Observed Variation of Received Waveforms in Multimode Fibre: Due to polarization, mechanical stress and wavelength changes

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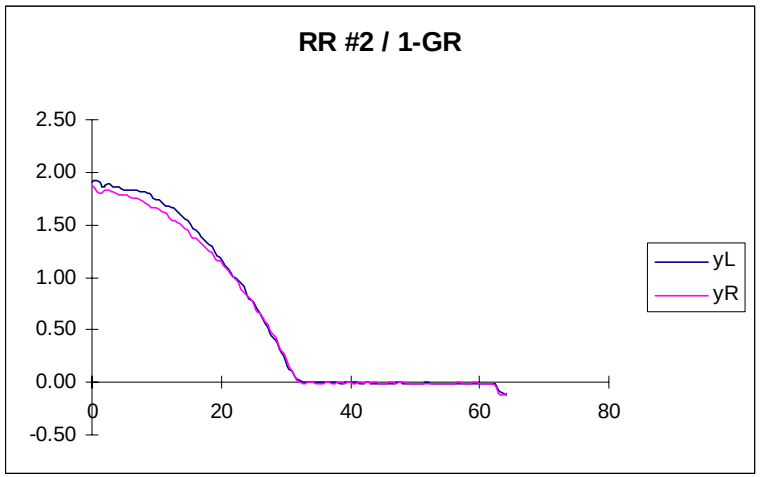
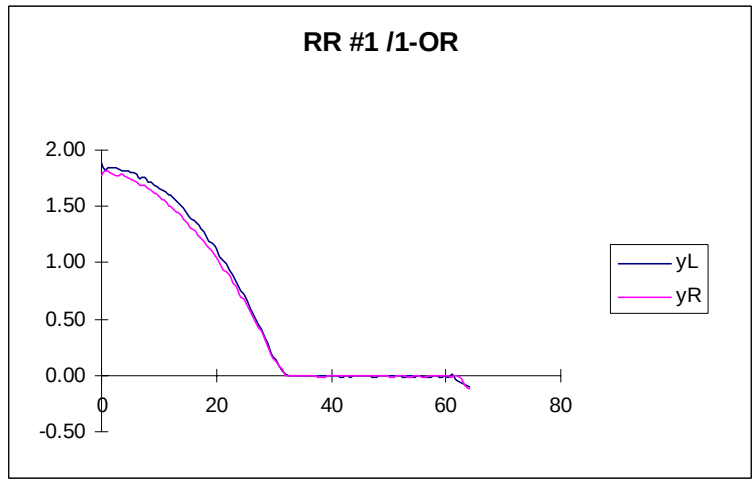
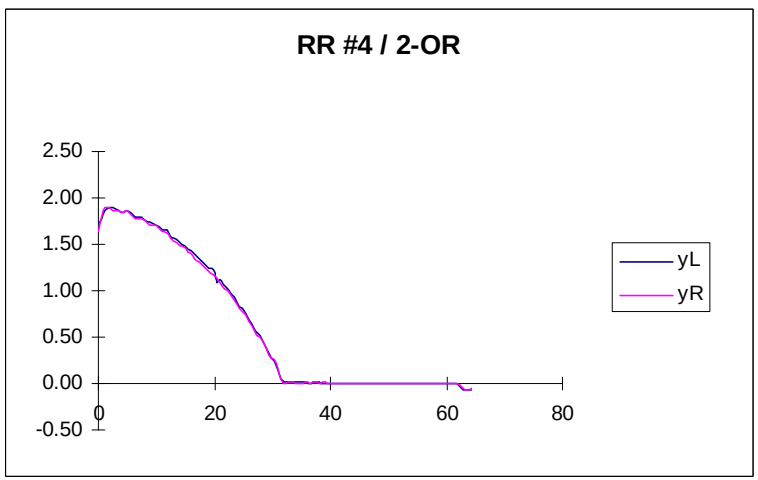
Variation of Waveforms in Multimode Fibre: Introduction

- Experimental Observations are reported for the effects of polarisation, mechanical stress and source wavelength when applied to multimode fibre.
- 3 test fibres are investigated using an EML and FP sources.
- A SMF polarizer is used to control the launch conditions.
- The complete transmission line incorporates a variable offset, an adjustable connector, a shaker, various lengths of fibre as well as the 3 test fibres.

Refractive Index Profiles of Fibres 1G, 1O and 2G from TIA 1996 Report and Measured Bandwidths



