

10Gbit/s Pulse Response of Multimode Fiber Simulation and Measurements

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- **Simulation of Worst Case Multimode Fibers**
- **Results of Pulse Response**
- **Comparison of Overfilled Launch with Offset Launch**
- **Confirmation of Simulation with Measurements**

Objective

- Derive (and explain) worst case pulse responses for the 10Gbit/s transmission over 300m of 62,5 μ m legacy multimode fibers with 1310nm

The result can be used to test and select algorithms for electronic dispersion compensation

Outline of the Analysis

Legacy FDDI-grade fibers are tested and selected using overfilled launch condition (OFL) (Bandwidth (BW)= 500MHz*km)

➔ Simulation:

- construction of fibers which reach BW of 500MHz*km with OFL
- calculation of pulse response for 10Gbit/s over 300m with OFL
- calculation of pulse response with offset launch (OSL) according to GbE

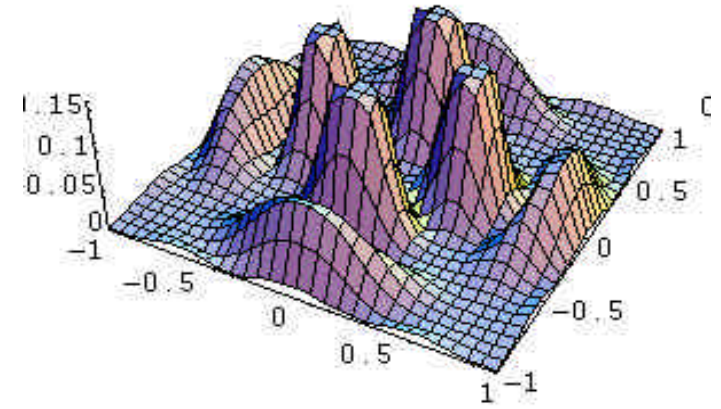
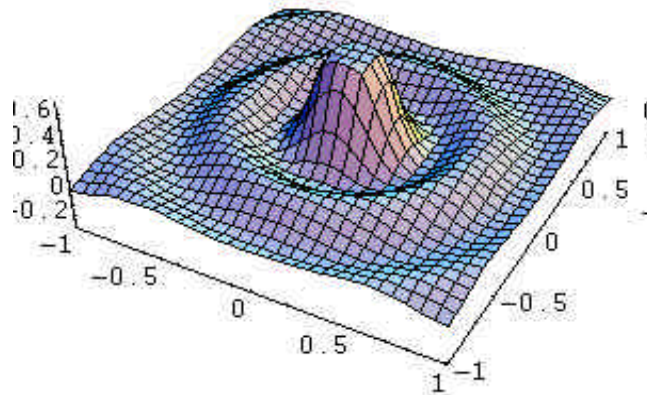
Measurement of pulse responses with 10Gbit/s on „worst case“ fiber

Simulation of Optical Transmission in Multimode Fiber

- Description of transmission behavior with $LP_{m,n}$ -Modes:

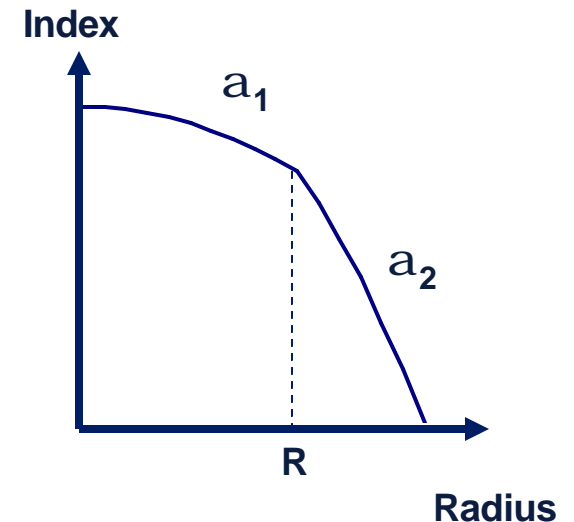
$$U_{m,n}(r, \mathbf{j}) = \begin{cases} F_{m,n}(r) \cdot \cos(m \cdot \mathbf{j}) \\ F_{m,n}(r) \cdot \sin(m \cdot \mathbf{j}) \end{cases}$$

