

Effect of Extrinsic Perturbation by Transverse Pressure, Bending and Tension Birefringence

Dr. C. M. Jadhao

Principal, MGI COET, Shegaon-444303 (MS), India

Abstract: Birefringence and polarization dispersion caused by elliptical core, twist, pure bending, transverse pressure and axial tension are studied by treating these deformations as perturbations to step-index single-mode fiber with a round core. These effects are formulated in terms of fiber structure and perturbation parameters and are compared comprehensively. The results show that as the transverse pressure is increased, the birefringence also increases. When transverse pressure is 0.8 KgW/m is applied the delta beta is -2.6731 rad/m and DGD is -1.835 ps/Km and it increased to -4.5761 rad/m and -3.7682 ps/Km respectively when transverse pressure in increased doubled. This also shows that the transverse pressure is more dominated to polarization and remains steady but birefringence varies to the wavelength. The results shows that as the bending radius increased the delta and DGD decreased and polarization is steady for the corresponding bending and wavelength but the delta beta is varying with wavelength for the corresponding bending radius, the Delta beta is -0.0527 rad/m and DGD is -0.0440 ps/Km for the bending radius of 0.20 m and this increased to -0.1463 rad/m and -0.1208 ps/Km respectively as bending radius decrease to 0.12 m. The results show that as spooled tension is increased the delta beta and DGD increases and also these increases as bending radius decreased. The Delta beta is -2.6909 rad/m and DGD is -2.2148 ps/Km for the spooled tension of 0.1936 N and it increases to -4.8969 rad/m and -4.0301 ps/Km respectively for tension increased to 0.3658 N at bending radius of 0.1m. The delta beta and DGD decreases to -1.2928 rad/m, -1.0639 ps/Km for tension = 0.1936N and -2.3958 rad/m, -1.9715 for tension 0.3658N respectively when the bending radius increased to 0.20m.

Keywords: FiberOptics, Birefringes, PMD, Bending, T Pressure

1. Extrinsic Perturbation Birefringence

Birefringence can also be created in a fiber when it is subjected to external forces in handling or cabling. Such extrinsic sources of birefringence include lateral stress, fiber bending and fiber twisting¹. All three of these mechanisms are usually present to some extent in spooled and field-installed telecommunications fiber². Extrinsic sources of birefringence include lateral stress, fiber bending and fiber twisting and the tension-coiled birefringence results from the lateral force exerted by the drum on the fiber in reaction to the tensile force³. Thus the analysis of following extrinsic perturbations is carried out

- Lateral stress or Transverse pressure birefringence
- Bending birefringence
- Fiber spooled with tension birefringence

1.1 Analysis of Extrinsic perturbation by Lateral stress or Transverse

When two equal and opposite forces p act across an axis of a fiber with a diameter d , the birefringence induced is linear. The fast axis of birefringence is aligned with the axis defined by the two opposite forces⁵. When force p applied to the fiber known as transverse pressure and the analysis of this extrinsic perturbation is obtained by using equations 1 and 2 for different transverse pressure p applied in KgW/m and results obtained are as shown in figure 1 and Table 1. The results show that as the transverse pressure is increased, the birefringence also increases. When transverse pressure is 0.8 KgW/m is applied the delta beta is -2.6731 rad/m and DGD is -1.835 ps/Km and it increased to -4.5761 rad/m and -3.7682 ps/Km respectively when transverse pressure in increased doubled. This also concludes that the transverse pressure is more dominated to polarization and remains steady but birefringence varies to the wavelength⁶.

