Analysis of Center Launch and Mode Filtering in Multimode Fiber Transmission

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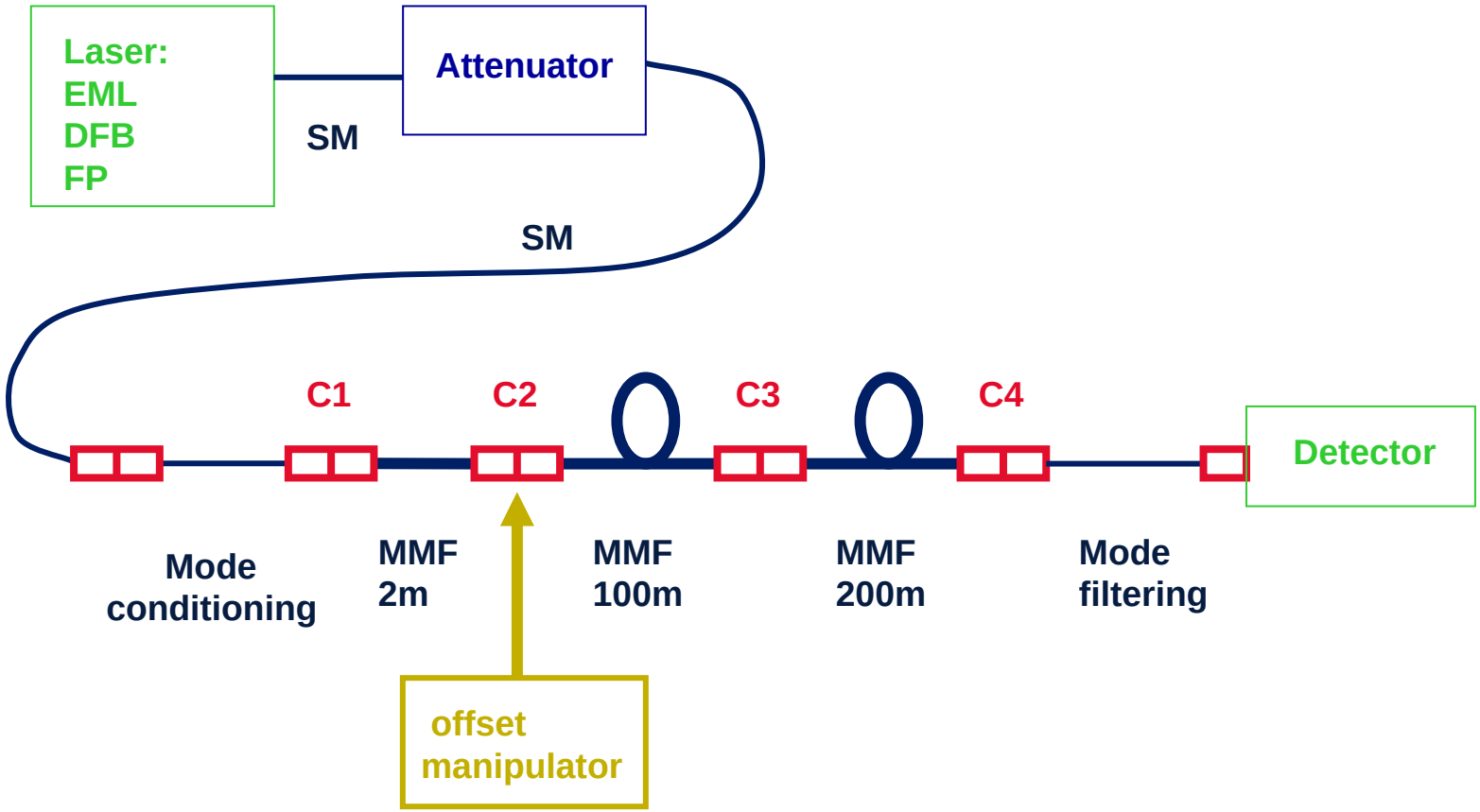
- **Experiments with central and restricted launch in combination with mode selective receiver**
- **Analysis of EML, DFB and FPL as sources**
- **Influence of connector offsets**
- **Influence of polarization**

