Safety light curtain system using a hemispherical mirror with multiple light sources

Yusuke Kenjo*, Ryosuke Suzue, Kohei Miyata, Shiyuan Yang
Kyushu Institute of Technology

1-1 Sensui-cho, Tobata-ku, Kitakyushu, Fukuoka, JAPAN 804-8550

*Corresponding Author. kenjou@boss.ecs.kyutech.ac.jp

Abstract

Light curtain systems are used to detect intruders in various cases and places. However, it is necessary to adjust the position of the light detecting element accurately in order to receive the irradiating laser light. We propose a new type safety light curtain system that uses a hemispherical mirror and an LED in this research. A hemispherical mirror can reflect irradiating light rays surroundings of 180° in the vertical direction and 360° in the horizontal direction^[2]. When an LED is at a position that is higher than the hemispherical mirror, the LED irradiating light can be reflected by the hemispherical mirror, even if the LED is arbitrarily set up. In the case that, the light of LED is intercepted when an intruder passes between the LED and the hemispherical mirror, the output voltage of the light detecting element decreases. We can set a proper threshold voltage value of the detecting element to judge whether an intruder passes or not. Our system uses a PSOC microcomputer to judge the output voltage of the receiving element with the threshold voltage value. In addition, the LED output light is modulated by 10kHz in order to avoid the influence of the surrounding turbulence light. Our experiment succeeded to detect intruder using the proposed system without accurate light axis setting.

Keywords : Safety light curtain, hemispherical mirror, non-accurate set up, arbitrarily set up, modulated light source

1. Introduction

Recently, intruder detecting systems are widespread for contactless to detect the invasion to the danger area and the

invasion prohibition district. The most popular technique uses light ray which cannot be most easily influenced by usage environment, although there are various techniques used in Intruder Detection Systems^[1]. Light curtain is one of the existing intruder detection systems that uses light ray. A light curtain system contains a source of light ray and a receiving optical device. The penetration type irradiates light directly from the light emission element to the light detecting element. The source light is condensed with lenses to a beam ray and reaches to the receiving optical device in a place away. The light ray is intercepted when an intruder passes between the source of light and the receiving optical device, and the output of the light detecting element decreases. The intruder can be detected by judging output of the light detecting element. However, it is necessary to adjust the optical axis from the source of light and to receiving optical device for this intruder detection system. Because of the directivity of the light irradiated from the light emission element the spot of light ray is very small so that the optical axis must be strictly adjusted. Therefore, it is impossible to set up arbitrarily, and convenience is scarce. In addition, when the system is set up in an arbitrary place for use, the source of light and the receiving optical device would be moved, it is necessary to adjust the optical axis at each installation. Therefore, it is mainly used in limited facilities such as factories and airports where the movement of the source of light and the receiving optical device are not needed, so that its generality is scarce. We propose a new system for light curtain using a hemispherical mirror in this research. In this system, we do not use high directivity light such as a LD, but low directivity light LED is used. The reflected light is irradiated to the light detecting element by using a hemisphere side mirror. The source of light can be turned to

the receiving optical device at any arbitrary position by the hemisphere side mirror and one need not to adjust the optical axis like the existing intruder detection system. According to the characteristic of the source light and the hemisphere side mirror, the source light is set up irradiating to the hemisphere side mirror, and the receiving optical device can be set up arbitrarily within the range where the reflected light from the source can be received. In addition, even if the source of light and the receiving optical device are moved, it does not need to adjust an optical axis in every case in the light part of receiving because with a hemisphere side mirror. Thus, this system can solve the unsuitable problem though use by carrying was unsuitable for an existing system.

2. Light curtain system with hemisphere side mirror

2.1 Principle and composition

Figure 1 shows the general view chart of light curtain system. Red high-power LED is used for the source of light in this research. The directivity of red high-power LED is low. Figure 2 shows the outline chart of the hemisphere side mirror. The hemisphere side mirror can project surroundings of $\theta_1=360^\circ$ and $\theta_2=\pm 90^\circ$ against Y axis by seeing light above. It is possible to reflect the source light by the hemisphere side mirror without adjusting the receiving optical device even if the source light is arbitrarily set up. And, if the source of light is placed higher than the hemisphere side mirror, the receiving optical element can receive the reflected light according to the characteristic of the hemisphere side mirror.