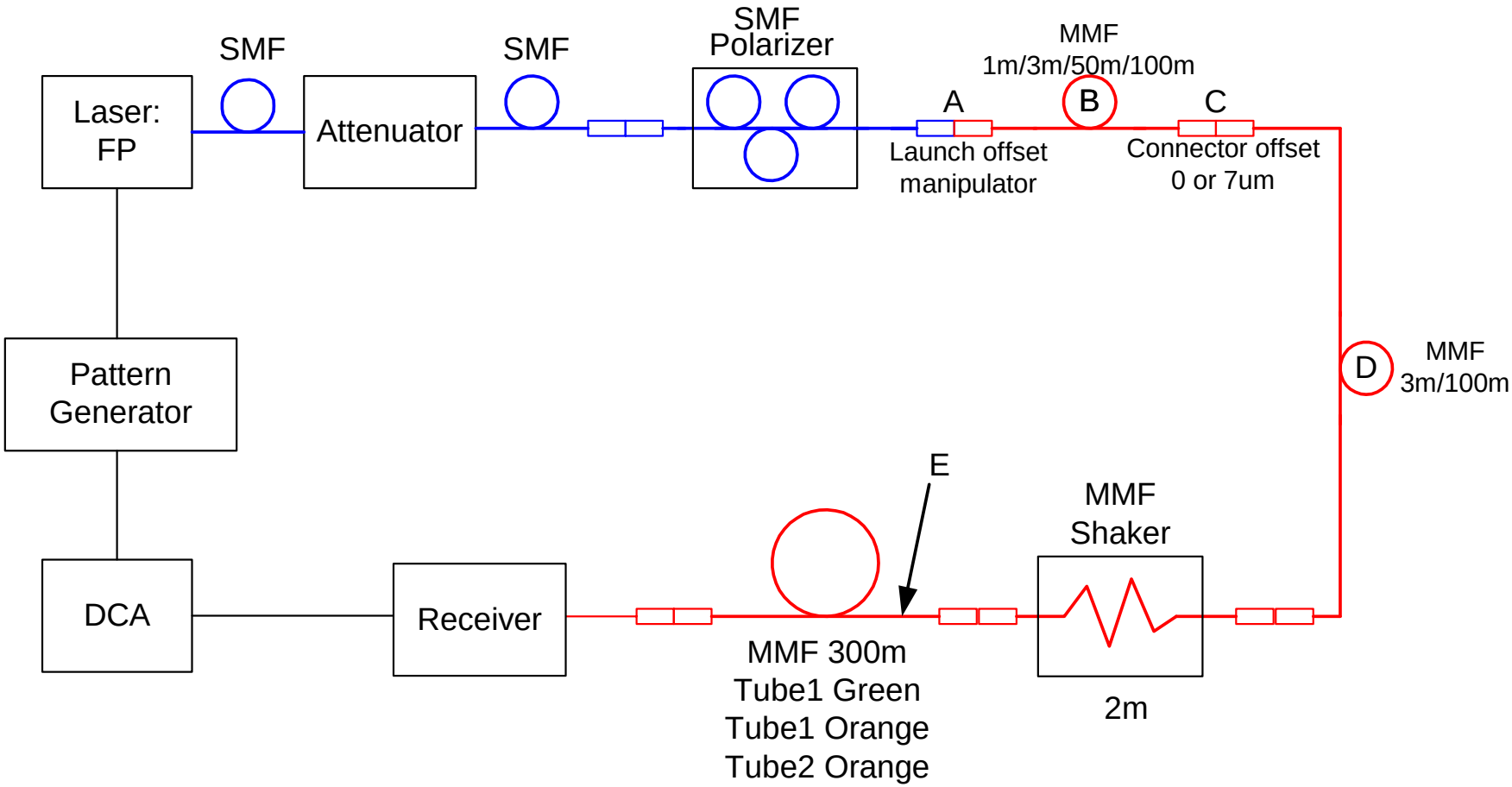




HPLB Bandwidth Measurements from 1997

Fibre	OFL BW	Centre Launch	Offset Launch	Units
1G	570	330	720	MHz.km
1O	1100	920	1350	MHz.km
2O	460	1200	555	MHz.km

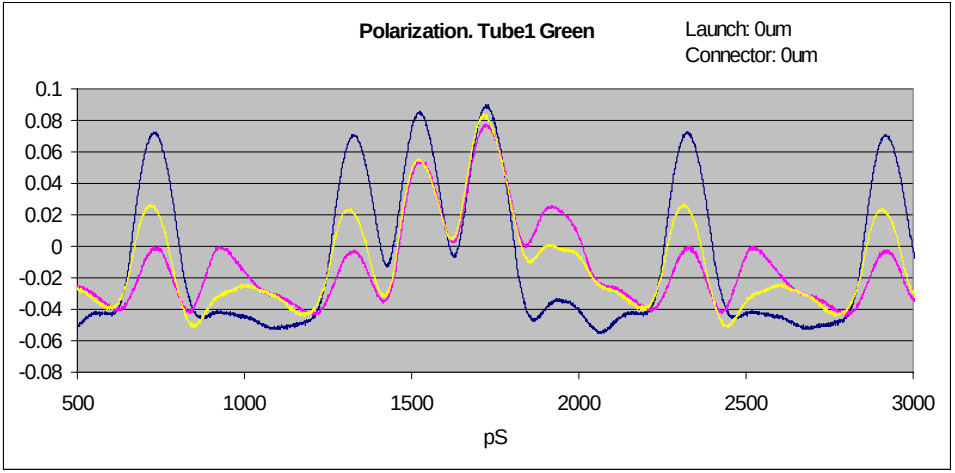
Variation of Waveforms in Multimode Fibre Experimental setup



When the shaker was used the measurements were also taken with the 0 or 7 um offset connector after the shaker. It was observed that it did not seem to matter where the connector was positioned.

Variation of Waveforms in Multimode Fibre
The effects due to Polarisation

- Measurements with FP laser (slides 5, 6 and 7)
- Variable offset SMF to MMF launch set at 0um, 5um or 15um
- Connector offset set at 0um or 7um
- Polarizer adjusted to show maximum and minimum waveform changes
- Pattern (16 bit word) set to 1000001010100000
- Fibres B & D lengths set at 3m
- On graphs the blue waveform is the short reference fibre condition


