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Optical Filter Design for Fluorescence Technique Based Phycocyanin Measurement Sensor Used In Water Treatment Plants

Vinayagam Mariappan[1], Sung Hwa Lee[2], Seungyoun Yang[3], Jintae Kim[3], Minwoo Lee[4†]

[1]*Graduate School of Nano IT Design Fusion, Seoul National Univ., of Science and Tech., Seoul, Korea*
vinayagam_m@hotmail.com
[2]*Department of Telecommunication & Information, Cheju Halla University, Seoul, Korea*
hwa2@chu.ac.kr
[3]*Fivetek LTD, Seongnam, Korea*
{neosya, jin85}@fivetek.com
[4]*IT Convergence Technology Research Lab, Seoul National Univ., of Science and Tech., Seoul, Korea*
Seoul, Korea
alsdnya@gmail.com

Abstract

Recently the water management department advised the water treatment industry to focus on deploy the chemical free and the environmentally responsible process to adopt on water treatment plants in every country. In this objective, water treatment process started using ultrasonic based phycocyanin extraction with fluorescence measurement techniques to detect the change in the yield of phycocyanin. This paper propose the design of optical filter model for fluorescence technique based immersive optical phycocyanin measurement sensor design. The proposed design uses the multi-wavelength sensor module for irradiating part, and this plays a role of removing a wavelength band other than 590 ~ 620 nm. The preliminary study on immersed phycocyanin sensor, the fluorescence value of picocyanin according to the ultrasonic intensity, treatment time and number of cells was measured using JM phycocyanin module to emulate the proposed design, and were compared performance of the proposed sensor emulation. In this design , the phycocyanin fluorescence value increased about 2.1 ~ 4.7 times as the ultrasonic treatment time increased as compared with JM phycocyanin module, and the phycocyanin fluorescence value within the analysis range was obtained by ultrasonic treatment within one minute.

Keywords: *Fluorescence, Phycocyanin, Optical, Biological Sensor, cyanobacteria, hyperspectral remote sensing, Optical Filter*

1. Introduction

The sustainable water management is today's recognized concern issue more than ever before all over the world and become the main objective in every social, political and scientific agenda due to the industrialization and environmental pollution with recent economic development. The algae population in

drinking water supply resources increasing public health attention in many countries makes the consideration on implementation of monitoring for effective development of water resource management system that leads to a reduce the risks incurred by the users of potentially contaminated water resource sites.

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Corresponding Author: alsdnya@gmail.com
Tel: +82-2-970-6431, Fax: +82-2-970-6123
Dept. of IT Convergence Technology Research Lab, Seoul National University of Science and Technology, Korea

The monitoring of the water resource bodies using a minifluorimeter specific to the fluorescence of phycocyanin, a pigment specific to cyanobacteria [1].

In the analysis of phycocyanin monitoring found that the total cyanobacterial biovolume and the concentrations of cyanotoxins (R (2) ≤ 0.22) [2]. The repeated freeze–thaw method and homogenization with mortar and pestle, Ultrasonic, and polytron homogenizer are the four effective methods used for phycocyanin extraction and found that the combined sonication/freeze–thaw method is suitable for measuring cyanobacteria phycocyanin content on lake water, even at low concentrations [3].

The effectiveness of water bodies monitoring methods is decided based on the detection accuracy on tempo

ral changes in water and that is achievable by sampling intervals, and then how samples are relate to the extent of temporal variation. The results on monitoring meso-eutrophic lake shows that relatively high errors in seasonal statistics analytic based on monthly sampling and moreover, the weekly sampling yielded analysis shows relatively small accuracy benefits compared to a fortnightly sampling [4]. In this research found that the required sampling design for specific water bodies monitoring area by adjusting the sampling interval to in-suit the actual temporal variation in the specific area, in addition to use previously collected data to estimate the temporal changes on water bodies [4].

This paper proposed the optical filter design for water immersive optical sensor to measure phycocyanin parameters using fluorescence technique. In this design the sensor is designed using Cortex-M3 with configurable temporal variation to adjust the sampling interval remotely without any physical changes in the designed sensor module. This papers address the optical filter design consideration and performance evaluation results to exploit the required design specification to design phycocyanin measurement sensor.

2. Phycocyanin Measurement Sensor for Water Treatment Plants

Phycocyanin is a pigment-protein complex along with allophycocyanin and phycoerythrin are water-soluble and the characteristic light blue color, absorbing orange and red light, particularly near 620 nm, and emits fluorescence at about 650 nm as shown in Figure 1.