Table 1: Birefringence Induced by Extrinsic Perturbation by Transverse Pressure ($\lambda = 1.55 \mu\text{m}$)

Transverse pressure (KgW/m)	Delta Beta (rad/m)	DGD (ps/km)
0.8	-2.6731	-1.8353
1.0	-2.8346	-2.3248
1.2	-3.3973	-2.8166
1.4	-3.8743	-3.2976
1.6	-4.5761	-3.7687

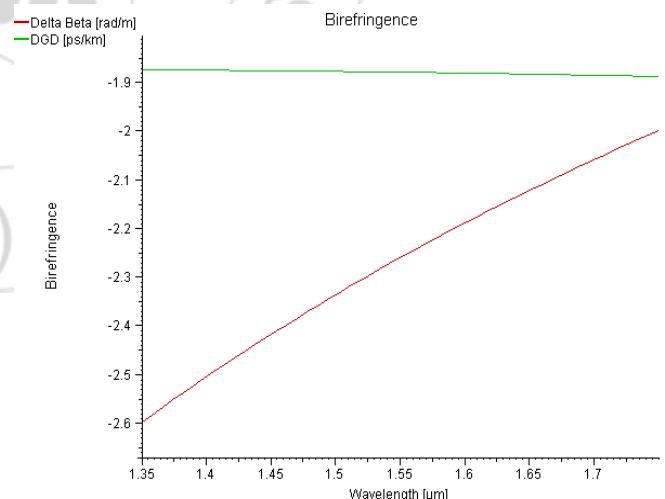


Figure 1(a): Birefringence Induced by Extrinsic Perturbation by Transverse Pressure with Lateral force ($p = 0.8 \text{ KgW/m}$)

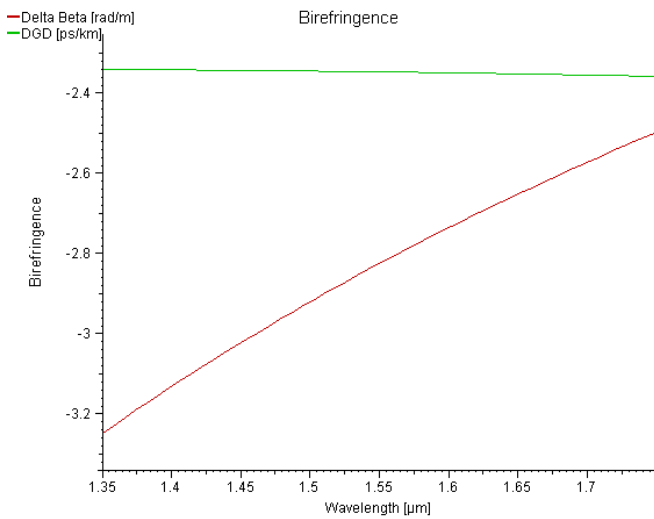


Figure 1(b): Birefringence Induced by Extrinsic Perturbation by Transverse *Pressure with Lateral force* ($p = 1.0 \text{ KgW/m}$)

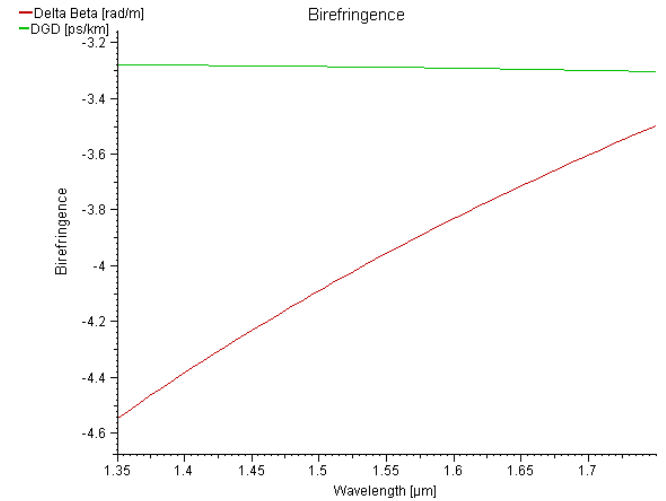


Figure 1(e): Birefringence Induced by Extrinsic Perturbation by Transverse *Pressure with Lateral force* ($p = 1.6 \text{ KgW/m}$)

