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A Study on the Photoreaction of Squids

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ABSTRACT : *In this paper, the potential of high-brightness LEDs as energy-saving light sources in place of metal halide lamps (MHLs) was studied to promote fishery efficiency. The photoreaction characteristics of 20 common squids (scientific name: Todarodes pacificus) in a fish tank when LEDs, each with a different color, and an MHL were irradiated onto them were compared and analyzed. For the experiment, an acrylic fish tank was designed, and red, green, blue, and white 30[W] LED modules and a 1.5[kW] MHL were designed, which had recently been used in squid-jigging ships. From the results of the experiment on the squids' photoreaction characteristics in accordance with each LED, it was confirmed that the most squids gathered around the light source when blue LEDs were irradiated with wavelengths of 450 ~ 490[nm], with excellent seawater penetration characteristics. Also, the results of the comparative experiment of six blue LED modules and an MHL showed similar levels of efficiency in fish-attracting effect.*

KEY WORDS : Fishing lamp, Phototaxis, Squids, High brightness LED, Metal halide lamp, Optical wavelength

1. Introduction

Most fishes such as squids, horse mackerels, mackerels, sardines, and sea breams have phototaxis characteristics. Using such fishes' photoreaction characteristics, the fishery efficiency of fishing lamps has been promoted.

Early fishing lamps were used as flammable ignition catalyzers along with the ingle, petroleum, and acetylene. As time passed, incandescent and halogen lamps were developed. Afterwards, with the demand for high light intensity, high-brightness discharge lamps such as MHLs replaced the incandescent and halogen lamps. The power consumption of an MHL for squids is higher by 1.5 ~ 3 [kW] than other lamps, however, because of its high light intensity, such that a fishing ship that uses an MHL consumes several hundred kWs of power per trip. Also, the intense radiation and harmful ultraviolet light from the lamp can cause skin disease among fishermen[1].

To overcome these limitations of the lamps, a study on LEDs is needed. LEDs have some advantages such as their high efficiency, long durability, low power consumption, and environmental friendliness[2], [3].

LEDs can also block harmful lights such as ultraviolet light by selectively irradiating light sources in desired wavelength ranges. Therefore, the development of fishing lamps using LED, a new lighting device, is rapidly progressing[4]~[6]. In this study, the photoreaction characteristics of squids to high-brightness red, green, blue, and white LEDs and an MHL were analyzed.

The squid-attracting effect of the LEDs was compared with that of the MHL in the experiment, and the potential of LED as an energy-saving light source was examined.

2. Experiment

2.1 LED Lamp

Fig. 1 shows an example of the prototype LED module and the MHL that were used in the experiment. Red, green, blue, and white LED modules were used to analyze the squids' reaction to each light color in the experiment. Also,

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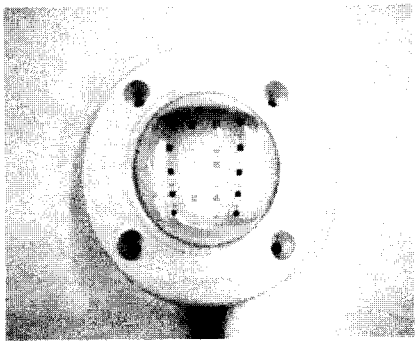
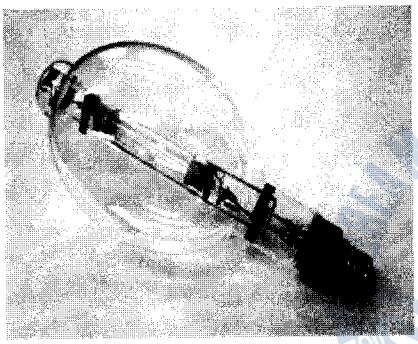
the photoreaction of the squids to the LEDs was compared with that to the MHL, which is mainly used in squid-jigging ships. The electrical specifications of the LED module and the MHL are shown in Table 1.



(a) Prototype LED module



(b) Metal halide lamp

Fig. 1 Light sources for fishing lamps

Table 1 Characteristics of incident wave

Light Source	Rated Voltage	Driving Current	Power Consumption
MHL	135 [V_{ac}]	11 [A]	1.5 [kW]
LED	12 [V_{dc}]	2.5 [A]	30 [W]

Additionally, a spectrometer (Avaspec-3648, AVANTES) was used to measure the lighting elements of each light source, and the wavelength range that most significantly influenced the squids' activity was studied.

The measured spectrum and intensity of each LED are shown in Fig. 2. The results show that the red, green, and blue LEDs had intensity ranges of 610 ~ 660 [nm], 490 ~ 550 [nm], and 450 ~ 490 [nm], respectively, and the white LEDs had wavelengths with the most visible ray range of 440 ~ 700 [nm][7].

