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# Temperature effects on the chromatic dispersion of standard single mode optical fibres

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We investigate the effect of temperature on the optical fibres chromatic dispersion and chromatic dispersion slope, once these parameters will affect dispersion compensation at high bit rates. Through numerical simulation we verify that the effect of temperature cannot be ignored in the design of dispersion compensation devices for high debit systems (40 Gbps).

## 1. Introduction

In the present, the transport in high debit WDM systems is realized over standard single mode fibres (SSMF). The variation of the chromatic dispersion and of the chromatic dispersion slope coefficients of optical fibres, will affect the dispersion compensation schemes for high debit systems (≥ 40 Gbps). There are several methods for chromatic dispersion compensation [1,2], however for these high debit systems the tolerances are tight, requiring a perfect management between the dispersion of the fibres and the value of the dispersion compensation devices.

The value of the chromatic dispersion is temperature dependent [3], even for buried optical cable they are subject to seasonal temperature variations higher than 40 °C [4], which combined with the long link extensions, are responsible for a degrading of the signal quality.

We have modelled the first and second order chromatic dispersion of single mode optical fibres, taking into account temperature effects, in particular the energy gap ascribed to the Si-Si bonds dependence on the temperature. Such energy dependence was experimentally measured, and used as input value for our numerical model. A comparison between the experimental values for the chromatic dispersion with the numerical ones, demonstrate that our model accounts well for the prediction of the experimental results [5,6].

## 2. Fibre chromatic dispersion

The chromatic dispersion of an optical fibre has two contributions, the material dispersion and the waveguide dispersion.

The refractive index of any optical material can be interpolated by the *Sellmeier* formula, which has a physical basis based in the Lorentz oscillator model. The material chromatic dispersion is manifested through the wavelength dependence of the core refractive index, $n_n$, by the following relation.

$$D_m(\lambda) = -\frac{\lambda}{c} \cdot \frac{\partial^2 n_n(\lambda)}{\partial \lambda} \quad (1)$$

where $c$ is the speed of light in the vacuum. Figure 1 shows the Silica refractive index value and slope.

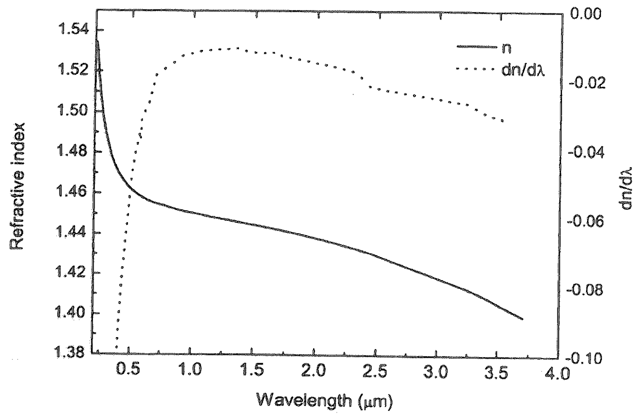


**Figure 1:** Silica refractive index value and slope.

The waveguide dispersion has a small contribution on the overall dispersion and is due to the signal propagation on the cladding region near the core.

The temperature dependence of $D_m$ is due to an enhancement in lattice vibrations with increasing temperature. The refractive index variation with respect to temperature is described by the thermo-optic coefficient, ($\partial n/\partial T$), which includes the electronic and optical phonons contribution. The electronic effects, in particular the temperature variations of the electronic absorption ascribed to the material energy band gap ($E_g$) have the dominant contribution. Therefore, the thermo-optic coefficient can be described in terms of the linear expansion coefficient $\alpha$ and of the temperature variation of the energy gap ($\partial E_g/\partial T$),



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$$2 \cdot n \cdot \left(\frac{\partial n}{\partial T}\right) = \left(-3 \cdot \alpha \cdot \left(n_1^2 - 1\right)\right) \cdot \left(\frac{\lambda^2}{\lambda^2 - \lambda_g^2}\right) + \left(-\frac{2}{E_g} \cdot \frac{\partial E_g}{\partial T} \cdot \left(n_1^2 - 1\right)\right) \cdot \left(\frac{\lambda^2}{\lambda^2 - \lambda_g^2}\right)^2 \quad (2)$$

where $\lambda_g$ the wavelength correspondent to the $E_g$ and $n_1$ is the less dispersive refractive index value.

