Variation in Multimode Fiber Response: Summary of Experimental Results

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Variation in Multimode Fiber Response: Summary of Experimental Results

- **Introduction**
  - A variation is observed in the output of multimode fiber (MMF) due to launch polarization and fiber movement.
  - The result is a variation of pulse shape or deformation of the transmitted pattern in the 10Gbit/s transmission.

- **Objective of the experiments**
  - Understanding of the basic cause of the effect
  - Attempt to explain the observed variations
  - Establish a set of results for a comparison with theoretic approaches

- **Experiments without connectors to separate fiber effect**
  - Various laser sources with controlled polarization
  - Precisely controlled offset launch SMF to MMF
  - 3 Test fibers (2x OM1-fibers, 1x OM3-fiber)

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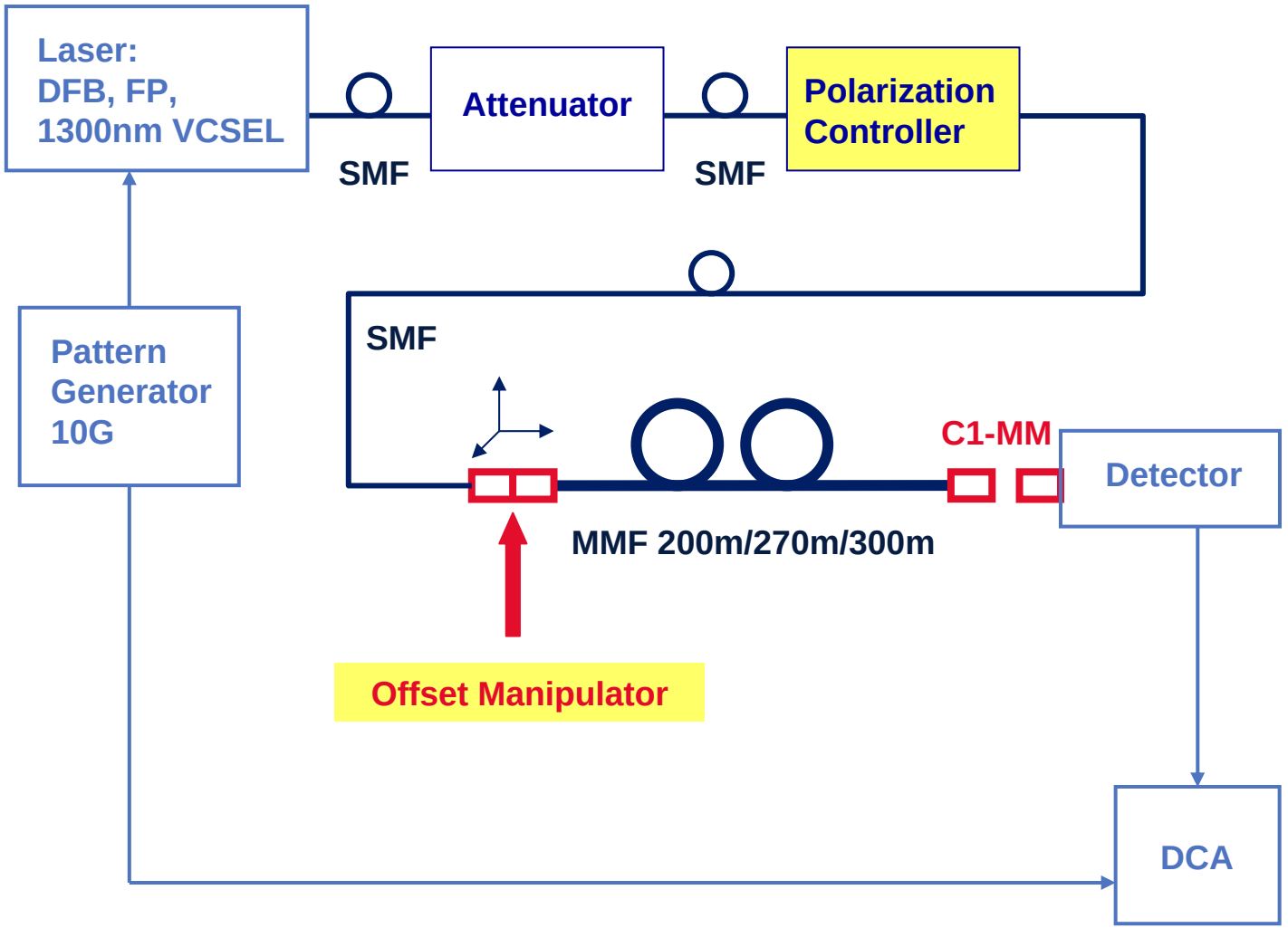
Variation in Multimode Fiber Response: Experimental Setup of Infineon Fiber Optics