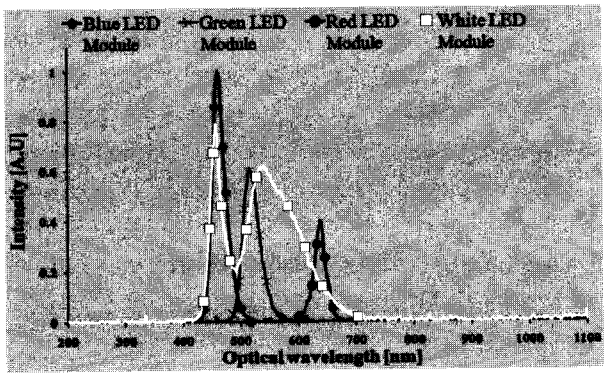


Fig. 2 The spectrum of the LED module

2.2 Experimental setup

A fluorescent lamp, a halogen lamp, and the white LED were used to investigate the phototaxis of squids. After shutting out all the lights in the dark room, one of the light sources was randomly illuminated, and the movement of squids was observed. In the experiment, all the squids gathered within 2 [m] from the irradiation point with respect to different light sources.

Consequently, it was confirmed that squids have phototaxis.

2.3 Procedure

The experimental setup is as shown in Fig. 3. To analyze the photoreaction characteristics of squids, a transparent acrylic fish tank (10 [m] wide, 2 [m] long, and 1.2 [m] tall) was designed and fabricated.

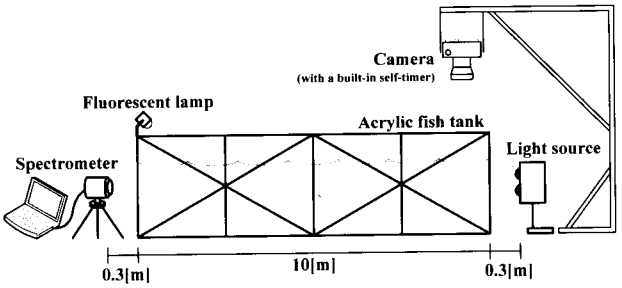


Fig. 3 Configuration of the experimental setup

To measure the light spectrum and intensity, the light source and spectrometer were placed in line with the fish tank. Also, to attract the squids in advance to the experiment, a fluorescent lamp was set above the farthest tank from the light source. The whole experimental setup was placed in a dark room to shut off all other lights except for the light sources that were used in the experiment.

3. Results and analysis

3.1 Photoreaction characteristic of squids in accordance with LED colors

Table 2 shows the analysis of the squids' photoreaction characteristics to LEDs with the red, green, blue, and white LEDs irradiated five times each. The squids showed the most sensitive reaction to the blue light and rarely reacted to the red light.

Table 2 The squids' photoreaction to the colors of the LED modules

(Unit : ind.)

Light Source	Experiments					Average
	1st	2nd	3rd	4th	5th	
R LED	0	1	2	0	1	0.8
G LED	5	4	6	7	5	5.4
B LED	11	9	12	13	15	12.2
W LED	8	9	7	7	9	8

From the analysis of the photoreaction of the squids and the spectrum of the LED light sources in Fig. 2, it was confirmed that squids react most sensitively to light sources within 450 ~ 490 [nm], such as to blue LED.

Such reaction characteristics of squids can be proven by the relative luminous efficiency curve in Fig. 4.

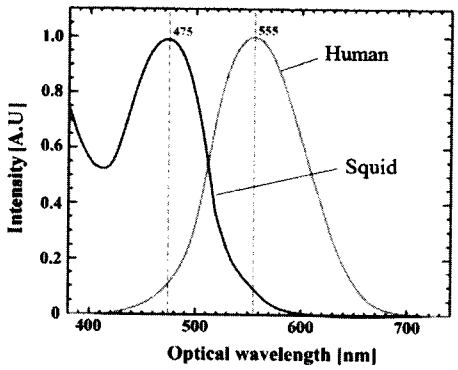


Fig. 4 The relative luminous efficiency curve

This curve shows the changes in visual sensitivity according to each wavelength of visible rays. The human eye is most sensitive to yellowish green rays at around 555 [nm]. Squids are most sensitive to blue rays at around 475 [nm]. Additionally, squids' movements are also related to the seawater penetration characteristics of red, green, and blue LEDs[8].

Fig. 5 shows the light intensity in seawater according to the distance from each LED. The blue LED has the highest intensity. The variations in the light intensity of the blue LED in deep seawater are shown in Fig. 6. From the results, it was predicted that the blue light source would effectively collect the squids that were mainly around 150 [m] deep.

