IPR / PIE Measurements on OM1 and OM3
Center, Offset and Vortex Launches

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January 5, 2005

Outline

- **Overview**
- **Setup**
  - **Block Diagram and General Notes**
  - **Fiber Types Tested**
  - **Source and Receiver Details**
  - **Launch Details**
  - **Connector Offset Simulation**
  - **Data Analysis Details**
- **Measurement Results**
  - **PIE Summary Comparison**
  - **Comparison of Launch Types on Individual Fibers – PIE and IPR**
  - **Full Set of IPR Curves**
- **Future Work Needed**
  - **OM2 Measurements**
  - **Experimental Study of Vortex Launch Tolerances**
  - **Experimental Study of Direct Center Launch – Typical Launch Characteristics and Resulting Impulse Response**

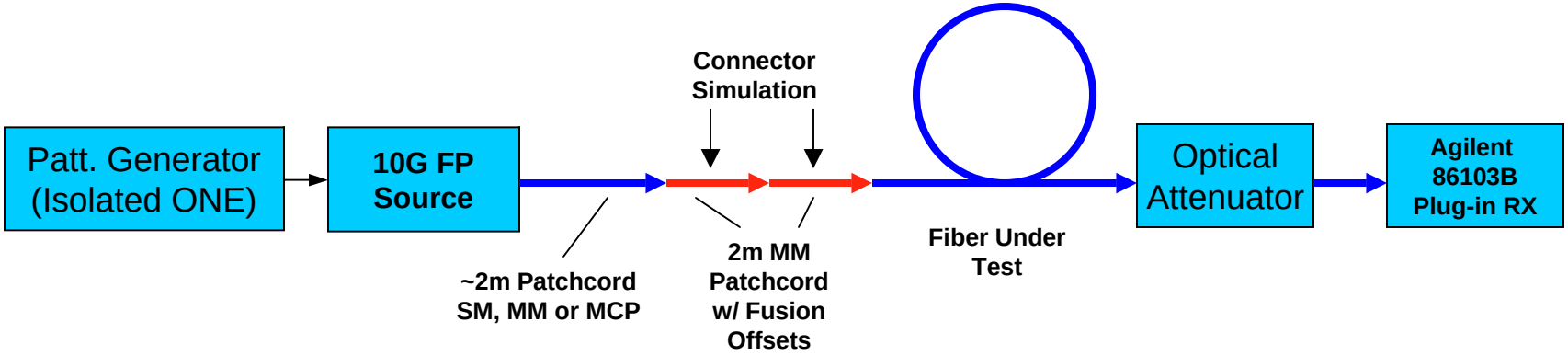
Acknowledgements

- **Thanks to Big Bear Networks for the Loan of the OM3 Fiber and for Providing PIE Code to Speed and Help Verify our PIE Calculations**
- **Thanks to Infineon for Loan of OM3 Sample**

Overview

- **Goal: Conduct Consistent IPR and PIE measurements on OM1 and OM3 fibers to Support Choice of TP2 Launch and TP3 Sensitivity Requirements**
  - **Investigate Feasibility of Integrated Launch Solution**
  - **Compare multiple launches:**
    - **Single Mode Center Launch (from SM fiber and 'TOSA')**
    - **Offset Launch (w/ 802.3z Mode Conditioning Patchcords)**
    - **Vortex Launch**
  - **Multiple Connector Offsets Before Fiber**
    - **None**
    - **Two 4 um Offsets**
    - **Two 7 um Offsets**

Experimental Setup



- **Source Gain Switched for Shortest Pulse, RX Bandwidth > 7.5 GHz (no BT filter)**
  - **Provided Highest Resolution**
  - **Post Processed for desired TX and RX response (not yet completed)**
- **No effort was obtained to manipulate polarization or fiber for best, worse or average PIE**
- **Care was taken to maintain fiber under test layout and other elements as launch type and connectors changed**

Fibers Tested

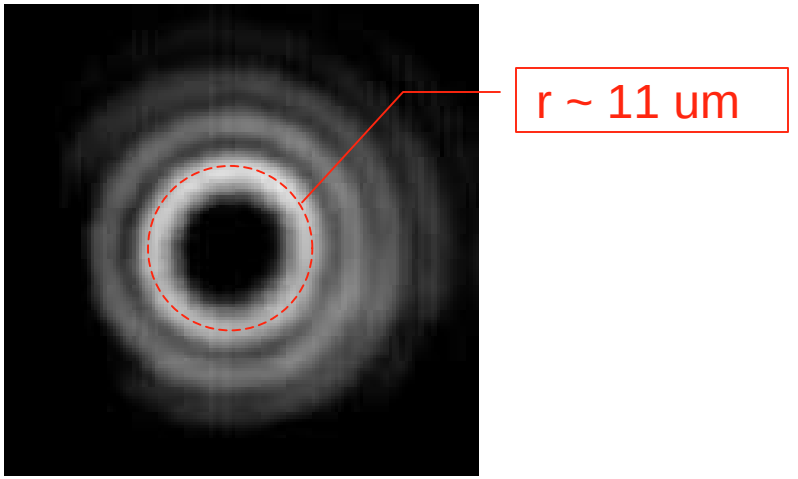
- **All fiber 300m unless noted**
- **OM1**
  - **6 fiber Cable 62/125 Spool – 850nm Worst Case Fiber (1998)**
    - **DMD Measurements from John Schlager at NIST**
  - **2 Purchased fibers selected at near OFL BW Limit**
- **OM3**
  - **350m Sample from Infineon**
  - **TIA 2.2 demo fibers – 6 Cable Blue Spool**

Fiber ID	Description	Length (m)	OFL (850/1310)
OM1-1	TIA RR- Orange	300	415/582
OM1-2	TIA RR- Green	300	414/1280
OM1-3	TIA RR- Blue	300	260/589
OM1-4	TIA RR- White	300	481/1352
OM1-5	TIA RR- Gray(Slate)	300	241/685
OM1-6	TIA RR- Brown	300	500/1231
OM1-7	Limit 1	300	166/513
OM1-8	Limit 2	300	164/530
OM3-1	TIA Demo Blue - Orange	300	
OM3-2	TIA Demo Blue - Green	300	
OM3-3	TIA Demo Blue - Blue	300	
OM3-4	TIA Demo Blue - White	300	
OM3-5	TIA Demo Blue - Gray	300	
OM3-6	TIA Demo Blue - Brown	300	
OM3-7	Infineon Sample	350	

Other Test Details

- **Source Details**
  - **FP Laser, Fiber Stub TOSA Package for All Tests but Vortex Launch**
  - **FP Laser, Lens and Vortex Element**
- **Launch Types**
  - **SMCL – Single-mode, Center Launch**
    - **2m SM jumper from TOSA to first MM Connection**
  - **OL – Offset Launch**
    - **Standard 802.3z Mode Conditioning Patchcord of same Core Size as Fiber Under Test**
    - **Thus 62/125 MCP (nom. 20 um offset) for OM1, 50/125 MCP (nom. 13 um offset) for OM3**
  - **VL - Vortex Launch – Same Launch Used for both OM1 and OM3**
    - **Vortex Element Aligned to Source for Desired Intensity Profile**
    - **Fiber Aligned to Source / Vortex Element for Maximum Power (Generally Yields Best PIE)**

