ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, No 6, June 2013

Design and Implementation of Single Mode Standard (NDSF) or Dispersion Shifted Fibres Channel.

[1] Anshu Kr.Tripathi , [2] Anil Kumar, [3] A.K.Jaiswal
[1,2,3]Dept. of ECE, SHIATS, Allahabad, (U.P.), India.

Abstract: The enormous bandwidth of optical fibres and advancement of optical communications technology together with the direct photon-photon amplification make possible several innovative configurations of optical transmission systems and distribution networks. Current deployment of optical signals over single mode optical fibres in the field are only based on single channels either at 1310 nm or 1550 nm windows, except in some field trail systems and networks. It is essential that the enormous bandwidth regions should be used extensively. Intense investigation and experiments of ultra-long and ultra-high speed optical communication systems have been carried out together with interests in the multiplexing of optical carriers in the same fibre channel; the wavelength division multiplexing techniques have been used as the unique technology. These systems benefit from the availability of erbium-doped optical amplifiers (EDFA) which can amplify multiple optical carriers with its certain flat optical gain spectrum without significant channel cross talk.

Keywords: lightwaves, monograpgh, microbending, propagation phasors, bandwidth regions.

I. INTRODUCTION

The complexity of optical communication systems employing WDM requires a comprehensive computer aided modelling platform in order to optimise design and experimental costs and evaluate the performance of the implemented networks. This monograpgh focuses on the development of a computer simulation package for optical communication systems, in particular the emerging technique WDM or multichannel optical systems would be closely investigated.

In the following sub-sections we describe the design and implementation of optical transmission channels. These include single mode standard (NDSF) or dispersion shifted fibres and dispersion compensated fibres, optical transmitters consisting of optical carriers generators and modulators; optical amplification devices mainly the Er doped fibre amplifiers and the multiplexing and demultiplexing optical devices for WDM and the optical receivers and demodulators. The modules are designed in modular form so that they can be interconnected as required by the system modellers.

II. DISPERSION COMPENSATING FIBRES

Single mode fibres are modelled with dominant linear dispersion factor being chromatic or group velocity dispersion (GVD), due to fibre index variation with the optical spectrum. Different lightwaves of the spectra propagate at different phase velocities and thus generate pulse broadening. In another word different spectral components are modulated by the pulse envelope travel at slightly different group velocities and arrive at slightly different times. Chromatic dispersion includes effects due to fibre materials and waveguide propagation phasors as function of optical wavelength. Polarisation mode dispersion (PMD), due to differential group delay between the two orthogonal linearly polarised modes of a pulse and the random birefringence of the fibre caused by microbending, is not included in this modelling version. Although the PMD is very small (below 0.1 ps/nm/km) as compared with that of the standard single mode optical fibre it is significant compared with that of the dispersion shifted fibre. The PMD can be included at ease in our model. These PMD effects would also reduce the nonlinear effects in WDM systems. Nonlinear self-phase modulation (SPM) and cross phase modulation due to mixing of optical waves of different wavelengths are also included. To ensure that the pulse shape remains unchanged due to dispersion effects over the long distance transmission, it is necessary to tailor the dispersion of optical fibres with a desire dispersion factor that would balance almost the dispersion effects generated during the propagation of optical pulses in a standard fibre at a certain length. For multi-wavelength systems, it is desirable to compensate for all channels over an entire wavelength window. This was found to be achievable with multi-clad fibres. To this end, two-clad and three-clad fibres are developed.

III. DESIGN OF DISPERSION-MODIFIED FIBRE

There are several main parameters in the design of a dispersion-modified fibre. With a single mode fibre, the dispersion factor in a fibre is contributed mainly material dispersion and waveguide dispersion [2]. The total dispersion factor D is thus simply the sum of two terms: the material dependent term and waveguide dependent factor as

$$D = D_M + D_W \qquad (1)$$

where the material dispersion factor defined as

$$D_M = -\frac{\lambda}{c}\frac{d^2 n_1}{d\lambda^2} \qquad (2)$$

and the waveguide dispersion factor by

$$D_W = -\left(\frac{n_1 - n_2}{\lambda c}\right) V \frac{d^2(Vb)}{dV^2} \qquad (3)$$

Where λ is the operating optical wavelength, n_1 and n_2 the respective refractive index of the core and cladding, V the normalised frequency, b the normalised propagation constant, and $V(d^2(Vb)/dV^2)$ is a universal parameter which describes the waveguide-dependent dispersion characteristics of an optical fibre.

