Optik 129 (2017) 30–34

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Study on improvement of CRI using RGB LED lights for underwater environments

Ming Hui Lai, Chinghua Hung *

Department of Mechanical Engineering, National Chiao Tung University, No. 1001, Ta Hsueh Road, Hsinchu 30010, Taiwan

ARTICLE INFO

Article history:
Received 16 August 2016
Accepted 19 October 2016

Keywords:
Underwater
Color rendering index
Scattering environments
LED devices

ABSTRACT

This study presents a novel LED (light-emitting diode) light source. The device was simulated in both air and underwater environments by using TracePro. This device can adjust the current to change the power of different colors (M-E-L-R, M-E-L-G and M-E-L-B) to improve its color rendering index (CRI) in different scattering environments. The simulated results were analyzed and used to build a design module for use in underwater LED devices. In underwater experiments, the ordered sequence of light efficiency values was M-E-L-G > M-E-L-B > M-E-L-*R*. Underwater measurements of the performance of the device confirmed the simulated results.

1. Introduction

Most color rendering index (CRI) requirements for light-emitting diode (LED) devices are intended to allow the projected light reach a natural white in general environments [1–4]. Hardy et al. [5,6] have analyzed characteristics of LEDs, such as power of illumination, luminous efficiency and color temperature, but did not conduct experiments on LEDs. Regarding LED design, Chao [7] analyzed the light-emitting angle and arrangement of LEDs underwater by using an average cosine method and compared results from experiments and simulations. Olsson [8] used a spherical lens to change ray angles and improved LED lighting efficiency. The CRI is critical characteristic of light sources for lighting applications. The color rendering performance of a source is determined by its spectral power distribution. CRI values in the 70 s are considered ‘acceptable’, and values greater than 80 are regarded as ‘good’ [9,10].

The LED light source used in the current study is an XLamp MC-E LED from CREE (Cree Inc.) [11]. The LED light source is a chip with a packaged size of 7 mm by 7 mm. It features a tiny volume LED containing four dies, each of which can emit different wavelengths: red (MC-E LED RED, M-E-L-R), green (MC-E LED GREEN, M-E-L-G), blue (MC-E LED BLUE, M-E-L-B), and white (MC-E LED WHITE, M-E-L-W). Moreover, it can change the four levels of current flowing to the four dies to emit light with various CRT and light efficiency.

* Corresponding author.
E-mail addresses: chhung@mail.nctu.edu.tw, chhung@faculty.nctu.edu.tw (C. Hung).

http://dx.doi.org/10.1016/j.ijleo.2016.10.064
0030-4026/

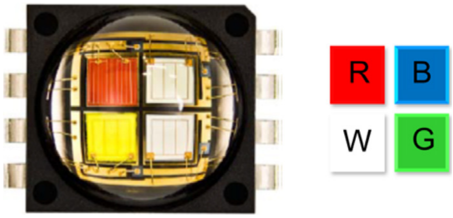

Fig. 1. Configuration of a MC-E LED light source.

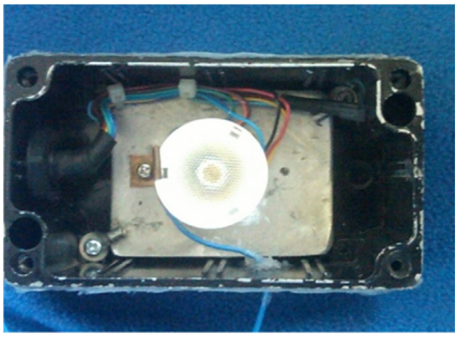

Fig. 2. MC-E LED device test module.

2. Design method and experiment

2.1. Design method

In this paper, color rendering variations for different levels of illumination and different combinations of wavelengths are discussed. To explore possible experimental conditions, a simulation model was established to simulate illumination values underwater by using TracePro® software (Lambda Research Corp.). Both experimental and simulation results were obtained. The experiments were conducted with the MC-E LED light source, and individual values of the illuminance levels and colors of the emitted light were measured in water 1, 2, and 3 m from the MC-E LED light source.

2.2. Parameters of LED

The MC-E LED used in these experiments contained four dies, namely M-E-L-R, M-E-L-G, M-E-L-B, and M-E-L-W (Fig. 1). At 350 mA, the lowest values of illumination were 30.6, 67.2,8.2, and 100 lm.

2.3. MC-E LED device

The MC-E LED device was composed of electrodes, four LED dies, and a lens with a reflector cup module (Fig. 2).

2.4. Underwater light field measurement

A water tank was created for this study. Measuring points were marked in the water tank at 1, 2, and 3 m from the light source, these fixed positions ensured that the light measurements were taken at precise distances from the light source. To avoid possible light reflection, the sidewalls of the tank were coated with black paint to absorb the light, as shown in Figs. 3(a) and (b).

2.5. Scattering simulation

Underwater Rayleigh scattering was stochastically simulated using a Monte Carlo algorithm in TracePro. The color effect from Rayleigh scattering is inversely proportional to the fourth power of the wavelength, meaning that shorter wavelength radiation-blue light is scattered in the atmosphere more than longer wavelength radiation-green and red light [12].