Optical fiber characterization by optical coherence tomography

Fernando A. M. Saccon, Marcia Muller, José L. Fabris
Programa de Pós-Graduação em Engenharia Elétrica e Informática Industrial - CPGEI
Universidade Tecnológica Federal do Paraná
Curitiba, PR, CEP 80230-901, Brasil

Abstract— **In this work we describe the application of time domain optical coherence tomography to characterize optical fibers. The system presents the capability to construct cross-sectional images of the fiber; however, as the aim of the work is to establish the refractive indexes profiles boundaries across the sample, the device works as a low coherence interferometer. The equipment resolutions are about 20 µm for axial resolution and 35 µm for transversal resolution, allowing multimode fibers to be investigated with the technique. Results for physical dimensions and refractive indexes are presented and discussed.**

Keywords- Optical coherence tomography; low coherence interferometry; optical fibers

I. Introduction

Optical coherence tomography (OCT) is an imaging technology that produces high-resolution cross-sectional images of materials and biological tissues [1] from a series of laterally adjacent depth-scans. OCT was originally developed for biomedical tomographic imaging and medical applications still continue to dominate the field. Non-medical OCT is still in incipient and in particular industrial OCT is being explored [2].

OCT is analogous to ultrasound, measuring the backreflection intensity of infrared light rather than sound. However, unlike ultrasound, the backreflection intensity is difficult to be measured electronically due to the high speed associated with the propagation of light. Therefore, a technique known as low coherence interferometry (LCI) is used.

An advantage that OCT presents over high-frequency ultrasonic imaging, a competing technology that achieves greater probing depths but with lower resolution, is the relative simplicity and lower cost of the hardware on which OCT systems are based [1].

The aim of this work is to determine the refractive indexes of optical fibers if the dimensions are known. The altogether core, cladding and coating characteristics are not normally provided by manufacturers due industrial patents, despite they are required for many applications especially in academic research. Through OCT we describe a way to quantify these data having previous information about the diameters of the layers.

II. Time domain OCT theory

The OCT technique is based on the interference of two low coherence beams, in which the longitudinal spacial resolution is determined by spectral bandwidth of the source, and depth penetration in the sample is a function of scattering and absorption coefficients.

The most common interferometer configuration employed today in time domain OCT systems is the fiber-optic Michelson interferometer, as shown in Fig. 1. In this type of interferometer, light from the broadband source is guided through a single-mode fiber (a fiber-optic beam splitter) to an evanescent mode coupler where half of the optical power is extracted to another single-mode fiber that conducts the light to the reference mirror. The remaining half of the light enters the sample [1]. Light retroreflected from the reference and the sample is recombined at the beam splitter, and half of it is collected by a photodetector in the detection arm of the interferometer. Half of the light is returned toward the source, where it is lost. In addition, the reference-arm light is typically attenuated by orders of magnitude to improve the signal-to-noise ratio (SNR). Thus, virtually 75% of the optical power supplied by the source is wasted in this typical configuration [3]. Other disadvantage of this configuration is that the dc signal and intensity noise generated by the light from the reference arm is added to the interference signal [1]. As the optical delay line in the reference arm is changed, light backscattered from the interfaces in the multilayered sample generates interference fringes on the detector, whenever the optical path difference between the arms is lower than the source coherence length. Temporal central position of the interference envelope is related to the depth of the interface in the sample, whereas its amplitude is related to reflectivity of the interface.

Some new interferometer designs for OCT incorporates optical circulators, unbalanced couplers, and (or) balanced detection, which are designed to optimize optical power efficiency and system SNR. In balanced configuration, these background noise components are cancelled by subtracting the photocurrents generated by two photodetectors [3], illustrated in Fig. 2. The interference signals add at the output of the detectors because they vary out of phase.