Appendix B

Appendix B presents an extended work for chapter 5 to demonstrate the potential of PDL to alter the SOP of an optical signal, consequently allowing orthogonality errors between two orthogonal multiplexed signals.

B.1 Orthogonality errors investigation and modelling results

Since PDL has the potential to alter the state of polarisation [1] of an optical signal, any polarisation sensitive device with PDL, such as a coarse AWG [2], will have the potential to degrade the degree of orthogonality θ, between two polarisation multiplexed signals SOP_1 and SOP_2 at the input of the device as shown in Figure B-1. Since the PDL is aligned with the vertical axis of the transmission i.e. TM, it only reduces the vertical component of the SOPs vectors, resulting in modified SOP'_1 and SOP'_2 with degree of orthogonality θ', consequently allowing for orthogonality error figure of θ-θ'. In the scenario for which the device, such as the AWG, is located in the distribution point of a network, following a good condition fibre, the SOPs are random when reaching the device, although still mutually orthogonal [1], resulting in varying polarisation error.

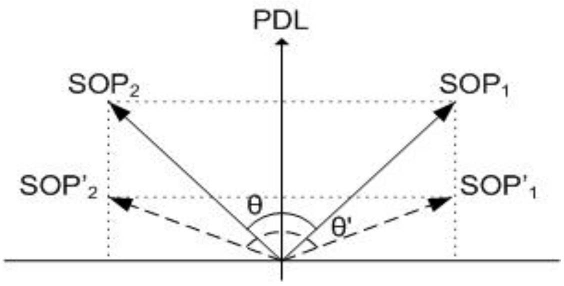


Figure B-1 Degradation in orthogonality due to PDL, with representation in Jones space

To demonstrate the effect of PDL on the reduction in orthogonality between the two polarisation multiplexed signals in the Gaussian AWG [2] passband at λ_2=1550 nm, the three fine wavelengths at λ_2^1=1553.33, λ_2^9=1550.12 nm and λ_2^{16}=1547.32 nm, corresponding to the longest, centre and shortest wavelengths were employed. In the simulation, a polarisation controller was utilised at the input of the AWG to alter each wavelength SOP, consequently a first input SOP_1 was formed by azimuth ψ_1 and ellipticity X_1 angles and the corresponding Stokes parameters were measured at the output of the AWG using a Stokes measurement unit. Subsequently, for the same wavelength, an orthogonal input SOP_2 was also formed by setting the ellipticity and azimuth to $X_2 = -X_1$ and $\psi_2=\psi_1+90$ respectively, and a second set of Stokes parameters enabled the orthogonality to be calculated using B.1 [1]. The entire Poincare sphere was scanned by varying the azimuth ψ_1 and ellipticity X_1 between -90° to 90° and -45° to 45° respectively in steps of 10°.

The scalar product, given by B.1 [1], of the two resultant vectors SOP'_1 and SOP'_2 is a measure of their orthogonality.

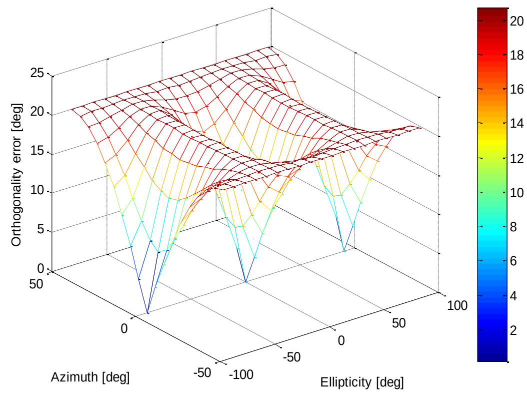
$$2\theta = \arccos\left(\frac{\vec{S}_1' \times \vec{S}_2'}{|S_1'| \times |S_2'|}\right) \tag{B.1}$$

Where S'_1 and S'_2 are the Stokes representation of the two resultant vectors SOP'_1 and SOP'_2 respectively and the angle between the two vector in the sphere space is 2θ [3, 4]. Consequently, the angel between the two vectors in real space (Jones space) is measured by θ.