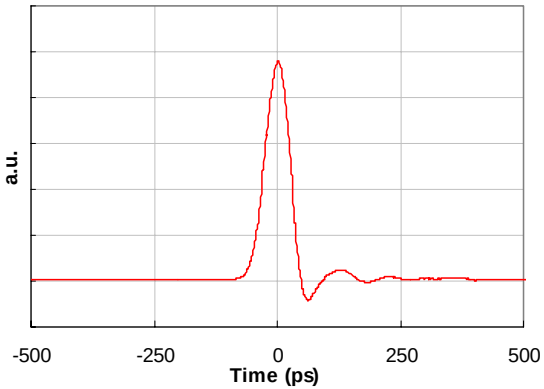
      Thus, Measurements Do Not Include First Connector Tolerance Effects for Integrated Vortex Launch



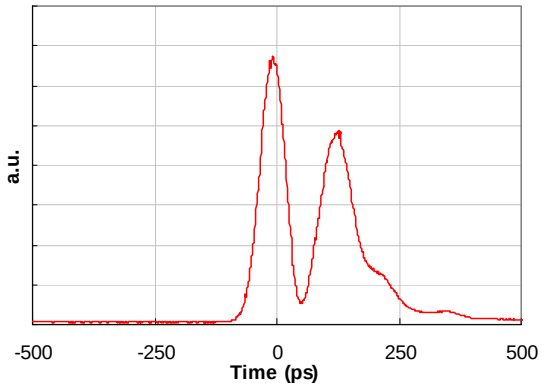
Other Test Details

- **Connector Error Implementation**
  - **3 Cases Tested:**
    - **No Connectors**
    - **Two 4 um Connectors Before Fiber Under Test**
    - **Two 7 um Connector Before Fiber Under Test**
  - **Patchcords with High Quality < ~ 1 um Errors and Controlled Offset Splice in Center Used to Simulate Each Offset Connector**
  - **Same Fiber Core Size as Fiber Under Test**

- **Data Analysis Details - TBC**
  - **(Deconvolution with Back to back data and Reconvolution TBC)**
  - **Data Taken with Shortest Pulse (<30 ps FWHM) and RX with no BT Filter**
  - **Deconvolved using back-to-back source to RX response for each measurement set.**
  - **Convolved with 1UI Rectangular Pulse, 47 ps r/f and 7.5 GHz BT4 Filter Responses for PIE calcs.**



Typical Back-Back IPR



Typical Raw Measurement

TBC

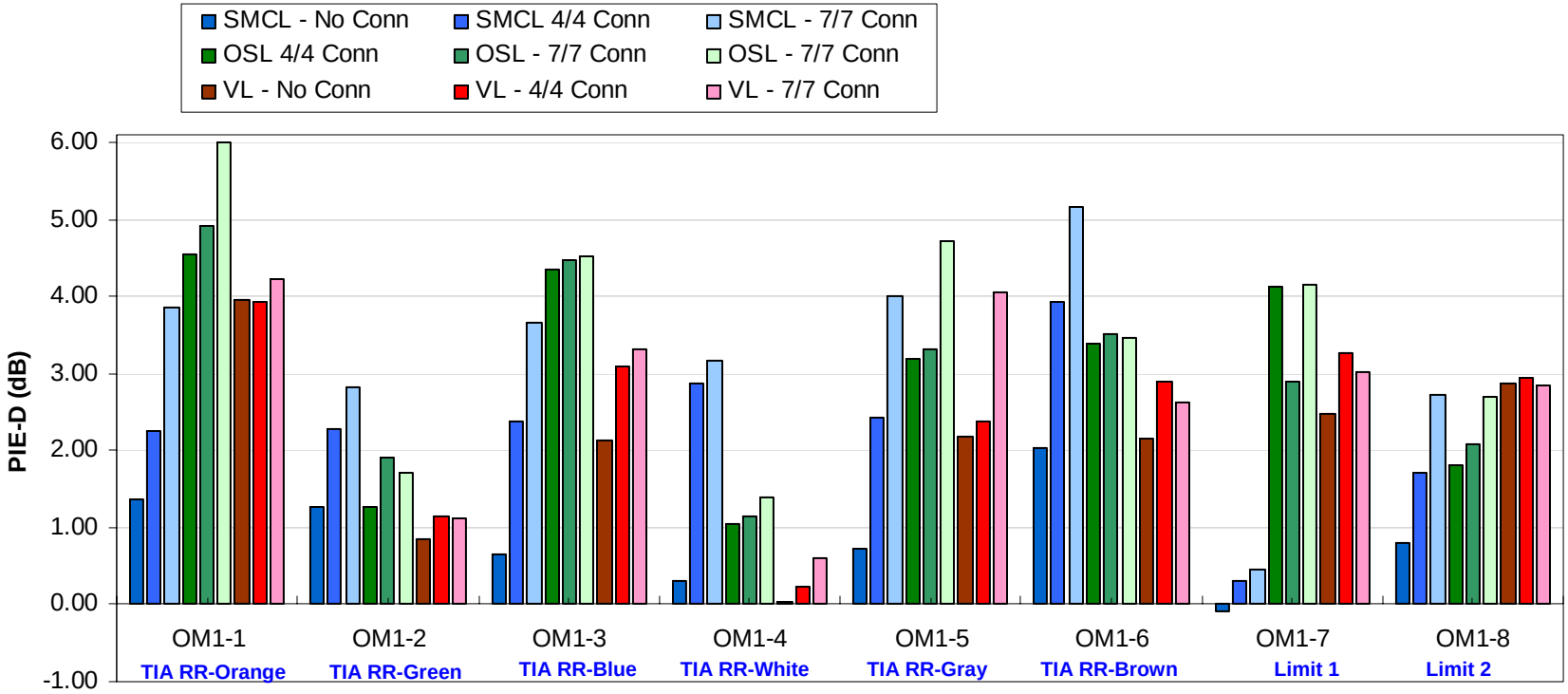
Processed for TX and RX Response

PIE Summary

- **Following is summary of PIE-D calculated from uncorrected data.**
  - **The source response is much faster than a 1 UI pulse with 47 ps Gaussian r/f**
  - **The RX is probably faster than 7.5 GHz and does not have BT rolloff**
- **Absolute PIE-D values are thus low (~1.3 dB?), but can be used for comparative purposes (since all have virtually identical back-to-back calibration measurements).**
- **Properly corrected PIE-D values in agreement with Bhoja / Ewen calculations will be provided as soon as possible**