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



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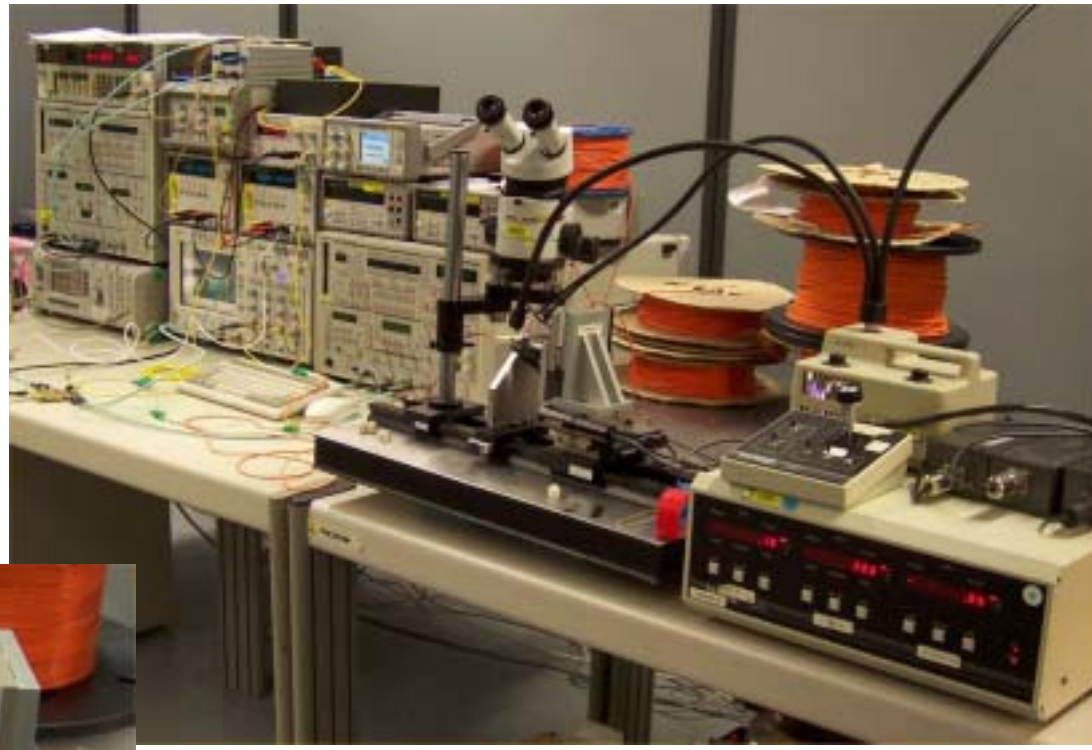
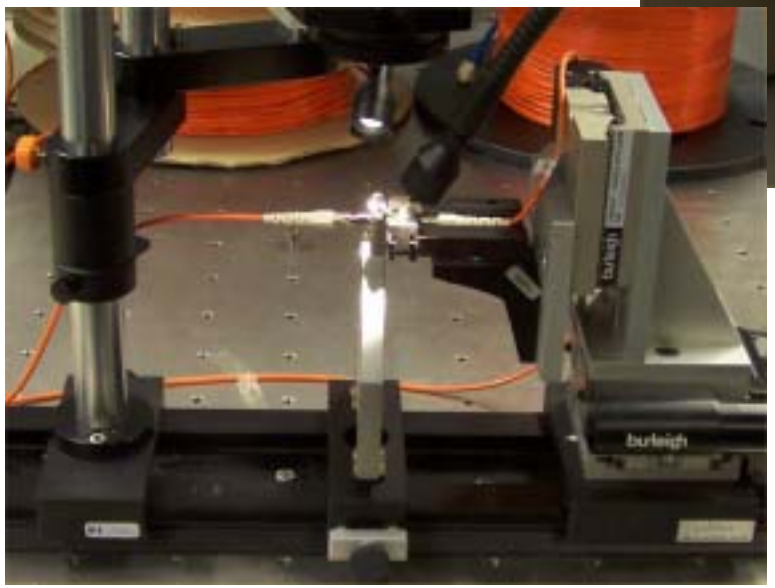
Setup for the Experiment





High precision manipulator
with scale controlled step size of 0,05µm

alignment of offset relative to fiber core

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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)

