Thermo-optic discrimination of aqueous solutions composition using a multimodal interference fiber optic sensor

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1 INTRODUCTION

Refractive index (RI) is a fundamental optical property that determines how light interacts with material. Some compounds exhibit similar RI when dissolved in water resulting difficult to differentiate them using traditional optical methods. To address this concern, the thermo-optical response provides a promising approach for their identification.

2 MOTIVATION

- Optical fiber sensors offer significant advantages, including high sensitivity, immunity to electromagnetic interference, ease of use, real-time operation and flexibility [1].
- The proposed method can be used for advanced applications in process monitoring and control in various scientific and technological disciplines where precise detection and quantification of compounds are crucial.

3 GOAL

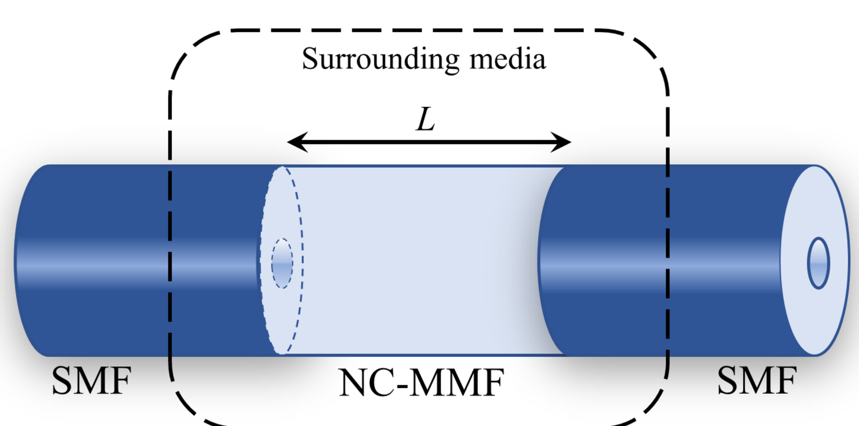
- Use an optical fiber sensor based on multimode interference effect (MMI) to characterize RI of aqueous solutions.
- Present 2 different chemical compounds whose RI behavior is indistinguishable in aqueous solutions and successfully discriminate between them using its thermo-optic response.

4 METHODS

The sensor device consists in a coreless multimode fiber segment (NC-MMF) spliced to two single-mode fiber segments (SMF). This structure is commonly called SMS. A transmission peak appears when light travels through the device, and it depends on the effective refractive index of the surrounding media and NC-MMF length [2].

Aqueous solutions of tris and fructose were prepared and their temperature-induced changes in RI were recorded at controlled temperature variations.

5 EXPERIMENTAL SET-UP



$$\lambda_{peak} = p\frac{n_{eff}W_{eff}^2}{L} \qquad p=1,2,3,\ldots$$

$$W_{eff} = W + \frac{1}{2}\left(\frac{\lambda_0}{\pi}\right)\left(n_r^2 - n_c^2\right)^{-1/2}\left[\left(\frac{n_c}{n_r}\right)^2 + 1\right]$$