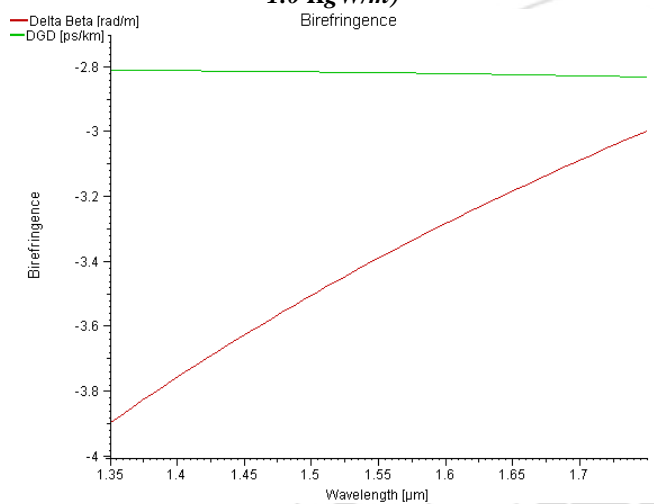


Figure 1(c): Birefringence Induced by Extrinsic Perturbation by Transverse *Pressure with Lateral force* ($p = 1.2 \text{ KgW/m}$)

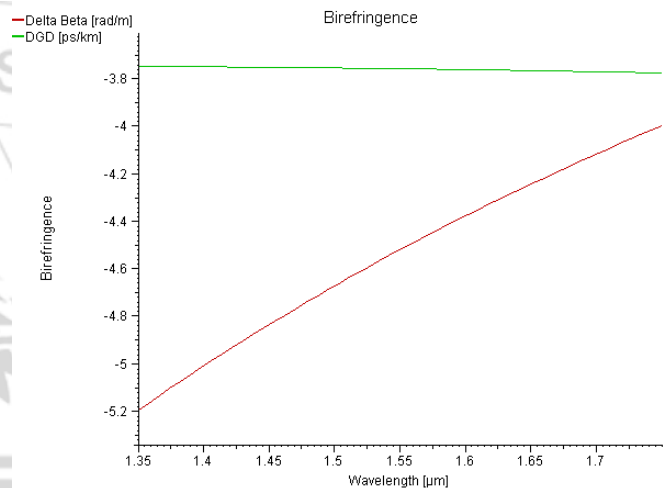


Figure 2(a): Birefringence(Delta Beta) Induced by Extrinsic Perturbation by different bending radius R_b

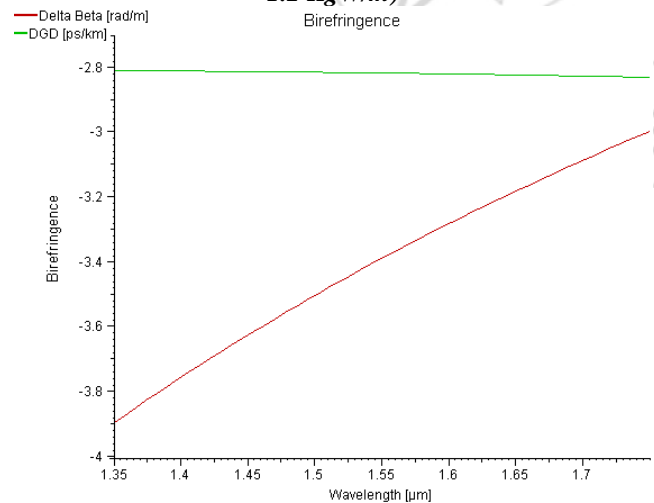


Figure 1(d): Birefringence Induced by Extrinsic Perturbation by Transverse *Pressure with Lateral force* ($p = 1.4 \text{ KgW/m}$)

1.2 Analysis of Extrinsic perturbation by Bending Birefringence

Bending on a fiber with a bending radius $R \gg a$ (fiber core) gives rise to a linear birefringence⁷. The fast axis of birefringence is perpendicular to the bending plane. The slow axis is aligned with the bending radius. The experimental results are obtained for extrinsic bending perturbation birefringence by using the equation 3 and 4 and results obtained are as shown in figure 2 and Table 2. The results shows that as the bending radius increased the delta and DGD decreased and polarization is steady for the corresponding bending and wavelength but the delta beta is varying with wavelength for the corresponding bending radius, the Delta beta is -0.0527 rad/m and DGD is -0.0440 ps/Km for the bending radius of 0.20 m and this increased to -0.1463 rad/m and -0.1208 ps/Km respectively as bending radius decrease to 0.12 m . These experimental results are having good agreement with theory⁴.