Polarization. Tube1 Green
Launch: 0um
Connector: 0um
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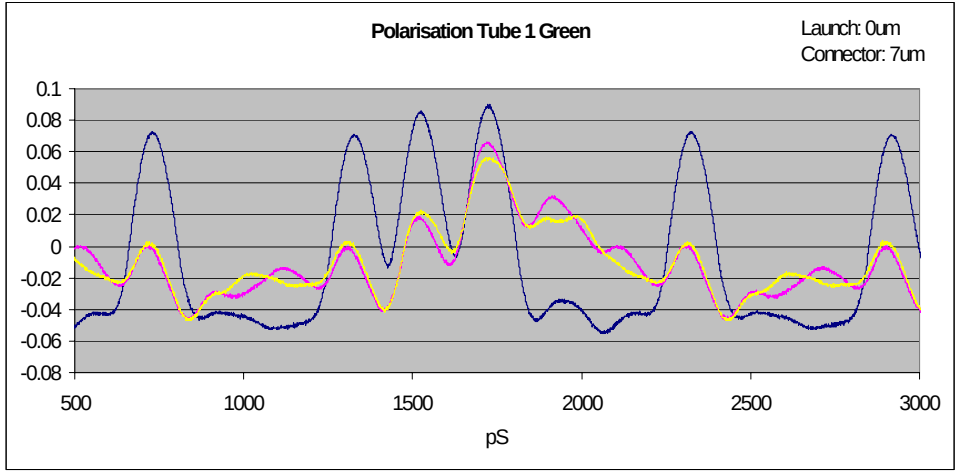
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Connector: 7um
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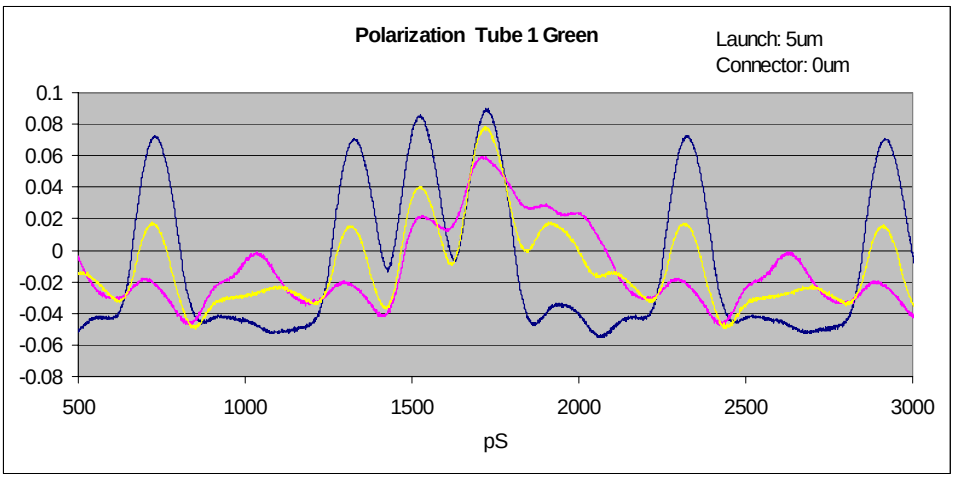
Polarization Tube 1 Green
Launch: 5um
Connector: 0um
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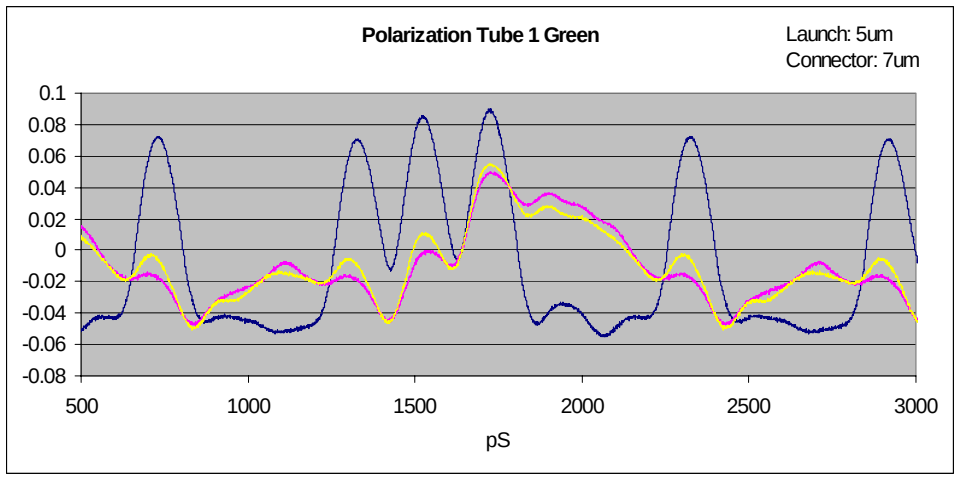
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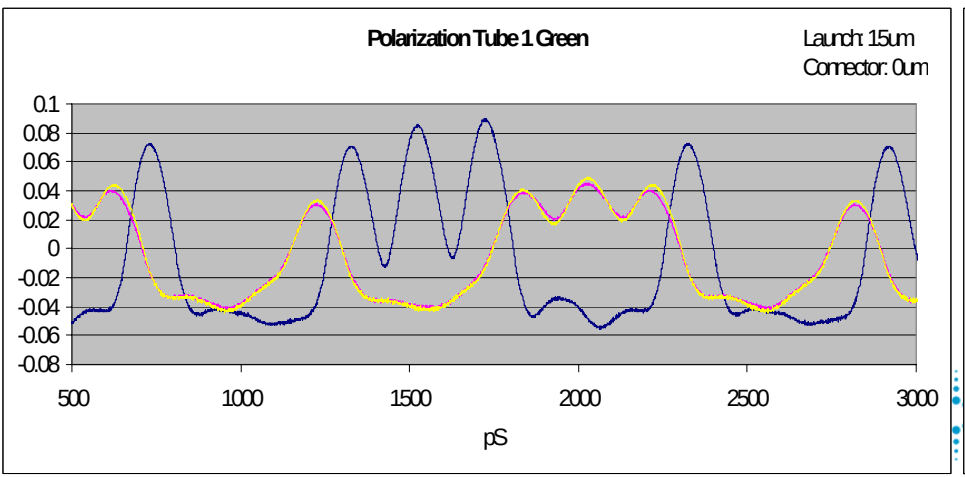
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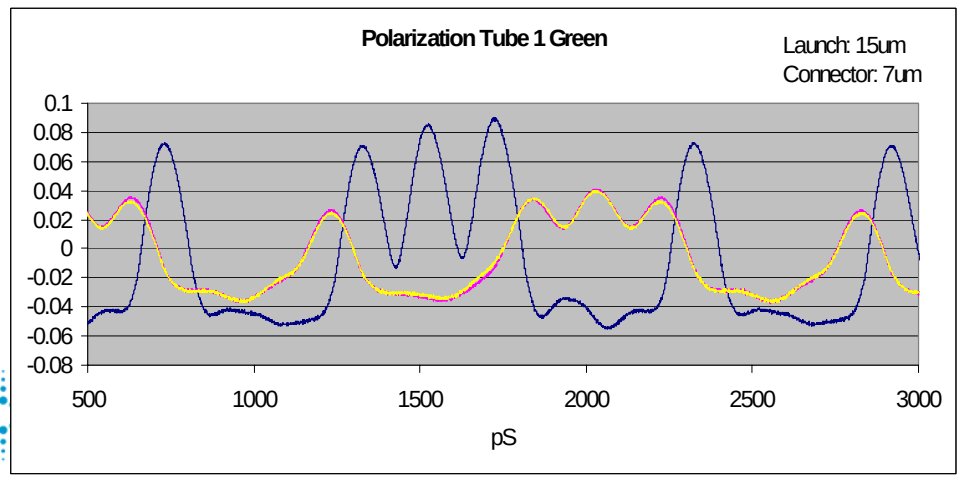
