Research on Optical Performance Testing of Deck-embedded Lamps

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Abstract: After working for a period of time, the optical performance of the ship's deck-embedded lamps may be attenuated, directly affecting the ship navigation and even helicopter's take-off and landing, so it is necessary to measure its optical characteristics frequently. Due to the disassembling difficulty and limited space for the ship's deck-embedded lamps, the traditional optical testing methods are difficult to apply. Based on the purpose of overcoming its implementation difficulty, the optical performance testing technology of deck-embedded lamps has been studied in this paper. The scheme design and physical realization of a portable device for deck-embedded lamps' intensity testing have been completed, including designs of mechanical structure, hardware circuit and software algorithm. The results show that the testing device can provide an environment that eliminates natural light interference, realizing the measurement, judgment and display of the optical characteristics of ship's deck-embedded lamps. The effectiveness of the device and the feasibility of the method have been verified.

1 Introduction

In recent years, LED has been rapidly developed in the field of industrial lighting, due to its advantages of energy saving, high efficiency and good reliability. With the maturity of LED technology and the popularization of LED lamps, the requirements for the characteristics and capabilities of the lighting sources have also increased. Ship deck lamps provide lighting for the entire ship, known as the "eyes" of the ship. While the deck-embedded lamps play an important role in ship navigation and even helicopter's take-off and landing. However, the ship's deck-embedded lamps may experience optical degradation after a period of operation. The current solution is usually through visual inspection by the staff to determine whether the optical characteristics meet the requirements, and complete maintenance and replacement regularly, lacking in timeliness and accuracy. Therefore, it is necessary to research the method and the device for testing the luminous energy efficiency and light intensity distribution of ship's deck-embedded lamps.

For the ship's deck-embedded lamps, the frequency of optical performance attenuation tends to increase with time, affecting the performance of the system. There are many related researches at home and abroad for the optical performance testing technology. Traditional optical performance testing methods are generally integrating sphere method and distributed photometer method. The Integrating sphere method, as described in [1], whose specific idea is to build a cavity sphere coated with white diffuse reflection material on the inner wall, as an ideal integrating sphere environment. One or more window holes are opened in the ball wall, which are used as light entrance holes and receiving holes for placing light detecting devices. The light entering the integrating sphere is reflected multiple times by the inner wall coating to form a uniform illumination on the inner wall, thus the light illumination and luminous flux can be calculated by the formula (1) and (2) respectively. In formula (1), *E(/lx)* is the total illuminance, Φ *(/lm)* is the measured luminous flux, ρ is the reflection ratio of the integrating sphere's inner wall, and *r(/m)* is the radius of sphere. In formula (2), Φ_s *(/lm)* and E_s*(/lx)*, are total luminous flux and illuminance of the standard light source. E_c *(/lm)* represents the illuminance of the measured light source.

$$E = \frac{\phi}{4\pi r^2}\frac{\rho}{1-\rho} \tag{1}$$

$$\phi_c = \frac{E_c}{E_s}\phi_s \tag{2}$$

There are multiple ways to implement the distributed photometer method. Reference [2] keeps the lamp in a static state and rotates the detector, while reference [3] keeps the detector in a static state and rotates the lamp. Detectors and lamps can also be rotated together according to certain rules, as presented in [4]. The essential principle is to change the relative position of the lamp and the measuring device under the condition of an optical dark room. Then obtain the illuminance value of each space position and calculate the light intensity by formula integration. However, the above two traditional methods have some defects as follows: 1) In order to eliminate the interference of ambient light during the measurement, the lamps must be disassembled and placed in a closed integrating sphere or brought back to the optical dark room. 2) They all have the problems of large space occupation, complicated device structure and high equipment cost. Particularly, for the ship's deck-embedded lamps' inherent difficulty to disassemble and replace, it's hard to implement successfully.

Aiming at the situation in which the driving ability or optical performance of the ship's deck-embedded lamps may deteriorate after a period of time, a portable device for deck-embedded lamps' intensity testing has been introduced in this paper, to complete the online measurement, processing and display of optical characteristics. The scheme content includes system composition, mechanical structure design and hardware circuit design. A method for judging the optical index is also introduced, and the working principle of the testing device is explained as well. The experiment results show that the testing device can realize the online measurement of the optical characteristics and determine whether it meets the index requirements, providing technical support and theoretical basis for staff decision-making.

2 System Solution Design

This chapter consists of three parts. Firstly, the system composition and working mechanism of a portable device for deck-embedded lamps' intensity testing are introduced in general. Then the design process of the mechanical structure of the device is described in detail, which is a three-stage retractable mechanical structure. Finally, the device's electronic circuit part, which realizing the acquisition, processing and display of optical signal is introduced completely.