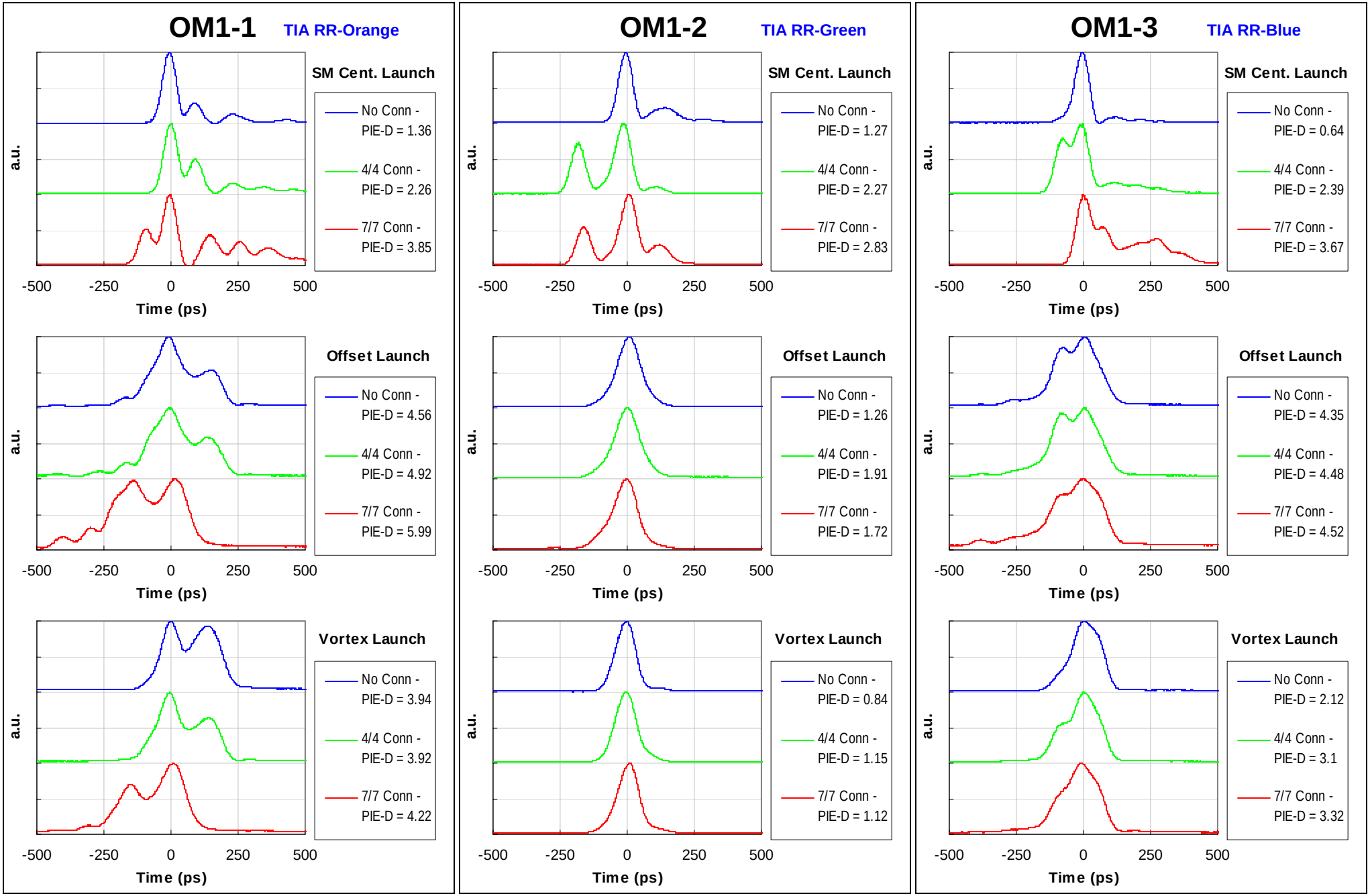
PIE-D raw	SM Center Launch			Offset Launch			Vortex Launch		
	No Conn	4/4 Conn	7/7 Conn	No Conn	4/4 Conn	7/7 Conn	No Conn	4/4 Conn	7/7 Conn
OM1-1	1.36	2.26	3.85	4.56	4.92	5.99	3.94	3.92	4.22
OM1-2	1.27	2.27	2.83	1.26	1.91	1.72	0.84	1.15	1.12
OM1-3	0.64	2.39	3.67	4.35	4.48	4.52	2.12	3.10	3.32
OM1-4	0.31	2.87	3.16	1.05	1.13	1.40	0.03	0.24	0.60
OM1-5	0.74	2.43	4.01	3.20	3.32	4.73	2.19	2.38	4.05
OM1-6	2.03	3.94	5.17	3.38	3.51	3.47	2.14	2.89	2.64
OM1-7	-0.10	0.30	0.44	4.12	2.90	4.15	2.48	3.27	3.03
OM1-8	0.80	1.72	2.73	1.81	2.09	2.70	2.87	2.95	2.85
OM3-1	0.56	1.12	2.94	1.86	2.38	4.19	3.47	3.98	4.51
OM3-2	0.56	0.94	3.18	1.04	1.43	2.79	0.93	0.94	1.89
OM3-3	0.80	1.54	4.03	1.60	1.81	2.87	1.92	3.38	4.42
OM3-4	0.62	1.32	3.90	2.38	3.06	5.22	-0.17	0.24	0.99
OM3-5	0.33	0.77	3.02	3.17	4.26	6.42	2.27	2.31	3.36
OM3-6	0.41	0.86	2.52	2.93	4.23	5.94	1.70	2.81	3.74
OM3-7	0.67	0.99	3.55	1.64	1.64	3.22	0.24	1.16	2.93