The material dependent dispersion factor of a silica-based optical fibre is due to variation of the refractive index n of silica with the optical carrier frequency, can be approximated by the Sellmeier equation as

$$n_1^2(\lambda) = 1 + \sum_{j=1}^{N} \frac{B_j \lambda^2}{\lambda^2 - \lambda_j^2} \qquad (4)$$

Where $\lambda_j = 2\pi c/\omega_j$ is the resonance wavelength at which electrons oscillate and B_j is the oscillator strength. These two parameters are calculated from an empirical fit of (4) to the measured dispersion curves and are tabulated up to N=3 for a number of fibres with different dopant concentrations in the core. The material dispersion factor generally does not alter when the resonance frequencies in the core region are stable at the operating frequency. Thus in order to synthesize the dispersion of an optical fibre it is required to select certain fibre material and the specifying its waveguide dispersion characteristics. From (3), D_w allows for two degrees of freedom in modifying its value. The relative index difference $\Delta = (n_1 - n_2)/n_1$ and the waveguide parameter $V(d^2(Vb)/dV^2)$ can be altered to achieve a dispersion value, but the two parameters often conflict in regard to fibre performance and may require compromises with one another.

IV. REFRECTIVE INDEX DIFFRENCE CALCULATION

For single mode fibre, current development keeps the refractive index difference at about 1% or less. However, for adequate power confinement within the core, it is desired to start the design with a high normalised frequency V, an important parameter that combines in an useful way the index difference Δ, the core radius a and the operating wavelength λ as defined by:

$$V = \frac{2\pi}{\lambda} a n_1 (2\Delta)^{\frac{1}{2}} \qquad (5)$$

Large V is required to reduce power leakage into the cladding, due to the variation of the spot size r_0 with V , which is approximated to within 1% accuracy by fitting the exact field distribution of the fundamental mode to a Gaussian distribution to give

$$\frac{r_0}{a}(V) = 0.65 + 1.619V^{-\frac{3}{2}} + 2.879V^{-6}, \qquad 1.2 \le V \le 3$$

$$\text{or} \qquad \frac{r_0}{a}(\lambda) = 0.65 + 0.434\left(\frac{\lambda}{\lambda_C}\right)^{\frac{3}{2}} + 0.0149\left(\frac{\lambda}{\lambda_C}\right)^{6}, \quad 0.8 \le \frac{\lambda}{\lambda_C} \le 2.0 \qquad (6)$$

Where r_0 is the wavelength dependent field radius or spot size, and a is the core radius.
λ_c is the cut-off wavelength **above** which a fibre supports only one mode, and it is related to V as

$$\frac{\lambda_C}{\lambda} = \frac{V}{V_C} \qquad (7)$$

where VC is the cut-off value **below** which only the fundamental mode is supported. V is theoretically 2.405 but can practically be 3.0. The upper limit on V in (6) is therefore to constrict the fibre to guide only the fundamental mode and reject all higher order modes, and the lower limit defines the range of curve fitting. From (1.5) large V requires large Δ, therefore the design while catering for the power will pay for a higher index difference. An approximation of the waveguide parameter $V(d^2(Vb)/dV^2)$ as a function of V is given by the following empirical formula to less than 5% error

$$V\frac{d^2(Vb)}{dV^2} \cong 0.080 + 0.549(2.834 - V)^2, 1.2 \le V \le 2.6 \qquad (8)$$