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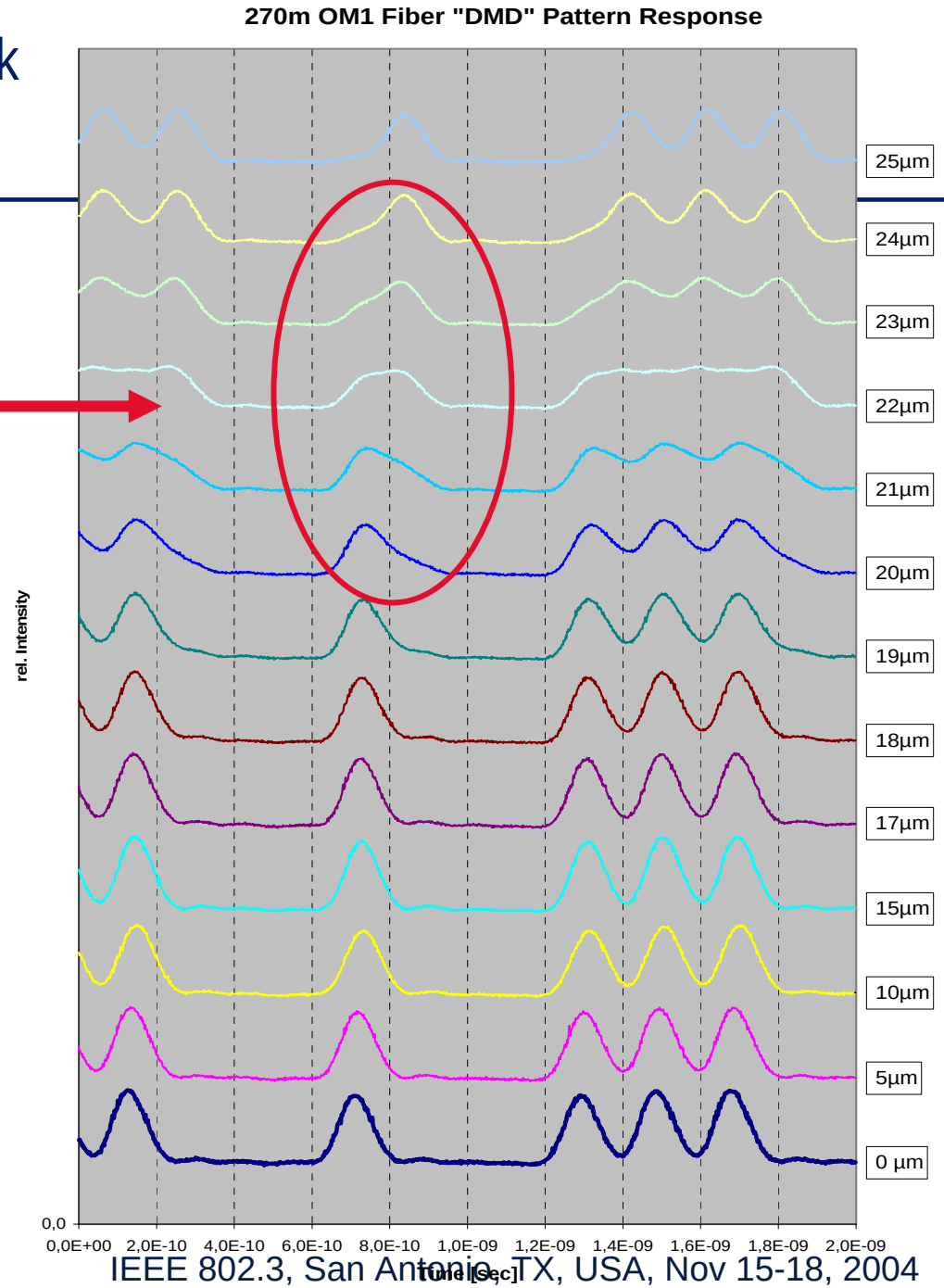
Example of a Fiber with a kink at a certain offset