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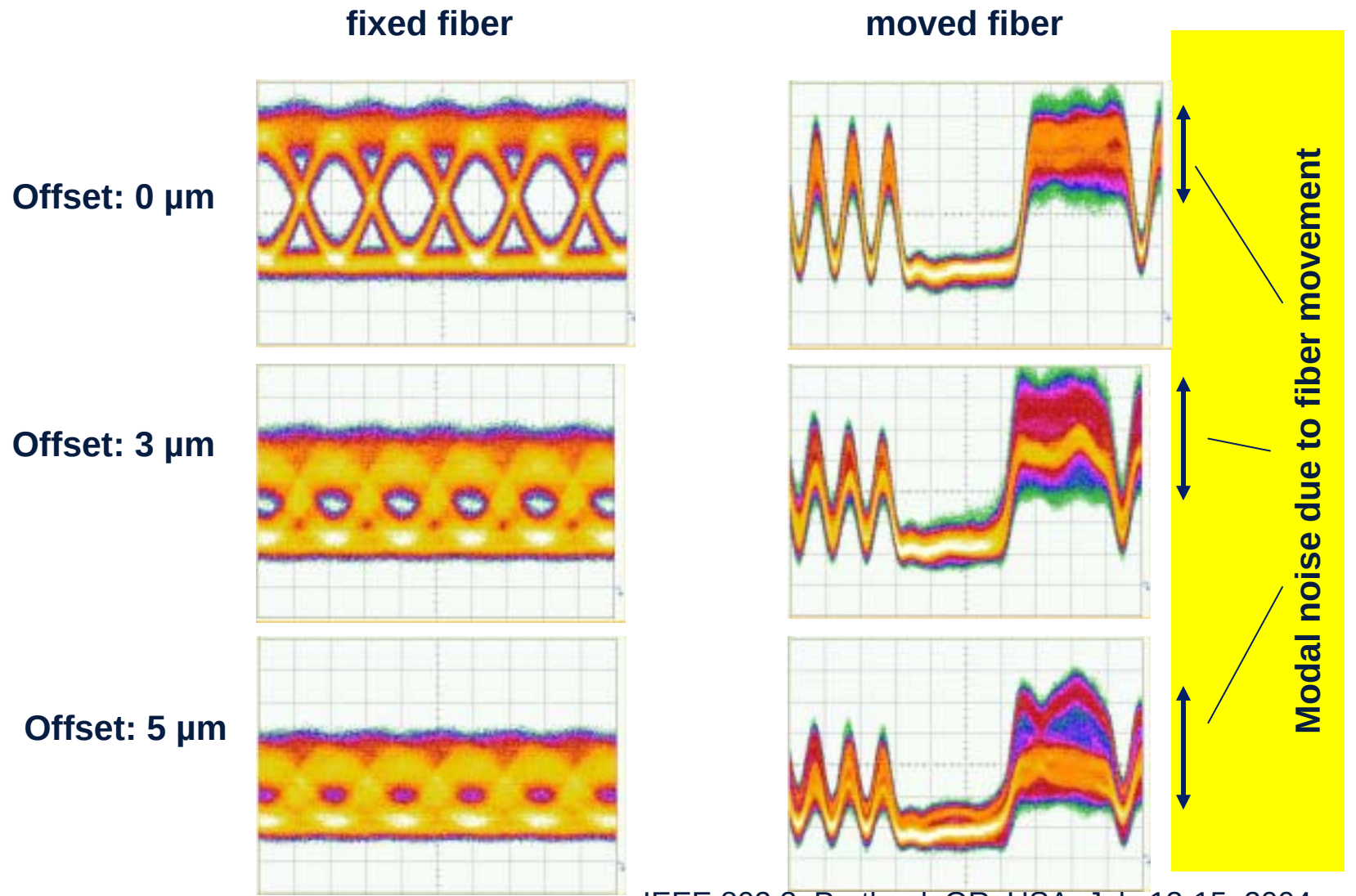
Center Launch Experiments
General Transmission Characteristic

- 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 patern by slowly moving the fiber (= modal noise effect of interference between modes)

External Modulated Laser
Eye Diagrams, Pattern Effects and Noise for various Offsets