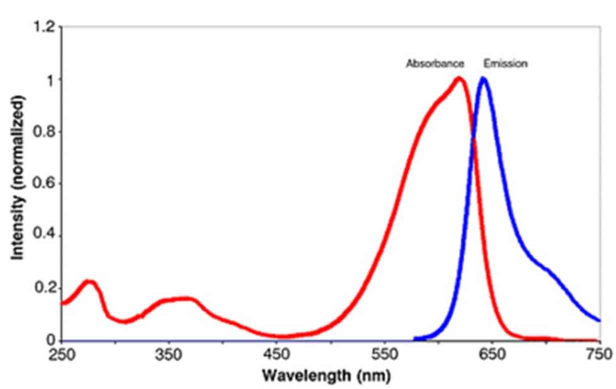


Figure 1. Phycocyanin Spectrum Characteristic

The submersible optical phycocyanin measurement sensor designed with fluorescence techniques are consist of five important optical components like a light source, a lens system to convey the exciting light to the sample volume, an another lens system to gather the emitted fluorescence, optical filters to separate the excitation and emission required wavelengths, and a photo detector. The submersible optical phycocyanin measurement sensor connected to the Cortex-M3 based in-situ self-diagnosable smart controller for integrated algae monitoring system in real-time[5], [6], [7].

3. Optical Filter for Fluorescence Anlaysis for Water Treatment Plants

The recent technology advancements in optical technology significantly improves the filters used for fluorescence spectroscopy. The optical filters (band / low / high pass filters) with very sharply defined filter edges can work from 10−5 to 10−6 blocking within 10~15 nm of the required optical transmission region and are suitable to use as excitation filters and emission filters. The fluorescence filters schematic is shown in Figure 2.

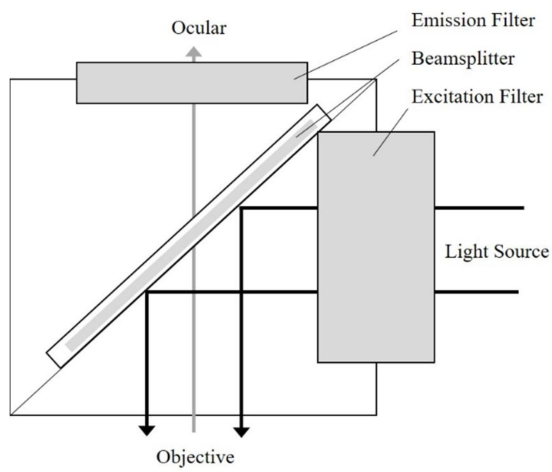
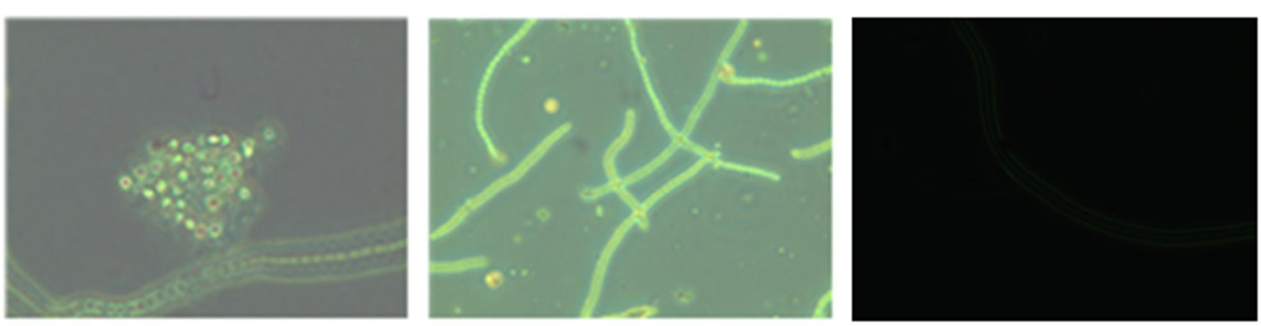


Figure 2. Schematic of Fluorescence Filters

The optical excitation filter transmits only the designed wavelengths of the illuminated light that efficiently excite a specific dye. The optical emission filter attenuates all of the light transmitted by the excitation filter and transmits the fluorescence emitted by the specific specimen. The optical filter performance evaluated for phycocyanin measure with the excitation / emission tests of Anabaena, Osillatoria and Microcystis and shows that the best fluorescence sensitivities were obtained in the test at 620nm / 640nm, Ocillatoria 620nm / 645nm and Micorcystis at 620nm / 645nm. The water treatment targeted phycocyanin extraction and analysis is shown in Figure 3.



(a) Microcystis Aeruginosa (b) Anabaena Affinis (c) Osillatoria Splendida

Figure 3. Targeted Cyanobacteria for Phycocyanin Extraction and Analysis

The excitation / emission spectra of cyanobacteria for phycocyanin extraction is shown in Figure 4. The results of the excitation test of phycocyanin extracted from these three cyanobacteria showed similar results to those of the natural state (in vivo), but as a result of the emission test, it is seen that the detection wavelength band is advanced by 5 to 10 nm.

