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Multi-wavelength Fiber-Optic Refractometer Based on Multimodal Interference and Surface Plasmon Resonance

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Summary:

We demonstrated a multi-wavelength fiber-optic refractometer using a multimode-coreless-multimode fiber structure, partially coated with a gold layer, in which multimodal interference and surface plasmon resonance are simultaneously excited. The transmission spectra exhibit three spectral dips, in the visible and the near-infrared regions whose wavelength position is determined by the refractive index of the surrounding medium. This enables the determination of the refractive index of a liquid sample at three different wavelengths to estimate its refrective index dispersion curve using Cauchy's equation.

Keywords: Fiber-optic sensors, multimodal interference, surface plasmon resonance, refractive index dispersion, acetaminophen concentrations.

Background, Motivation and Objective

The measurement of the refractive index is one of the most widely used methods for the determination of a sample purity. However, most optical fiber refractometers reported so far operate at a single wavelength [1,2], which limits the ability to provide information of the content of a mixed sample. To address this limitation, refractometers using different wavelength sources have been developed [3,4], however, these configurations increase the complexity and cost of the system.

In this work, we propose a fiber-optic device that, using an incoherent white-light source and an optical spectrum analyzer, enables the simultaneous measurement of the refractive index at three wavelengths [5]. Based on these measurements, the spectral dependence of the sample's refractive index can be estimated using the Cauchy model.

Description of the New Method or System

A fiber-optic refractometer was developed based on the simultaneous excitation of multimodal interference and surface plasmon resonance, enabling the measurement of the refractive index of liquids at three different wavelengths using a single broadband light source. With these refractive index values and using the Cauchy model, it is possible to estimate the dispersion of the liquid sample. The refractometer proposed here reduces the complexity and cost of measurements compared to setups that require multiple light sources. In addition, this optical fiber refractometer can be used for in situ measurements, making it suitable for monitoring and quality control applications.

Results

To construct the sensor, as shown in Fig. 1, two segments of multimode optical fiber are joined to a 29 mm segment of coreless fiber, which, through multimode interference, produces a transmission band at 790 nm and an attenuation band at 1560 nm. Subsequently, a 3 nm chromium adhesion layer and a 30 nm gold film, were deposited over section of 10 mm length of the coreless fiber to generate surface plasmon resonance in the visible region.

To calibrate the refractometer, the device was immersed in different Cargille oils with refractive index in the range of 1.30 to 1.40. As shown in Figs. 2(a), 3(a), and 4(a), the three dips in the transmission spectra exhibit a red shift as the refractive index increases, although with different sensitivities. From these spectra, the minimum of each dip is identified and used to obtain the polynomial calibration curves shown in Figs. 2(b), 3(b), and 4(b). With these curves is possible to determine the refractive index of an unknown substance by monitoring the wavelength position of the three dips minima in the transmission spectrum.

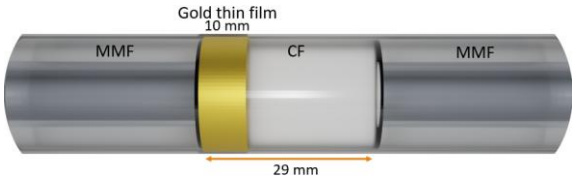

Fig. 1. Schematic of the fiber-optic refractometer.

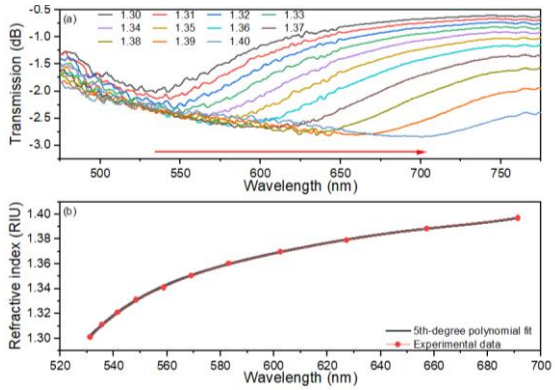

Fig. 2. (a) Partial transmission spectra of the plasmonic resonance as a function of the refractive index of the surrounding medium. (b) Corresponding calibration curve.

