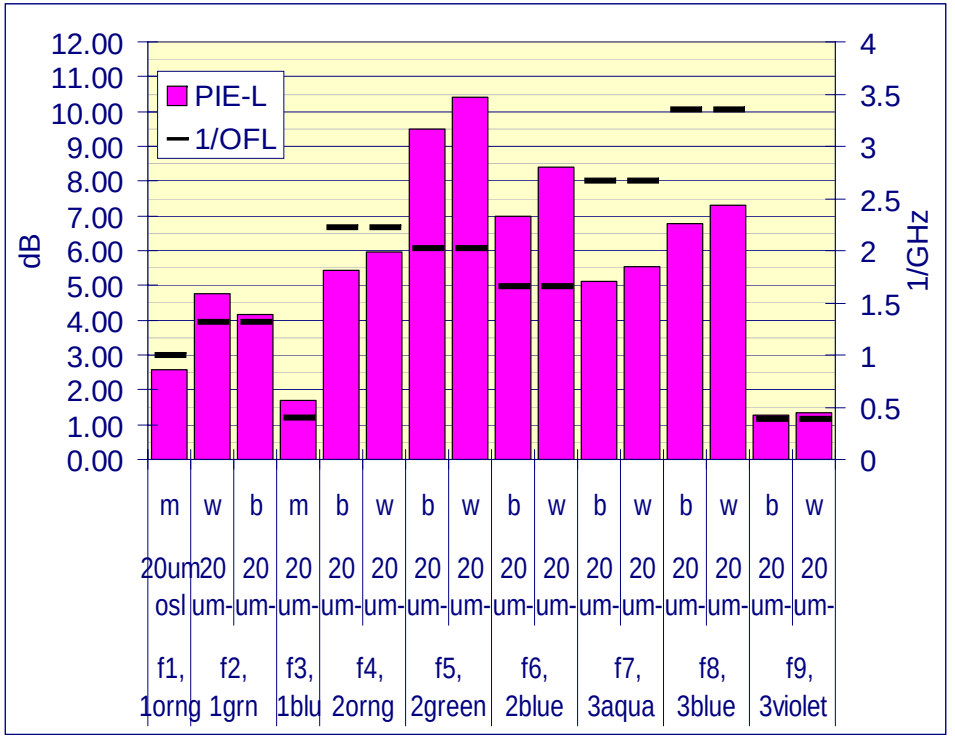


All fibres below 4.5dB PIE-D for best and worst case IPR

5/9 fibres below 4.5dB PIE-D for best and worst case IPR
All fibres below 5.6dB

