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Dual Fabry-Perot Interferometric Fiber Sensors for Refractive Index Monitoring of Salt and Sugar Solutions Using Broadband Spectral Analysis

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Abstract

The precise monitoring of chemical concentrations in liquids is critical for environmental, industrial, and biomedical applications. Optical fiber sensors, particularly those based on Fabry-Perot interferometry (FPI), offer high sensitivity, tolerance to harsh environments, and multi-sensing capabilities, making them ideal for detecting refractive index changes in various solutions. This study presents the design and implementation of an FPI sensor for real-time monitoring of refractive index changes in salty and sugary aqueous solutions. The sensor comprises two distinct open-cavity Fabry-Perot sensor heads, each tailored to a specific solution. The cavities are fabricated by chemically etching the tip of a single-mode optical fiber using Hydrofluoric acid (HF) and then splicing it with a cleaved single-mode fiber to form air-gap microcavities. The two sensor heads differ in cavity length, allowing them to produce unique interference patterns within a combined reflected spectrum. A broadband light source is directed into the system via a circulator and a 50/50 coupler, enabling simultaneous interrogation of both sensors. The reflected signals from each sensor are recombined and analyzed using an optical spectrum analyzer (OSA). As the concentrations of salt and sugar are gradually increased, corresponding shifts in the interference fringes are observed due to changes in the refractive indices of the solutions. The difference in cavity lengths enables spectral separation of the two sensor signals. A Fast Fourier Transform (FFT) is applied to the combined spectrum to isolate each sensor's contribution based on their distinct spatial frequency responses. The change in the refractive index of the solution can be estimated using the Free Spectral Range (FSR - distance between two adjacent peaks). The proposed FPI sensor system successfully demonstrates the ability to simultaneously monitor and distinguish refractive index changes in two different liquid solutions using a compact and cost-effective optical setup. The technique shows strong potential for multi-parameter sensing applications in chemical, biomedical, and environmental monitoring.

Keywords: Fabry-Perot Interferometer, Concentration, Fast Fourier Transform, Free Spectral Range

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