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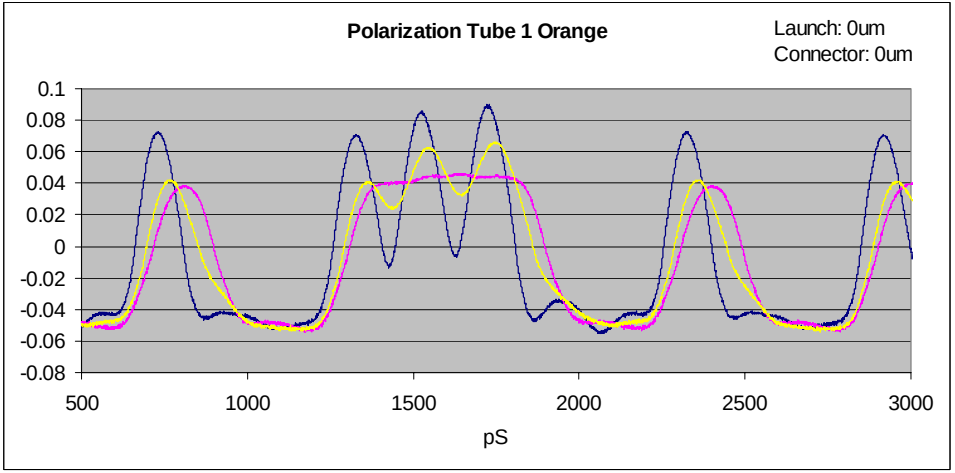
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Launch: 0um
Connector: 0um
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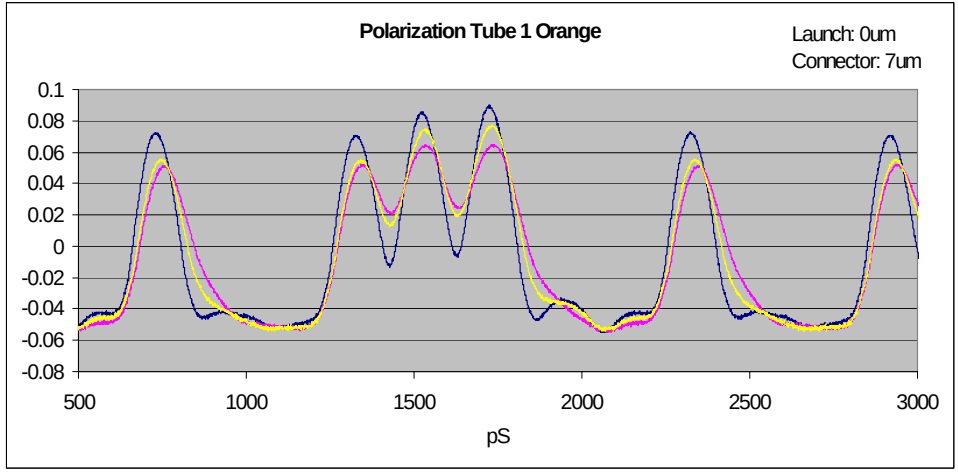
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Connector: 7um
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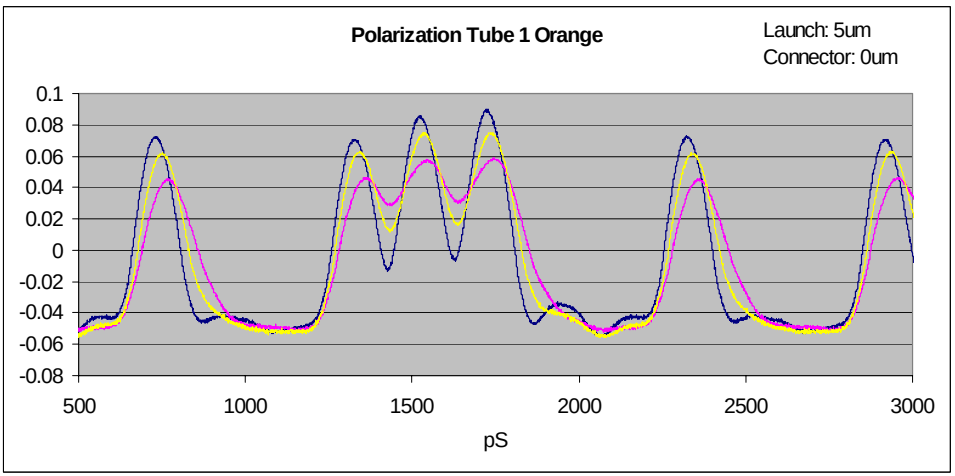
Polarization Tube 1 Orange
Launch: 5um
Connector: 0um
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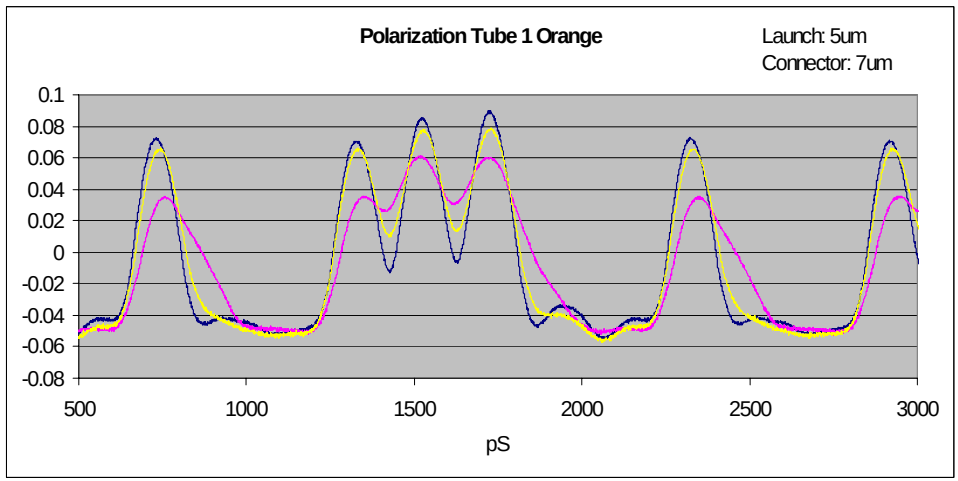
Polarization Tube 1 Orange
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Connector: 7um