Uncorrected PIE-D Summary – OM1 Fiber

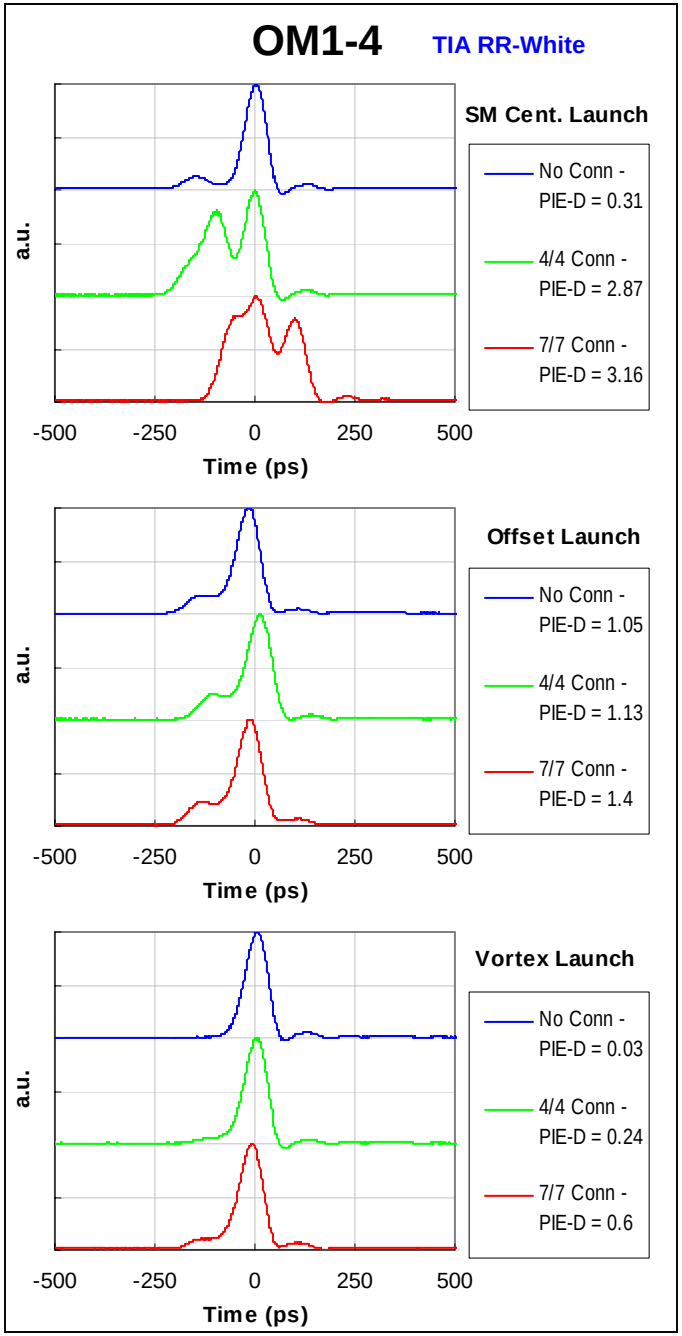


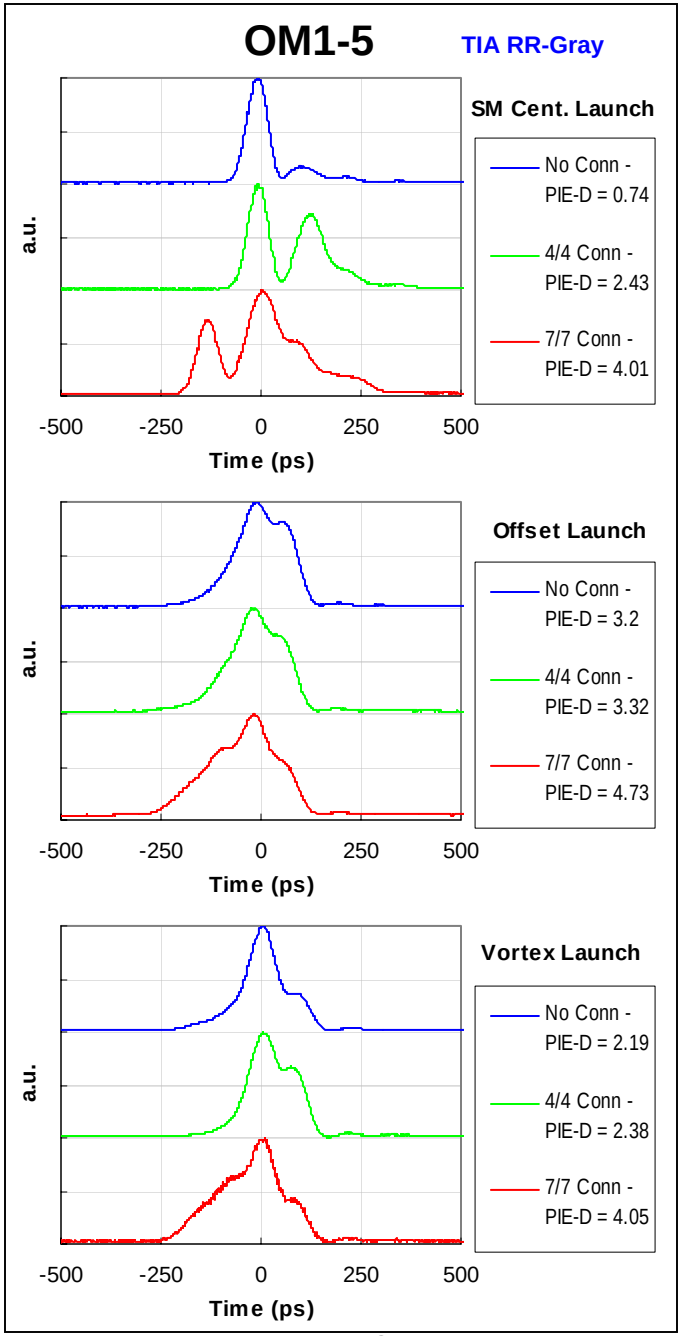
- **Commentary on OM1 Measurements (relative PIE-D)**
  - **Center Launch Generally Best Choice Without Connectors, ignoring other issues (e.g. polarization)**
  - **Offset and Vortex Launch Generally Vary Less with Connectors**
  - **Vortex Compares Favorably to Offset Launch in Virtually All Cases**
  - **Examination of Impulse Responses (following pages) suggests Vortex Launch is Particularly Favorable for Shorter Finite EDC Implementations**

