# Simultaneous measurement of twist and transverse-stress through a dual-mode fiber assisted Sagnac Interferometer

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## 1. Introduction

Dual-mode fibers (DMF) find exciting applications in optical communications and sensors with attractive features that standard single-mode fibers (SMF) do not possess [1]. We report our recent progress on DMF based optical sensors, and show the potential of utilizing the spatial dimension for multi-parameter sensing with discrimination capability. We first show a discrete type Sagnac interferometer (SI) structure with a short SMF, utilizing the interference between counter propagating beams. Then, a dual mode fiber possessing selectively excited $LP_{01}$ and $LP_{02}$ modes is incorporated in the Sagnac loop for a simultaneous and a wide dynamic-range measurement of applied transverse stress and twist. The research problem was then analyzed on the avenue of associated theoretical considerations in order to interpret the experimental observation and the resulting accuracy.

## 2. System Configuration and Results

Figure 1 is a schematic of a typical Sagnac interferometric configuration. The fundamental component of such interferometer is a fused directional fiber-coupler whose output ports are connected to a *test fiber* (SMF/DMF) by means of splice ($C_1$ and $C_2$) to form a loop [2,3]. A flat magnetic base is used to hold the fiber and to provide variable transverse-stress [4]. Another unit of fiber rotator is incorporated at the other end of the test fiber to hold it straight and to provide a regular twist. Theoretically, the electric field at the transmitting port of a SI is evaluated as:

$$\begin{pmatrix}E_{out,x}\\E_{out,y}\end{pmatrix}=\begin{pmatrix}(2\alpha-1)J_{xx} & (1-\alpha)J_{xy}+\alpha J_{yx}\\ -\alpha J_{xy}-(1-\alpha)J_{yx} & (1-2\alpha)J_{yy}\end{pmatrix}\begin{pmatrix}E_{in,x}\\E_{in,y}\end{pmatrix};\quad J=\begin{cases}T_1.C_1.I_{LB}F_L.C_2.T_2 & ;\ SMF\\ T_1C_1H_{D,L_1}I_{LB}F_LH_{D,L_2}C_2T_2; & DMF\end{cases}$$

where, α is the intensity coupling coefficient of coupler, '*J*' is the Jones matrix of loop and is equal to the product of the transmission matrix of elements constituting the loop (Fig.1). It was observed (theoretically and experimentally) that the influence of the twist is intimately linked with inherent linear birefringence that is present in the Sagnac loop (Fig.2). The shifting of the highest peak in the transmittance curve was found to be a *signature of induced linear birefringence* (transverse-stress) while the intensity

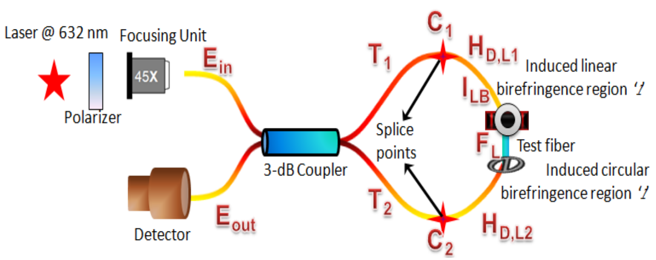


Fig. 1. Schematic of a DMF assisted Sagnac Interferometer.

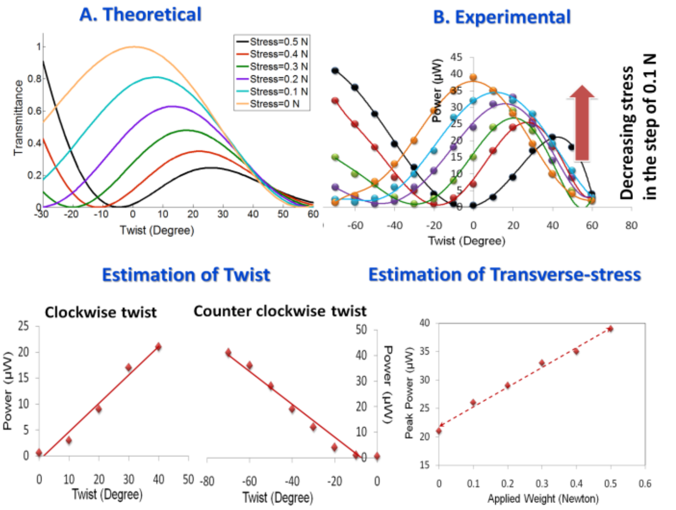


Fig. 2. Transmittance characteristics of SI with a DMF incorporated in the loop (a) Theoretical (b) Experimental (c) Estimated twist (d) Estimated transverse stress.

variation along the highest peak measures the *applied twist*. The theoretical analysis is in good agreement with our experimental results and gave the first indication of how to proceed in the experiment.

## 3. Conclusion

We report an experimental method to vary the transmission through a Sagnac interferometer (SI) employed with elasto-optically induced linear and circular birefringence(s). We also demonstrate simultaneous measurement of transverse stress and twist through a rugged, low cost, compact fiber optic interferrometric configuration operating over a wide dynamic range. It is observed that an ideal transmission characteristic can be achieved by suitably configuring the combination of dual-mode fiber placed in the loop, applied transverse stress and twist.

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