- Performance of transmission by parabolic index profiles are modeled with Laguerre-Gauß-Polynoms
- Example: $LP_{0,2}$ und $LP_{2,4}$

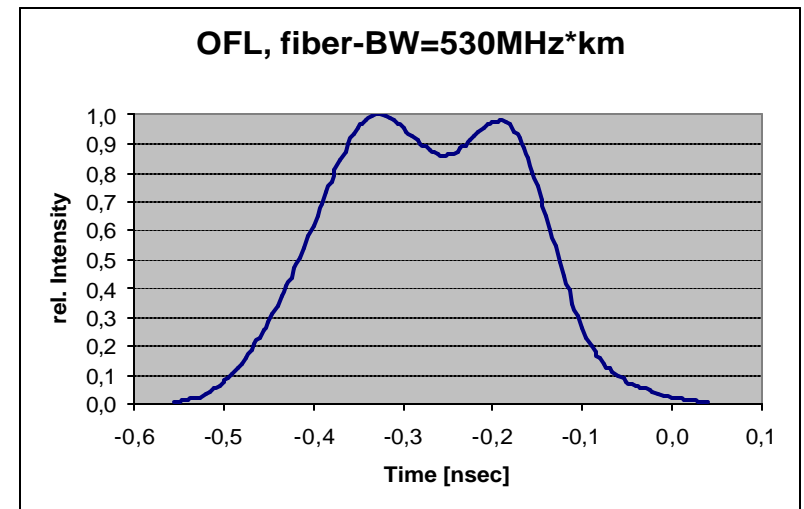
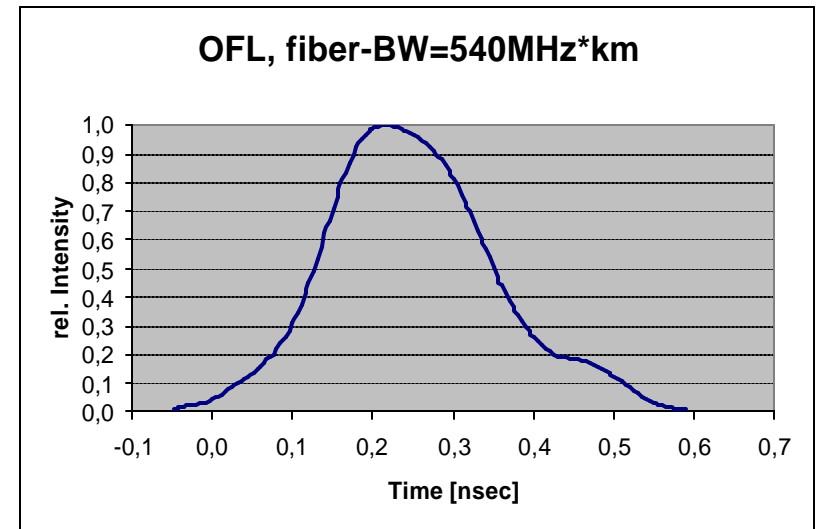
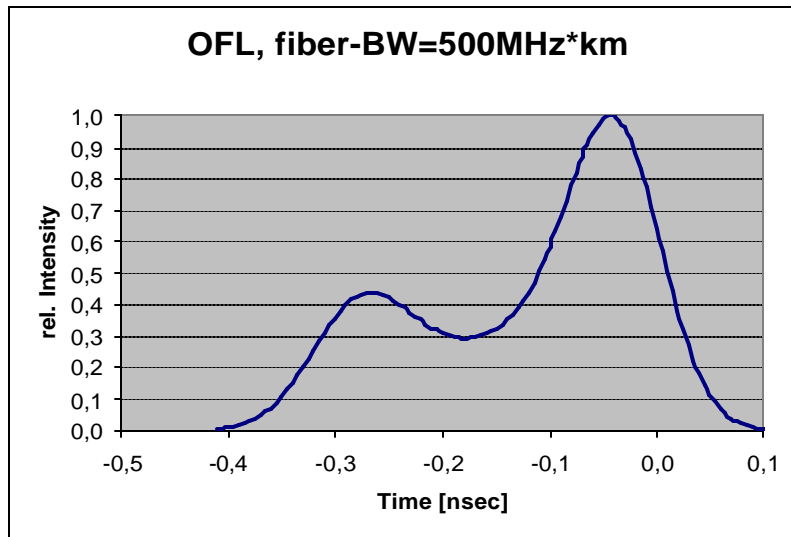


