Characterisation of birefringence in optical fibres

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by

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Summary

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Polarisation mode dispersion has now become one of the main limiting factors in land based systems, and continues to be an issue in the design of submarine systems. This thesis describes a theoretical and experimental investigation of linear and twist induced circular birefringence and polarisation mode dispersion in single mode optical transmission fibre. The main original contributions described in this thesis are:

- An analytical solution has been obtained for the differential group delay (DGD) in the presence of elastic twist. This solution is in excellent agreement with the extensive set of DGD measurements reported here, and it allows the prediction of the optimum twist rate needed to minimise the DGD in an optical fibre.

- The DGD of different types of fibres: standard-step index fibres (S-SMFs), dispersion shifted fibres (DSFs), spun DSFs, erbium doped fibres (EDFs) and distributed EDFs (DEDFs) have been measured as a function of twist. Spun fibre showed the lowest initial DGD while the first reported measurements on DEDFs showed unacceptably large DGD values for high bit-rate soliton transmission.

- From simulation and measurement, an empirical equation has been obtained for commercial spun fibre manufactured with sinusoidal spin, which allows the determination of the minimum spin (RMS value) required to obtain a fibre with low DGD.

- A conventional OTDR has been modified to a polarimetric OTDR to analyse the backscattered SOP, and from this the birefringence characteristics are obtained along the fibre. A matrix-vector description has been developed to analyse POTDR data from fibres with twist. The developed theory has been verified by detailed experimental results, and it is shown that if twist is ignored when present, it can lead to a large error in the estimated values of birefringence and DGD obtained from such measurements.

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To my two sons Jonas and Lukas who I love,
my mother and in remembrance of my father

A man's heart plans his ways,
but the Lord directs his steps.

Proverbs 16:9

Contents

List of abbreviations

ASE	Amplified Spontaneous Emission
CA	Compensator-Analyser
ccw	Counter Clockwise
cw	Clockwise
DCF	Dispersion Compensating Fibre
DEDF	Distributed Erbium Doped Fibre
DGD	Differential Group Delay between the two possible orthogonal polarisation modes. Often normalised to length and given in ps/km
DOP	Degree of Polarisation
DPD	Differential Phase Delay
DR	Dynamic Range
DSF	Dispersion Shifted Fibre
EDF	Erbium Doped Fibre
EDFA	Erbium Doped Fibre Amplifier
GCA	General Compensator Analyser
GPIB	Genera Purpose Interface Bus
IM-DD	Intensity Modulation Direct Detection
JME	Jones Matrix Eigenanalysis
LCP	Left Circular Polarisation
LEP	Left Elliptical Polarisation
NEP	Noise Equivalent optical Power
NRZ	Non-Return-to-Zero
OTDR	Optical Time Domain Reflectometry
PDL	Polarisation Dependent Loss
PEM	Polarisation Eigen Modes
PDG	Polarisation Dependent Gain
PMD	Polarisation Mode Dispersion, mean DGD value over wavelength range. Often normalised to the square root of the fibre length and given in $ps/\sqrt{km}$
PSP	Principal States of Polarisation
RCP	Right Circular Polarisation
RMS	Rout Mean Square
RPM	Rotations Per Minute

POTDR	Polarisation Optical Time Domain Reflectometry or also used as Polarimetric Optical Time Domain Reflectometer.
RCP	Right Circular Polarisation
RZ	Return to Zero
SNR	Signal to Noise Ratio
SOP	State Of Polarisation
S-SMF	Standard Single Mode Fibre
TAT12	Transatlantic system, Length ≈ 6400 km with optical amplifiers and operating at 5 Gbit/sec
WDM	Wavelength Division Multiplexing
WWW	World Wide Web