EMB, WCMB and ROFL Testing

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David Cunningham & Mark Nowell
Hewlett-Packard Laboratories,
Filton Road
Bristol BS12 6QZ
UK.
dgc@hplb.hpl.hp.com

Outline

- Introduction to some bandwidth reduction physics
- Definitions of EMB, WCMB and ROFL
- Experimental results
- An example conditioned launch
- Conclusions

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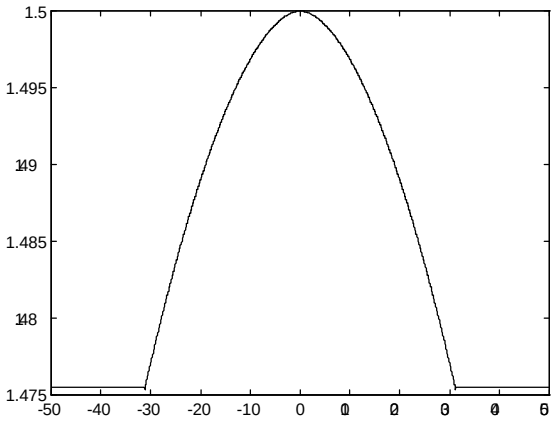
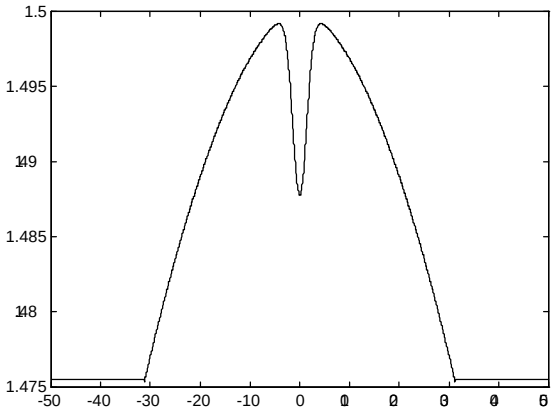
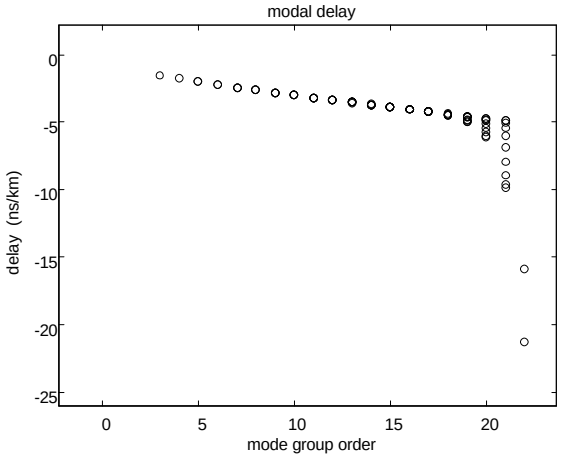
Theory: *Effect of central index dip - a=1.8, 62MMF*

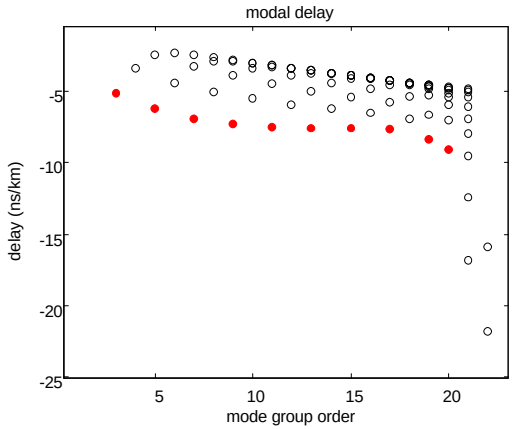
Refractive index





Modal delay





- *Note this is only one example of a mechanism that can alter link bandwidth with laser launches.*

