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Oral ☐ / Poster ☒ / The same ☐ Topic: Applications of Photonic Technologies

Near Infrared diffused reflectance on tissue simulating phantoms for optical applications

P. Demosthenous[1] and M. Baer [2]
[1] Cyprus Research & Innovation Center Ltd (CyRIC),72, 28th Octovriou Ave, Engomi, 2414 Nicosia, Cyprus
[2] Institute of Microwaves and Photonics (LHFT) and Erlangen Graduate School for Advanced Optical Technologies (SAOT), Cauerstr. 9, 91058 Erlangen, Germany
Tel.: + 357 22-282828
E-mail: p.demosthenous@cyric.eu

Summary: We demonstrate a series of experiments that examine near infrared (NIR) diffused reflectance on low-cost optical tissue phantoms compose of water, gelatin, and/or titanium dioxide (TiO_2) powder. Such samples are commonly used in optical applications to simulate human tissue, where TiO_2 powder is used as the scattering agent. The experiments use a NIR Distributed Feedback Laser (DFB) at spectral around 2.274μm, where water presents relative low absorption coefficient compared to other substances such Ethanol that could provide blood alcohol concentration (BAC) measurements. The results demonstrate a fusibility study on using diffused reflectance on tissue phantoms in comparison to finger measurements, for optical applications similar to the optical detection of exogenous substances on human body.

Keywords: Near Infrared, Diffused Reflectance, Tissue Phantoms, Distributed Feedback Laser, Blood Alcohol Concentration.

1. Introduction

This paper examines the fusibility on detecting Ethanol on human body, for determine blood alcohol concentration (BAC), by using NIR diffused reflectance on tissue phantoms in comparison to finger measurements. The optical setup uses an integrating sphere for the efficient collection of the diffused light from the sample, and at the same time examines the fusibility of a touch-based oriented detection.

2. Materials and Methods

The experiments use an Integration sphere that is known to be beneficial in some spectroscopic applications, especially in scattered/diffused reflectance or transmittance measurements [1]. Moreover, integrating spheres are used to enhance the collection of backscattered light in non-invasive sensing applications such as, finger photo plethysmography for determine blood constituents [2], and quantum cascade laser spectroscopy for glucose sensing [3]. In order to examine near infrared (NIR) diffused reflectance on simulating tissues, the experiments use, low-cost optical tissue phantoms [4] composing of water, gelatin, and/or titanium dioxide (TiO_2) powder. Such samples are commonly used in optical applications to simulate human tissue.

3. Measurement of tissue phantoms

3.1. Sample Preparation

Gelatin samples were prepared within glass chemistry vials that are transparent to NIR light. The dry components (gelatin, TiO_2) were filled into the glass vials and shaked. Then the water was added quickly, to prevent clogging of the gelatin. The mixture was shaken until the gelatin was soaked with water. Then the mixture was heated in the microwave at full power. To prevent the TiO_2 powder to settle down, the vial was placed in a custom-made sample-shake carousel until the mixture reaches a semi-solid consistency. When preparing samples with ethanol, the ethanol is added to the mixture after cooking. This prevents the ethanol from evaporating and changing its concentration in the mixture.

3.2. The optical setup

The optical setup for the measurements uses the Thorlabs NIR integrating sphere (IS200-4) in combination with Sacher DFB Laser (2.274μm) and Roithner RW-16 LED at roughly 1.6 μm (Fig. 1).

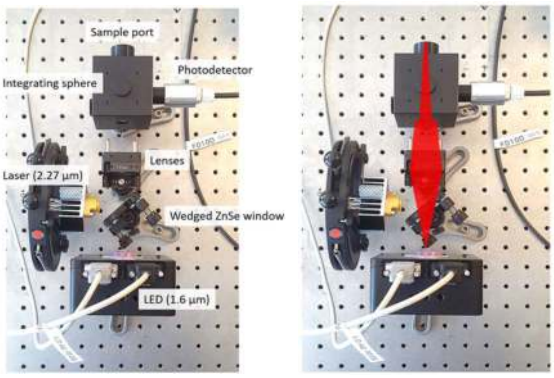

Fig. 1. Optical setup, which combines two NIR light sources (left). Beam path for the LED light source (right).