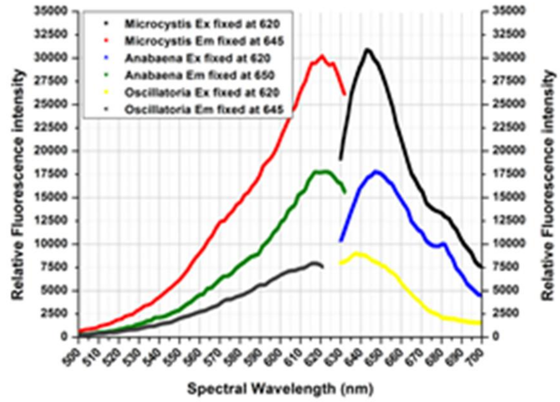


Figure 4. Excitation/Emisiion Spectra of Cyanobacteria

4. Design and Analysis for Phycocyanin Measurement

The optical filter used in the biosynthetic sensor module detection part for phycocyanin measurement, and the optical filters plays a role of removing other wavelength band other than 645 ~ 665nm. The fluorescence wavelength of picocyanin is known to be about 650 nm. Only the wavelength of picocyanin band is detected and other wavelengths are removed to obtain better results [5], [6], [7]. The optical filter design specifications are described in the Table 2.

Table 1. Optical Filter Design Specification

Useful Range	643-665nm
FWHM	30nm
Tolerance	+/-5nm
Peak Transmission	≥85%
Surface Quality	40/20

The proposed optical filter design uses the low power H10722-XX photo detector module from Hamamatsu for fluorescence detector sensor design for picocyanin measurement. Hamamatsu PMT package is designed by metal with low power consumption. To evaluate the designed optical filter, the irradiation wavelength to be applied to the phycocyanin module was selected from 610 to 620 nm and the detection wavelength was selected from 640 to 650 nm. The designed optical with Table 2 specifications and optical response performance measures are shown in Table 3.

Table 2. Designed Optical Filter Response Measures

Wavelength (nm)	Optical Response (%)	Wavelength (nm)	Optical Response (%)
720	0.06	530	0.02
710	0.06	520	0.26
700	0.09	510	0.23
690	0.26	500	0.03
680	3.14	490	0.03
670	53.47	480	0.00

Wavelength (nm)	Optical Response (%)	Wavelength (nm)	Optical Response (%)
660	89.25	470	0.00
650	91.95	460	0.03
640	61.11	450	0.14
630	3.52	440	0.11
620	0.17	430	0.12
610	0.08	420	0.12
600	0.05	410	0.04
590	0.09	400	0.35
580	0.04	390	0.46
570	0.06	380	1.01
560	0.18	370	0.01
550	0.04	360	0.00
540	0.03	350	0.00

In addition, the design support to adjust the wavelength optical filter anytime as user need to change. In this analysis, we found that the phycocyanin fluorescence value increased about 2.1 ~ 4.7 times as compared with JM phycocyanin module, within the analysis range was obtained by ultrasonic treatment within one minute. The designed optical filter housing model structure that can attach a phycocyanin measurement sensors detection optical filter is shown in Figure 5.

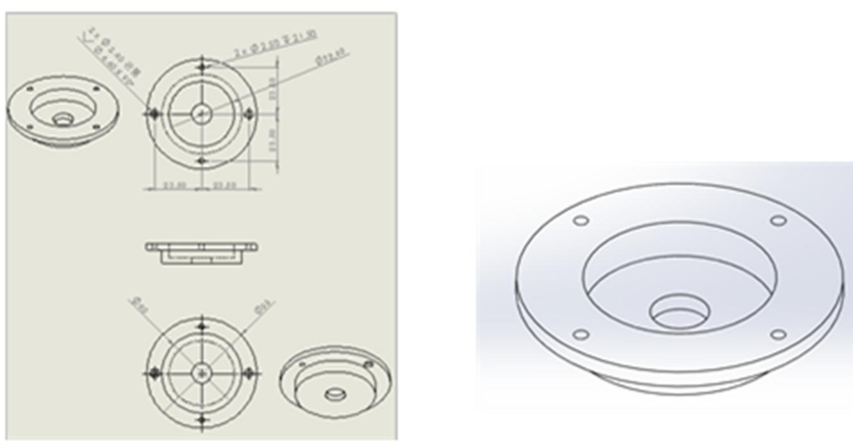


Figure 5. Optical Filter Housing Model Diagram

The designed optical response measures from Tables 3 shows that the designed optical filters allows light wavelengths 640~670nm and rejects the other wavelength band other than 640 ~ 670m. This helps to measure the fluorescence wavelength of picocyanin in water bodies.

5. Conclusion

This paper presented the design and consideration for optical filter to measure and monitor the phycocyanin using fluorescence technique for water treatment plants. The optical filter excitation / emission performances are evaluated with Anabaena, Osillatoria and Microcystis based fluorescence sensitivities measures and proved that phycocyanin is extracted from wavelength 620nm~645nm in all fluorescence sensitivities measures. The optical filter is designed using low power H10722-XX photo detector module from Hamamatsu as a part of Cortex-M3 based sensor module with configurable temporal variation sampling methods. The designed optical filter effectively measure the phycocyanin parameters with the light wavelengths 640~670nm and the performance of phycocyanin fluorescence values increased more than 2.1~4.7 times as compare to JM phycocyanin module.

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