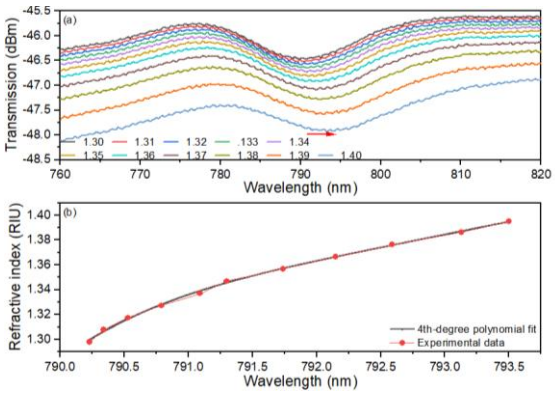

Fig. 3. (a) Partial transmission spectra of the transmission band as a function of the refractive index of the surrounding medium. (b) Corresponding calibration curve.

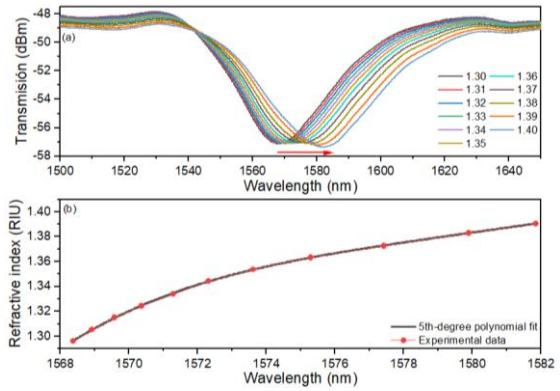

Fig. 4. (a) Partial transmission spectra of the attenuation band as a function of the refractive index of the surrounding medium. (b) Corresponding calibration curve.

To test the broadband refractometer, liquid samples of acetaminophen in water were prepared at concentrations of 1, 2, 4, and 6 mg/mL. Based on the obtained spectra, the refractive index values were interpolated at three different wavelengths; subsequently, their dispersion was calculated using Cauchy's equation. Fig. 5 shows these curves, which reveal an increament of the refractive index as the acetaminophen concentration increases; furthermore, the curves for 2, 4, and 6 mg/mL retain a similar shape.

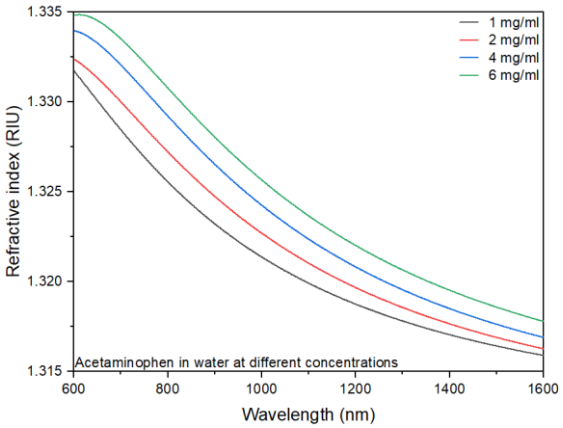

Fig. 5. Refractive index dispersion for different concentrations of acetaminophen in water.

References

[1] P. K. Rastogi, Optical Measurement Techniques and Applications, Artech House (1997).

[2] P. Gong, X. Li, X. Zhou, Y. Zhang, N. Chen, S. Wang, S. Zhang, Y. Zhao, Optical fiber sensors for glucose concentration measurement: A review, Optics & Laser Technology 139, 106981 (2021); doi: 10.1016/j.optlastec.2021.106981

[3] K. Karpienko, M. Wróbel, M. Szczerska, Determination of refractive index dispersion using fiber-optic low-coherence Fabry–Perot interferometer: Implementation and validation, Optical Engineering 53, 077103 (2014); doi: 10.1117/1.OE.53.7.077103

[4] D. Zhu, R. Chen, W. Jia, H. Zhu, Q. Zhang, S. Han, Refractive index measurement based on multi-wavelength laser interferometer, Proceedings of SPIE 11899, 118990Y (2021); doi: 10.1117/12.2601193

[5] E. Galván-Navarro, M. Alonso-Murias, E. Rodríguez-Sevilla and D. Monzón-Hernández, "Broad-spectrum all-fiber optic refractometer for alcoholic beverages identification," *Optics and Lasers in Engineering*, under review, 2026.M. Mouse, D. Duck, The Beagle Boys for President, *Journal of Applied Nonsense* 13, 123-134 (2011); doi: 10.1234/s10000