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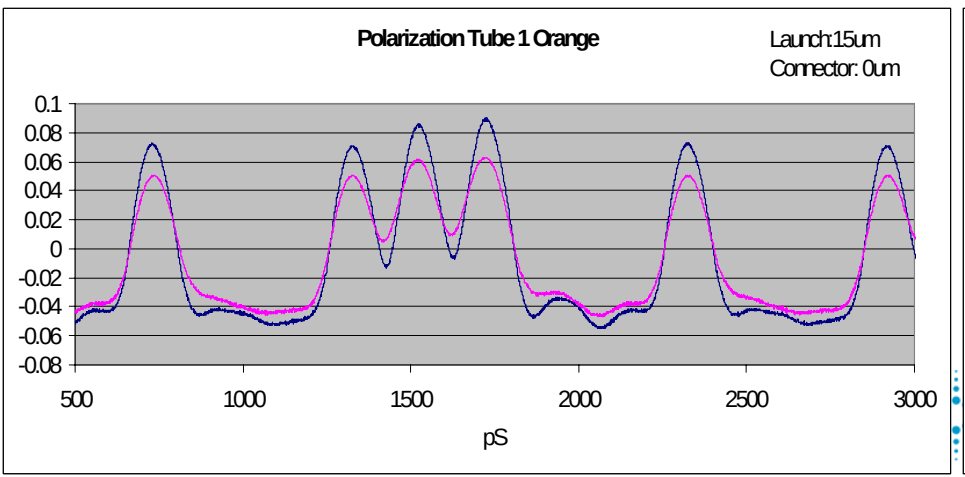
Polarization Tube 1 Orange
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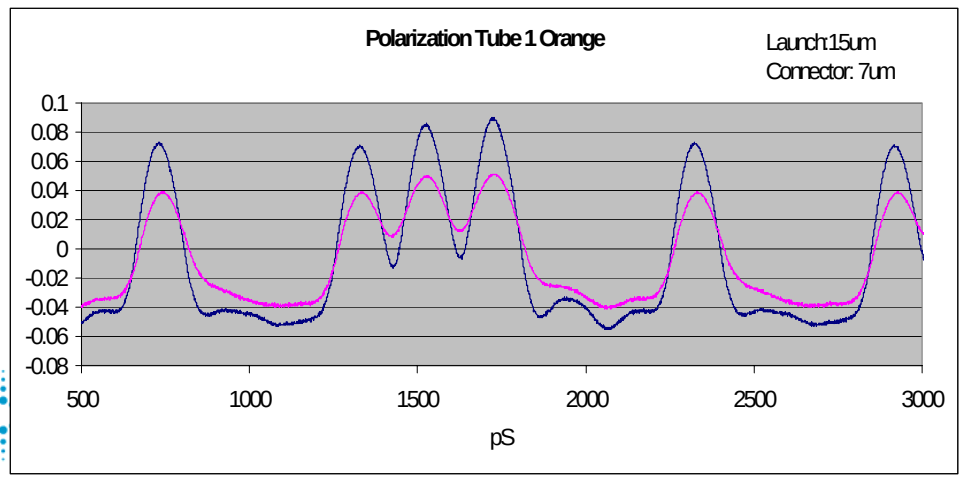
Polarization Tube 1 Orange
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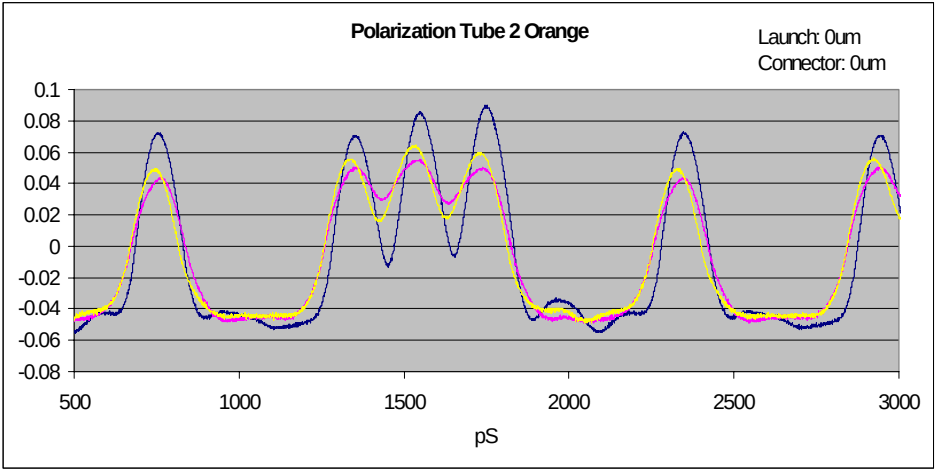
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Connector: 0um
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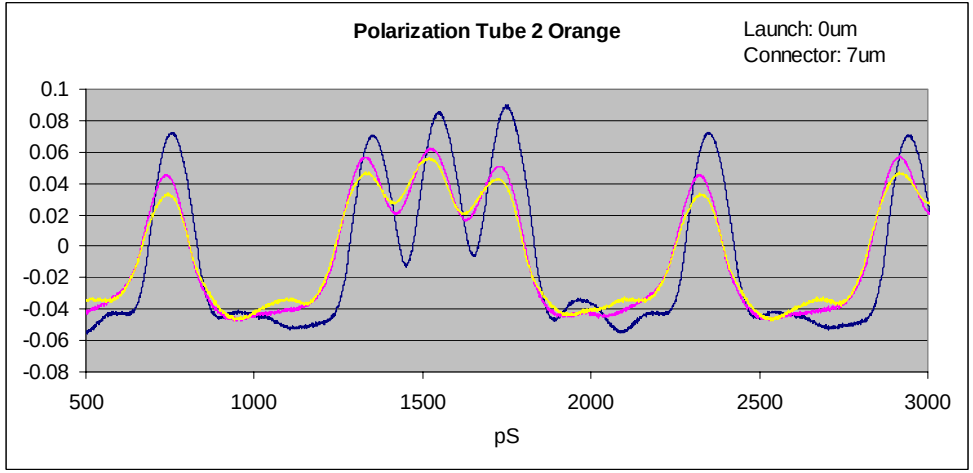
Polarization Tube 2 Orange
Launch: 0um
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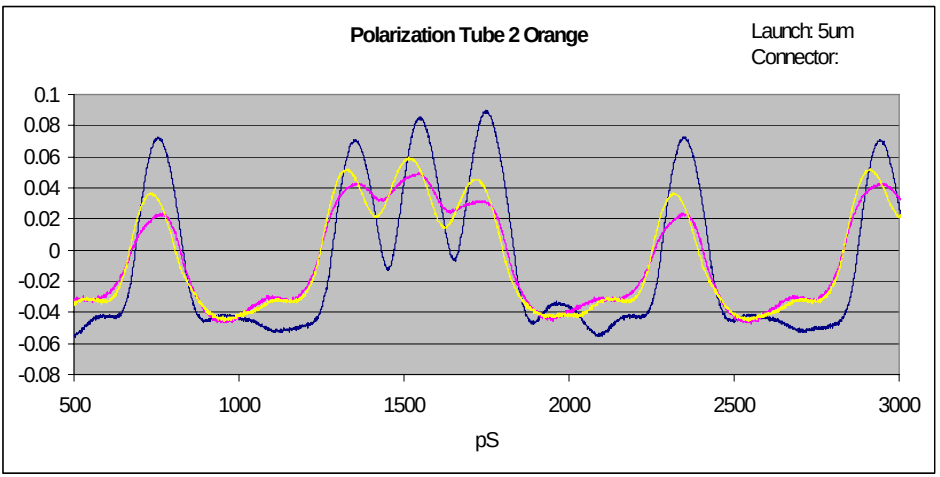