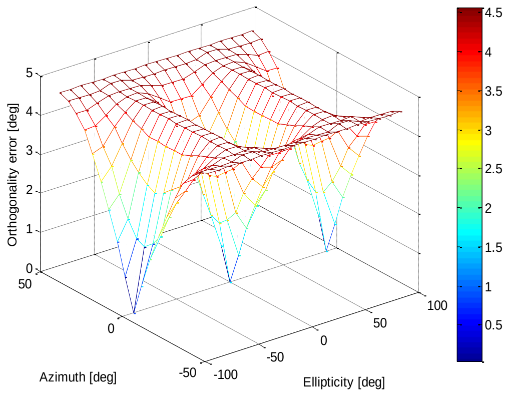
Figure B-2 displays the orthogonality error mapping at coarse channel λ_2=1550 nm for the three wavelengths located at centre and both edges of the passband. As expected, due to increasing PDL at the edges of the passband, Figures B-2(a) and (c), for the longest and shortest wavelengths demonstrate up to 20° and 11° orthogonality errors respectively which could potentially result in significant crosstalk.

On the contrary, Figure B-2 (b) for the centre wavelength at λ_2^9=1550.12 nm exhibits moderate orthogonality error of up to 4.5° due to low induced PDL at the centre of the passband [5].

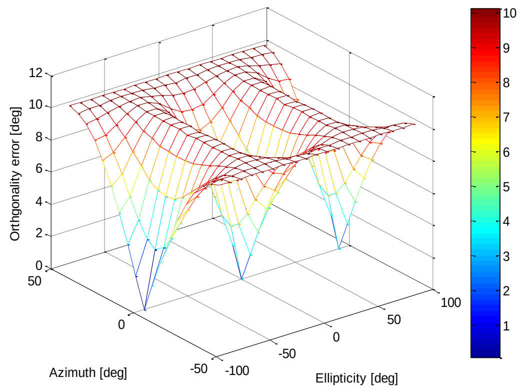
Finally, Figures B-2(a), (b) and (c) suggest that an orthogonality error of approximately 0° can be achieved for all fine wavelengths in the scenario where the two SOP vectors are aligned with the device vertical and horizontal transmission modes. This is particularly true if the AWG is located in the OLT and as a result the orthogonality can be maintained.



(a)



(b)



(c)

Figure B-2 Effect of PDL on orthogonality error vs. operating wavelength. (a) λ_2^1=1553.33 nm, (b) λ_2^9=1550.12 nm, (c) λ_2^9=1547.32 nm

To observe the tendency for the maximum orthogonality error in the passband, Figure B-3 displays the orthogonality error versus operating wavelength. As becomes evident from the figure the maximum error varies from approximately 0° for the fine wavelength λ_2^{11}=1549.32 nm near the centre fine wavelength λ_2^9 to more than 20° for the longest wavelength at λ_2^{16}=1553.33 nm. Similar results have been observed for all other coarse channels.

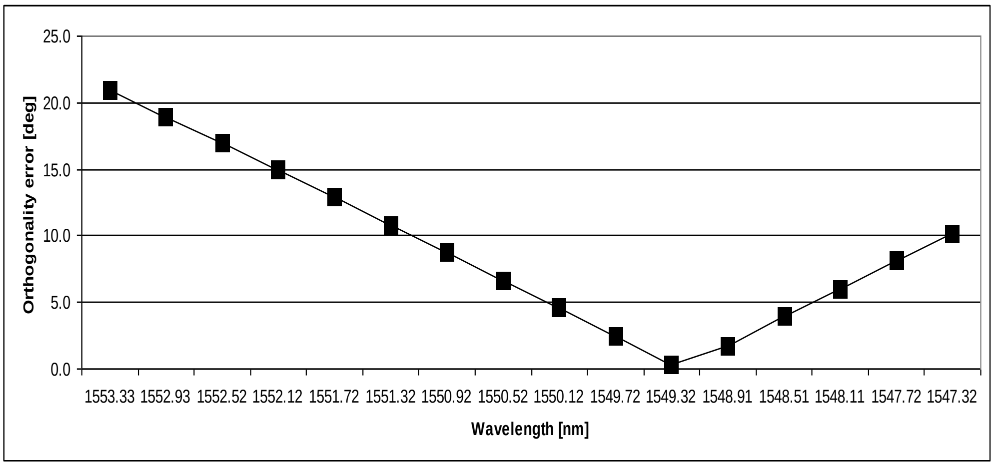


Figure B-3 Maximum orthogonality error versus operating wavelength in the passband

B.2 References

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