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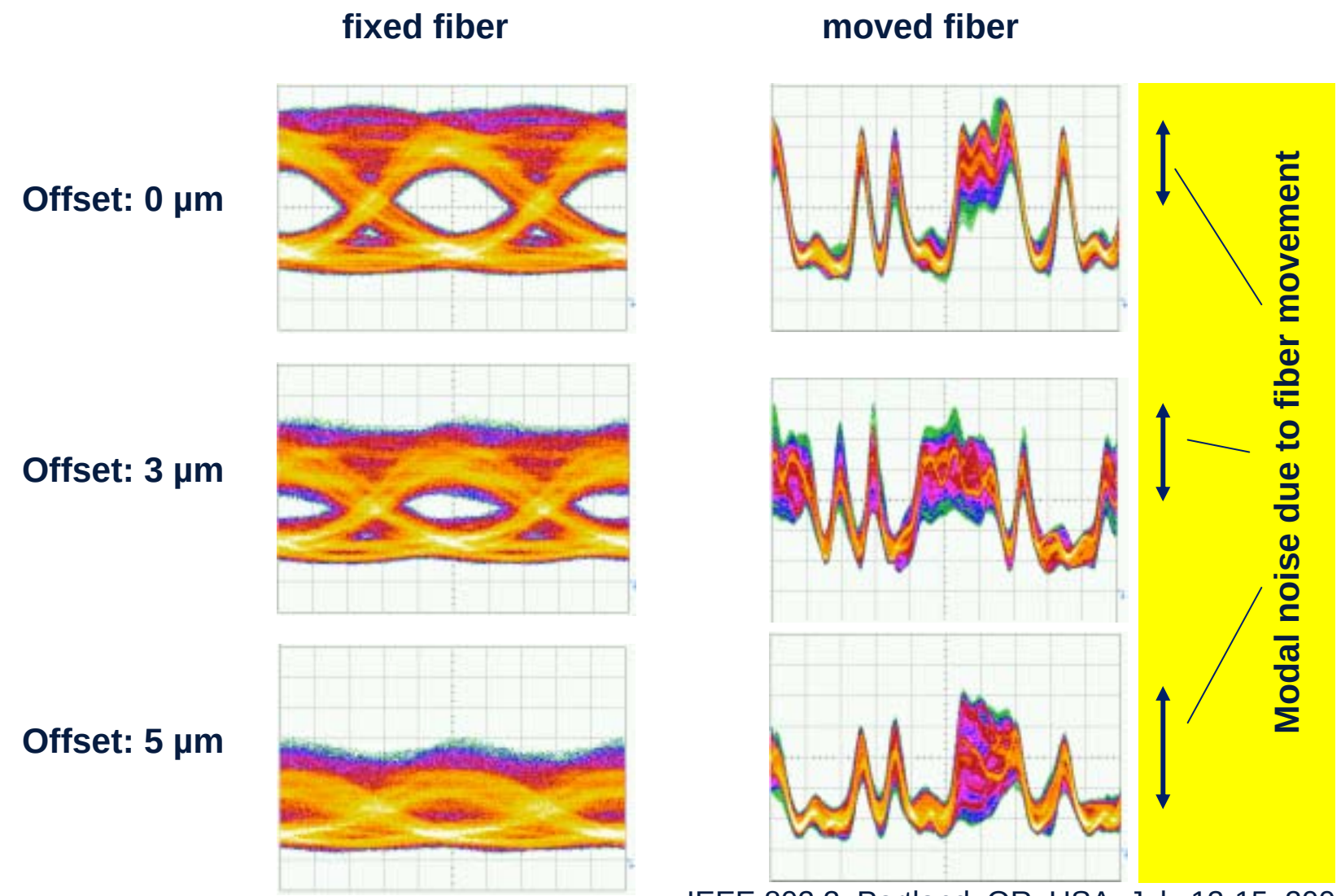
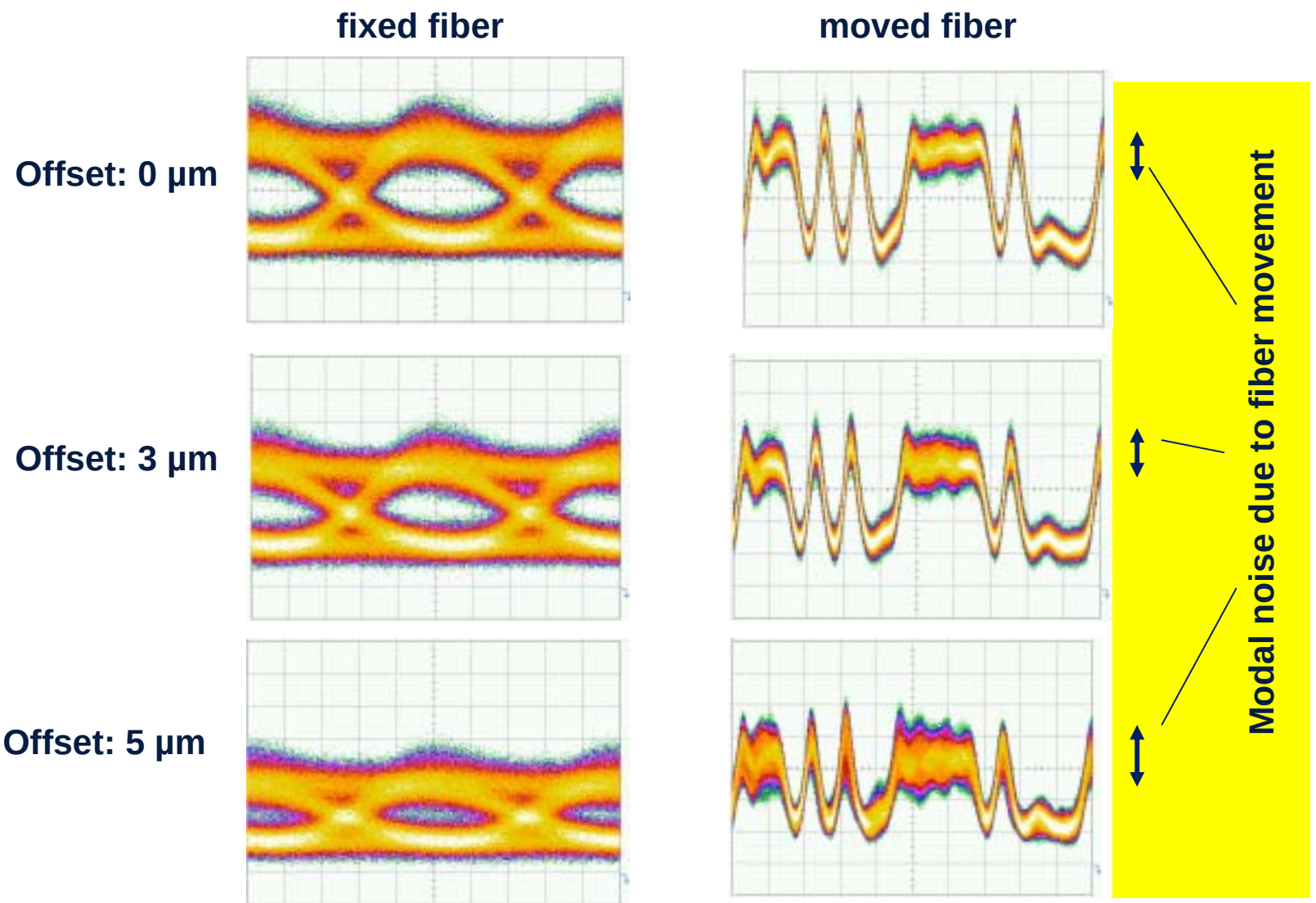
DFB- Laser
Eye Diagrams, Pattern Effects and Noise for various Offsets



