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Fiber Non-Linearity Estimation Through Four Wave Mixing

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Abstract: Optical wavelength converters are very important devices in optical (DWDM) systems. Among numerous wavelength technologies (FWM) in optical fibres is attractive. Because it offers strict transparency to amplitude, frequency and phase. They also have the ability to convert multiple wavelengths simultaneously and to invert optical spectra. Four wave mixing conversion efficiency depends upon fibre non-linearity. The effects of fibre non-linearity play a decisive role in the design and performance of modern optical communication links. So, it is important to measure the nonlinear promising technique for determining fiber non-linearity (γ). This study investigates a way of estimating fibre non-linearity through four-wave mixing process.

Key words: Optical fibre communications, fibre measurement, computer networks, conversion, FWM, Iraq

INTRODUCTION

Non-linear effects in optical fibres such as stimulated raman scattering (srs), stimulated brillouin scattering (sbs) and optical kerr effect have many useful applications in telecommunications and in optical signal processing (Agward, 2001; Okuno *et al*., 1999). The optical kerr effect in which the refractive index changes with optical power leads to various secondary effects such as self-phase modulation, cross-phase modulation, modulation instability and four-wave mixing. Applications using kerr effect include optical parametric amplification, frequency conversion (Stolen and Bjorkholm, 1982), optical phase cojucation (Wen, 1997), pulse compression (Sauer *et al*., 2003) and regeneration (Li *et al*., 2004). Each of these applications requires properly designed single mode fibres with high non-linearity, right dispertion properties and low attenuation. This non-linear coefficient in optical fibres is determined by two factors (Lee *et al*., 2006). The first one is the non-linear refractive index (n_2) with depends on the fibre matrial. Optical fibres used in communications do not posses a high non-linearity coefficient, however the non-linear phenomena can be observed at very high intensities of light and at large transmission distances (Agward, 2001).

Although, the power used at transmission of signals is not very high intensity in the fibre is very high (several mWor tens of mW), the light intensity in the fibre is very high (Wen, 1997). This is owing to the fact that the cross section of the fibre is very small 10^{-7} or 10^{-8} cm^2 for single mode fibres, so the light intensities acting upon a fibre reach as much as several GW cm^{-2} such an intensity value is sufficient for inducing nonlinear effects, thus significantly influeusing the light propagation in a fibre over different distances. The second one is the effective area of the fibre which is related to fibre design. Non-linear optical fibres have been used as wavelength converters through the process of four-wave mixing (Xiao *et al*., 2008). This study discusses the process of fibre non-linearity estimation through the four-wave mixing process.

Four-wave Mixing (FWM): Four-wave mixing in optical fibres is an effect prodused by the intensity dependent refractive index occurs when ≥ 2 wavelengths of light propagate together through an optical fibre. Light is generated at new frequencies using optical power from the original signals. This generation of new frequencies is subjected to a condition known as phase matching (Shibata *et al*., 1987). Assuming that self and cross-phase modulation (SPMXPM) are ignored. The power of the generated wave is given by Leong *et al*. (2006):

$$p_3(l) = \eta\gamma^2 p_1 p_2 \mathrm{Exp}(-\alpha l)\left[\frac{[1-\mathrm{EXP}(-\alpha L)]^2}{\alpha^2}\right] \quad (1)$$

Where:

L = Fibre length

α = Fibre attenuation coefficient

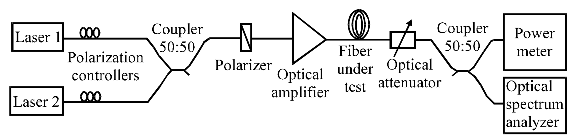

Fig. 1: The determination of fibre non-linear coefficient

Fig. 2: The fibre non-linear coefficient

γ = Non-linear coefficient of the fibre
η = FWM efficiency for w_3

The non-linear coefficient γ is given by:

$$\gamma = \left[\frac{2\pi n_2}{\lambda A_{eff}}\right] \quad (2)$$

Where:
A (eff) = Effective fibre core area
λ = Wavelength
n_2 = Fibre non-linear refractive index

The determination of fibre non-linear coefficient can be done by using FW as shown in Fig. 1 and 2.

RESULTS

As the severity of the non-linear effects is dependent on the intensity distribution inside the fibre it is convenient to use the non-linear coefficient $[n_2/A_{eff}]$

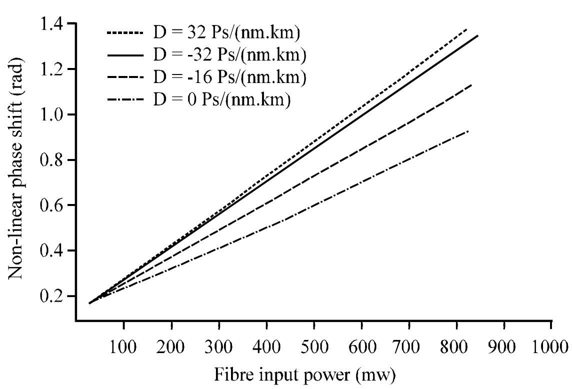

Fig. 3: Fibre input power

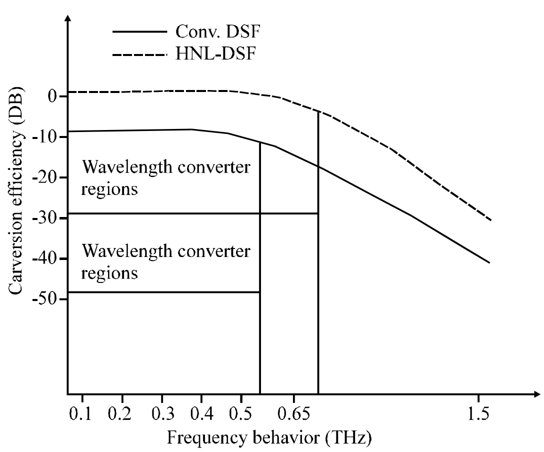

Fig. 4: Frequency behavior of wavelength converter regions

converient. To represent the magnitude of this phenomenon. The non-linear coefficient $[n_2/A_{eff}]$ can be determined directly from the slope of the non-linear phase shift as a function of optical power (neglecting the effects of dispersion) (Fig. 3 and 4).

CONCLUSION

The non-linear coefficient can be determined from the slope of the non-linear phase shift as a function of the optical input power. To take account for chromatic dispertion, one has to solve the SNDE and add the effect of chromatic dispertion to the result obtained.

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