Dispersion penalty measurements on SMF and NZDSF fiber

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1 Introduction:

Dispersion in optical fibers is caused by the refractive index of glass being a function of wavelength, which results in the spectral components of a pulse traveling at different group velocities along the fiber. Hence chromatic (material) dispersion broadens optical pulses beyond their time slot, leading to inter-symbol interference (ISI). A second component of dispersion in optical fibers is known as waveguide dispersion. This component arises because the proportion of light traveling in the fiber core versus cladding is a function of wavelength. The dispersion coefficient of a fiber is defined as $D = d(1/v_g)/d\lambda$. The typical dispersion coefficient of single mode fiber (SMF) is 16 ps/nm.km at 1550 nm. Non-zero dispersion-shifted fibers (NZDSF) such as LEAF™ [1] and TrueWave-RS™ [2] have lower dispersion coefficients than SMF (~4ps/nm/km).

Dispersion induced pulse broadening results in eye closure, which in turn leads to higher bit errors. Increasing the launched power can compensate for this eye closure. Hence, the effect of dispersion can be measured in terms of a power penalty or dispersion penalty. In a dispersion limited system, a higher link budget is therefore necessary. This leads to increased transmit power or higher receiver sensitivity requirements.

In this paper, we report on the results of using an Inphi driver amplifier and receiver to build an 80km fiber link with 3 different fiber types (SMF and NZDSF fiber). The dispersion penalty was measured for each fiber type, in order to determine if the system has an adequate power budget.

2 Measurement setup:

An Inphi 1310DZ driver was used to amplify a pseudo-random bit sequence of length 2^{31}-1 @10Gb/s and drive a dual Mach-Zehnder modulator. External bias tees were used to bias the modulator at its 3dB operating point. The tunable laser was set to 1550nm and an output power of 10dBm. 1.5dBm of average modulated optical power was launched into the fiber. The fiber loss in all 3 types is approximately 0.2dB/km, leading to fiber loss of approximately 16dB. An Inphi 1341TL TIA was packaged with a photodiode and used as the 10G receiver. An optical attenuator was used to vary the power incident on the 10G receiver. Back to back measurements on the receiver were performed prior to coupling the

[1] LEAF is a registered trademark of Corning.
[2] True-Wave-RS is a registered trademark of Lucent Technologies.

modulator output into 3 different types of fiber: Standard single mode (SSMF), Corning's Large Effective Area fiber (LEAF) and Lucent's True Wave Reduced Slope (TWRS). The SSMF and TWRS spans were of length 80km, while the LEAF span was 88km. Bit Error Rate (BER) measurements were performed at the output of each span to infer the penalty due to dispersion in optical fiber. Eye measurements were made on a Tektronix CSA 8000 sampling oscilloscope.