FP- Laser

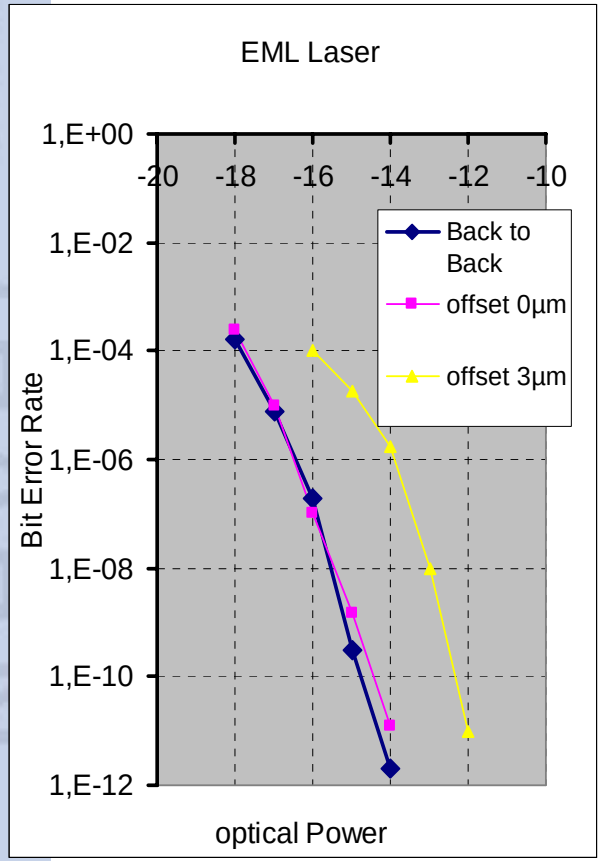
Eye Diagrams, Pattern Effects and Noise for various Offsets