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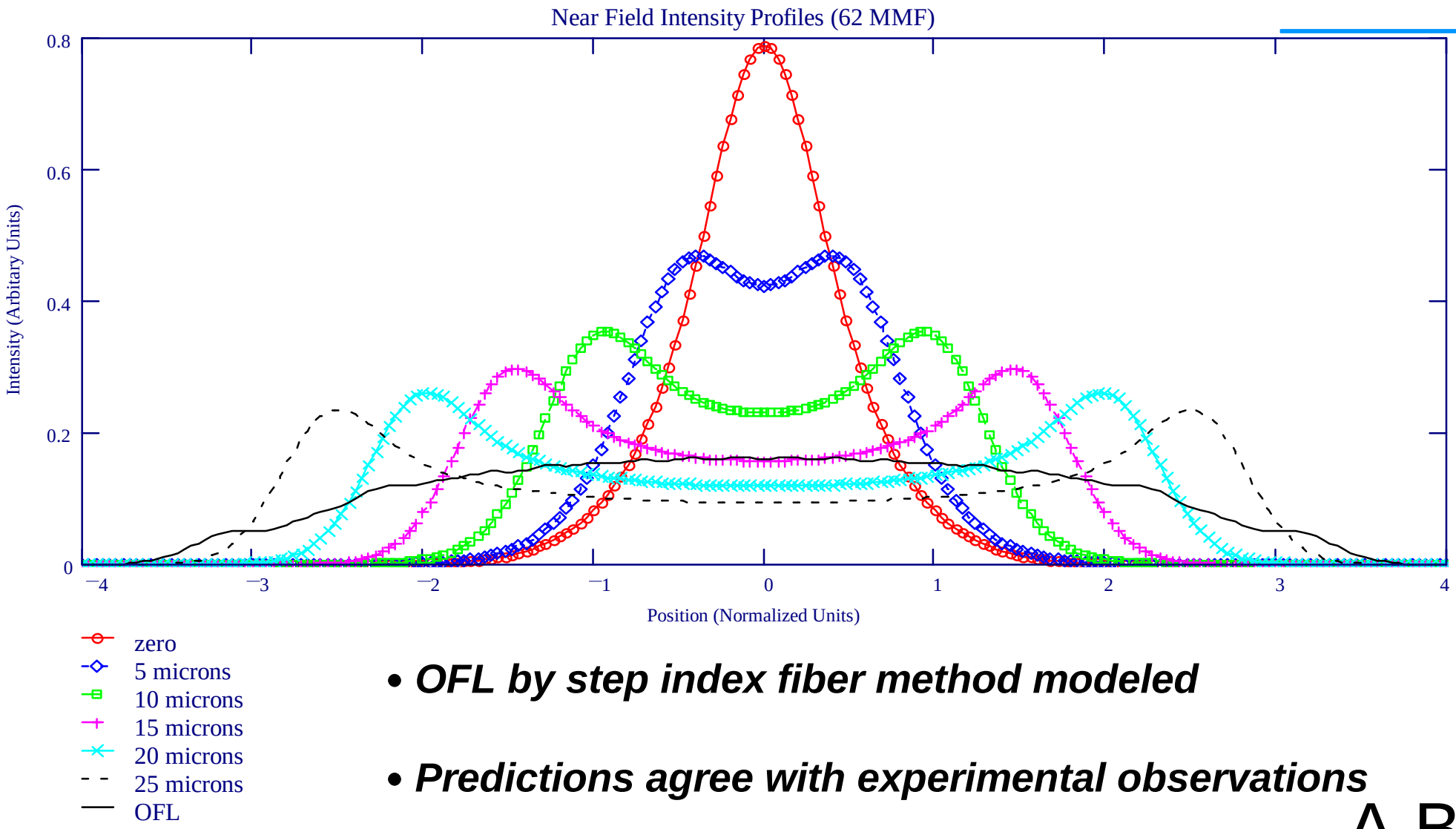
Theoretical Calculation Of Near Field Intensity Profiles For SMF Launch: Various SMF Offsets



- ***OFL by step index fiber method modeled***
- ***Predictions agree with experimental observations***

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Bandwidth 'Collapse' due to Mode Coupling at Connectors: Experimental Observations

- With Center Launch (LWL or SWL, SM or MM Source):

  - *offset at Tx interface or initial few connectors causes bandwidth collapse for a small percentage of fibers,*

  - *after bandwidth has collapsed mode coupling at further MMF connectors increases bandwidth and it cannot collapse again.*

- With Offset SMF (Mode Scrambling) Launch:

  - *OFL bandwidth achieved for offsets ~ 15 mm in all cases*

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Definitions

Effective modal bandwidth (EMB): the actual modal bandwidth observed in a link for a specific fiber with a specific source.

Worst case modal Bandwidth (WCMB): the lowest bandwidth that may occur in a fiber under any reasonable launch conditions

Unconditioned launch: a launch which has not been designed specifically to modify the bandwidth of the fiber from its OFL value in a controlled and repeatable manner.