Polarization Tube 2 Orange
Launch: 5um
Connector:
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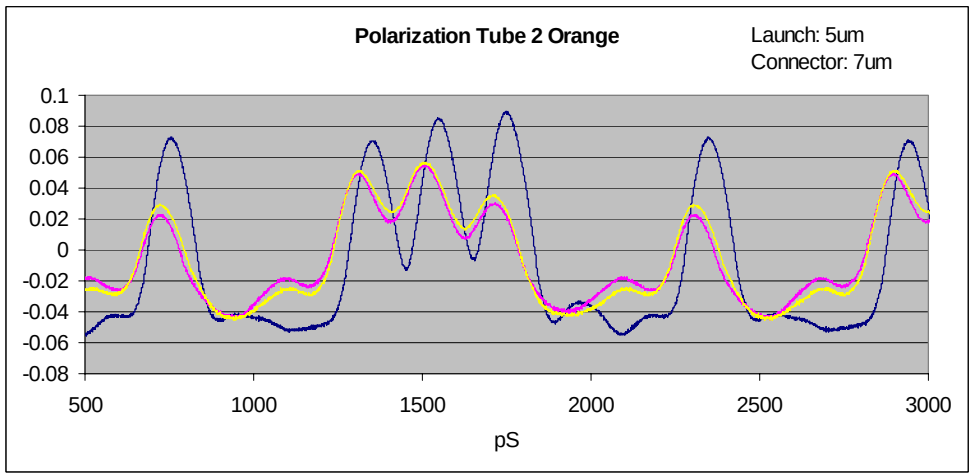
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Launch: 5um
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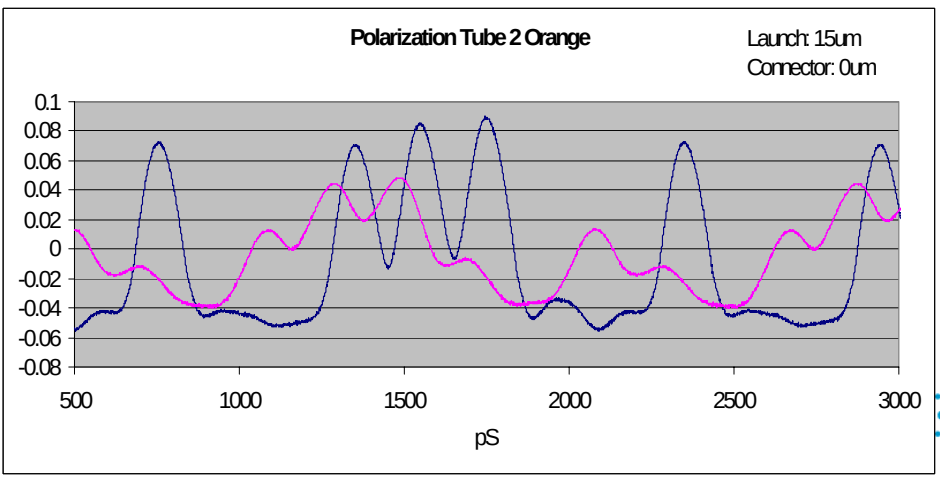
Polarization Tube 2 Orange
Launch: 15um
Connector: 0um
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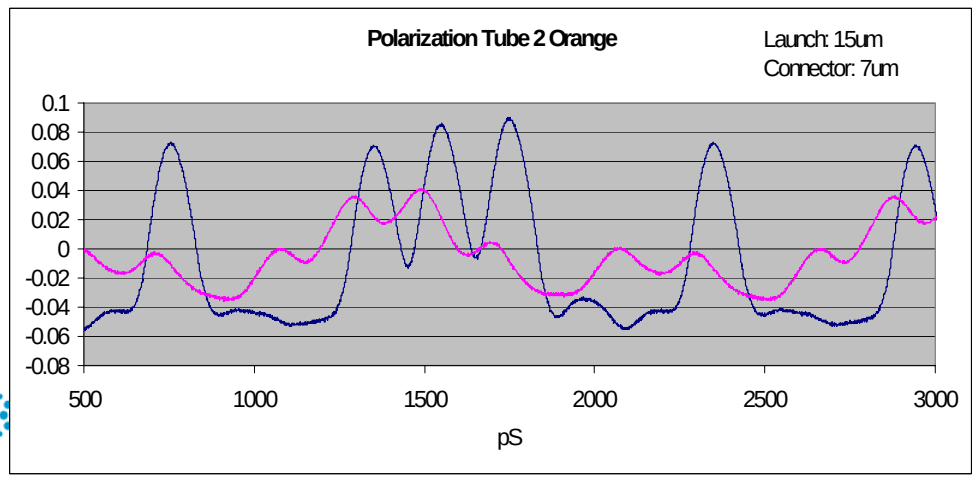
Polarization Tube 2 Orange
Launch: 15um
Connector: 7um
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Variation of Waveforms in Multimode Fibre:
PIE-D extracted from measurements