Construction of Worst Case Fibers

- With OFL most optical power is transmitted in larger radii
- Fibers with two areas of different refractive index are created. Transition between these areas is in region of larger radii.
- Free Parameters:
 - exponent α_1 for area one
 - exponent α_2 for area two
 - radius of the transition between the two radii



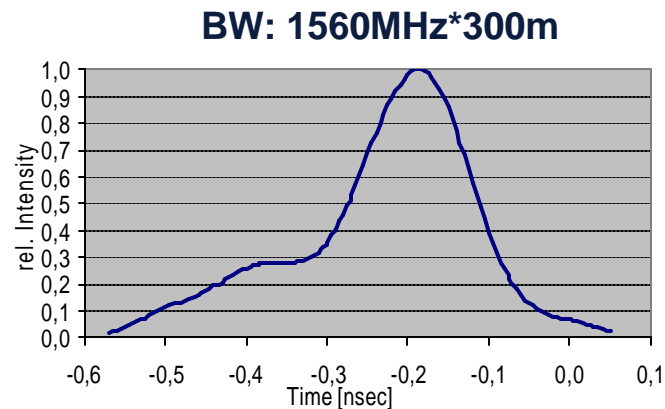
OFL- Pulse Responses of Various Fibers



Pulse Responses with radial offset - Example Fiber A

Comparison of Pulse response of OFL with OSL

OFL

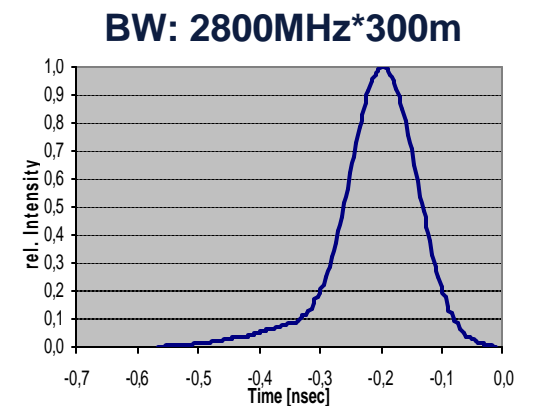
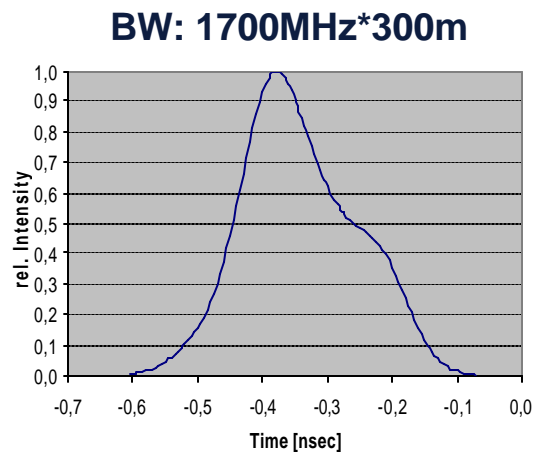
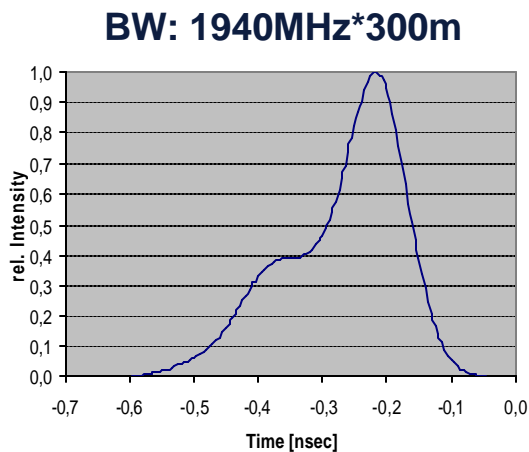