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Radial Overfill Launch (ROFL)

ROFL produced when:

1. a spot of laser light is projected onto the core of the multimode fiber,

2. the laser spot is approximately symmetrical about the optical center of the multimode fiber,

3. the optical axis of both the fiber and the laser beam are approximately aligned,

4. the angle of divergence of the laser beam is less than the numerical aperture of the multimode fiber,

5. the laser spot is larger than the core of the multimode fiber.

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Worst Case Modal Bandwidth (WCMB)

One means of determining the WCMB for a fiber is to employ the following test methodology;

1. The fiber bandwidth should be measured using the standard OFL measurement.

2. The fiber bandwidth should be measured using the Radial Overfill Launch (ROFL) method described below.

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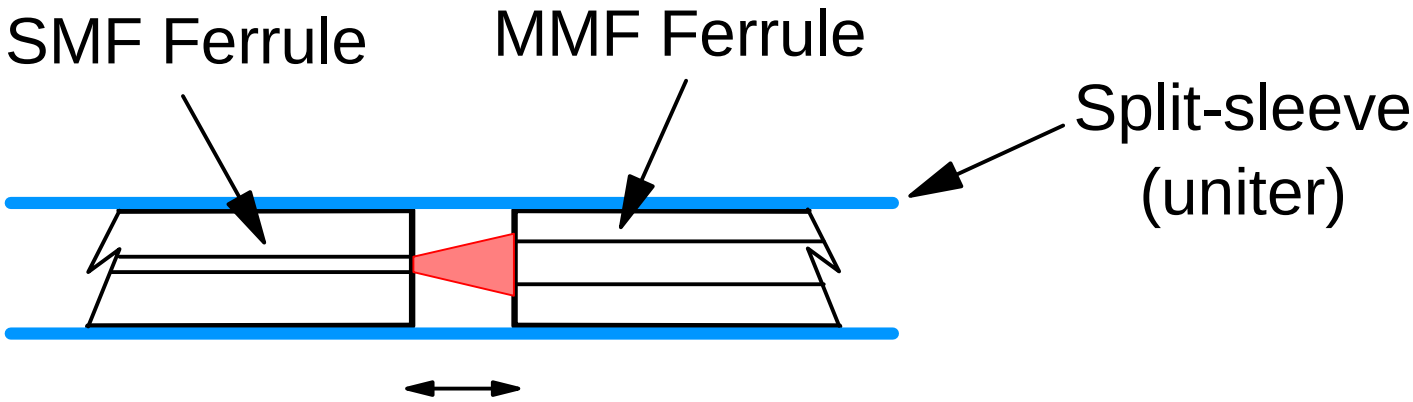
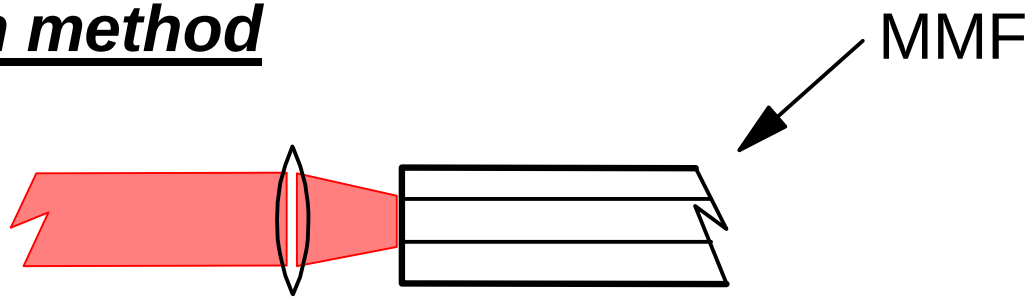
ROFL: Test Methods

Pullback method (preferred)



Separation of endfaces to induce coupling loss (0.5dB, 1 dB, 2dB +/-0.2dB)

Lens system method



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Statistics on ROFL Method

Number of samples:	**44**
Mean:	**0.02**
Standard deviation:	**0.1**

Normalized so that zero indicates that the result of ROFL method equaled the lowest measured bandwidth with a direct launch source or the OFL bandwidth (whichever was lowest for particular fiber).