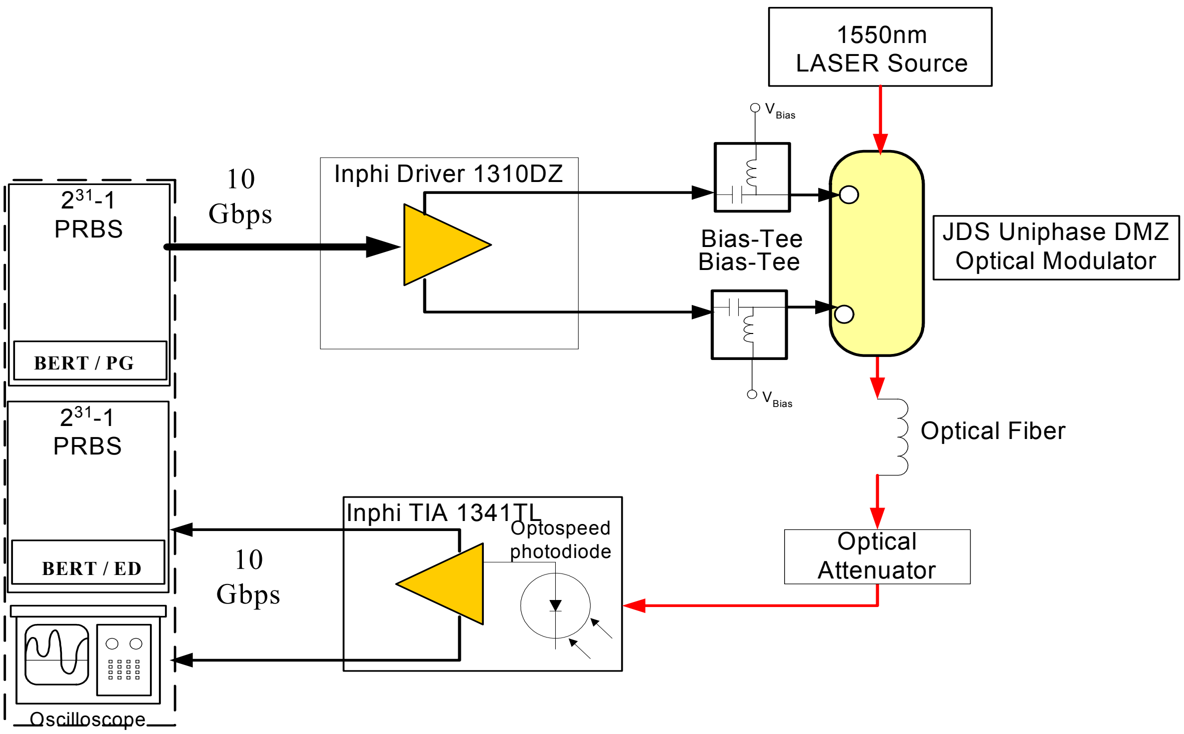

Figure 1: Measurement setup to test Dispersion Penalty

3 Measured Data:

Figures 2 and 3 show the measured electrical eyes after 80km of SSMF and TWRS. Note that the "1"s are more dispersed than the "0"s, since there is more power in a 1 than a "0". This results in the pointed shape of the pulse. The "101" sequence is effected the most, resulting in the power in the "0" rising. Note that the crossing percent decreases. For SSMF, with a higher dispersion coefficient, the eye closure is obviously more severe than for the TWRS fiber.