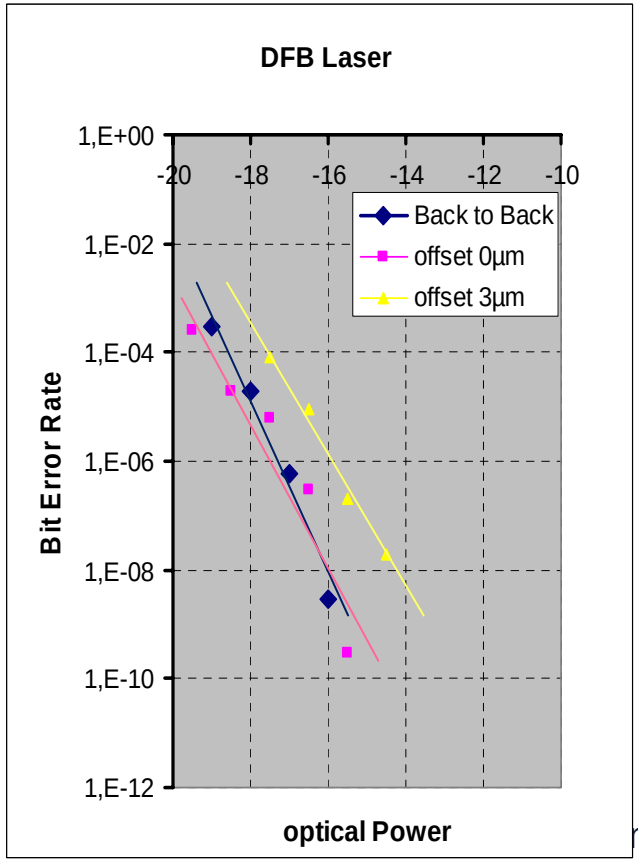


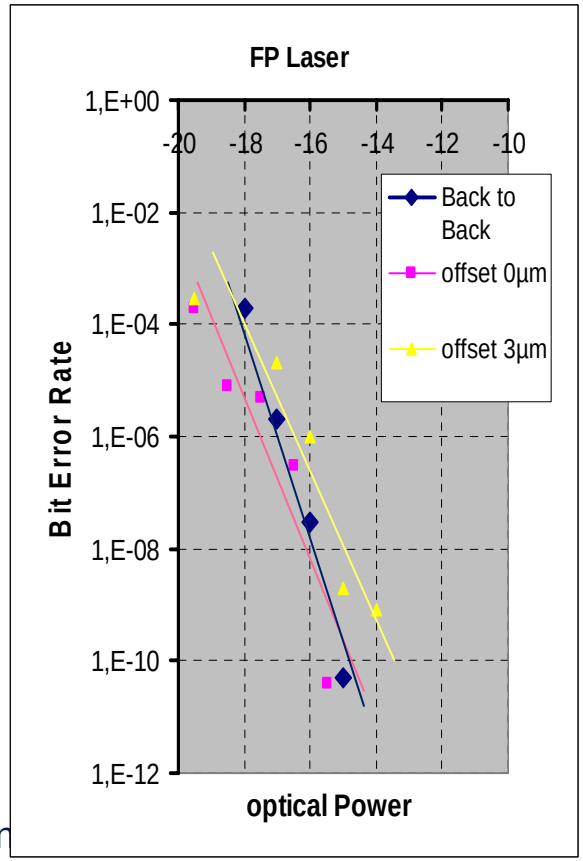
Experiments: Transmission over 300m Multimode Fiber
BER Measurements with Fixed Fiber

