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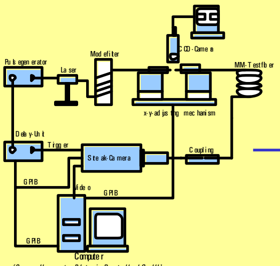
High Resolution Differential Mode Delay Analysis of LASER-optimized Multimode Fibers

High Resolution Differential Mode Delay (HRDMD) measurement

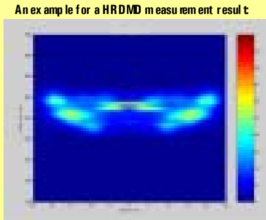
FiberCore Jena AG has a high resolution, high accuracy measurement equipment to determine the DMD-structure of a Multimode fiber. A Single-Mode fiber scans the face surface of a Multimode fiber and excites selected modegroups.

Parameter	High Resolution DMD	Conventional DMD
spot diameter in µm	5	17
time resolution in ps	2	50
scan step in µm	1	2



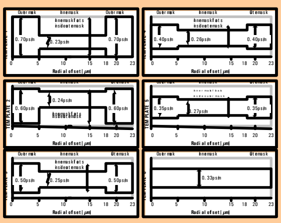
[Source: Hamamatsu Photonics Deutschland GmbH]

An example for a HRDMD measurement result



Specification of 10GbE fibers with HRDMD

As transmission speeds reach 10 Gb/s DMD measurements become the only reliable method of ensuring bandwidths. With the declared DMD requirements in IEEE 802.3ae a minimum effective bandwidth of 2000MHz* km can be ensured by using transmitters specified by IEC 61280-1-4. To reduce the complex description of the mode structure two radial masks are introduced and analyzed. The following illustration contains the DMD condition for these radial masks. The fiber have to meet at least one of these DMD templates.



[Source: ECSC 86A]

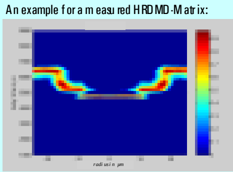
Additional to this condition the fiber DMD shall not exceed 0.25 ps/m for any of the following radial offset intervals.

Interval number	R_{INNER} (µm)	R_{OUTER} (µm)
1	7	13
2	9	15
3	11	17
4	13	19

Refractive index profile optimization based on HRDMD

HRDMD provides feedback to enable accurate and precise control of the Preform manufacturing process. Therefore it is possible to adapt the refractive index profile of the fiber directly to a nearly parabolic profile.

An example for a measured HRDMD-Matrix:

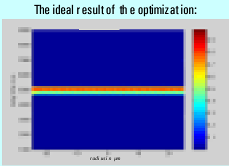


With a theory developed by K. Petermann it is possible to determine the profile deviations of the current Profile- to the ideal Profile-Structure

$$\Delta f_D(r_p) = \tau(r_p) - \frac{r_p^2}{a^2}\tau(a) - 4r_p^2 \int_{r_p}^{a} \frac{\tau_w(r)}{r^3} dr$$

Δf_D : profile correction
r_p : radial position
τ : standarized delay time
a : core radius

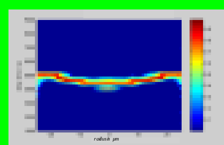
The ideal result of the optimization:



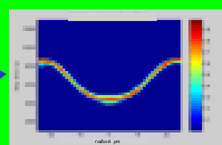
Determination of Effective Modal Bandwidth by HRDMD

Measurement of the DMD-behavior at 850nm can be transformed to get information about the DMD behavior at 1300nm. Therefore it is possible to calculate Effective Modal Bandwidths (EMB) for different launch conditions like Overfiled or Restricted Mode Launch for both wavelengths. Different launch conditions cause a difference in mode exciting and therefore a different respective EMB. This EMB can be determined with knowledge about the Mode Power Distribution. In that way the fundamentals are now available for future deployments of Vertical Cavity Surface Emitting Lasers (VCSEL) at 1300nm.

Transformation from 850 nm to 1300 nm

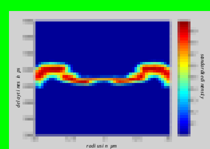


HRDMD Matrix at 850 nm



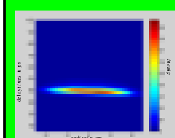
HRDMD Matrix at 1300 nm

Simplified illustration of the procedure to calculate the Effective Modal Bandwidth



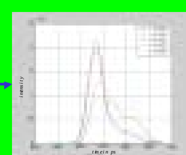
1. Measured HRDMD Matrix at 850 nm

3. Weighting functions simulate different launch conditions



2. HRDMD reference of the measurement system

Determination of Pulse Response



4. Pulse Response for different launch conditions

Fourier transformation and bandwidth determination for every launch condition