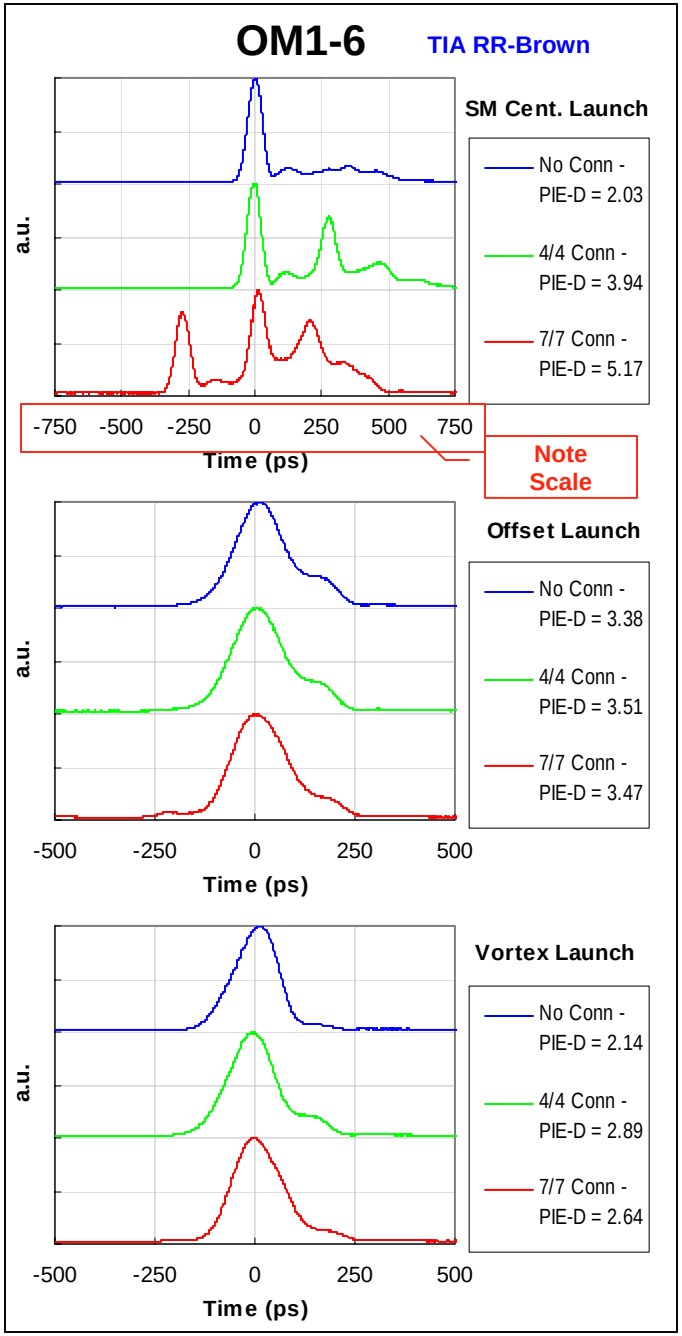
IPR Graphs (Raw Data) – OM1 1 - 3



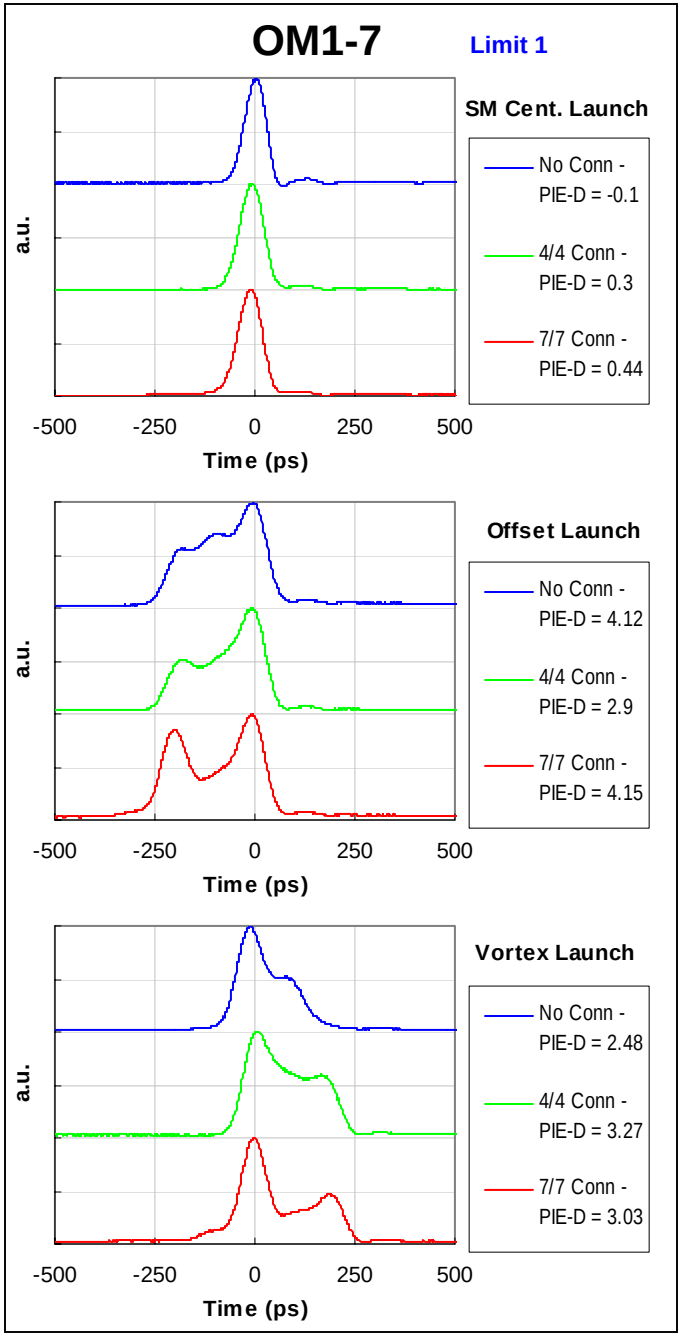
IPR Graphs (Raw Data) – OM1 4 - 6

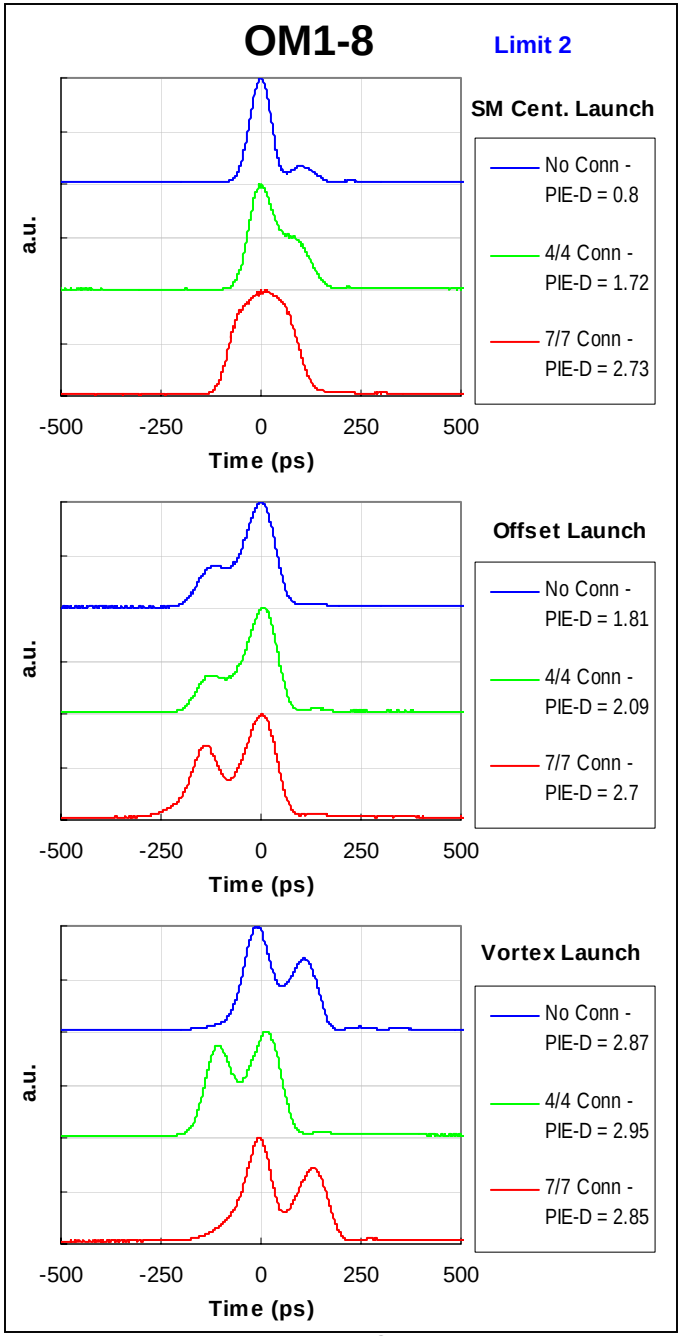






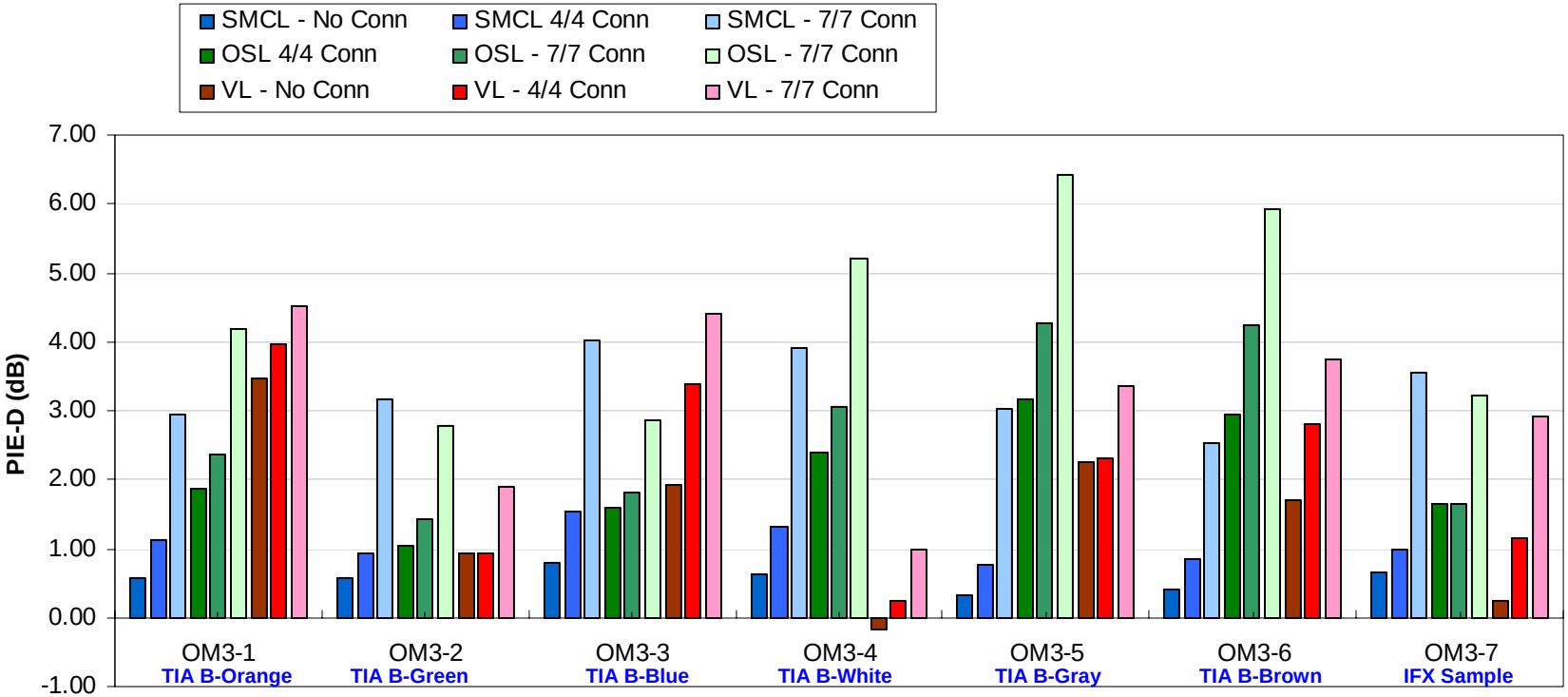
IPR Graphs (Raw Data) – OM1 7-8