OSL

17 μ m

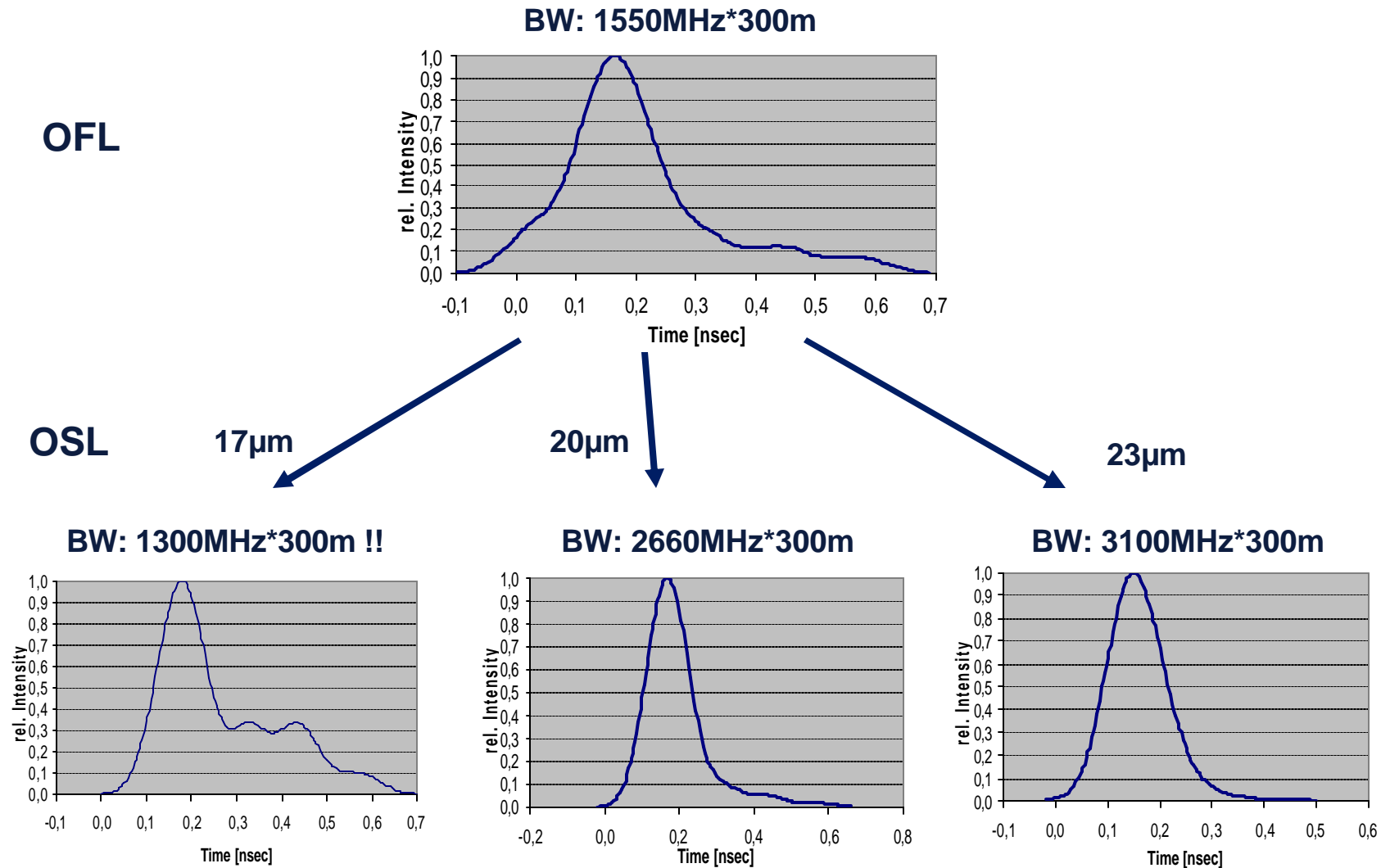
20 μ m

23 μ m



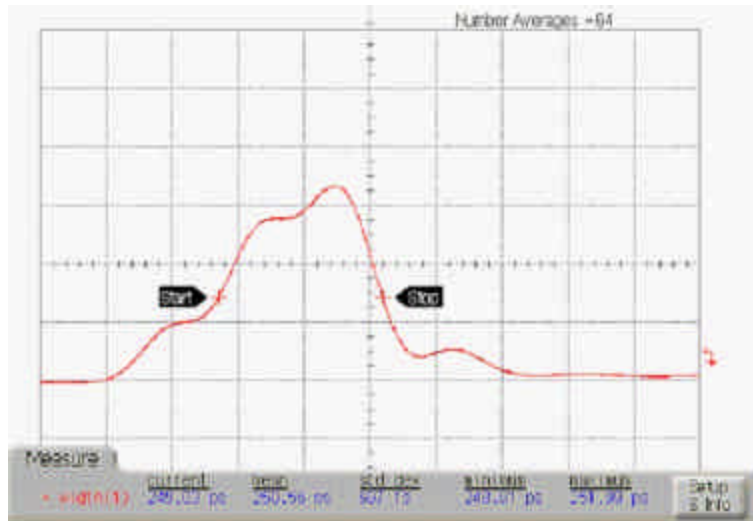
Pulse Responses with radial offset - Example Fiber B

Comparison of Pulse response of OFL with radial offset launch