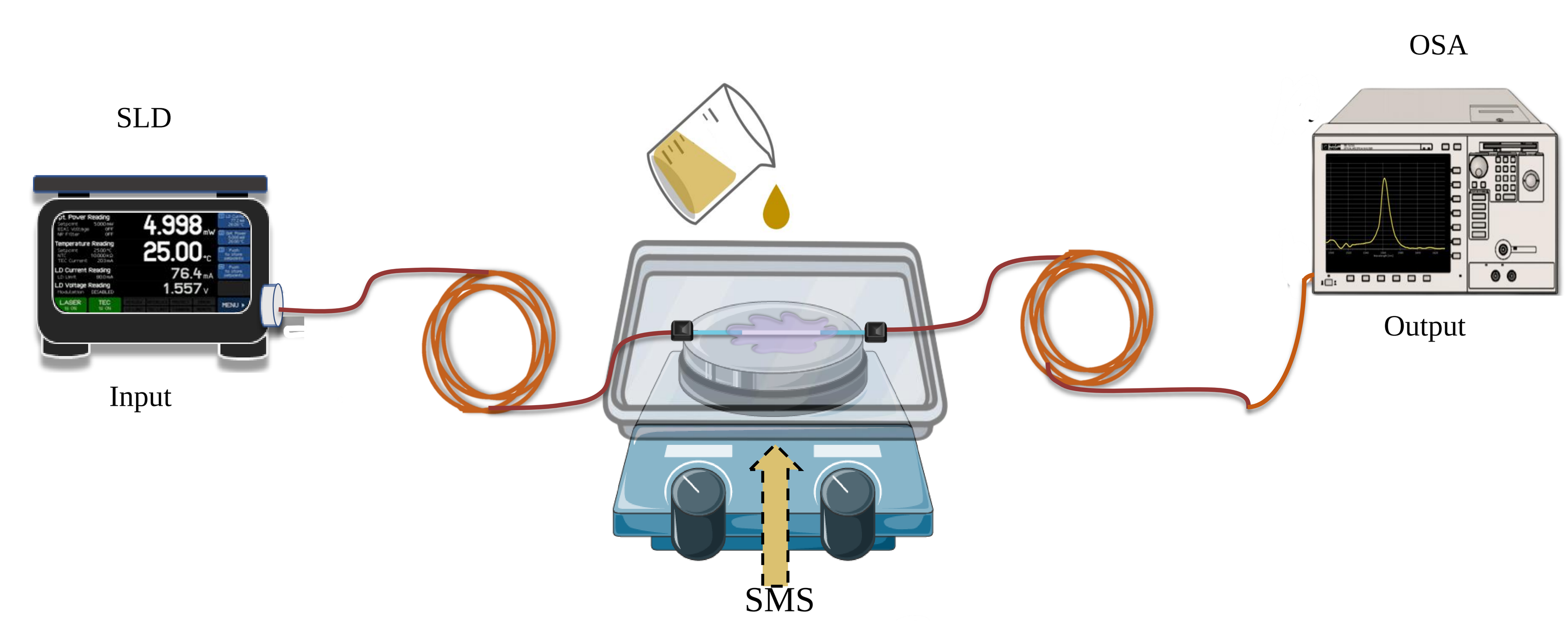


Figure 1. Experimental setup

6 RESULTS

Total spectra shift of 7.95nm for Tris and 8.25nm for fructose were measured.

The thermal response was evaluated at a concentration of 30% in 30ml using a hot plate, with the sensor submerged and covered (Figure 1) and samples were made at temperature from 25 °C to 45 °C, in increments of 2.5 °C (Figure 4), presenting a positive spectral displacement and a nonlinear dependence on temperature.

The measured thermal sensitivity was 0.14433 nm/°C for Tris and 0.1852 nm/°C for fructose.

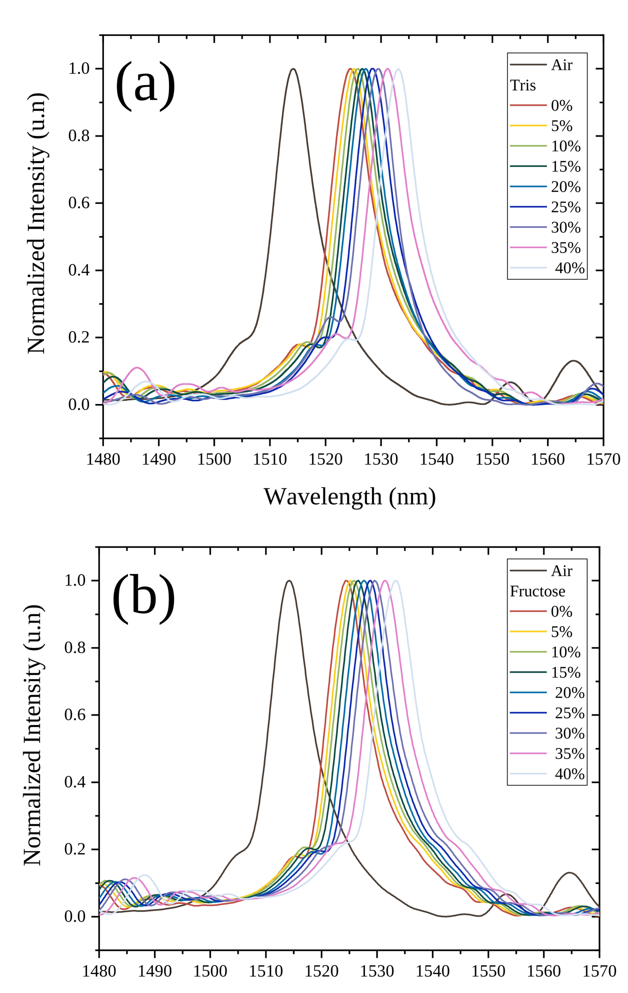


Figure 2. Spectral response of the optical fiber device for Tris (a) and fructose (b)