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



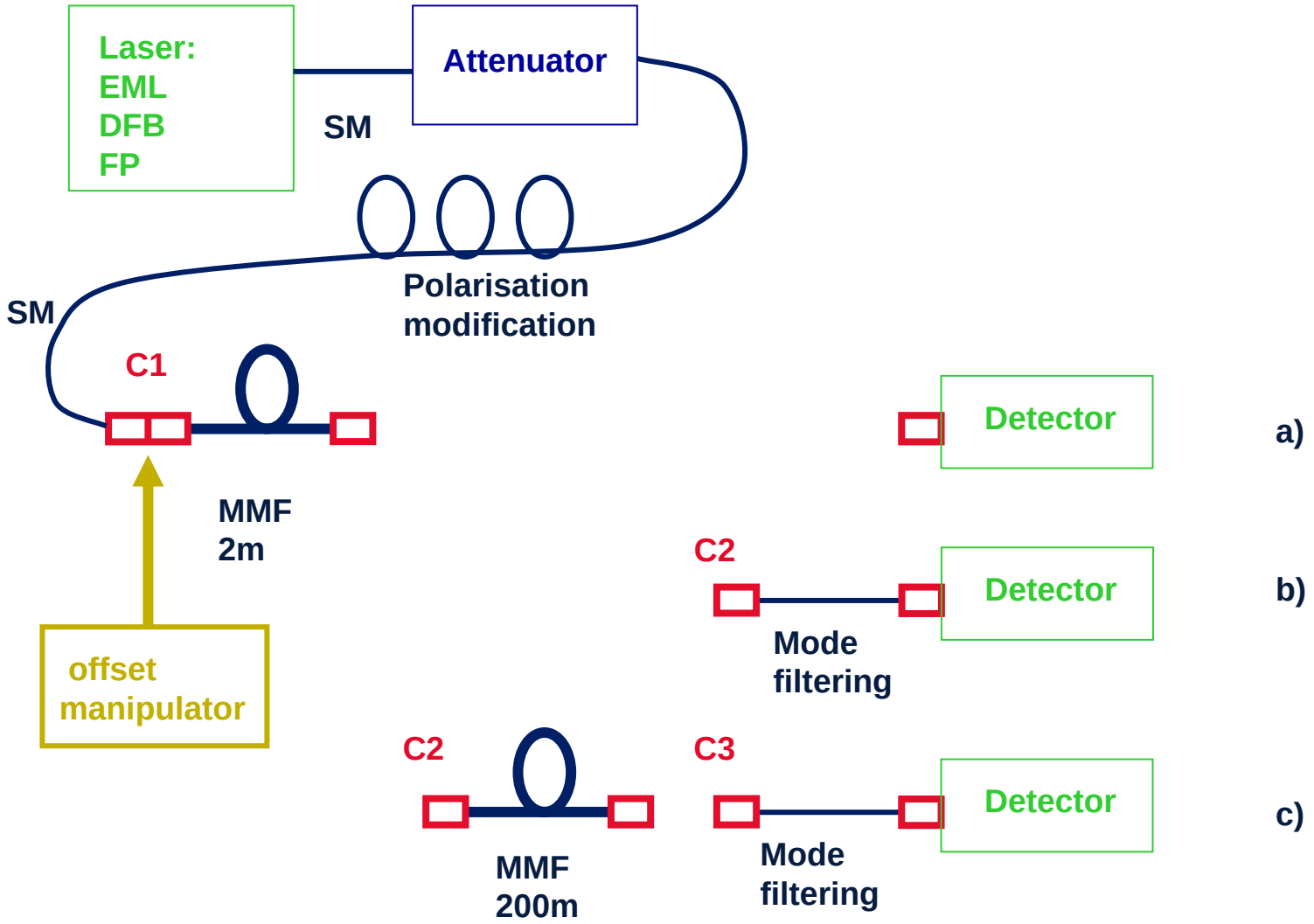




Polarization Sensitivity of Transmission

- 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

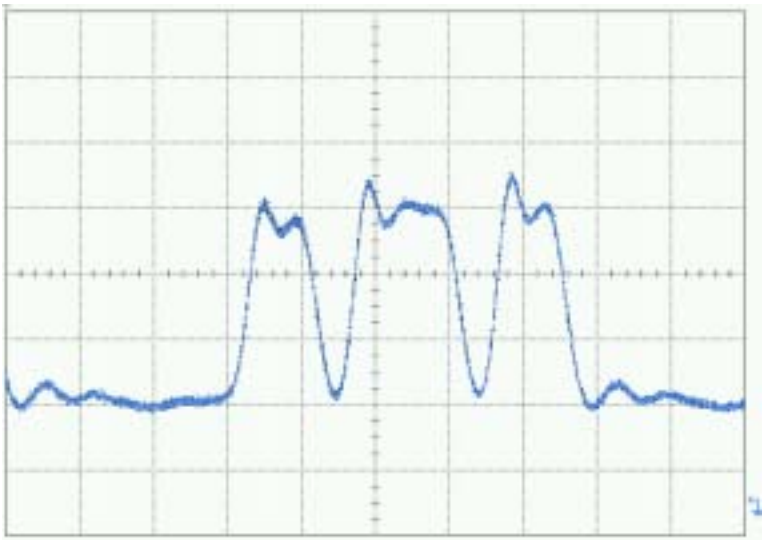
Center Launch Experiments
Polarisation Sensitivity of Launch Condition



Center Launch Experiments
Polarisation Sensitivity of Launch Condition SM – MM, 2m

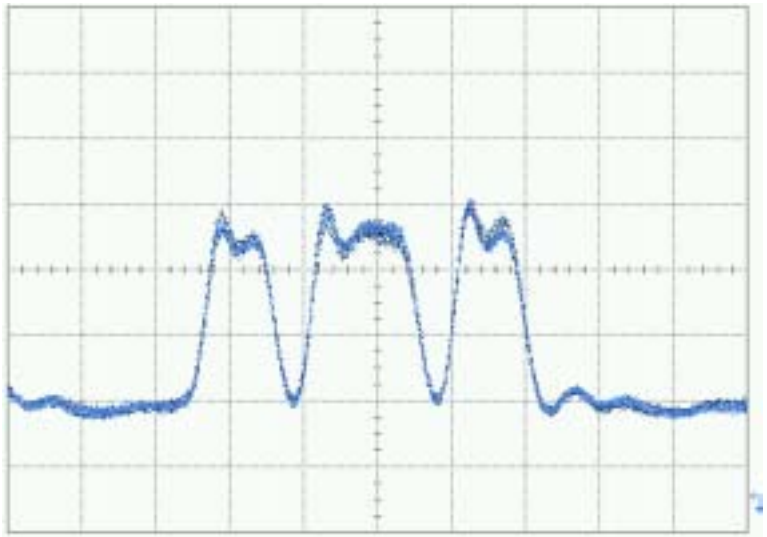
Single mode fiber to
Multimode fiber
Offset: 5 µm
w/o mode conditioning at RX

