SIMULTANEOUS SENSING OF MULTIPLE SAMPLES WITH A SINGLE SPECTROMETER

Introduction

In a previous application we described how a side illuminated optical fiber, coated with a fluorescent substance, can be used to perform multiple points sensing with a single spectrometer. In a second application, we also described a bare core fiber that can be used to determine nitrate using UV absorption. In this application we document a colorimeter that combines these two techniques to perform simultaneous sensing of multiple samples.

Background

The first side illuminated optical fiber sensor was reported by a group of AT&T Bell Lab researchers in 1989 [1] who described a fluorescent cladding fiber sensitive to molecular oxygen. Soon afterwards, in 1990, this author started working on this field [2], [3], [4], [5], [6] and, in the process, reduced this technology to practice with a series of experiments that resulted in different patents throughout the world.[7], [8], [9] He discovered and patented: an optical fiber with multiple sensing points; [7], [8] a sensitive cladding fiber that uses absorption instead of fluorescence; [8], [10], [11] , [12] a multiple point bare core optical fiber; [9], [13] a side illuminated tapered optical fiber [8], [9]; simultaneous sensing of multiple samples [8], [9] and others.

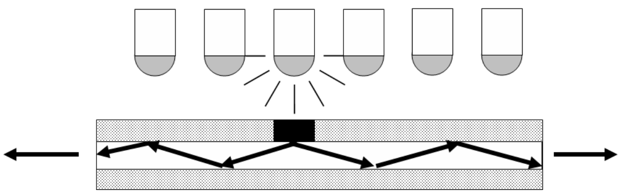

Figure 1a. Light source #3 probing a fluorescent cladding optical fiber and its associated fiber section.

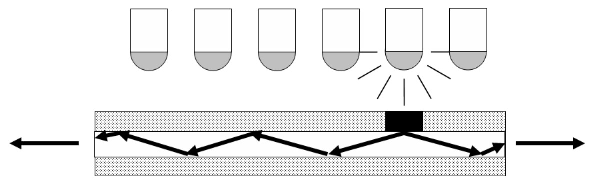

Figure 1b. Light source #5 probing a fluorescent cladding optical fiber and its associated fiber section.

Unlike axial illumination, side illumination can use several light sources along the fiber length to generate multiple signals (see Fig. 1a and 1b). This allows the probing of the optical fiber at different positions along its length using simple switching techniques while increasing the system redundancy. Multiple sources can also simultaneously illuminate a single sample to increase the fiber's signal, and consequently, its sensitivity.

While Figures 1a and 1b illustrate an active cladding optical fiber, it is also possible to use a bare core fiber in its place. One possible configuration involves the simultaneous measurement of multiple samples along the optical fiber. If sources of different and non-overlapping spectral distributions are used, see Figure 2a, it is possible to make simultaneous measurements of multiple samples. Accordingly, *n* light sources are deployed along a bare core optical fiber: each of them illuminates different samples which absorb the incoming light. A fraction of the light that survives through each sample is coupled into the bare core fiber and guided to a USB-2000 spectrometer. Since the spectral distributions of the sources do not overlap, it is possible to simultaneously separate each signal with a spectrometer.

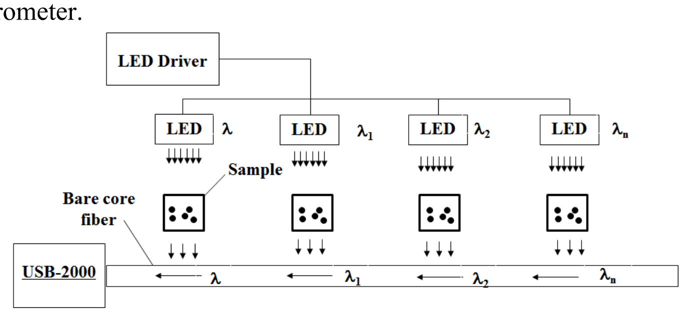

Figure 2a. Simultaneous multiple point sensing with a bare core optical fiber (not in scale).