12-96 Set PIE Metrics for 20um OSL

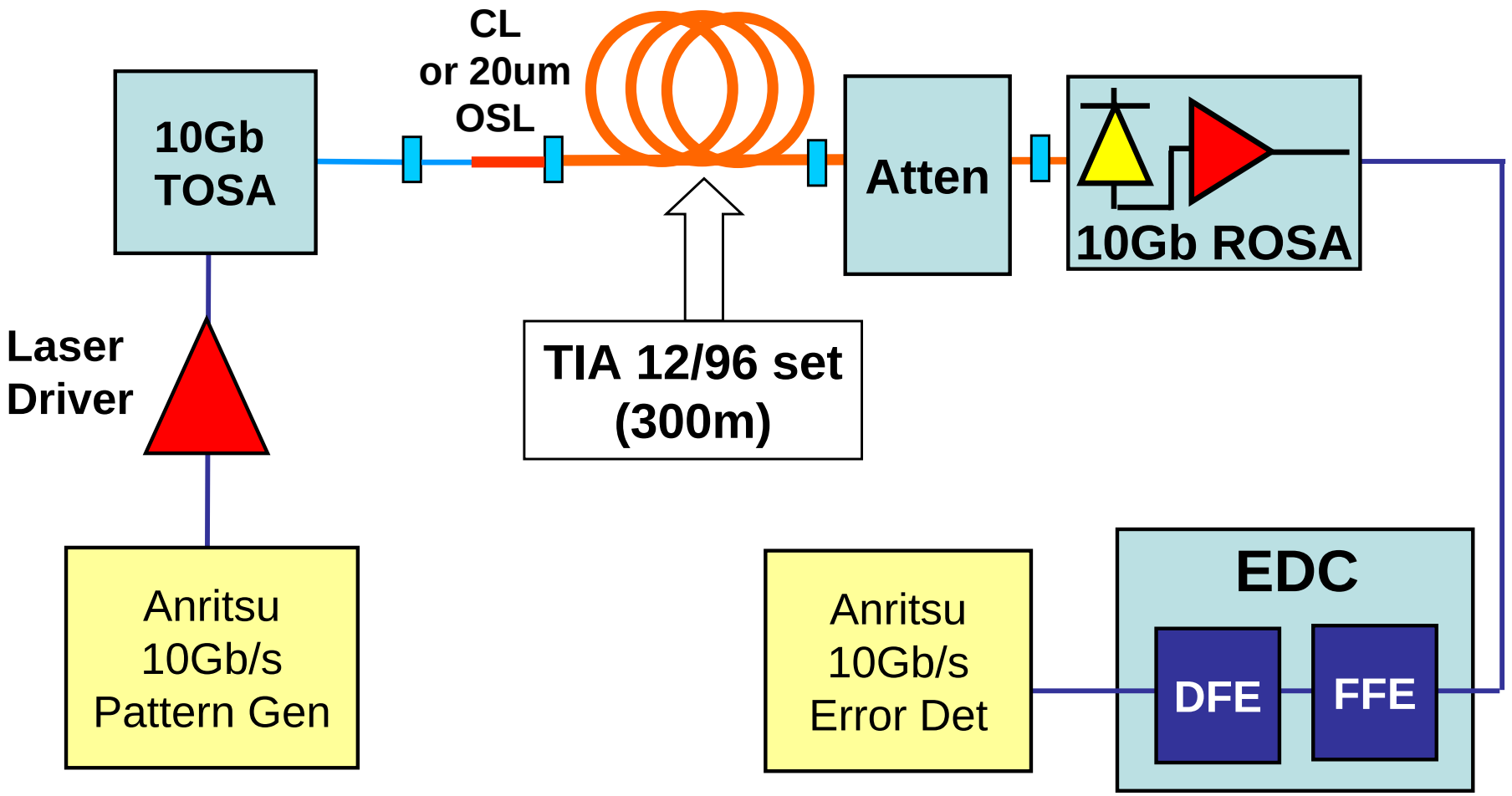




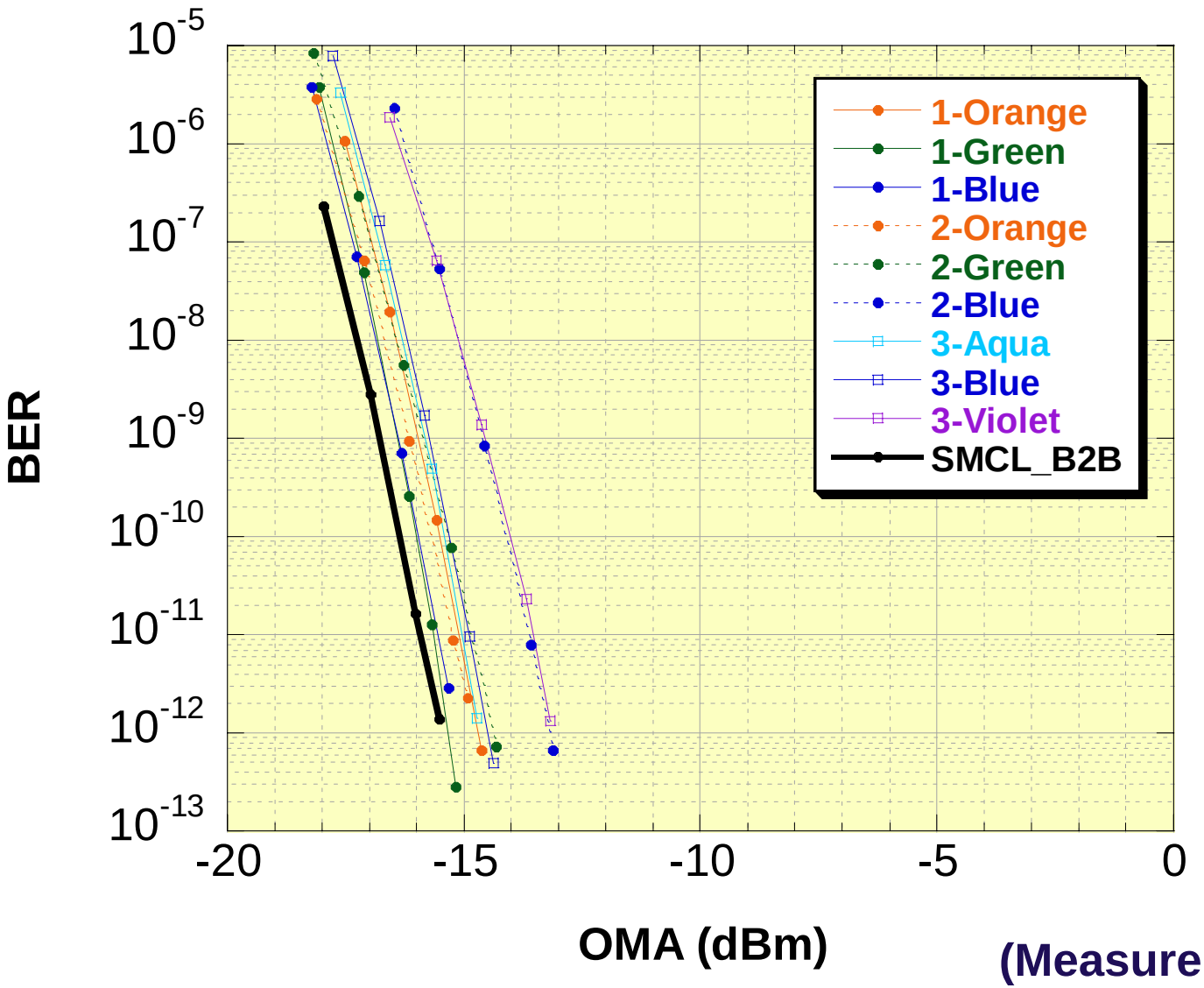
4/5 compliant fibres (OFL Bw>500MHz) below 4.5dB PIE-D for best and worst case IPR
All compliant fibres <5dB

3/5 compliant fibres (OFL Bw>500MHz) below 4.5dB PIE-L for best and worst case IPR
All compliant fibres <8.5dB