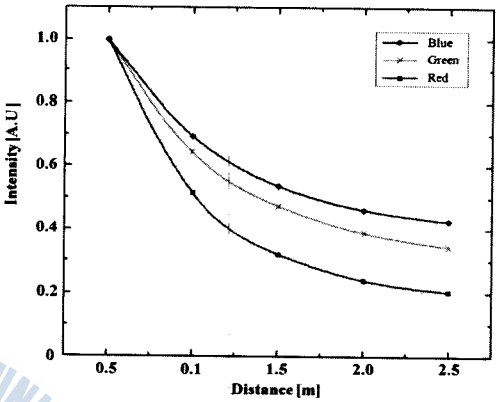


Fig. 5 The seawater penetration of the LEDs

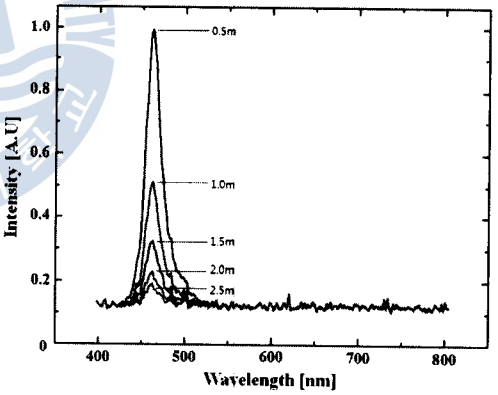


Fig. 6 The variations of the light intensity of the blue LED in the deep seawater

Therefore, it was confirmed that the 450 ~ 490 [nm] blue LED had the greatest fish-attracting effect, followed by the green LED and the red LED, in that order.

3.2 Photoreaction characteristic of squids to the blue LED and the MHL

The photoreaction characteristics of the squids to the MHL and the blue LED, which appeared to have been the most effective in fish attraction in the experiment, were observed. The spectrum of the MHL was measured, and the

intensity of the MHL was compared with that of the LEDs in range of 450 ~ 490 [nm]. The total intensity of the MHL in the wavelength range of 450 ~ 490 [nm] was 9.989 [A.U]. In the case of the blue LED, because the total intensity of the three blue LEDs was 5.481 [A.U], the intensity was increased by adding LEDs so that the experimental conditions would be the same as those with the MHL.

Fig. 7 shows the result of the spectrum analysis of the six blue LEDs and the MHL. The result was 10.085 [A.U], which was almost equal to that of the MHL.

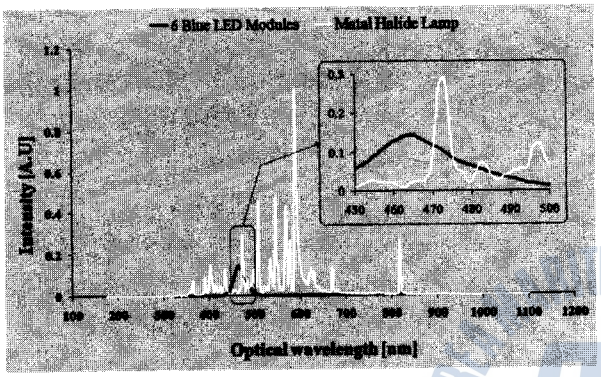


Fig. 7 The spectrum of the six blue LED modules and the MHL

Table 3 shows the results of the photoreaction characteristics of the squids using the six blue LED modules and the MHL. From the results, it was confirmed that the squids showed similar reactions to the MHL and the six blue LEDs.

Table 3 The squids' photoreaction to the six blue LED modules and the MHL

(Unit : ind.)

Light Source	Experiments					Average
	1st	2nd	3rd	4th	5th	
B LED	20	19	20	18	19	19.2
MHL	18	20	19	17	20	18.8

4. Conclusion

In this paper, the photoreaction of squids was analyzed for the development of LED fishing lamps that could replace the MHLs that are currently being used in fishery. The wavelength to which squids react most sensitively was measured by analyzing the spectrum of different colored LED light sources and the photoreaction of the squids to each of them. According to the results, the light within the range of 450 ~ 490 [nm], the main wavelength of the blue LED, was the most effective in fish attraction. Six blue LEDs were needed to raise the intensity to that of the 1.5 [kW] MHL, at 450 ~ 490 [nm], and the light sources showed similar degrees of effectiveness in luring the squids. The six blue LED modules consumed 180 [W], which is about one-eighth of the power that the MHL consumed. Also, the weight of the six LED modules, including of their power supply, was about one-seventh of that of the MHL system.

Therefore, blue LEDs have the best potential to replace the MHLs that are currently being used in squid-jigging ships, because they have advantages such as low ultraviolet light and heat radiation and low power consumption.

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