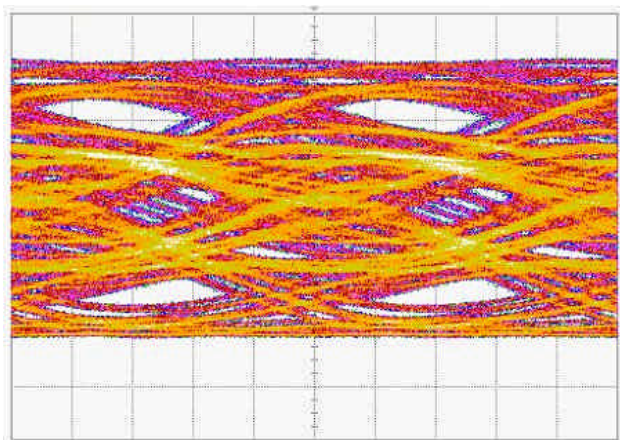
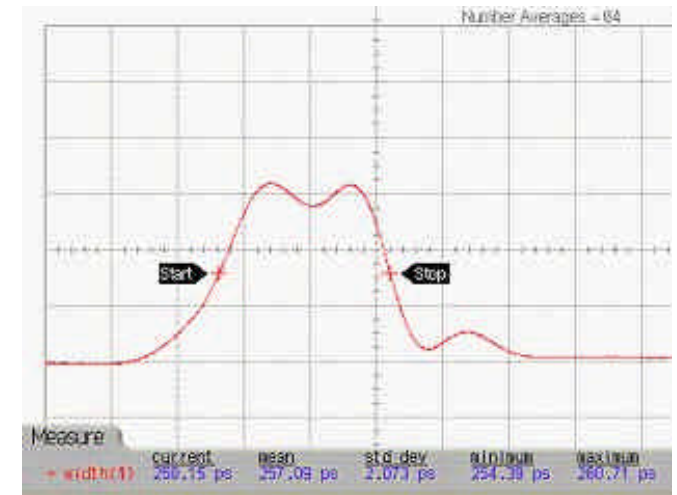


Experiments with „worst case“ Fiber - Pulse Response after 300m with OSL Launch DM Laser