10.3Gb/s System Test Bed



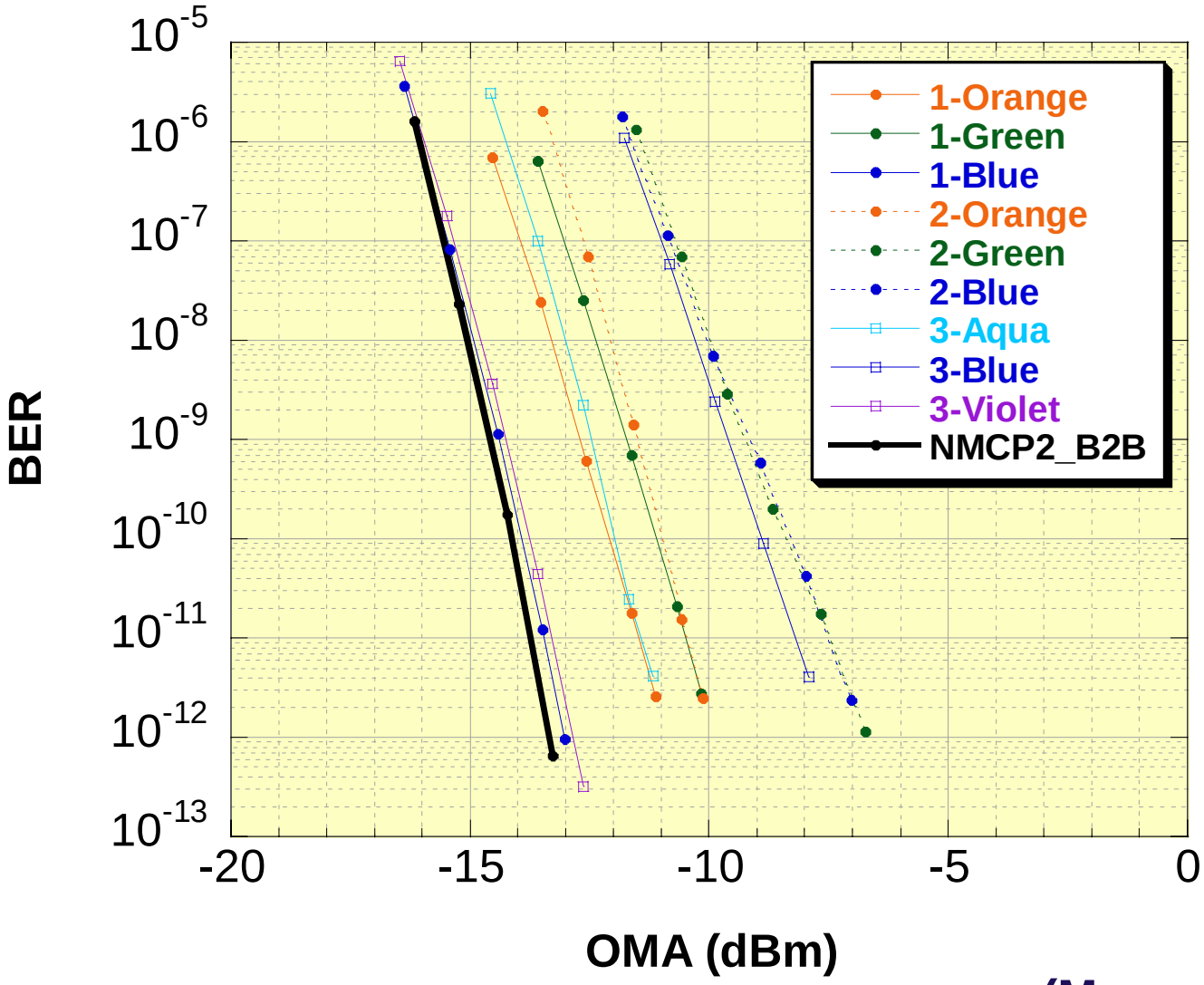
TIA 12-96 300m MMF Round Robin: CL Results



- Measurements made with discrete FFE and DFE IC's
  - Limited dynamic capability

(Measurements made Oct. 2003)

TIA 12-96 300m MMF Round Robin: OSL Results



- Measurements made with discrete FFE and DFE IC's
  - Limited dynamic capability

(Measurements made Oct. 2003)

