Development of Cost-effective Liquid Core Waveguide Spectrophotometer for Iron Determination

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Abstract

A simple, sensitive, and cost-effective liquid-core waveguide (LCW) absorption spectrophotometer was developed. The system enhances total internal reflection (TIR) by increasing the refractive index of the liquid core using glycerol, enabling a long optical path within a compact design and improving detection sensitivity. The device was applied for trace determination of Fe^{3+} via colorimetric complexation with SCN^-. Under optimal conditions, a linear range of 10–400 nM, LOD of 5.9 nM, LOQ of 19.7 nM, and RSD < 3% were achieved. The method was successfully applied to determining free Fe^{3+} in serum as non-transferrin bound iron (NTBI).

Introduction

Liquid core waveguide (LCW) improves the sensitivity of spectrophotometric analysis by extending the optical path length (b). According to the Beer-Lambert Law (Eq. 1), sensitivity is directly proportional to this path length. In an LCW, light is confined within the liquid core via total internal reflection (TIR). This phenomenon occurs when incident light strikes the interface at an angle greater than the critical angle (θ_c), as defined by Snell's Law (Eq. 2):

$$A = \varepsilon bc \qquad ..(1) \qquad \theta_c = cos^{-1}\left(\frac{n_2}{n_1}\right) \qquad ..(2)$$

Conventional LCW systems typically employ Teflon AF tubing (RI=1.29) as the cladding material because its RI is lower than that of the aqueous liquid core (RI=1.33). However, due to the high cost of Teflon AF, this study proposes a cost-effective alternative using fluorinated ethylene propylene (FEP) tubing (RI=1.34). To maintain the TIR conditions, a modified core solution is utilized to ensure the liquid core retains a higher RI than the FEP tubing.

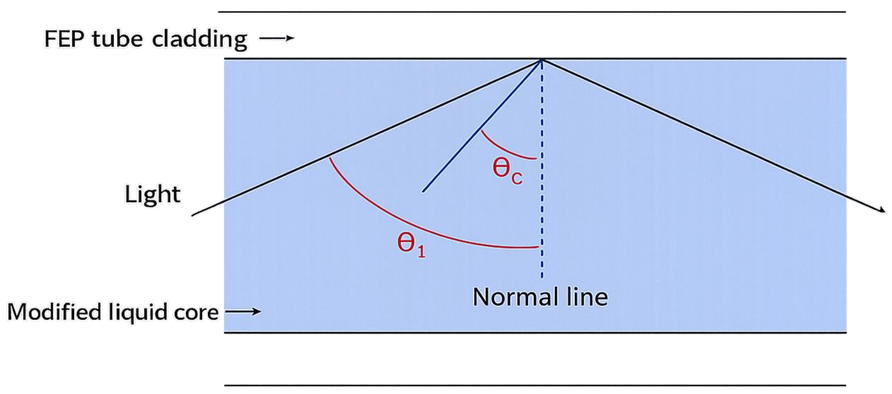
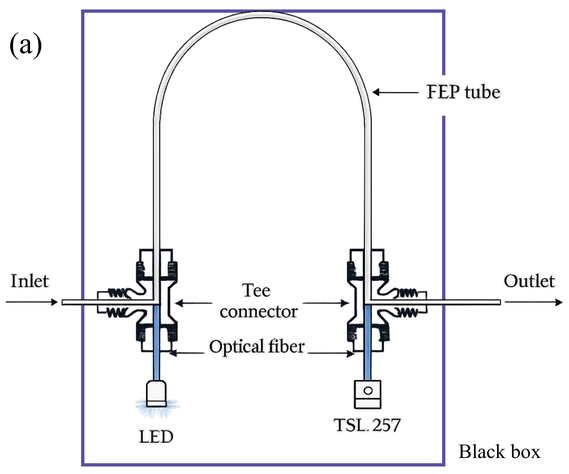


Fig. 1 Cross-section of the FEP tube illustrating total internal reflection (TIR) at the liquid-cladding interface

Experiment



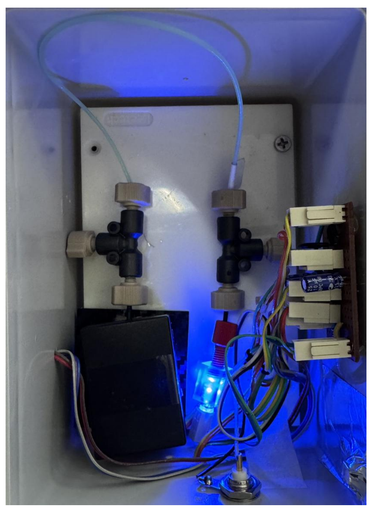
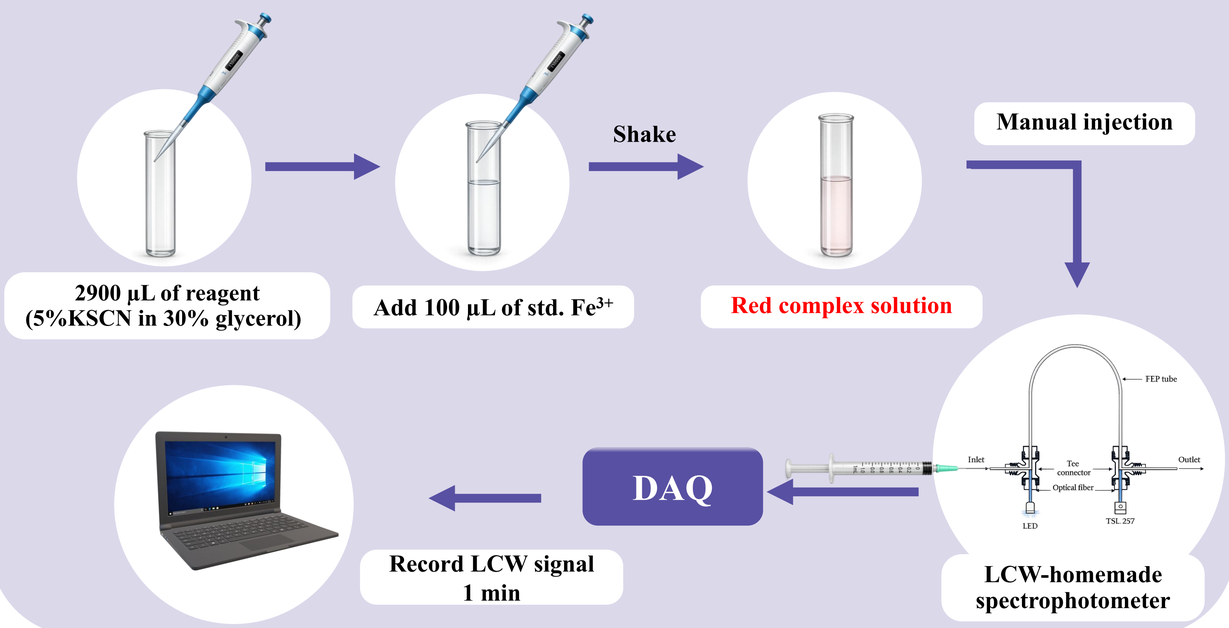