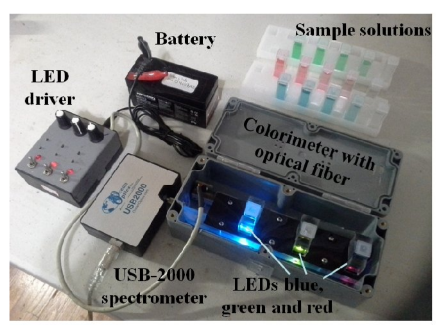

Figure 2b. Actual picture of the whole system illustrated in Fig. 2a.

Proof of Concept

The following setup was used to prove the above concept (Figure 2b):

1. A bare core optical fiber mounted inside a colorimetric box.
2. Three LEDs with non-overlapping spectral distribution (see Fig. 3a).
3. A multichannel LED driver to power each LED.
4. Red, blue and green food dye solutions with concentrations between 0 and 5 drops per 0.5L of water and
5. An Ocean Optics USB-2000 mini spectrometer.

The red, blue and green solutions were placed inside a cuvette and simultaneously illuminated by the blue, green and red LEDs, respectively (see Figure 2b). Ensuring that each solution is illuminated by a different color LED increases the amount of absorption and the sensitivity of the system. The resulting spectral distributions for three different concentration samples are shown in Figure 3a: as the dye concentration increases the light intensity decreases. Also, each graph represents three simultaneous absorption measurements in the red, green and blue. Although it is illustrated only three simultaneous measurements, this number can be increased with sources of different wavelengths having narrower spectral distributions: the narrower the spectral distribution, the larger the number of simultaneous measurements is possible.

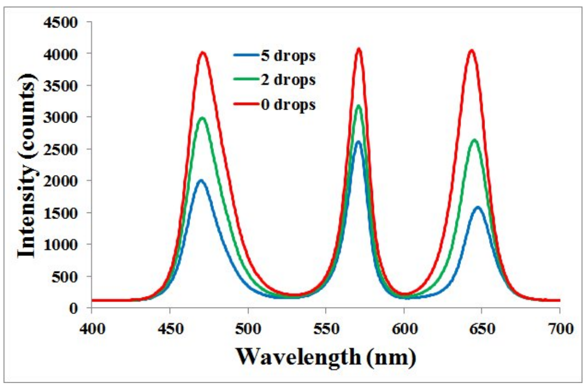

Fig. 3a. Spectral curves of the first, second and third sensing points of the fluorescent cladded optical fiber.

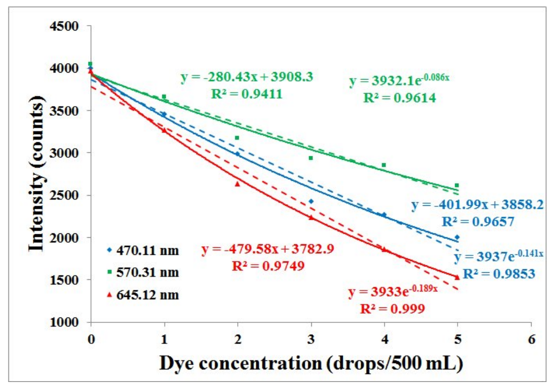

Fig. 3b. Spectral curves of the first, second and third sensing points of the fluorescent cladded optical fiber.

From the data collected, a calibration curve was also plotted (Fig. 3b) at three different wavelengths: 470.11nm, 570.31 nm and 645.12 nm, corresponding to the peak wavelength of the LEDs. It can be seen that the red light LED, which illuminated the cuvette with the green solution, has the largest sensitivity of all.

Conclusions

Simultaneous measurement of different samples with an optical fiber side illuminated at different wavelengths was demonstrated using an Ocean Optics mini spectrometer. This is a rather inexpensive and flexible technique that can be used towards a multitude of commercially available colorimetric measurements such as nitrate, phosphate, magnesium, calcium and other ions. Although this proof of concept presented only colorimetric measurements, this same technique can be adapted for fluorescence, scattering, index of refraction and others.

References

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