Evaluation of Dispersion Characteristics of Conventional Single-Mode Fibers

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Abstract – **The use of Chromatic dispersion, dispersion slope and relative dispersion slope as dispersion characteristics are discussed. The results for two types of single-mode fibers in S+C band are presented.**

Keywords – **Chromatic dispersion, Single-mode fibers, Dispersion slope, RDS, Dispersion compensation**

I. Introduction

The chromatic dispersion is the most significant limitation factor of the fiber length for high-speed optical transmission systems. This limitation is more relevant for DWDM systems with high count of channels. The diverse types of fibers have significant differences in their dispersion characteristics. The new NZDS optical fibers have small values of chromatic dispersion in C and L bands [1]. At the same time, most of the optical networks today, use conventional single-mode fibers (G.652). These fibers were designed originally for single channel operation at 1310 nm. They have dispersion of 15-18 ps/nm.km in the 1550 nm window. At the datasheets can only be found dispersion values at 1300 an 1550 nm, as well values for dispersion slope (S_0) at zero dispersion wavelength (λ_0). When increasing the needs of transmission capacity, the operation of these fibers in C as well in S band (1460-1530) nm becomes very important [1].

II. Chromatic Dispersion Characteristics

The broadening of the optical pulse, travelling within a single-mode fiber can be calculated as follows:

$$\Delta t_{out} = \sqrt{(\Delta t_{in})^2 + (DL\Delta\lambda_{mod})^2 + (DL\Delta\lambda_{sour})^2} \tag{1}$$

where: Δt_{in} – length of input pulse; D – chromatic dispersion; L – fiber length; $\Delta\lambda_{mod}$ – modulation spectral broadening; $\Delta\lambda_{sour}$ – source spectral width;

Usually $\Delta t_{in} \ll \Delta t_{out}$, then the pulse broadening will be approximately:

$$\Delta t_{out} \approx |D|\Delta\lambda_{eff} L \tag{2}$$

where

$$\Delta\lambda_{eff} = \sqrt{\Delta\lambda^2_{mod} + \Delta\lambda^2_{sour}}.$$

At small values of D (near zero dispersion wavelength) and at high bit rates, the dispersion high-order components must be taken into account:

$$\beta_2(\omega) = \beta_2 + \beta_3(\omega-\omega_0) + \frac{\beta_4}{2}(\omega-\omega_0)^2 + \frac{\beta_5}{6}(\omega-\omega_0)^3 \tag{3}$$

where β_2 – dispersion value of the fiber at the reference frequency ω_0; β_3, β_4 and β_5 – high order dispersion coefficients. β_2 [ps^2/km], correspond to chromatic dispersion $D(\lambda)$ [ps/nm.km], and β_3 [ps^3/km] – to dispersion slope $S(\lambda)$ [ps/nm^2.km] respectively [4].

The dispersion coefficients β_4 and β_5 must be taken into account at small values of the dispersion and ultra high bit rates (40 Gbit/s and more) [2]. The first two coefficients (β_2 and β_3) only can be used for evaluation of the dispersion at transmission speeds up to 10 Gbit/s:

$$\begin{aligned} D(\lambda) &= \frac{dt_g}{d\lambda}\ \text{[ps/nm.km]} \\ S(\lambda) &= \frac{dD(\lambda)}{d\lambda}\ \text{[ps}^2\text{/nm.km]}. \end{aligned} \tag{4}$$

The relative dispersion slope (RDS) of the fiber is a good assessment of the possibilities for dispersion compensation. RDS is the ratio between the dispersion slope (S) and the dispersion (D):

$$\text{RDS} = \frac{S}{D}\ \text{[1/nm]}. \tag{5}$$

The first condition to get precise broadband compensation is that the dispersion compensating fiber (DCF) should compensate dispersion and dispersion slope of the transmission fiber. This can be achieved by matching the RDS of DCF to that of the transmission fiber.

III. Results

Two typical G.652 single-mode fibers whose characteristics conform to the characteristics of SMF28 (Corning Inc.) and SMF (Alcatel) were modeled with FiberCad.

Dispersion slope and RDS are calculated with the obtained values of D in (1460-1560) nm wavelength band. Fig. 1 shows the chromatic dispersion in the above band for both fibers.

The chromatic dispersion for 1460 and 1550 nm, determined with FiberCAD simulation, matches the values given in data sheets by the manufactures.

The calculated dispersion slope for both of fibers are shown on Fig. 2.