2.1. System Composition

The system block diagram is shown in Figure 1, consisting of three parts as followed. 1) Mechanical part: it can provide a dark room environment for the measurement of lamps' optical indicators. The unique three-stage retractable structure is easy to carry, with the advantages of small size and light weight. In order to ensure the accuracy, it should be placed in the stretched state during the measurement. When not in use, it can be placed in a contracted state. 2) Electronic circuit part: it includes power module, probe detection and laser calibration module, arithmetic circuit module and panel display module, converting light signals into electrical signals for online measurement, data processing and panel display. 3) Software logic part: the specific testing characteristics of a certain type of deck-embedded lamp are modelled, and a software logic judgment mechanism is designed to check whether the optical characteristics meet the indicators.

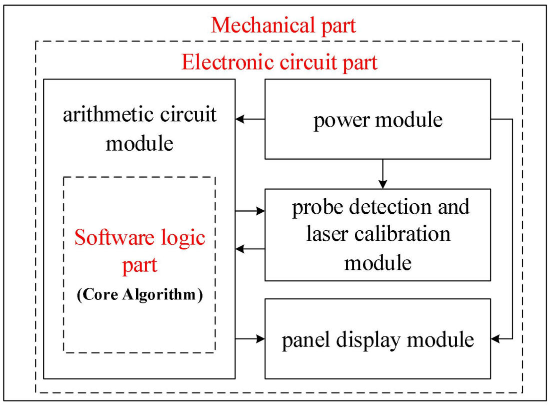

Figure 1: System block diagram.

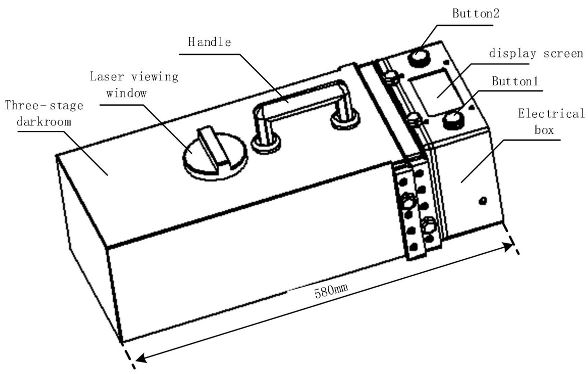

Figure 2: Mechanical structure in a contracted state.

2.2.Mechanical Part

The mechanical part is a three-stage retractable structure, both portable and lightweight. It can provide a dark room environment for the optical performance testing of deck-embedded lamps, free from the interference of ambient light. Mechanical structure in a contracted state is shown in Figure 2. According to the existing photometric distribution test standards, whether it is a light source or a lamp, the distance between the light emitting surface and the test probe should be sufficiently far (at least 80cm or more), to ensure that the light source or the lamp can be regarded as a point light source [5]. Therefore, the device needs to be placed in the extended state when measuring, as shown in Figure 3. The red dot is the position of the lamp's light outlet, and the red rectangle is the detection plane. There are 9 illuminance probes of Hanoptics Company and a cross calibration laser, installed on the detection plane, as shown in Figure 4. In order to achieve low weight while maintaining mechanical strength, polyoxymethylene composite materials are used. The length of the device in different states is shown in the figure, which is about 290mm wide and 240mm high. The total weight does not exceed 8kg.

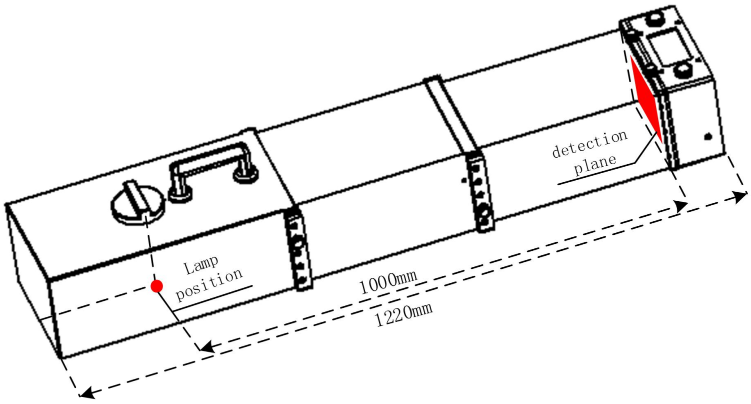

Figure 3: Mechanical structure in a extended state.

