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Applications
Engineering Note

Transmission Skew in Optical Fiber Ribbons

AEN057, Revision 4

Introduction

Variations in the optical fiber manufacturing process at the microscopic and macroscopic levels (e.g., dopant concentration and dispersion) may result in optical fibers of the same fiber type (e.g., single-mode or 62.5/125 µm) having dissimilar light transmission characteristics. As a result, identical pulses of light traveling through two different fibers of the same type may propagate at slightly different speeds and emerge with slightly different shapes. These phenomena are due to minute differences in the indices of refraction (IOR) and pulse dispersion characteristics of the individual fibers. These effects are negligible for the vast majority of optical fiber ribbon applications and can be minimized by using fibers with closely similar optical properties. They only become significant when running very high-speed (i.e. multi-gigabit), synchronized, parallel processing applications over multiple fibers in the same optical fiber ribbon.

For cabled optical fiber ribbons, other factors must also be considered. External stresses (e.g., micro bending or macro bending) imparted on fibers may also affect individual fiber light transmission characteristics. Additionally, small differences in the lengths of individual fibers in a given length of ribbon (i.e., excess fiber length) will affect the arrival times of pulses traveling through the various fibers in that ribbon. These cabling effects can be minimized by careful control of the various cable manufacturing processes.

These factors can also be compensated for by some of newer system electronics offered by some electronics manufacturers.

Skew Definition

Corning Cable Systems defines ribbon skew as the maximum difference in time of flight (TOF) of a pulse traveling through each of the different fibers in an optical fiber ribbon, measured in picoseconds (ps), and normalized to a unit length (i.e. ps/m). Pulses are transmitted at specific wavelengths (e.g., 850/1300 nm for multimode fiber and 1310/1550 nm for single-mode fiber) and using the same launch conditions in order to minimize system errors due to differences in system electronics.

Note that the total measured TOF (TOF_T) for each fiber includes the TOF of the pulse through the test bench (TOF_S). TOF through the fiber (TOF_F) is then:

$$TOF_F \text{ (ps)} = TOF_T - TOF_S$$

Ribbon skew is then:

$$\text{Skew(ps/m)} = (TOF_{F(max)} - TOF_{F(min)})/\text{(Ribbon length)}$$

Where $TOF_{F(max)}$ is the maximum TOF for a pulse traveling through any of the fibers in the ribbon, and $T_{F(min)}$ is the minimum.

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Published: 04/28/2017

Skew Measurement

When measuring ribbon skew, the factors having the greatest impact on the accuracy and repeatability of the measurement are sample preparation, launch conditions and the method of pulse detection.

In preparing a ribbon for test, it is imperative that care be taken to ensure the ends of the ribbon are even, and that no fiber is any longer or shorter than any of the others. An offset across a ribbon edge caused by poor sample preparation can introduce significant errors in skew measurement due to differences in the individual fiber lengths. For this reason, breaking any of the fiber ends will require the sample to be reworked.

Variations of the launched pulses can be kept to a minimum by using consistent and repeatable launch conditions. Launch conditions for multimode fiber are set in accordance with EIA-455-54, “Mode Scrambler Requirements for Overfilled Launching Conditions to Multimode Fibers.” This procedure is the same as that listed in Annex B.3 of HIPPI-6400-OPT (working draft), “High-Performance Parallel Interface – 6400 Mbit/s Optical Specification.” Differences in the characteristics of the individual pulses (e.g., shape, center frequency, spectral width, etc.) can contribute to significant errors in skew measurement. The Fiber Optic Test Procedure (FOTP)-54 can also be used for testing single-mode fiber ribbons at 1300 nm. For skew measurements of single-mode fiber ribbons at 1310 and 1550 nm, Corning Optical Communications uses a phase-shift method with single-mode launch and receive conditions.

With respect to pulse measurement, there are several ways of marking the arrival time of an individual pulse (See Figure 1).

1) Arrival of the leading or trailing edge of the pulse (points D and A in Figure 1)
2) Average arrival time of the two -3 dB points, one from each side of the pulse peak (points B in Figure 1)
3) Arrival of the peak power point of the pulse (points C in Figure 1)
4) Arrival of 50 % of the integrated power (points E in Figure 1)

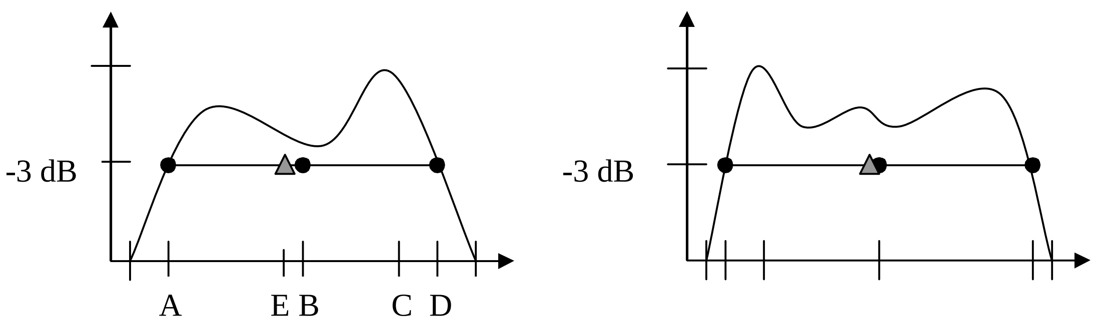

Figure 1: Examples of Arrival Time Marking for Different Pulse Shapes

Of these, Corning Optical Communications uses option 2 (points B in Figure 1) to determine the pulse time of arrival. Corning Optical Communications feels that this method provides the highest degree of repeatability with the requisite level of accuracy.

Summary

Ribbon skew is a measure of the difference in time of flight between pulses traveling through the fibers in an optical fiber ribbon. It is the result of the differences in the light transmission characteristics and lengths of the individual fibers in an optical fiber ribbon imparted by the fiber, ribbon and cable manufacturing processes, and occurs with both single-mode and multimode fiber.

Published: 04/28/2017

The effects, which are only significant when running very high-speed (i.e. multi-gigabit), synchronized, parallel processing applications over multiple fibers in the same optical fiber ribbon, can be minimized by improved process controls and by using fibers with similar optical properties. Sample preparation, launch conditions and detection criteria play significant roles in the accuracy and repeatability of skew measurements. In some instances, skew can be compensated for by system electronics.

Published: 04/28/2017