Result:
No pattern variation with polarisation



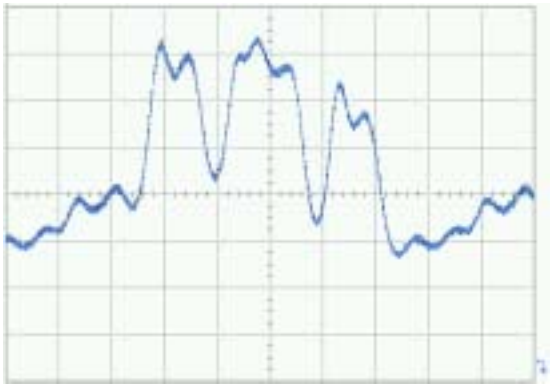
Single mode fiber to
Multimode fiber
With mode conditioning at receiver
Offset: 5 µm

Result:
No pattern variation with polarisation,
Some noise due to attenuation



Center Launch Experiments
Polarisation Sensitivity of Launch Condition SM – MM, 200m

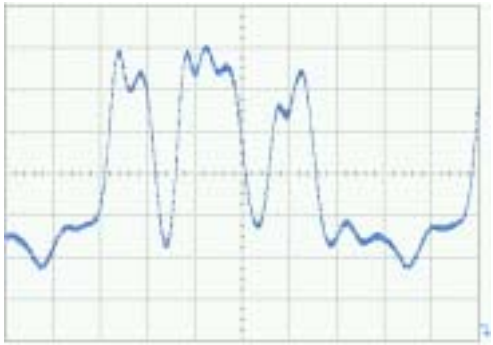
Single mode fiber to
Multimode fiber (2 + 200m)
Offset: 0 µm
w/o mode conditioning at RX



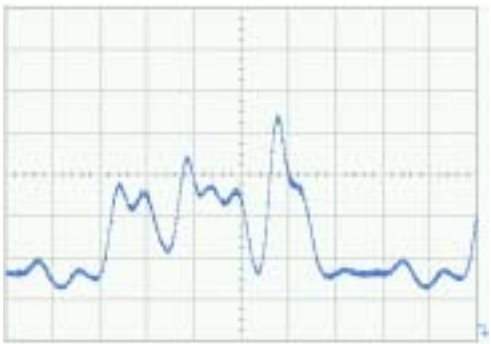
Result:
Some Pattern variation with polarisation

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

P1



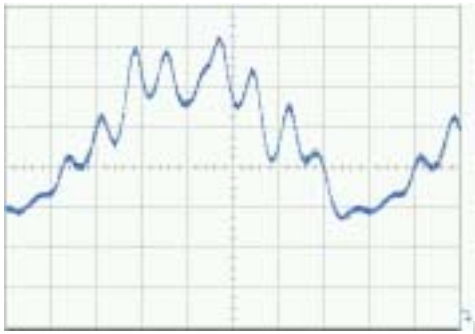
P2



Result:
Pattern variation with polarisation
but still possible to recover

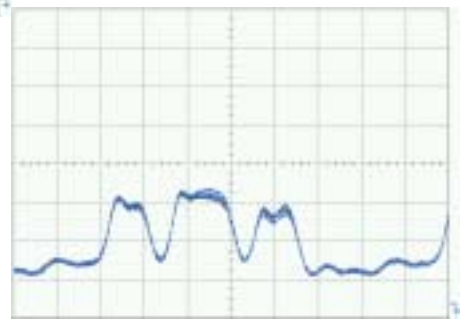
Center Launch Experiments
Polarisation Sensitivity of Launch Condition SM – MM, 200m

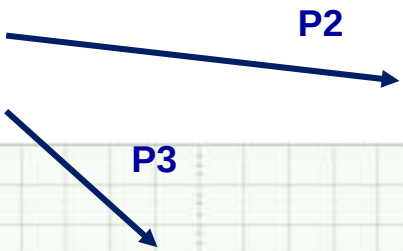
Single mode fiber to
Multimode fiber (2 + 200m)
Offset: 5 µm
w/o mode conditioning at RX

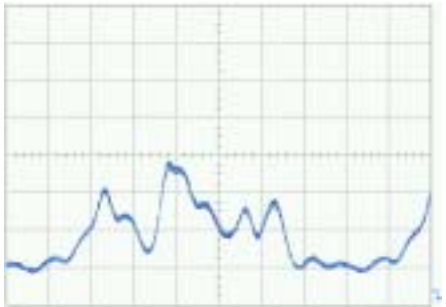


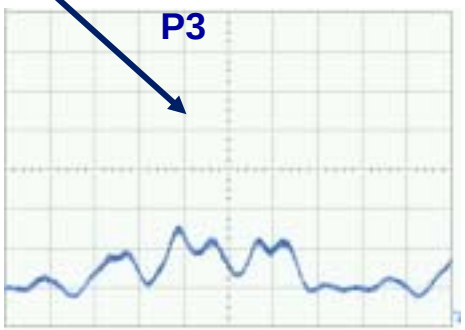
Result:
Destroyed pattern

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

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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)

Center Launch Experiments
Conclusion

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!