SIDE ILLUMINATED OPTICAL FIBER SENSOR FOR NITRATE USING UV ABSORPTION

Introduction

Absorption spectroscopy is an important tool in the analytical laboratory. It can be used in the visible, infrared and ultraviolet, UV, to determine the concentration of different analytes. UV spectroscopy, for instance, can be used to determine the concentration of nitrate in water using free space optics and this has been used in commercially available instruments. In this application note, we describe a new technique that uses side illumination of a bare core optical fiber by an UV source. This technique can be used with several UV light sources to increase the signal of the sensor and, consequently, its sensitivity. We performed these measurements with Ocean Optics USB-2000 spectrometer and UV LEDs that are commercially available.

Background

The first absorption based side illuminated optical fiber sensor was reported by this author in 2009 [1] and [2]. Initial experiments in the visible demonstrated this technique and, soon afterwards, it was extended to the UV. Figure 1a illustrates this technique: several light sources, with a wavelength that can be absorbed by a given analyte, are deployed along a bare core optical fiber. Some of its light passes through the analyte and is absorbed, a fraction of this absorbed light couples into the fiber and propagates towards the fiber end faces. The higher the concentration of the analyte the more light is absorbed. Experiments have also demonstrated that the analyte can be located either between the source and the fiber (see Fig. 1a) or behind the fiber (Fig. 1b). One of the advantages of this technique is that it is possible to increase the signal of the sensor, and consequently, the fiber sensitivity, by simultaneously turning on two or more light sources. Nitrate is known to have an absorption spectrum in the near UV and we combined this technique with our side illuminated fiber to calibrate our nitrate ion sensor.

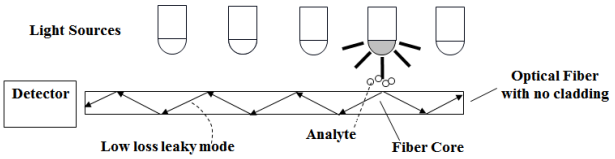

Figure 1a. Light source probing a bare core optical fiber. The analyte, e.g., nitrate in water, is between the source and the optical fiber.

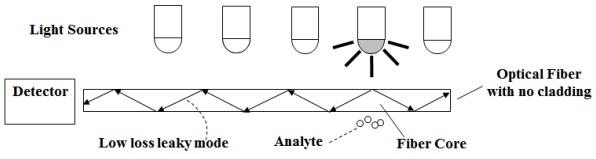

Figure 1b. Light source probing a bare core optical fiber. The analyte, e.g., nitrate in water, is behind the optical fiber.

Nitrate has an absorbance peak at 305 nm so we purchased an UV LED in this region for our experiments.

Experimental Setup and Results

The setup used in this application is illustrated in Fig. 2. It consists of

1. A tapered bare core plastic optical fiber with core diameter varying from 1 to 2 mm.
2. Three UV LEDs with peak wavelength at 310 nm (each LED simultaneously illuminating a 2 cm long fiber section).
3. An LED driver to power the LEDs and
4. An Ocean Optics USB-2000 mini spectrometer.

The fiber was mounted over an acrylic support and a black container was attached to hold the calibrating nitrate solutions. With the fiber attached to the spectrometer, the LED lights were turned on and the spectral output of Figure 3 was measured. Notice that the peak of the UV source is located at the wavelength 617 nm corresponding to the second harmonic of the peak wavelength of the LED. A broadband emission with peak at approximately 400 nm is also shown and this is due to intrinsic fluorescence of the plastic fiber.

Fig. 2. Mini-spectrometer and side illuminated optical fiber.

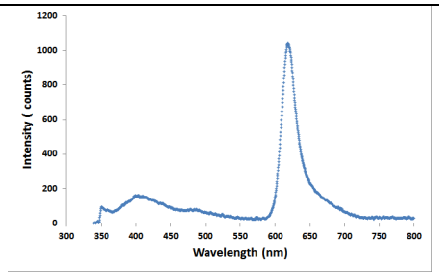

Fig. 3. Spectral output from the optical fiber while side illuminated by UV LEDs.

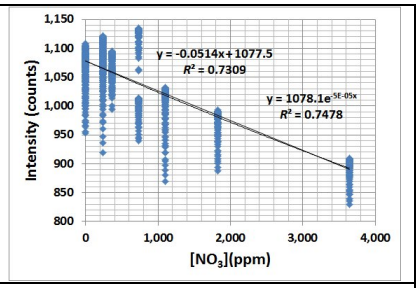

Figure 4. Data obtained with seven calibrating solutions.

Seven nitrate solutions were prepared to calibrate sensor with the following concentrations: 0, 233, 365, 729, 1,101, 1,823, 3,645, 5,504, 7,290 and 9,149 ppm. As each solution was poured into the black container, a light intensity measurement was taken nearby the peak wavelength: at the 600 nm reading which corresponds to a 300 nm wavelength (see Fig. 4).

It can be clearly seen that the UV signal decreases with nitrate concentration. According to the value of R indicated in the graph and the number of data-points, N=1,801, the confidence level is very close to 100%. The slope of the linear curve is a measure of the sensor sensitivity which is equal to 0.0514 counts/ppm of nitrate: for a resolution of 1 count in the spectrometer, this implies a resolution of 20 ppm in nitrate concentration.

Conclusions

For the first time, we demonstrated a side illuminated absorption based optical fiber nitrate sensor in the UV. Three UV LEDs were simultaneously lit to increase the fiber signal and the intensity was read with an Ocean Optics USB-2000 mini-spectrometer. The data was fit to a linear curve having a very high confidence level.

References

[1] C. O. Egalon, "Side Illuminated Multi Point, Multi Parameter Optical Fiber Sensor". US Patent 8,463,083, Priority date: 30th January 2009.

[2] C. O. Egalon, "Side Illuminated Multi Point, Multi Parameter Optical Fiber Sensor," International Bureau, IB, Pub. No.: WO/2010/088591, International Application No.: PCT/US2010/022715, Priority date 30th of January 2009.