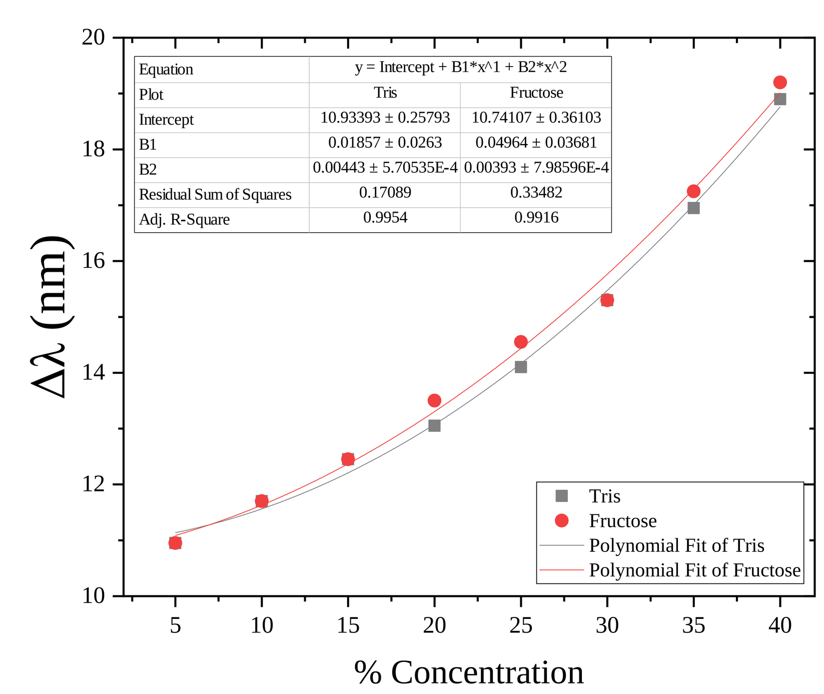


Figure 3. The spectral shift of the peak wavelength, with respect to the baseline condition, as a function of the concentration of tris and fructose.

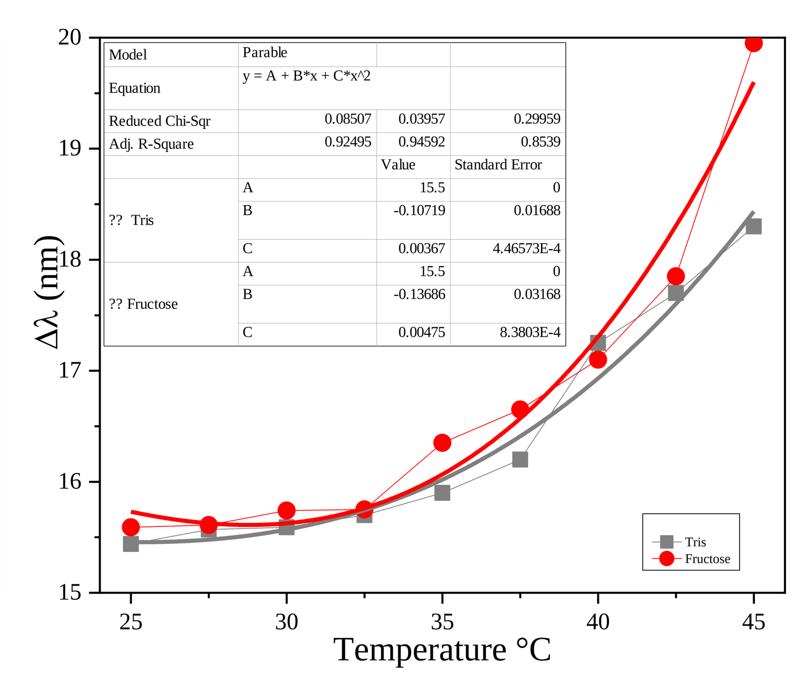


Figure 4. Response of the spectral shift of the peak wavelength when applying temperature for tris and fructose.

7 CONCLUSIONS

The SMS sensor has the potential as a superior alternative to traditional sensors due to its dual sensitivity to refractive index and temperature. Its unique ability to differentiate solutions with similar optical characteristics but different thermal responses make it valuable for real-world applications, including process control, food quality assurance, and biomedical analysis. The sensor's versatile design opens doors to advancements in industrial and scientific sensor technology.

REFERENCES

1. E. Udd, W.B. Spillman Jr., "Fiber Optic Sensors: An Introduction for Engineers and Scientists". John Wiley & Sons: Hoboken, NJ,
2. L.B Soldano, E.C.M. Pennings, "Optical multi-mode interference devices based on self-imaging: Principles and applications". J. Light. Technol. 1995, 13, 615–627.