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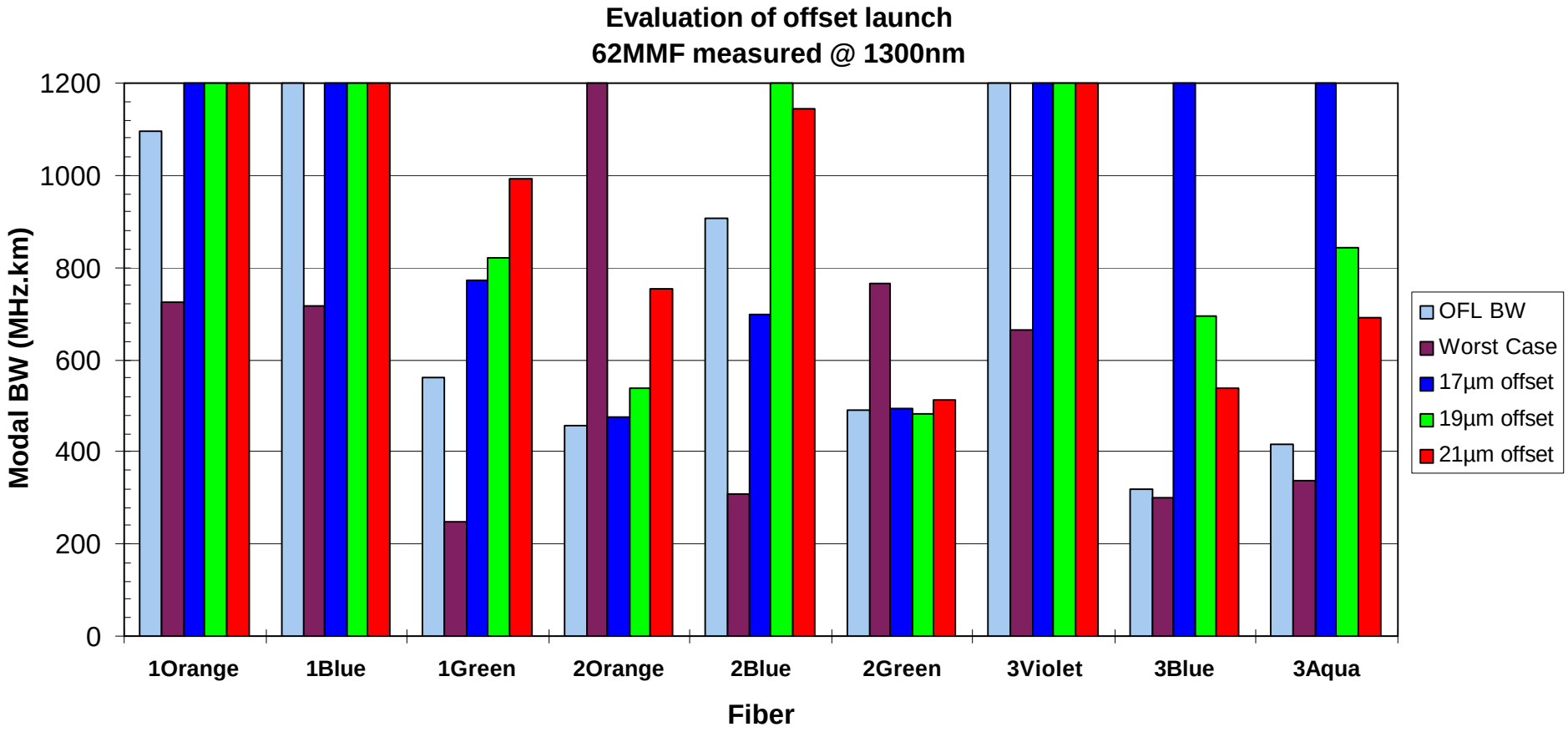
Offset Launch Experimental Results



- *At least OFL bandwidth achieved on all fibers with offset SMF launch as predicted by theory*

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Patchcord Mode Scrambler Power Budget Example: 62 MMF, LWL

Tx Power at output of SMF/MMF Scrambler: -5 to -13.5 dBm

Rx sensitivity: -19 dBm

Total Connector Loss: 1.8 dB

EMB: 500 MHz.km

Link Length: 550 m

- *It would be good to allow for this and other scrambler possibilities by slightly shifting power budget before Working Group ballot.*

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Conclusions

- Basic physics of EMB effect understood
- EMB, WCMB and ROFL defined
- WCMB test method defined and it works!
- Example conditioned launch described

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