Fig. 2 (a) Schematic diagram of the liquid core waveguide (LCW) detection cell and (b) the integrated, homemade LED-based long-path spectrophotometer system

Analytical procedure



Result

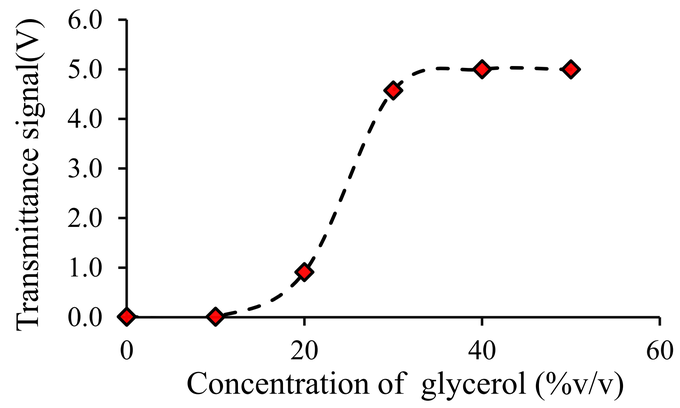


Fig.3 Transmittance signal of the LCW effected concentration (%v/v) of glycerol

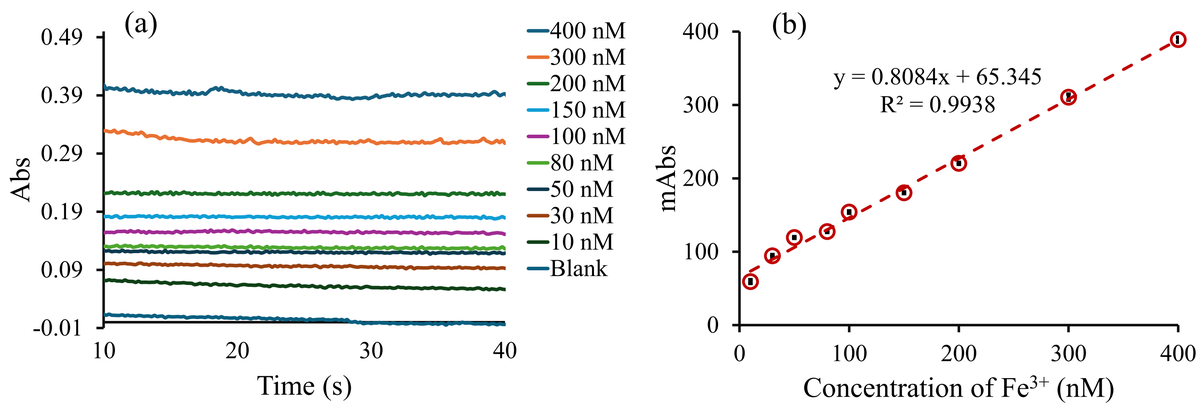


Fig. 4 (a) Absorbance signal and (b) calibration graph of 30%v/v glycerol modified LCW with 5% w/v KSCN for Fe^{3+} determination with using a homemade LED-based long-path spectrophotometer

Table 1 Analytical performance of the proposed LCW for Fe^{3+} determination

Analytical performance	Result
Linear range (nM)	10-400
Limit of detection (LOD) (nM)	5.9
Limit of quantification (LOQ) (nM)	19.7
%RSD	<3%

Table 2 The recovery of Fe^{3+} determination in serum sample using the proposed LCW method

Sample	Added Fe^{3+} (nM)	Found Fe^{3+} (nM)	%Recovery
serum no.1	0	65	-
	30	95	101
	50	113	96
	100	184	119

Conclusion

- This study successfully developed a simple and cost-effective LCW spectrophotometric system for the determination of Fe^{3+} using thiocyanate chemistry.
- The method was successfully applied to the determination of Fe^{3+} in serum samples as non-transferrin bound iron (NTBI), with satisfactory recoveries ranging from 96–119%, demonstrating its potential as a sensitive and low-cost approach for trace iron analysis.

Acknowledgments

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References

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