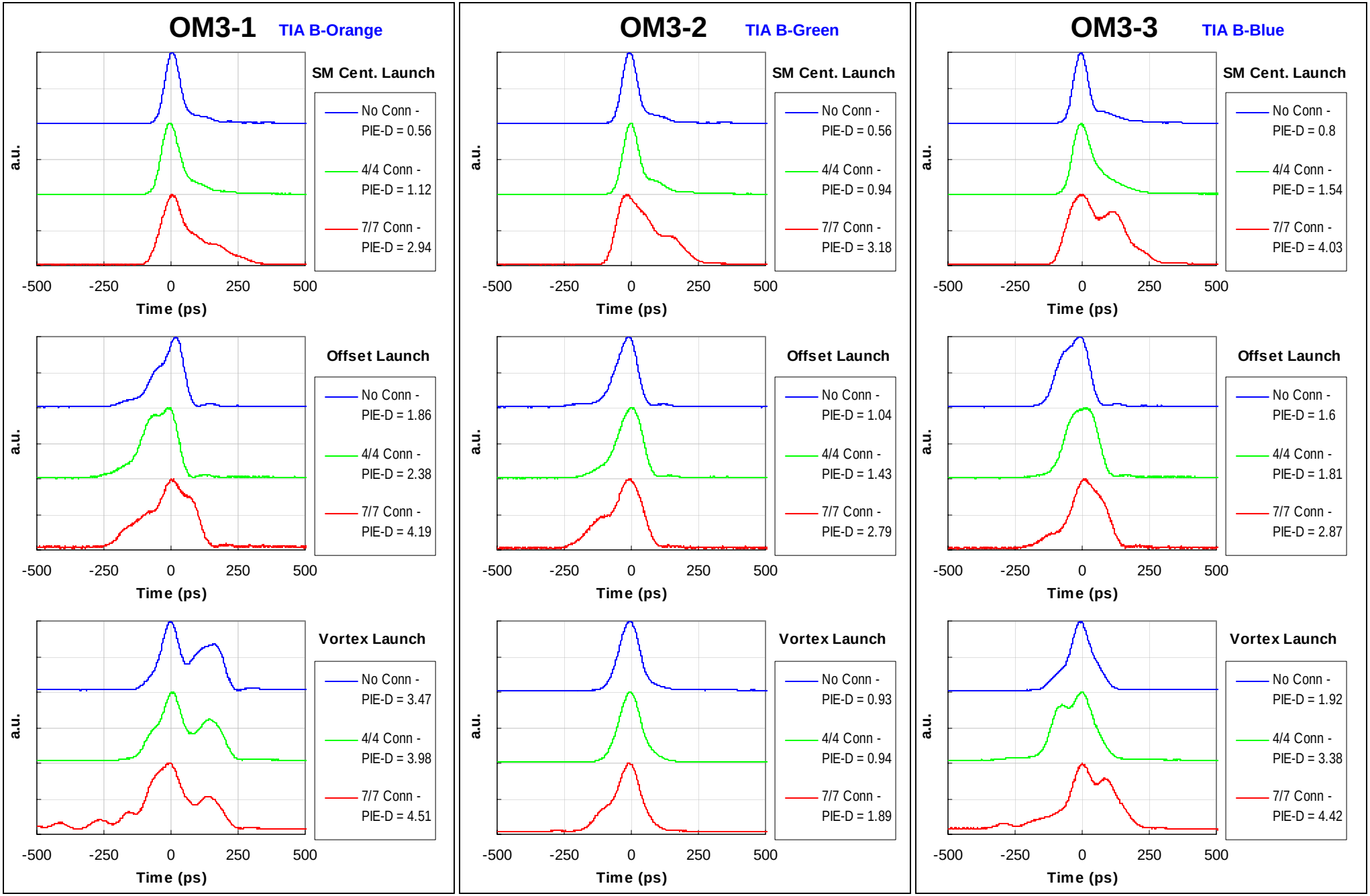
- **Notes on IPR Plots**
  - **Raw Scope Data (Uncorrected for B-B Response)**
  - **Centered on Highest Point Relative Time Alignment of Plots is Not Meaningful**
  - **PIE-D Labels are 'Uncorrected Values' (Don't Include 1 UI / 47 ps r/f TX or 7.5 G RX BW)**