Solving equation (1) and (2) we could obtain the first and second order chromatic dispersion dependence with temperature, which are -1.26 $\times 10^{-3}$ $\pm$ ps nm$^{-1}$ km$^{-1}$ K$^{-1}$ and 2.00 $\times 10^{-6}$ ps nm$^{-2}$ km$^{-1}$ K$^{-1}$, respectively.

## 3. Implications on 40 Gbps systems

We simulate a 40 Gbps point to point optical system, with 40 km of SMF fibre and a dispersion compensation module, which compensate exactly the dispersion of SMF for a 20 ° C temperature. The $\beta_2$ and $\beta_3$ coefficients of the SMF fibre were changed to reflect the effect of temperature, between – 40 ° C and 80 °C.

Figure 3 show the Q factor as function of the SMF fibre temperature. The degradation due to the temperature induced dispersion is clearly observed.

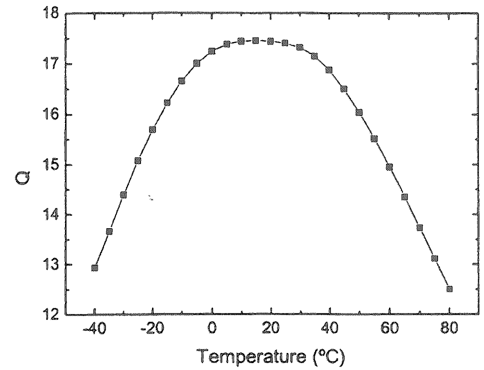
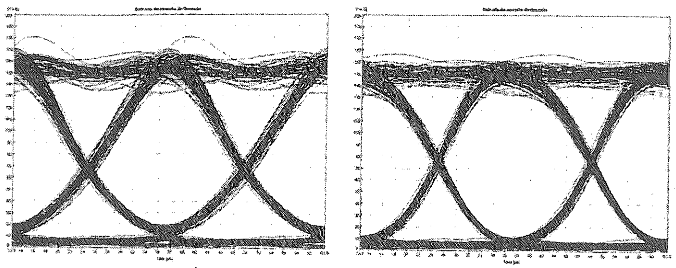



**Figure 2:** System Q factor as function of the SMF fibre temperature.

The degradation can be observed in eye diagrams, displayed in figure 3, obtained for two different temperatures of the SMF fibre (- 40°C and 20 °C).



a) b)

**Figure 3:** Eye diagram for deferent SMF temperatures. a) – 40 °C, b) 20 °C

The simulation results show that the temperature of the fibre has a high contribution in the performance of 40 Gbit/s systems.

**Acknowledgements**

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# Optical Gain Characteristics of Rayleigh Backscattered Lasing in Several Fibre Types

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**Abstract**

The authors show experimental results about a novel lasing scheme based on oscillations between fibre Bragg gratings and the Rayleigh back scattering effect. Multiple oscillations occurring in these virtual cavities, in the C-band, pumped by Raman in E-band, are able to generate gain in the U-Band. Experimental results of the gain characteristics are going to be presented for installed cables encompassing G.652, G.653 and G.655 fibres.

**Introduction**

Wavelength-division multiplexing (WDM) transmission systems with huge number of channel count has been recognized as the most adapted model build large capacity optical transport networks.

The available channel count in WDM transmission systems has been limited by the gain bandwidth of optical amplifiers. Exploitation of wide-band optical fiber amplifiers and new working bandwidths, such as L-band (1564-1625 nm) and U-band (1625-1675 nm), are therefore indispensable devices and approaches for the future optical networks.

In particular, the high Raman gain required for longer spans or high splitting ratios is inevitably accompanied by the increased penalties of associated intrinsic phenomena, for example the Rayleigh backscattering. Rayleigh effects can stem either from double Rayleigh backscattering (DRS) or from discrete reflection of the forward propagating signal followed by Rayleigh backscattering (RS) [1].

The DRS has been studied[1-3], modelled and characterized[4] by many authors. It is known that the process is a result of multiple reflections of light inside the fibre.

To achieve a complete control on the randomly lasing action induced by the DRS, a set of FBG's has been introduced before the fibre, and these will reflect back Rayleigh reflected power at specific wavelengths. These reflections will seed the DBS spontaneous lasers and force the lasing to occur at the FBG wavelengths.

**Experimental Setup**

The Experimental Setup is shown in Fig.1 following the reported in [5].