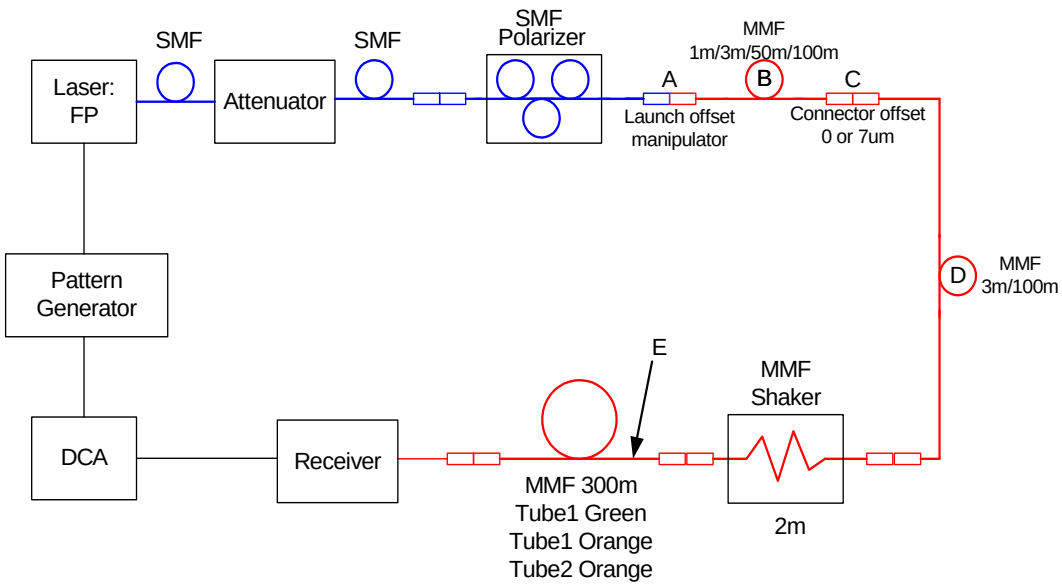
Fibre	Launch (um)	Connector (um)	min (dB)	max (dB)
Tube 1Green	0	0	1.8	3.7
	0	7	3.1	3.5
	5	0	2.5	3.1
	5	7	2.6	2.8
	15	0	1	1.4
	15	7	1	1.1
Tube 1 Orange	0	0	1.2	1.6
	0	7	1.1	1.3
	5	0	1.2	1.7
	5	7	1.7	1.8
	15	0	1.7	1.7
	15	7	1.2	1.2
Tube 2Orange	0	0	0.8	0.9
	0	7	1.1	1.2
	5	0	1.1	1.4
	5	7	1.6	2.1
	15	0	2.7	2.7
	15	7	3	3