Table 2: Birefringence Induced by Extrinsic Perturbation by BENDING ($\lambda = 1.55 \mu\text{m}$)

Bending Radius (m)	Delta Beta (rad/m)	DGD (ps/Km)
0.12	-0.1463	-0.1208
0.14	-0.1075	-0.0888
0.16	-0.0823	-0.0680
0.18	-0.0651	-0.0537
0.20	-0.0527	-0.0439

1.3 Analysis of Extrinsic perturbation by Bending under Tension Birefringence

If we consider a pure axial stress applied to the fiber, simple symmetry considerations show that there is no induced birefringence. But winding a fiber with axial tension „f“ onto a drum introduces an additional linear birefringence that adds to the bending birefringence. This tension-coiled birefringence results from the lateral force exerted by the drum on the fiber in reaction to the tensile force⁸. Using the equation 5 and 6 the experimental results have been carried out. The results are obtained by applying the spooled tension under different bending conditions for example the results are obtained for bending radius of 0.1,0.15, and 0.2, are as shown in figure 3,4 and 5 respectively and Table 3

Table 3: Birefringence Induced by Extrinsic Perturbation by Spooled tension for different bending radius ($\lambda = 1.55 \mu\text{m}$)

Tension (N)	Rb = 0.1		Rb = 0.15		Rb = 0.2	
	Delta Beta rad/m	DGD ps/Km	Delta Beta rad/m	DGD ps/Km	Delta Beta rad/m	DGD ps/Km
0.1936	-2.6909	-2.2148	-1.7471	-1.4379	-1.2928	-1.0639
0.2943	-3.9809	-3.2763	-2.6071	-2.1456	-1.9378	-1.5947
0.3658	-4.8969	-4.0301	-3.2178	-2.6481	-2.3958	-1.9715

The results show that as spooled tension is increased the delta beta and DGD increases and also these increases as bending radius decreased⁹. The Delta beta is -2.6909 rad/m and DGD is -2.2148 ps/Km for the spooled tension of 0.1936 N and it increases to -4.8969 rad/m and -4.0301 ps/Km respectively for tension increased to 0.3658 N at bending radius of 0.1m. The delta beta and DGD decreases to -1.2928 rad/m , -1.0639 ps/Km for tension = 0.1936N and -2.3958 rad/m , -1.9715 for tension 0.3658N respectively when the bending radius increased to 0.20m. These results are having good agreement with theory⁴.

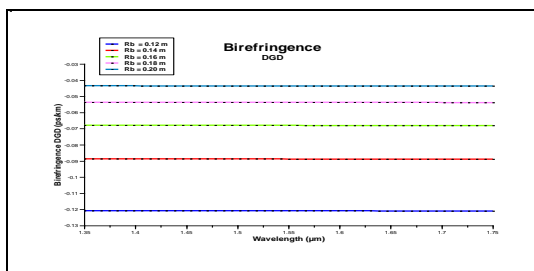


Figure 2(b): Birefringence(DGD) Induced by Extrinsic Perturbation by different bending radius Rb

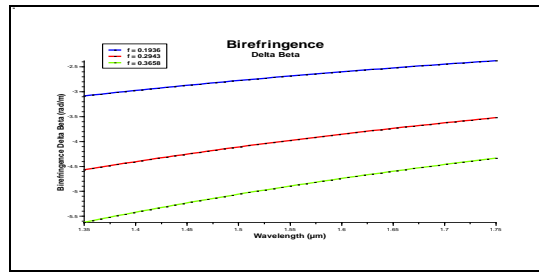


Figure 3(a): Delta Beta Induced by Extrinsic Perturbation by Fiber spooled with different axial tension (f) with Bending radius of Rb = 0.10m