Uncorrected PIE-D Summary – OM3 Fiber

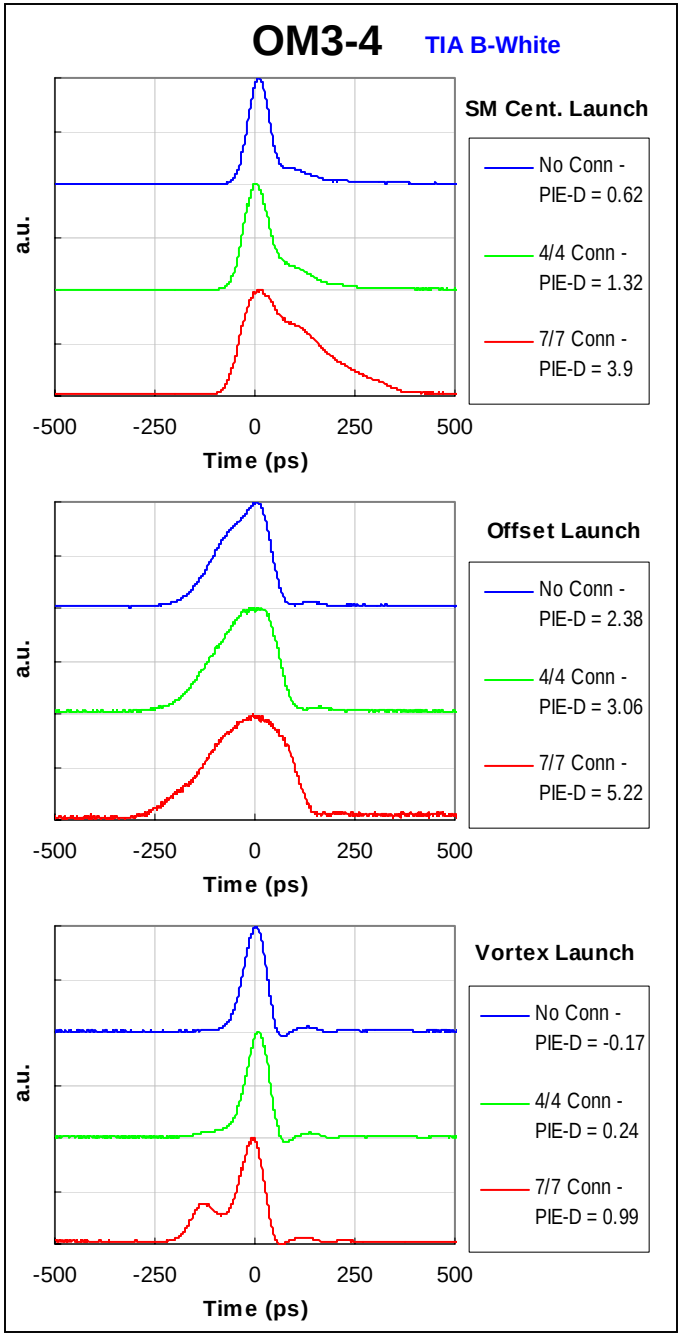


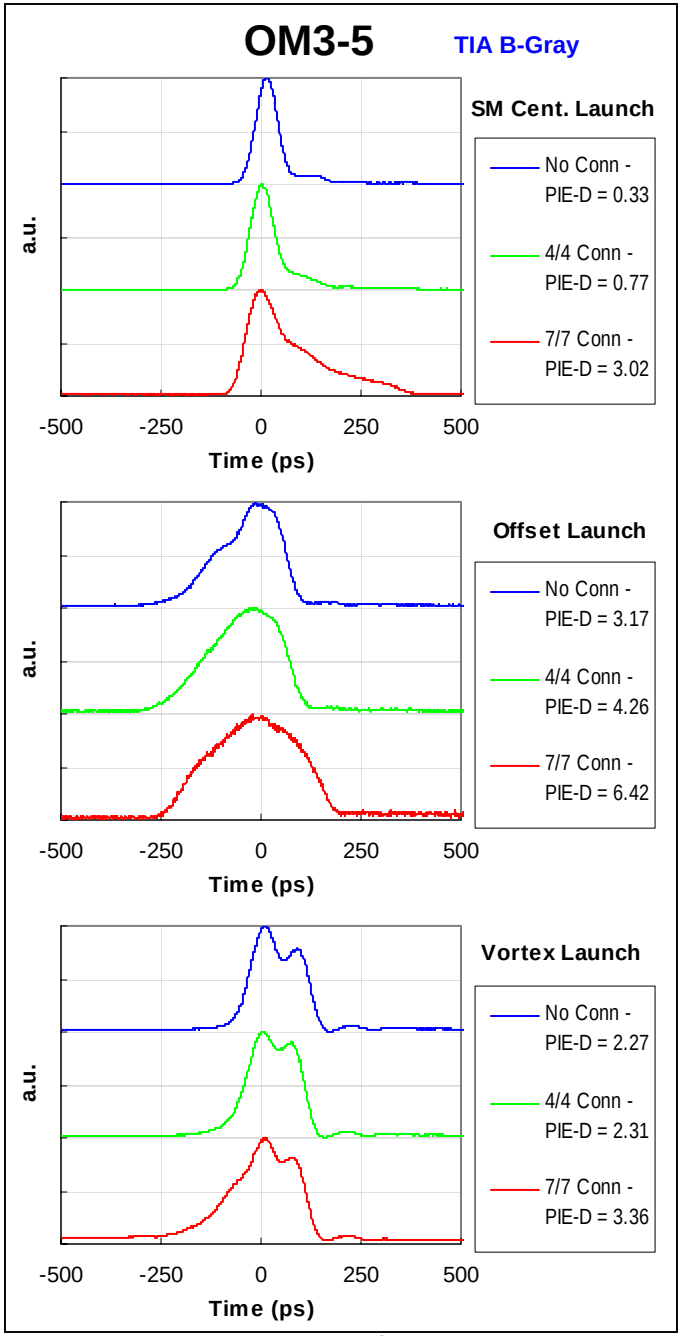
- **Commentary on OM3 Measurements (relative PIE-D)**
  - **Center Launch Best for No Connectors and Intermediate (two 4 um offset) Connector Case.**
  - **Offset Launch (50/125 MCP) Results in Worst PIE-D Values with Worst Connectors (two 7 um)**
  - **Single Vortex Launch Usually Better than Offset Launch**
  - **Vortex Launch Has Significantly Different IPR Shape than Offset (see following pages)**
  - **Worst Vortex Values Compare Favorably to Worst Center Launch Cases.**