Variation of Waveforms in Multimode Fibre: Additional Measurements

- EML source also used.

- Linear polarisation was measured at points A & C. Fibre B had its length changed from 1m to 3m

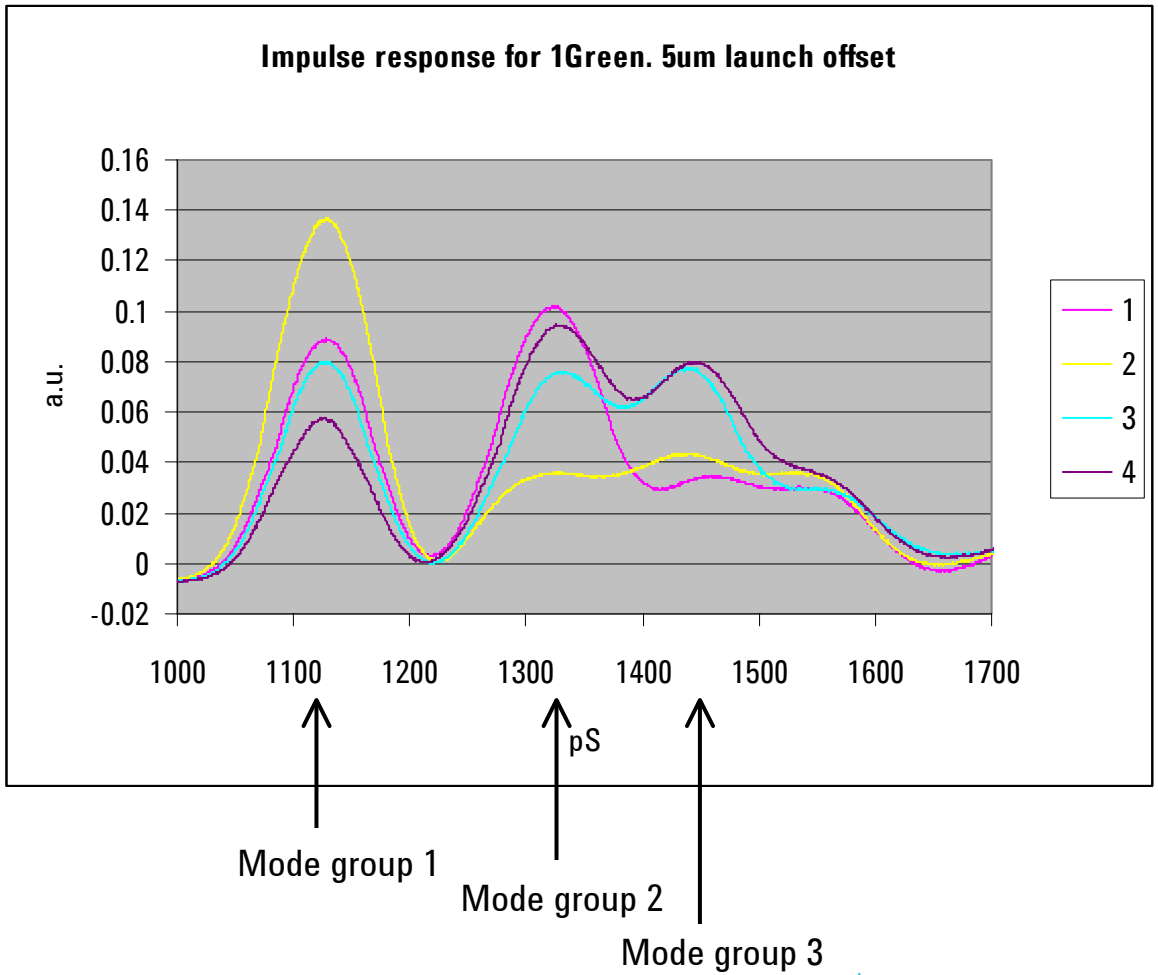
- Effects of waveform responses were observed with different lengths of fibre between the polarizer and shaker; with and without connector offset and also the effect of mechanical movement on the fibre with no connector (Reference point E)



Variation of Waveforms in Multimode Fibre

Detailed impulse response: Observed mode group coupling

- Input to fibre was a single impulse from an EML



- Four waveforms captured from changing polarisation launch or hand moving the shaker.

Area under each waveform (1000ps to 1700ps)			
1	2	3	4
48.86	49.32	50.31	51.92

- Power is conserved.

- Power is coupled between mode groups.

1

Variation of Waveforms in Multimode Fibre Observations: polarization

- Linear polarization is lost in multimode fibre by 3m. Extinction ratio from 17.1dB to 6.9dB when centre launched and to 1.5dB when 20um offset launched.

- Variations in waveforms are observed when the launch polarization is changed. The actual amount of disturbance depends on the fibre. For those fibres with central defects (1Green), the effect is most pronounced around a few microns from its centre.

- For the three fibres tested: the larger the offset the less the effect of polarization launch. [That is not to say it has disappeared but that the mixing is within similar bandwidth modes.]

- Changing the source to an EML produced the same results.

- The 0um to 7um connector offset can reduce the delta in waveform with polarization (1Green and 1Orange), but can also enhance the effect (2Orange 5um)

Variation of Waveforms in Multimode Fibre:
Observations (cont)

- The effects observed with polarization also occur with the shaker. Independent of the fibre distance (up to 100m) between the shaker and launch. *That is change in polarization or shaking the fibre are equivalent. No new states were observed with fibre movement as compared to polarizer.*

- In all cases of either polarisation or mechanical stress changes, the waveform changes were slow. Power was not lost in the process as the areas under each waveform are within 6% of each other.

- The waveform variation can be created when just the 300m test fibre is moved (at point E): In this case there is no connector except at the receiver.

- We believe that the effect is not intrinsically a launch effect but is an enhanced form of mode coupling between modes groups (definitely observed).

Consequences for 10GBASE-LRM specification

- 10GBASE-LRM Fibre models (Monte Carlo and 108) contain waveforms of the type observed: no new fibre impulse responses required.
- The rate of change is very slow, 10's of Hz.
- Since no new IPR are involved EDC penalty assumptions (PIE_D and implementation allowance) can be estimated from current fibre models.
- Don't need a detailed theory of this effect to write specification, the effect is easily dealt with at an engineering level.

- Specification should either:

  Informatively, alert implementers that the channel impulse response may vary at 10's of Hz and recommend that the equalizer adaptation time be faster than this.

OR

Include a simple, slow equalizer adaptation conformance test.