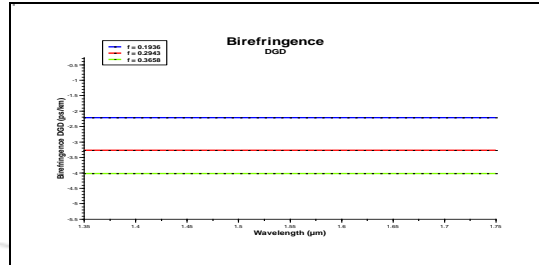


Figure 3(b): DGD Induced by Extrinsic Perturbation by Fiber spooled with different axial tension (f) with Bending radius of Rb = 0.10m

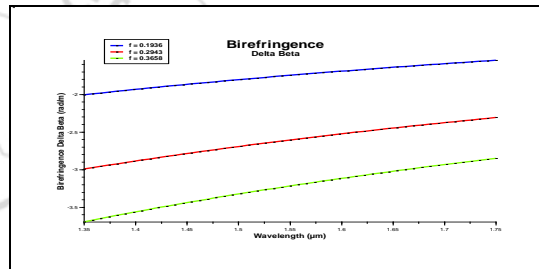


Figure 4(a): Delta Beta Induced by Extrinsic Perturbation by Fiber spooled with different axial tension (f) with Bending radius of Rb = 0.15m

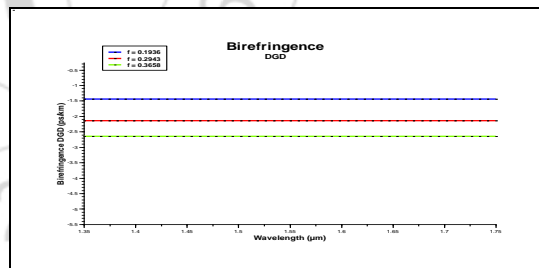


Figure 4(b): DGD Induced by Extrinsic Perturbation by Fiber spooled with different axial tension (f) with Bending radius of Rb = 0.15m

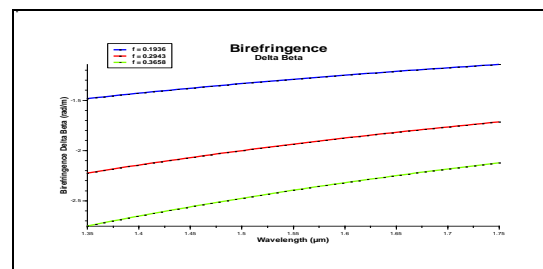


Figure 5(a): Delta Beta Induced by Extrinsic Perturbation by Fiber spooled with different axial tension (f) with Bending radius of Rb = 0.2m

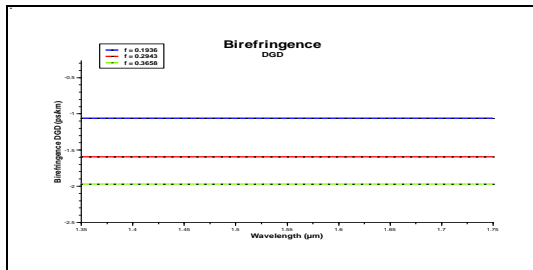


Figure 5(b):DGD Induced by Extrinsic Perturbation by Fiber spooled with different axial tension (f) with Bending radius of $R_b = 0.2m$

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2. Conclusion

Birefringence and polarization dispersion caused by elliptical core, twist, pure bending, transverse pressure and axial tension are studied by treating these deformations as perturbations to step-index single-mode fiber with a round core. These effects are formulated in terms of fiber structure and perturbation parameters and are compared comprehensively. Birefringence depends strongly on the factors viz-elliptical core, twist, pure bending, and transverse pressure, while polarization dispersion depends on the factors viz-elliptical core, pure bending and transverse pressure⁹⁴. Birefringence and polarization dispersion caused by several elastic deformations and an elliptical core deformation in step-index single-mode fibers have been formulated and compared.

References

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