Analysis of Center Launch and Mode Filtering in Multimode Fiber Transmission

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- Experiments with central and restricted launch in combination with mode selective receiver
- Analysis of EML, DFB and FPL as sources
- Influence of connector offsets
- Influence of polarization
Overview on Experiments

- 3 Laser sources: EML, DFB, FP
- Fiber launch with centered restricted launch conditions and standard offset launch
- Transmission on legacy FDDI-grade MM fiber (bad fiber) using low order modes only
- Controlled offset of multimode fiber connectors
- Centric mode filtering at the receiver
- Experiments on polarization dependence of the transmission
Center Launch Experiments
Experimental Setup

Laser: EML, DFB, FP
Attenuator

C1 C2 C3 C4

Detector

Mode conditioning
MMF 2m
MMF 100m
MMF 200m
Mode filtering
offset manipulator
Setup for the Experiment

High precision manipulator with scale controlled step size of 0.05µm

alignment of offset relative to fiber core
Center Launch Experiments
Measurements with Three Laser Sources (EML, DFB, FP)

- For offsets of 0µm, 3µm and 5µm:
  - Eye diagram with fixed fiber
  - Pulse pattern with slightly moving fiber

- BER measurements (with fixed fibers)
Center Launch Experiments
General Transmission Characteristic

- Mode filtering at RX adds loss of about 2dB (without connectors)
- 5µm offset between MM fibers results in a further 2,5dB loss
- Strong signal degradation with offset
- Very large changes in the data pattern by slowly moving the fiber
  (= modal noise effect of interference between modes)
External Modulated Laser
Eye Diagrams, Pattern Effects and Noise for various Offsets

Offset: 0 µm

Offset: 3 µm

Offset: 5 µm
DFB- Laser
Eye Diagrams, Pattern Effects and Noise for various Offsets

Offset: 0 µm
Offset: 3 µm
Offset: 5 µm
FP- Laser
Eye Diagrams, Pattern Effects and Noise for various Offsets

<table>
<thead>
<tr>
<th>Offset: 0 µm</th>
<th>Offset: 3 µm</th>
<th>Offset: 5 µm</th>
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Fixed fiber

Moved fiber

Modal noise due to fiber movement
Experiments: Transmission over 300m Multimode Fiber
BER Measurements with Fixed Fiber

Result:
Even small offset causes additional penalty
FP Laser with similar or even better performance than DFB and EML!

Limited accuracy only, results are dependent on fiber placement

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**EML Laser**

**DFB Laser**

**FP Laser**
Polarization Sensitivity of Transmission

- Center and offset launch of single mode fiber into multimode fiber
- Observation of signal variations at the end of the transmission line caused by polarization orientation
- Comparison of 2m and 200m transmission with and without mode filtering
Center Launch Experiments
Polarisation Sensitivity of Launch Condition

Laser: EML DFB FP

Attenuator

Polarisation modification

Detector

Detector

Detector

Detector

offset manipulator

MMF 2m

SM

SM

C1

C2

C3

Mode filtering

Mode filtering

MMF 200m

IEEE 802.3, Portland, OR, USA, July 13-15, 2004
Center Launch Experiments
Polarisation Sensitivity of Launch Condition  SM – MM, 2m

Single mode fiber to Multimode fiber
Offset: 5 µm
w/o mode conditioning at RX

Result:
No pattern variation with polarisation

Single mode fiber to Multimode fiber
With mode conditioning at receiver
Offset: 5 µm

Result:
No pattern variation with polarisation,
Some noise due to attenuation
Center Launch Experiments
Polarisation Sensitivity of Launch Condition  SM – MM, 200m

Single mode fiber to
Multimode fiber (2 + 200m)
Offset: 0 µm
w/o mode conditioning at RX

Result:
Some Pattern variation with polarisation

Single mode fiber to
Multimode fiber (2 + 200m)
With mode conditioning at receiver
Offset: 0 µm

Result:
Pattern variation with polarisation but still possible to recover
Center Launch Experiments
Polarisation Sensitivity of Launch Condition   SM – MM, 200m

Single mode fiber to Multimode fiber (2 + 200m)
Offset: 5 µm
w/o mode conditioning at RX

Result:
Destroyed pattern

Single mode fiber to Multimode fiber (2 + 200m)
With mode conditioning at receiver
Offset: 5 µm

Result:
Recovered Pattern  but …
strong variation with polarisation
Center Launch Experiments
Polarisation Sensitivity of Launch Condition, Results

- Strong sensitivity of the pattern on polarization changes if there exist any offsets in the transmission line!
- Recovery of the signal is not possible in all cases
Center Launch Experiments
Summary of Results

- **Sources:**
  - EML, DFB and FP laser show similar results, FPL slightly better

- **Restricted receiver coupling:**
  - 2dB + X additional loss, X depends on connector offsets (e.g. 4dB)
  - large additional modal noise because of mode filtering at the receiver
  - it is possible to recover the signal, but no guarantee for all situations of the transmission line

- **Connector offsets:**
  - 5µm offset introduces 2.5dB loss + large additional modal noise

- **Polarization:**
  - connectors in the transmission line cause power fluctuations induced by variation of the input polarization (twist of SM fiber)
  - Small effect only, if standard offset launch is applied
Combination of central launch and optimized mode selective receiver can enable an error free transmission over 300m multimode fiber.

but

connectors introduce large distortions, and you have to pay for it with:

large power penalty,
large modal noise,
large polarization sensitivity,

And you can not guarantee that it is working tomorrow as today!