Significant change of pulse response within offset area of 2 µm –
change from precursor to postcursor

- Change of pulse response caused by change of polarization or fiber stress

- No change of pulse response with SM launch at smaller radii



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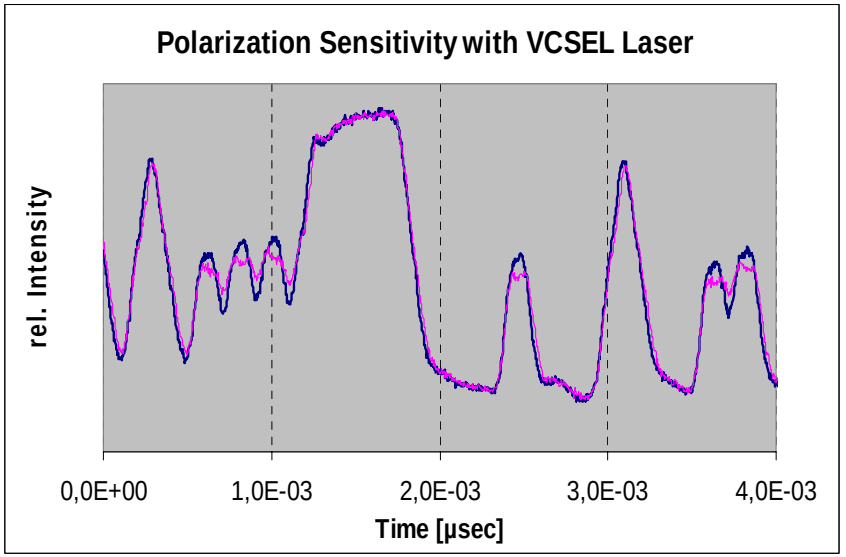
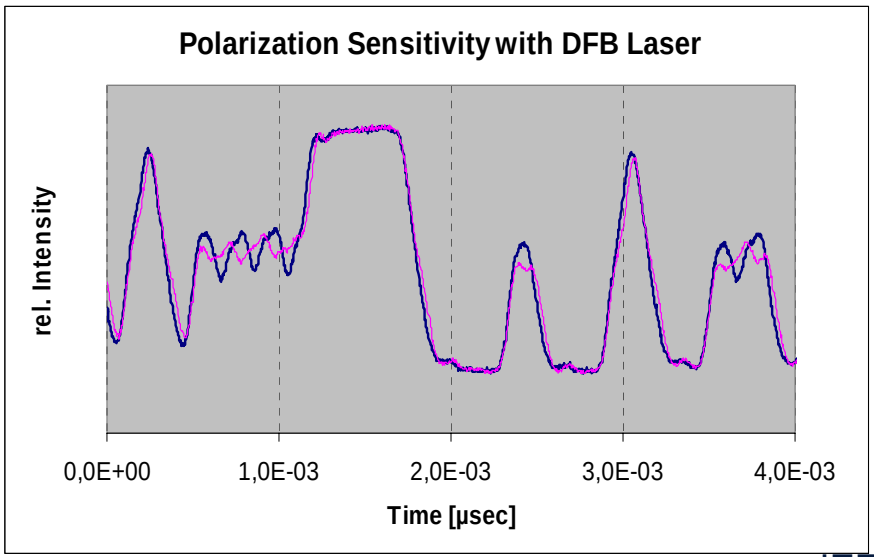
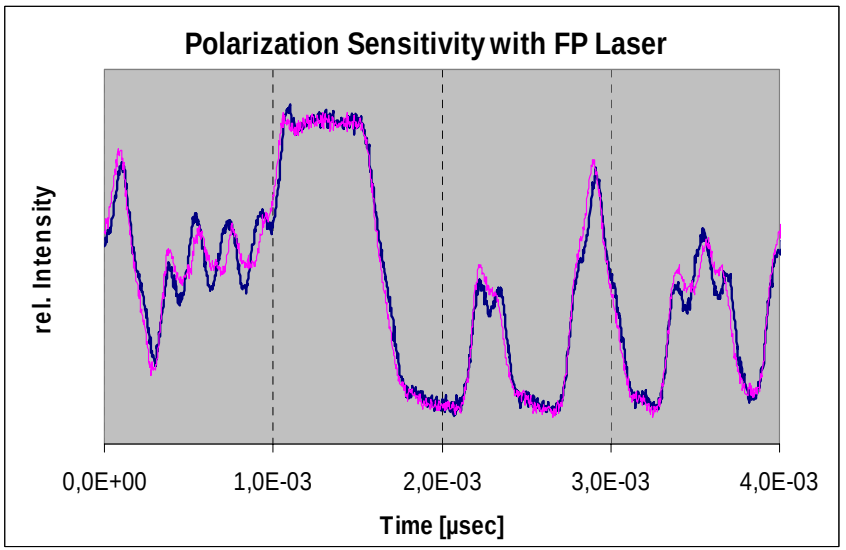
Fiber with a kink at a certain offset
Polarization effect with various laser sources