With cable position A

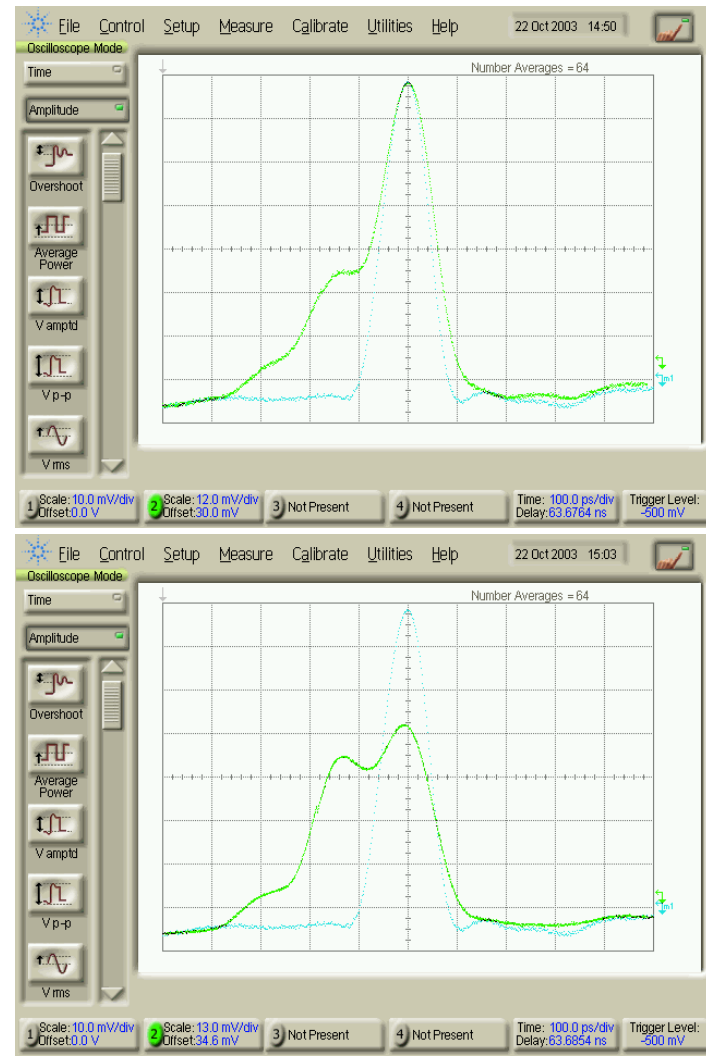
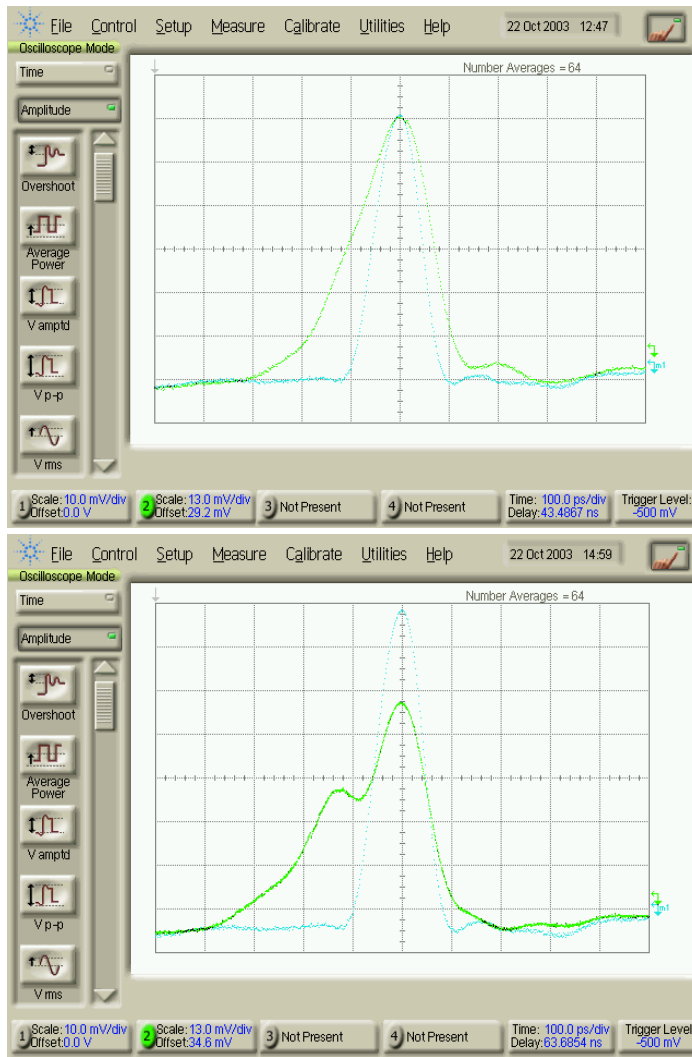


With some cable twisting



**Resulting eye diagramm
for 10Gbit/sec**

Experiments with „worst case“ Fiber - Pulse Response after 300m with OSL Launch EM Laser



Test data using the same setup with 62.5µm MMF

What have we learned:

- The basic pulse precursor, postcursor and double pulse are demonstrated by using simple two-exponent refractive index profiles
- Offset launch condition defined in GbE should exceed the specified fiber bandwidth in most cases but it can not be guaranteed.
- Small variations of 2-3 μm of the offset can cause significant change in pulse response.
- Pulse shape can vary if the power distribution in the fiber is changing (e.g. by change of fiber bending)
- Experiments confirm the pulse shape simulations