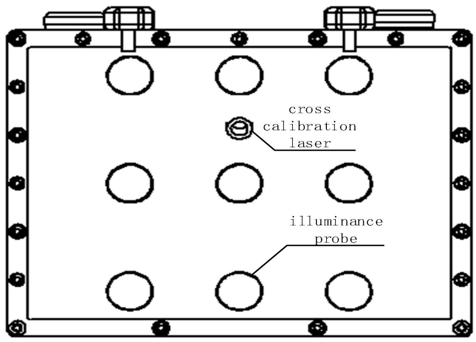

Figure 4: Structure of detection plane.

2.3.Electric Circuit Part

The circuit part includes power module, probe detection and laser calibration module, arithmetic circuit module and panel display module. Power module is a 24V / 5Ah lithium battery, working for the entire machine, whose operating temperature range is -30 ° C to 70 ° C. Probe detection and laser calibration module includes 9 light probes and a cross laser. The cross laser can be triggered to calibrate the relative position of the deck-embedded lamp and the testing device. The light probes are uniformly distributed, covering a range of ± 3 ° horizontally and 2 ° -9 ° vertically. 9 probes communicate with the MCU through the RS485 protocol. As the core part, the functional diagram of arithmetic circuit module is shown in Figure 5. The MCU of the arithmetic circuit is stm32f103, and the voltage is converted to 3.3V through URB2405-20W and LM1117IMPX-3.3 to power the smallest system. The battery voltage is fed to the stm32 via the voltage sampling ratio calculation circuit of the rail-to-rail op amp OPA2340UA for power display. The laser is powered separately through B0505S-1WR2 at the same time. The RS485 signal is connected to the communication pin of stm32 through MAX485 circuit. Finally, STM32 completes the communication with the serial port screen through MAX232. Some typical circuits are shown in Figure 6. Panel display module contains a display screen showing the optical measurement information, and two buttons for powering up the control system and the cross laser.

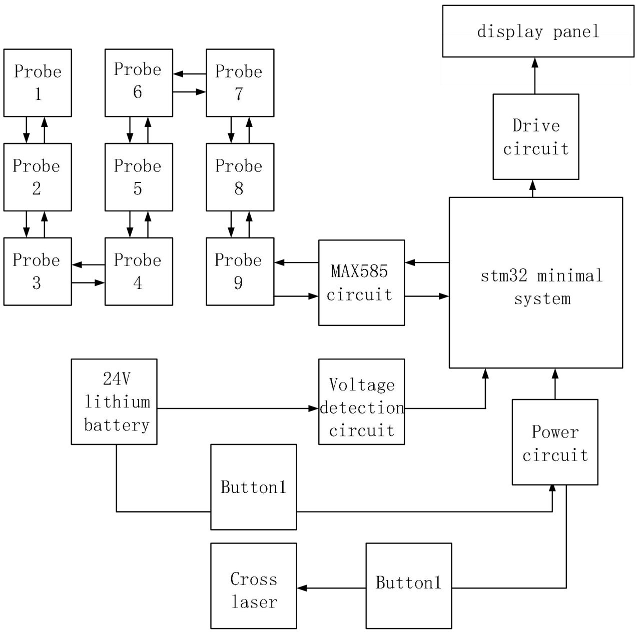

Figure 5: Diagram of arithmetic circuit module.

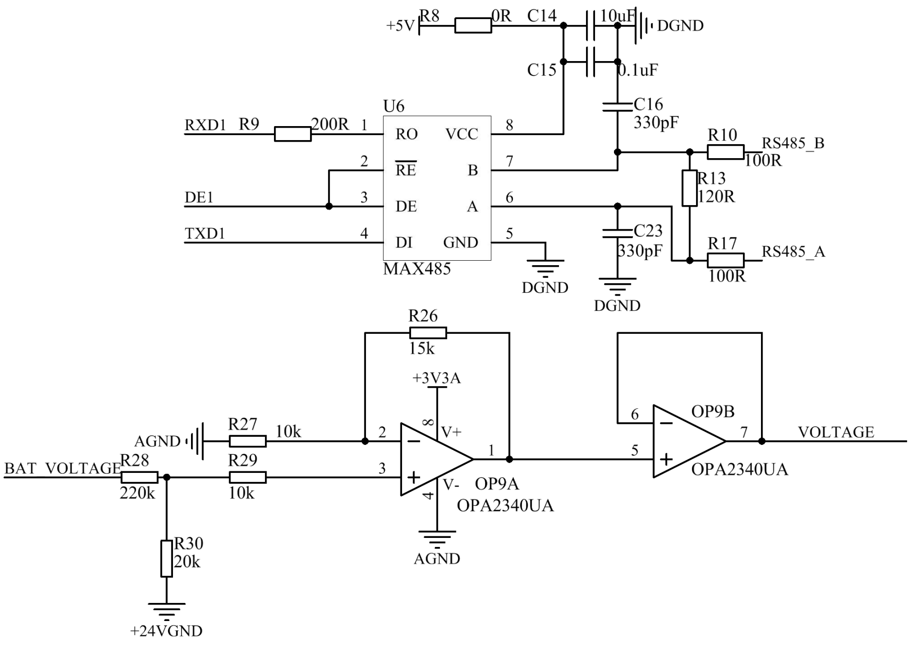

Figure 6: Typical circuit schematic.