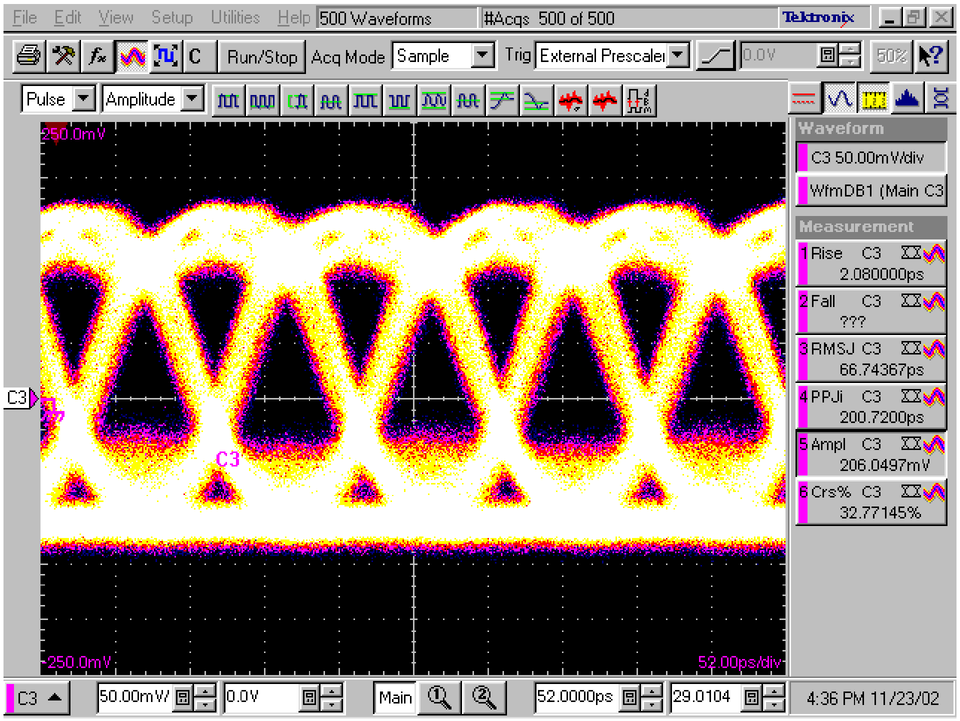

Figure 2: Electrical eye after 80km of SSMF

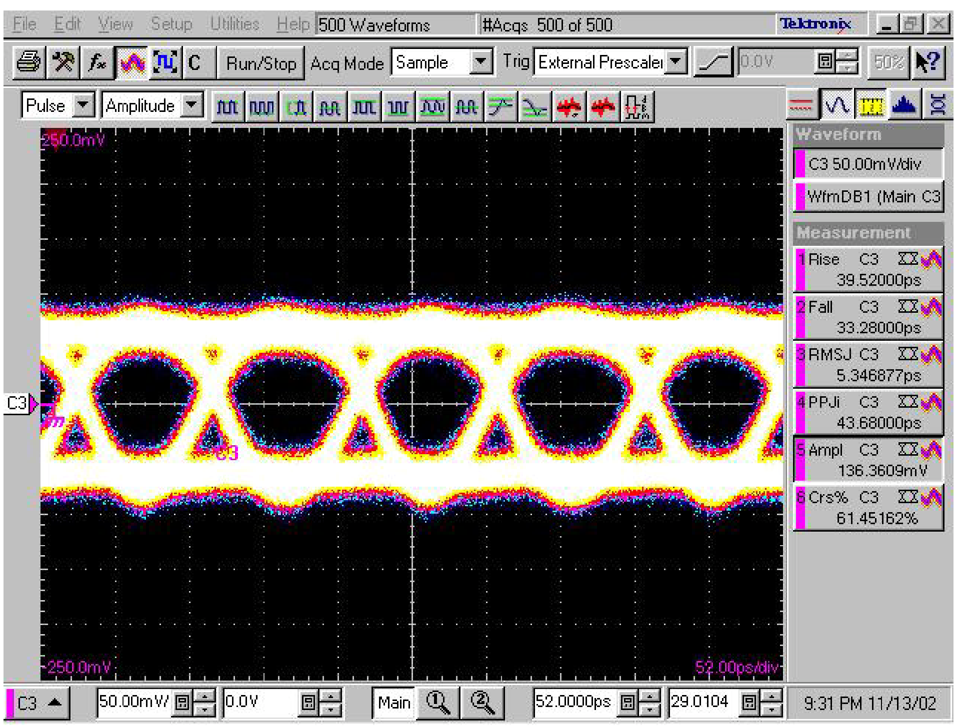

Figure 3: Electrical eye after 80km of TWRS (inverted TIA output)

Figure 4 shows the BER curves for the 3 types of fiber indicating the dispersion penalty. For SSMF, the penalty is about 2.5dB at a BER of $1e^{-12}$, while the LEAF and TWRS fibers show almost no penalty. The BER curve for SMF indicates that –16.5dBm of optical power is required at the receiver in order to achieve a BER of $1e^{-12}$. With a launch power of 1.5dBm, and 80km of fiber loss, we still have a link margin of 1dB. For the LEAF and TWRS fibers, the link margin is about 3.5dB.

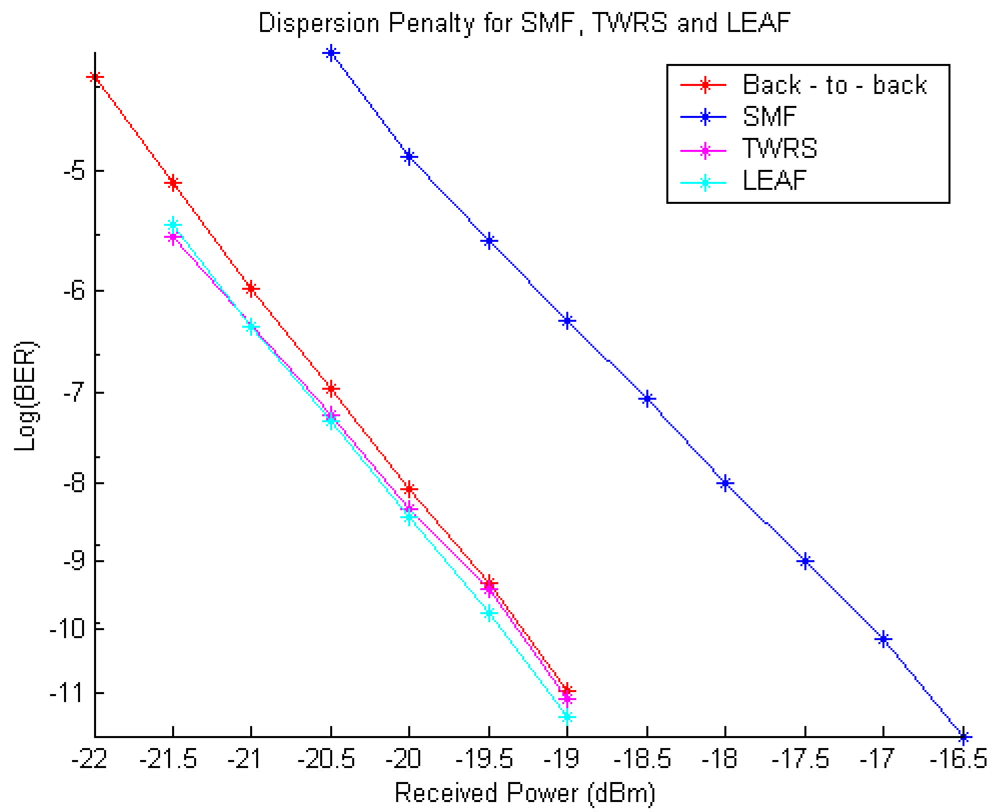

Figure 4: BER curves for SSMF, TWRS and LEAF

3.1 Summary:

We have demonstrated a dispersion limited 80km fiber link with an Inphi 1310DZ driver amplifier and 1341TL receiver. With an ECL laser and a receiver sensitivity of –19dBm, the link margin is about 1dB. Distributed feedback (DFB) lasers are currently available with 20mW (13dBm) of output power; the link margin can thus be increased even further. For the NZDSF fibers and a 13dBm DFB laser, the available power budget will possibly enable us to achieve a BER of $1e^{-12}$ even after 100km.