$$b(V) = \left(1.1428 - \frac{0.996}{V}\right)^2, \ 1 \le V \le 3 \qquad (9)$$

A dispersion compensating fibre is usually required to be short to minimise loss and thus required a high dispersion level in the anomalous region to cancel the normal dispersion in existing standard fibre. With eq.(1.3), a high dispersion requires a large waveguide parameter and it is obvious from Figure (1.1) that the waveguide parameter and the normalised spot size are conflicting. As the waveguide parameter gets larger, the normalised spot size /a also grows, which implies some fraction of mode field penetrates into the fibre cladding. The fraction of mode power confined in the core can be determined by

$$\frac{P_{core}}{P_{Total}} = 1 - \exp\left(-\frac{2a^2}{w^2}\right) \qquad (10)$$

where for V=2.4, 75% of mode power is contained in the core. This reduces to 22% when V=1.2. As the approximation for the waveguide parameter given in (8) is valid only in the range 1.2 = V = 2.6, it cannot be made any larger for a large dispersion. Instead the index difference Δ has to be altered to achieve the required waveguide dispersion according to (3). When Δ gets larger, the core diameter by (5) will get smaller. This will cause more loss of mode power in the cladding, and eventually an upper limit of dispersion value realisable will be reached beyond which the core diameter will be too small for light guiding or Δ will be too large to realise. Therefore we concern with two main parameters in the design of an optical fibre: the core radius a and the index difference Δ at an operating wavelength λ or within a window of a wavelength range.

V. CONCLUSION

The self-phase-modulation SPM refers to the nonlinear phase shift in the optical wave caused by the optical field itself. Such effect is generally negligible at low power levels (normally below 10 mW) but becomes significant when the peak intensity of the pulse is sufficiently high to cause appreciable change in the refractive index of silica fibre. This intensity induced index variation, referred to as the Kerr nonlinearity, produces a nonlinear phase shift in the carrier wave and leads to spectral broadening of the pulse. For WDM systems, the nonlinear effects are expected to further enhance with the phase shift for a channel depends not only on the power of that channel but also on the power in the adjacent channels, the so called cross phase modulation (XPM). In general, dispersion and nonlinearity act together along the length of the fibre. The Split Step Method obtains an approximate solution by assuming that in propagating the optical field over a small distance h, the dispersive and nonlinear effects can be pretended to act independently.

VI. REFERENCES

[1]. Linke, (1985) 'Modulation induced transient chirping in single frequency lasers', IEEE J. Quant. Elect., pp. 593-597.

[2]. Bickers and L.P. Westbrook, (1985) 'Reduction in laser chirp in 1.5um DFB lasers by modulation pulse shaping', Elect. Lett., pp. 103-104.

[3]. Koyama, (1988) 'Frequency chirping in external modulators', IEEE J. Lightwave Tech., pp. 87-93.

[4]. P. Agrawal and N. K. Dutta, (1986) Long-wavelength semiconductor lasers, Van Nostrand Reinhold.

[5]. C. Cartledge and A. F. Elrefaie, (1991) 'Effect of chirping-induced waveform distortion on the performance of direct detection receivers using traveling-wave semiconductor optical preamplifiers', IEEE J. Lightwave Tech., pp.209 - 219.

[6]. Rai X. and Xu G., (1994) 'SPICE model for the intrinsic noise of laser diodes', J. Optical Comm. , pp. 135-137.

Prof.A.K.jaiswal working as HOD at Shiats in Electronics and Comm. department . He completed his B.Sc. in science from allahabad university also completed his M.sc in science from Allahabad University and completed his M.Sc. (Tech.) in Electronics and radio engineering from Allahabad University Area of specilization optical fiber comm. and control system.

Anil kumar is working as Assistant Professor at Shiats. He completed his B.E. from D.D.V. Gorakhpur university Gorakhpur and M.Tech from B.H.U Varanasi . area of specilization VLSI , mocrostrip antenna and artificial neural network.

Anshu Kumar Tripathi completed B.tech in year 2010 from BBS college Allahabad. Presently pursuing M.tech from Shiats allahabad in electronics and comm. Engineering with specialization in communication system.