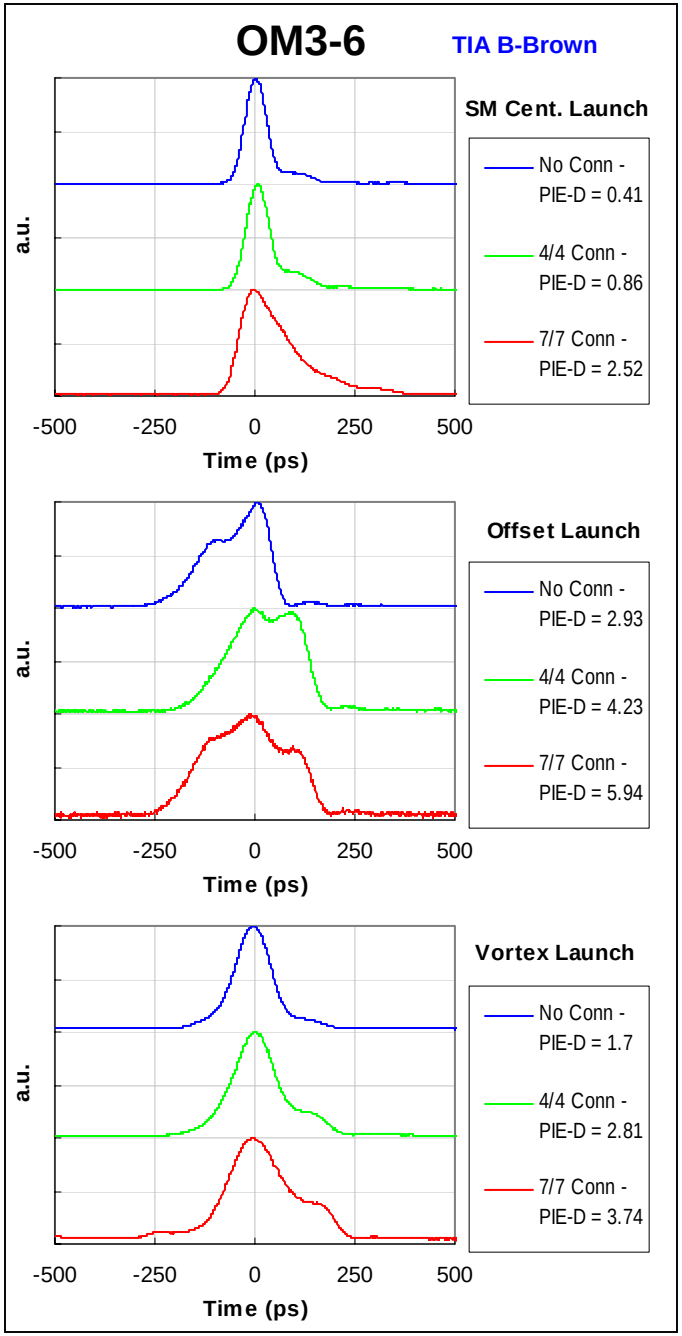
IPR Graphs (Raw Data) – OM3 1 - 3



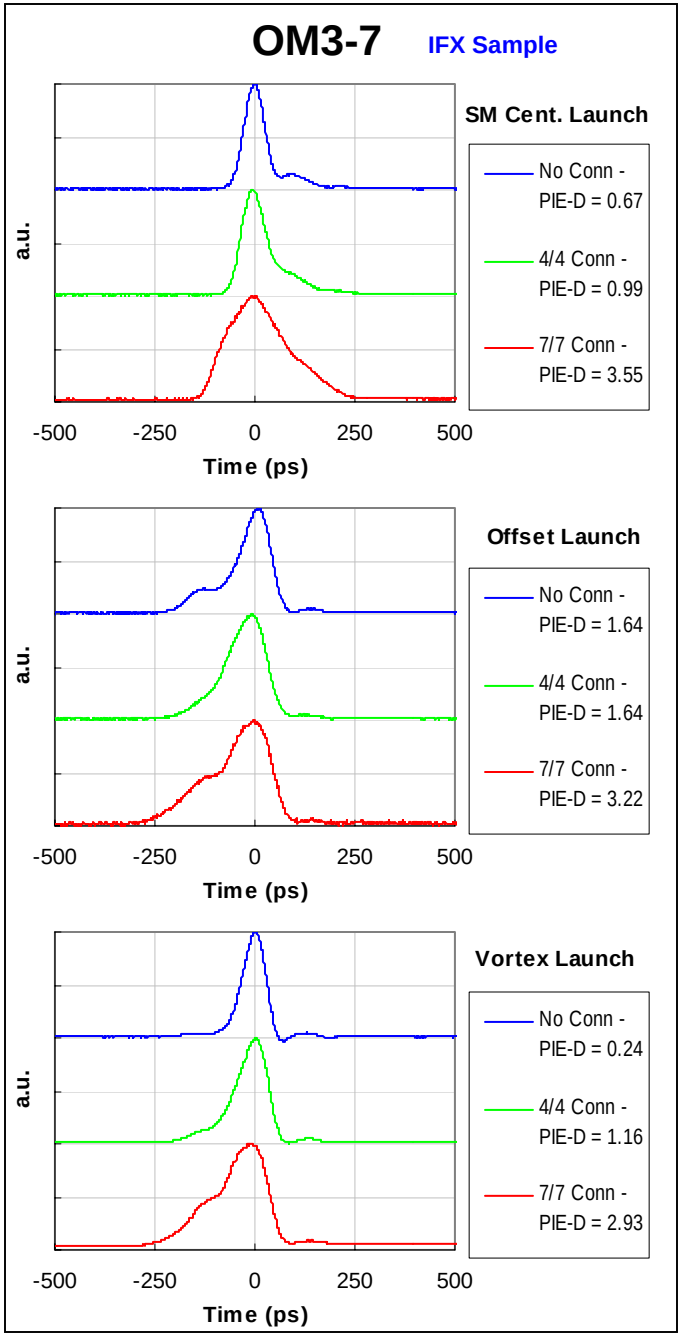
IPR Graphs (Raw Data) – OM3 4-6







IPR Graphs (Raw Data) – OM3-7



- **Notes on IPR Plots**
  - **Raw Scope Data (Uncorrected for B-B Response)**
  - **Centered on Highest Point Relative Time Alignment of Plots is Not Meaningful**
  - **PIE-D Labels are 'Uncorrected Values' (Don't Include 1 UI / 47 ps r/f TX or 7.5 G RX BW)**

General Conclusions

- **Vortex Launch Performs Equal to or Better than Offset Launch in Most All Cases.**
- **Single Mode Center Launch is Clearly Best for OM3**
- **Offset Launch (at least standard 50 um MCP) is Probably Unacceptable for OM3**
- **Vortex Launch for OM3 is Not As Good as Center Launch But May Be Good Enough**
- **Of the Launches Tested, Vortex Launch Appears the Best for a Single Integrated Launch for both OM1 and OM3, and May Be Good Enough to Meet Needs**
- **Care Should Be Taken Before Ruling Out the Vortex Launch As An Alternative for OM3**
- **More Work is Needed on Experimental Verification of Vortex Tolerance Issues and Sensitivity to Polarization / Manipulation**

Future Work

- **Calculate Correct Absolute PIE-D Values by Deconvolving Measurement System and Convolving with 1 UI / 47 ps Gaussian Pulse / 7.5 G BT RX**
- **Similar Tests for OM2 – Need Suitable Test Fiber Spool !**
- **Test Vortex Launch with Tolerance Conditions**
  - **Lateral Offsets: 0 – 10 um**
- **Study Real SM TOSA Launches**
  - **Measure Typical SM TOSA Output Spots**
  - **Measure PIE on representative Fibers / Connector Arrangements**
  - **Compare to Performance to SM Center Launch**
- **Measure Encircled Flux at TP2 for Various Launches**
  - **Mode Conditioning Patchcords**
  - **Vortex Launch + 50/125 and 62/125 Patchcords**
  - **Center Launch into 50/125 and 62/125 Patchcords**
  - **We Could Use Encircled Flux Analysis Software !**