Chapter 3
A Step-Index Multimode Fiber-Optic Microbend Displacement Sensor Wavelength Dependent Loss

Sami D. Alaruri
Independent Researcher, USA

ABSTRACT

In this chapter, the wavelength dependence of bend loss in a step-index multimode optical fiber (100 μm core diameter; fused silica) was investigated for fiber bend radii ranging between 2.0 and 4.5 mm using six laser excitation wavelengths, namely, 337.1, 470, 590, 632.8, 750, and 810 nm. The results obtained from fitting the bend loss measurements to Kao's model and utilizing MATLAB® indicate that bend loss is wavelength dependent and transmission loss in multimode optical fibers increases with the decrease in the fiber bend radius. Furthermore, the response of a microbend fiber-optic displacement sensor was characterized at 337.1, 470, 632.8, 750, and 810 nm. Measurements obtained from the microbend sensor indicate that the sensor output power is linear with the applied displacement and the sensor output is wavelength dependent. Lastly, references for industrial and biomedical applications of microbend fiber-optic sensors are provided. Finally, a brief description for the transmission loss mechanisms in optical fibers is given.

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INTRODUCTION

Loss introduced by bends in optical fibers has been recognized as a factor which contributes to the attenuation of the optical signal transmitted along an optical fiber (Marcuse, 1976a, 1976b; Berthold, 1995; Lagakos, Cole & Bucaro, 1987; Arya et al., 1995; Al-Aruri, 1991; Boechat, Hall & Jones, 1991; Donlogic, 2009; Schermer & Cole, 2007; Kao, 1982; Snyder, White & Mitchell, 1975; Lagakos & Bucaro, 1987). Decreasing the optical fiber bend radius increases the transmitted signal loss due to the transfer of power from the guided modes to the radiation modes supported by the core of the optical fiber. Considerable theoretical and experimental research has been conducted on the subject of wavelength dependence of bend loss in single-mode optical fibers (Marcuse, 1976a, 1976b; Berthold, 1995; Lagakos, Cole & Bucaro, 1987; Arya et al., 1995; Al-Aruri, 1991). However, due to the complex nature of bend loss in multimode fibers there are few publications in this area (Boechat, Hall & Jones, 1991; Donlogic, 2009; Schermer & Cole, 2007; Kao, 1982; Snyder, White & Mitchell, 1975). The mathematical models proposed by Kao (1982) and Snyder, White, and Mitchell (1975) are two examples of theoretical models dealing with the subject matter of bend loss in multimode optical fibers.

The primary goal of this work is to examine the wavelength dependence of bend loss in multimode optical fibers at low power levels (<10 mW) and to compare experimental measurements to the values predicted by Kao's model. Here, it is worth noting that Kao's model was selected in this work for modeling the bend loss in multimode optical fibers as a function of wavelength because of the model simplicity.

Additionally, this work provides a discussion for the results obtained from a displacement multimode optical fiber microbend sensor at 337.1, 470, 632.8, 750 and 810 nm laser wavelengths.

Microbend fiber-optic sensors utilize the modulation of the laser beam intensity guided through the optical fiber core as the transduction mechanism for detecting environmental parameters (Lagakos & Bucaro, 1987; Yao & Asawa, 1983; Donlagic & Zavrsnik, 1997). Owing to the several advantages of fiber-optic sensors (i.e., low cost, small weight and size, EMI/RF noise immunity) when compared with electric/electronic sensors, fiber-optic microbend-based sensors found their unique place into numerous industrial and biomedical applications (Matias, Ikezawa & Corre, 2017; Udd & Spillman, 2011; Kron, MacDoughall & Mendez, 2014). Some of these applications include variable optical attenuators (VOA) (DeBoynton & Uschitsky, 2001; Ao & Furuichi, 2006), which are widely used in fiber amplifiers and lasers (Alaruri, 2012), monitoring structures deformation (Ribiero et al., 2011), pressure (Roriz et al., 2013; Fields et al., 1980), temperature (Li et al., 2009; Berthold et al., 1987; Lumholt et al, 1991), stress (Remouche, Georges & Meyrueis, 2013),

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