DFB Laser at 2.274 μm corresponds to an absorption peak of Ethanol, while 1.6 μm LED has been chosen for baseline measurements where ethanol and water absorption is low. Both light sources are combined using a wedged ZnSe window. As neither the Laser nor the LED are perfectly collimated, two lenses, f1=80 mm and f2=100 mm, are used to collimate/focus the light within the integrating sphere.

The setup is aligned in a way that the light that enters the integrating sphere completely, leaves the integrating sphere at the opposite port.

3.3. Ethanol samples with gelatin and TiO_2

For the measurements with ethanol samples, two samples with 17% ethanol and two samples with only water have been prepared using the proposed method. Each of these samples has been measured twice. Further, a measurement with the sample port open has been conducted. The results of the detected light intensities are presented in Fig. 2. The signal processing uses simultaneous signal acquisition by synchronous detection of orthogonal frequency components algorithm [5]. The ratio of the Laser and LED intensity is also shown in Fig. 3. The diffuse reflectance of the samples is rather weak, but comparable to a finger as will be shown in the next section. Unfortunately, there is no significant difference between the samples with and without ethanol. Therefore, there is an obvious limitation on getting lower limits of detection for BAC measurements.

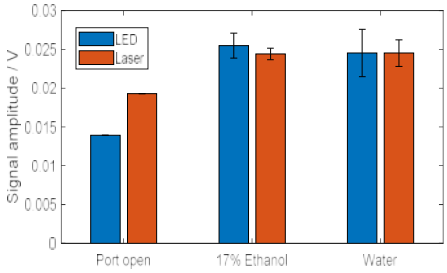

Fig. 2. Measurement of gelatin samples with TiO_2, with and without ethanol.

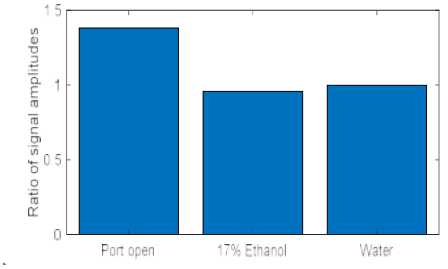

Fig. 3. Ratio of the Laser and LED signal amplitude.

4. Measurement of finger 'sample'

As a final experiment, similar measurements have been conducted, but this time on a real finger 'sample'. The sample port was covered with a thin glass plate and diverse prepared fingers have been pressed against the glass plate: a) Dry finger, b) Finger soaked for >5 min in pure ethanol, c) Finger soaked for >5 min in water. In addition, a measurement with the plain glass plate was done. The results are given in Fig 4 and Fig. 5. Worthy of note is the little difference between all measurements which proves that such touch-based systems lead to quite repeatable results. Unfortunately, there is again a very little difference between the finger soaked in ethanol and the finger soaked in water, similarly to the measurement that uses gelatin tissue phantoms.

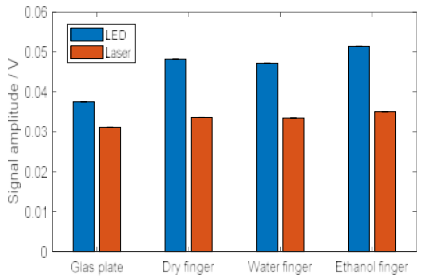

Fig. 4. Measurement of dry finger, water, and Ethanol-soaked finger.

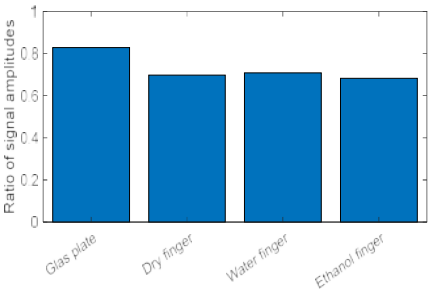

Fig. 5. Laser & LED signal amplitude ratio of Fig. 4.

5. Conclusions

Although the repeatability of these experiments was quite promising, a differentiation between ethanol concentrations in tissue phantoms and a finger is hardly possible via diffused reflectance.

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