The dispersion slope in the S-band remains less then 0.07 ps/nm^2.km. As expected, this value decreases with increasing of wavelength. If the RDS is known it is possible to determine the usable bandwidth of the fiber. It is defined as

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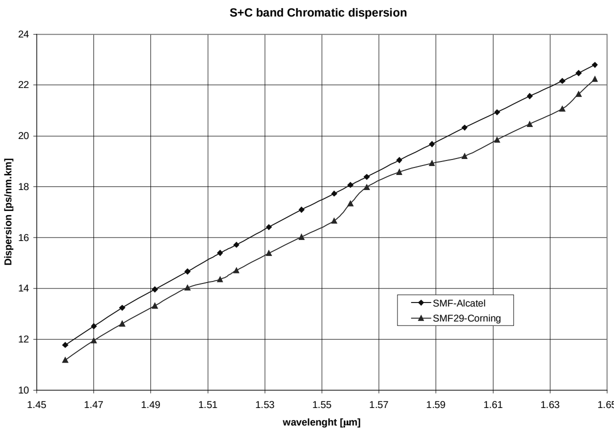

Fig. 1. Dispersion changes in S and C band

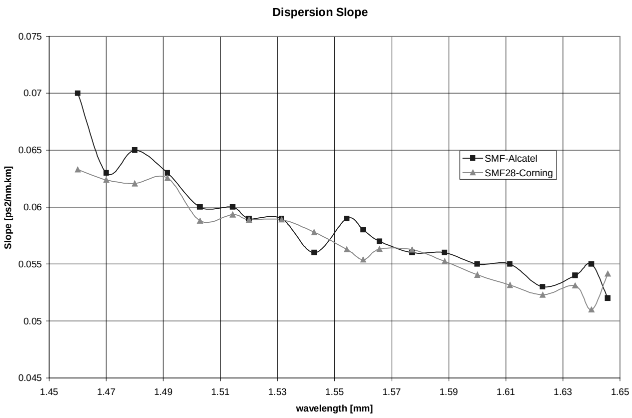

Fig. 2. Dispersion changes in S and C band

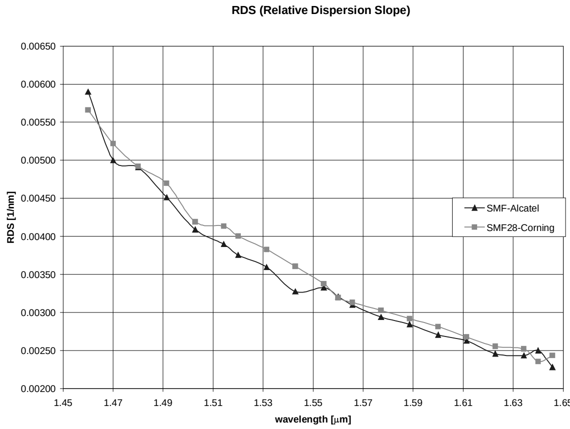

Fig. 3. The RDS changes in 1460-1560 wavelength band

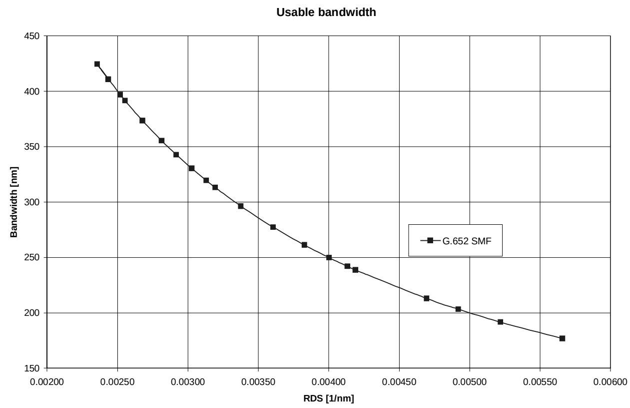

Fig. 4. Bandwidth vs. RDS for G.652 optical fiber

the maximal wavelength band in which the residual dispersion after compensation is less than 1 ps/nm [6].

As we can see in [6] the usable bandwidth and RDS are inverse proportional. We have determined the RDS for both fibers as Fig. 3 shows.

The values of RDS for the whole wavelength range are between (0.0022 and 0.0059) 1/nm. The calculated usable bandwidth vs. RDS of the transmission fiber is shown on fig. 4.

IV. Conclusion

The obtained results show that the G.652 SMF have relative small values of chromatic dispersion in S-band. Dispersion slope is approximately the same as that of the DCF. This allows the use of G.652 SMF at these wavelengths even in multi channel applications. In C-band the dispersion is grater, but dispersion slope has smaller values, which allows better dispersion compensation. Dispersion compensating fibers can be used for dispersion compensation in both C and S bands. The obtained results for dispersion and dispersion slope of conventional single mode fibers at different wavelengths in S and C band ca be used to find the appropriate DCF and compensations scheme.

References

[1] Y. Danziger, D. Askegard, An Innovative Approach to Chromatic Dispersion Management that enables optical Networking in Long-haul high-speed transmission systems, *Optcal Networks Magazine* Vo.2 Issue 1, Jan/Feb 2001

[2] G. Novak, Exact chromatic dispersion theory of optical fibers, *Optik* No.10 1999, Urban & Fischer Verlag

[3] Lars Gruener-Nielesen, Bent Edvold, Status and future promises for dispersion compensating fibers, *Proc. of OFC 2002*, May 2002.

[4] Fiber_CAD, Optical Fiber Design Software, Technical Documentation, Optiwave Corporation 2000

[5] Marie Wandel, Poul Kristensen et al, Dispersion compensating fibers for non-zero dispersion fibers, *Proc. of OFC 2002*, May 2002

[6] Jacob Rathje, Lars Gruener-Nielesen, Relationship between Relative Dispersion Slope of transmission fiber and the usable bandwidth after dispersion compensating, *Proc. ECOC 2002*