3. Operating Mode

3.1. Software Logic

When the testing device is placed in an extended state, the deck-embedded lamp can be regarded as a point light source. The illuminance probes, possessing cosine correction, can accurately measure illuminance, with a repeated measurement accuracy of 1%. Its characteristics are shown in the Table 1.

Table 1: Characteristics of illuminance probes.

Probe series	Power environment	Communication format	Brightness range	Wavelength range
Colour-probe	24V-100mA	RS485	$\leqslant 10^6$ Lux	400nm-760nm

In an example, the light probes are uniformly distributed, covering a range of ± 3 ° horizontally and 2 ° ~ -9 ° vertically. In order to obtain the light intensity information. We need to convert the physical quantity through the formula (3). L_c *(/cd)* and E_c *(lux)* represent the light intensity and luminous flux of the measured point, while r is the distance between light exit and measured point. In formula (4), *Ls (/cd)* is the light intensity value of the reference light source. *coe* is the discriminant factor, taken 0.96 in this example, inferring the maximum acceptable attenuation. If L_{ce} *(/cd)* is greater than L_c *(/cd)*, the judgement result is fail. Figure 7 shows the coordinates of the probe's angular horizontal and vertical positions, and distance from the light exit.

$$L_c = E_c \cdot r^2 \tag{3}$$

$$L_{ce} = L_s \cdot coe \tag{4}$$

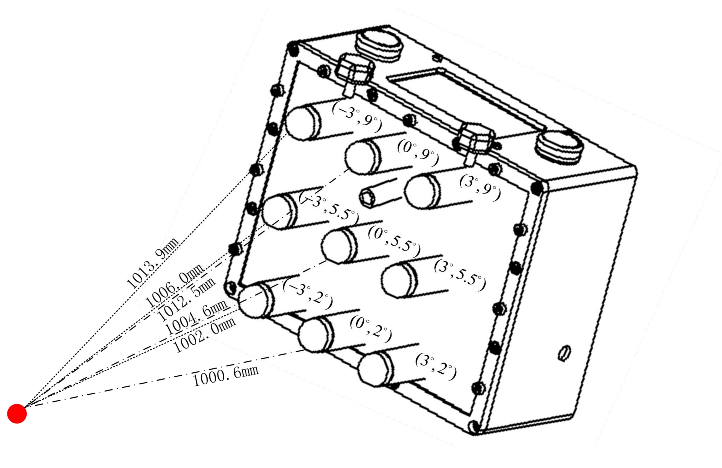

Figure 7: Diagram of arithmetic circuit module.

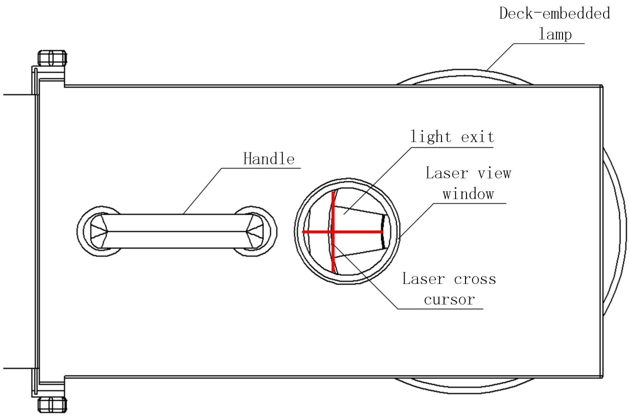

Figure 8: Position calibration effect.

3.2 Testing Steps

The following steps are required when using the testing device in this paper.

1) Place the testing device above the work lamp under test and stretch it to the extended state.

2) Press the two buttons in turn to power up the system and the cross laser respectively, open the upper cap and watch through the laser viewing window. Move the device to adjust the relative position. Until the cross laser cursor and the light exit are as shown in Figure 8, the calibration is completed. Then turn off the button 2.

3) Touch the measurement icon on the display screen, the information of illuminance, light intensity, chromaticity, and whether it meets the requirements of the 9 detection positions can be displayed on the display screen.

4) Close the button1 and restore the device to the contracted state after the measurement is completed.

4. Conclusions

The experiment results show that the testing method in this paper can realize the measurement, judgment and display of the optical characteristics of ship's deck-embedded lamps, possessing certain validity and feasibility.

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