Section of a 2^7-1 bit sequence after 270m of OM1 fiber with 875 MHz*Km, Observed patterns using SM launch with two orthogonal polarizations.

Result: similar effect with all 3 sources







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Variation in Multimode Fiber Response: Results (I)

1. Variation in MMF response is observed without any connector and without any mode selective loss (it is **not** a modal noise effect)

2. The effect is sensitive to :
   - change of polarization orientation of launch
   - mechanical stressing of the fiber (vibration etc. …)

3. The effect is maximal if the light is launched into the area of the core of the MMF which shows large distortions of the refractive index profile. The effect is observed with:
   - launch close to center in fibers with a dip in the center
   - offset launch in fibers with a kink
   - several offsets in fibers with strong profile distortions

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Variation in Multimode Fiber Response: Results (II)

4. The effect is **not** observed :
   - in fibers with small distortions
   - with offset SM launch at radii with no or small distortions of the index profile

5. The effect is observed to be a power exchange between neighboring modes or mode groups
   - If there is a time delay between the modes at the end of the fiber this power exchange generates a change of the pulse response of the fiber

6. Various laser transmitters used in combination with the same fiber configuration show a similar effect
   - FP-laser
   - DFB- laser
   - 1300nm VCSEL

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Variation in Multimode Fiber Response: Results (III)

7. The effect seems to be an intrinsic property of the multimode fibers
   - it increases with the transmission length of the fiber

8. Connectors have no primary influence
   - in selected combinations of connectors with a fiber with profile distortions, connectors can reduce or enforce the effect because there is an uncertainty of the core position caused by the radial tolerances of the MM connectors.

9. Changing the polarization of the fiber launch or moving the fiber with fixed input polarization produces the same pulse variation.

10. The effect can be reproduced well if it is possible to reach the exact configuration of polarization, offset position, fiber stress, ….

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Variation in Multimode Fiber Response: Explanation of the effect

- The effect is induced by fiber movement, bending or vibration. That indicates that mechanical stress has a strong influence. This is explained by the induced birefringence which influences polarized light.

- All MM fibers have large internal mechanical stress as the result of the material composition and the manufacturing process. This stress may generate some power transfer between modes if the direction of the polarization is changing.

- Deviations from circular symmetry of the core dimensions and symmetry of the stress may also induce this effect.

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Variation in Multimode Fiber Response: Consequences for EDC Implementation

- The observed pulse forms are similar to the known pulses (e.g. which can be simulated from the 108 fibers from the Cambridge model)
- These pulse forms are considered for the TP3 testing (Petre *et al.)*
- The new addition to the transmission is the observed time variation of the pulse form which may be caused by temperature changes or time varying mechanical stresses like vibrations. Since these effects are mechanical, the frequencies are in the order of some 10 Hz maximum.
- Therefore, it seems that the effect does not produce an additional penalty as long as the EDC is tested in TP3 for the various pulse forms. As a new item, the dynamic change of the pulse form should be considered in the requirements of the EDC.

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