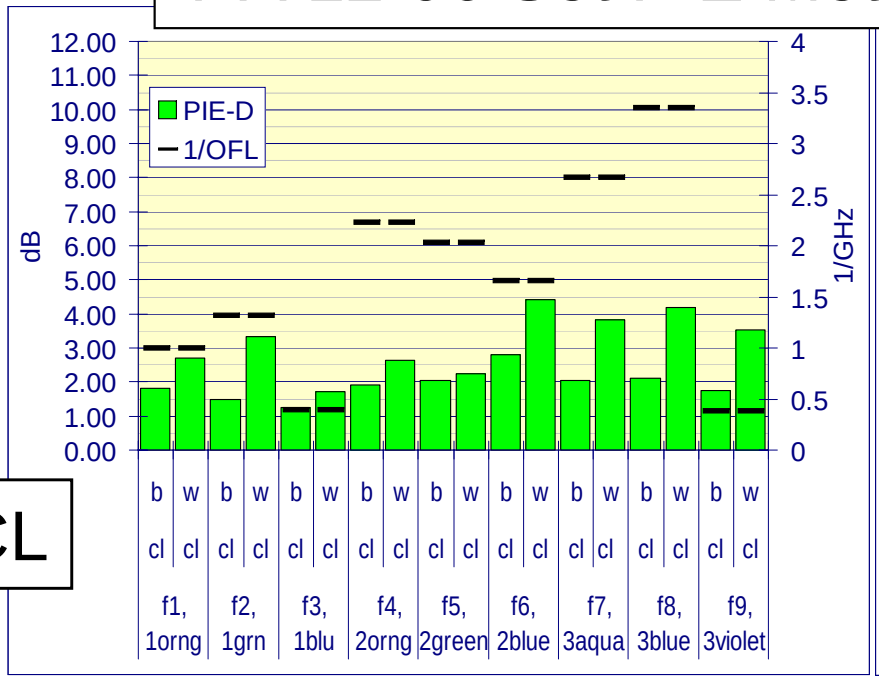
Discussion & Next Steps

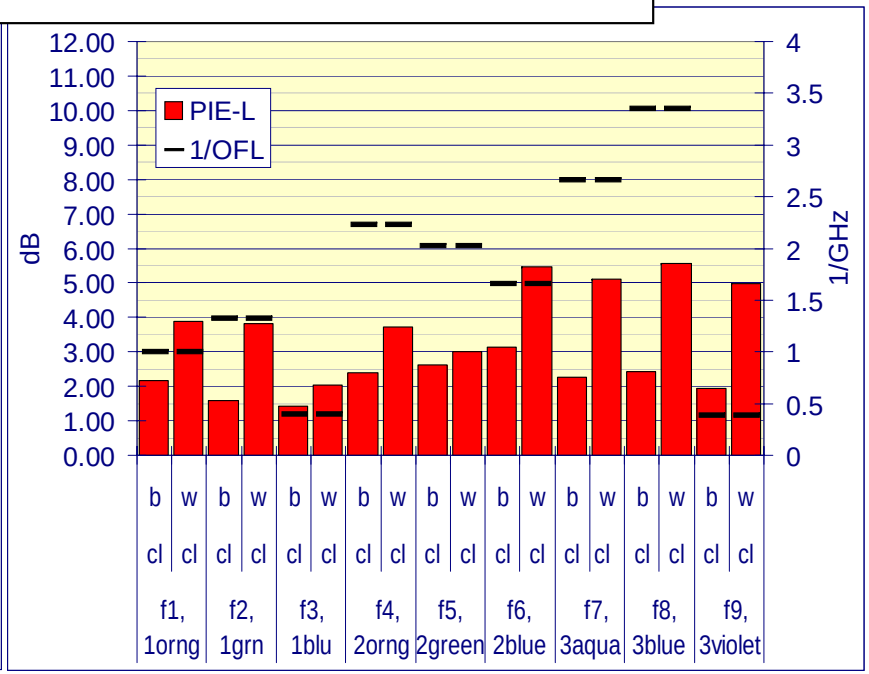
- Simulations
  - DFE architecture required for 300m performance
  - Will repeat with adopted ’81 restricted’ model & OM1 Monte Carlo model as provided by the channel ad-hoc group
  - Additionally, will need to include connector off-sets
- Experimental
  - 5dB PIE-D budget covered all 300m TIA 12-96 fibres for CL
  - 7.5dB PIE-D budget covered all 300m TIA 12-96 fibres with OSL (in & out of spec fibers)
    - High off-set connectors will impact budget required
  - BER testing: 6.5-7dB power budget for OSL
    - NB: includes EDC implementation penalty and un-equalized dynamic effects of the 2-chip set-up
  - Additional testing with the agreed connector/channel from the channel ad-hoc sub-task group planned
- Early implementations (circa 2003) demonstrate 300m over FDDI-grade fiber is challenging but possible

Back up

TIA 12-96 Set PIE Metrics for CL and OSL

CL





OSL