Fig 1. General view chart of light curtain system.

At this time, light from the source light is intercepted when an intruder passes between the source of light and the reflector (hemisphere side mirror), and the output voltage of the light detecting element (photodiode) decreases. When the output voltage becomes less than a threshold voltage, it is judged that a person passed between the source of light and the receiving optical device, and sounds the warning sound.

2.2 Source of light

In this research, light from the irradiating source is reflected by the hemisphere side mirror, and the reflected light is received by a light detecting element. The hemisphere side mirror has to extract only the signal of the source light because turbulence light is also reflected to the light detecting element. There, frequency modulation is carried out for the distinction between the source of light and the turbulence light. Because the turbulence light such as fluorescent lamps has low frequency components, it is necessary to modulate the source light to a very high frequency. Then, the frequency of the source light is modulated to 10kHz in this research. The source light is modulated with a timer IC. Figure 3 shows the oscillation circuit that a timer IC was used (Refer to LMC555CN). Figure 4 shows the oscillating wave pulse from the oscillation circuit. The frequency of this pulse wave is determined by the next equations, while the time intervals TH of on and TL of off are shown in Fig. 4.

$$T_L = 0.693(R_1 + R_2)C_1 \quad (1)$$

$$T_H = 0.693 \times R_2 \times C_1 \quad (2)$$

$$f = \frac{1}{T_H + T_L} \quad (3)$$

Fig 2. Outline chart of hemisphere side mirror.

Fig 3. Frequency modulation circuit.

Parameters of the oscillation circuit can be determined by using Eqs. (2.1)~(2.3). Timer IC outputs the wave pulse of 10kHz when uses $R_1=450\ \Omega$ and $C_1=470\ \text{pF}$ and $C_2=10\ \mu\text{F}$. In addition, it is necessary to use a strong source light in order to reduce the influence of the turbulence light because the turbulence light contains all frequency components. In this research, a red high-power LED with 3W output (Refer to OSR5XME3C1S A.2) is used for the light emission element. This LED can emit light strongly compared with a general LED, and the directivity is low. Thus, the influence of the turbulence light can be reduced, and it becomes easy to be reflected to the light detecting element.

Fig 4. Oscillating wave pulse from frequency modulation circuit.

Fig 5. Circuit chart of signal processing.

Fig 6. Output wave form when person passes between devices.

2.3 Signal processing circuit

Figure 5 shows the circuit chart of the signal processing. In this signal processing circuit, the direct current element from the output current of the light detecting element is removed. Current-voltage conversion is carried out and about 10kHz frequency component is the extracted by the current-filter circuit, and then the signal is amplified. Therefore, the turbulence light including a variety of frequency elements can be removed, and only the signal of the source light that is modulated to 10kHz can be extracted.

2.4 Setting of threshold voltage

A PSoC microcomputer is used in this research. The analog to digital conversion is performed and the threshold voltage is set using this PSoC microcomputer. When it is judged that a person passed between the light source and the receiving optical device, it sounds a buzzer. Figure 6 shows one example of the output wave form when the person passes between devices and the source of light is intercepted. In this research, the intruder detection is judged by the change in the output voltage. The source light is shut out when a person passes between the light source and the receiving optical device and the output voltage decreases.

Fig 7. Overlapping the signals.

It is judged whether a person passed between the light source and the receiving optical device or not, and the buzzer rings when the output voltage becomes less than threshold. However, the output does not become 0V, because it cannot completely intercept light from the source of light even if a person passes between the source of light and the receiving optical device. So it is uneven to the output according to the distance of source of light to receiving optical device when a people intercept light from the source of light. Mistakes of judgment will occur when a constant threshold voltage is used. Therefore, we make experiments on the determination of threshold voltage in Sect. 3.2. As a result, it is understood that the output of receiving light from the source of light become 60% or less when a people intercepts light from the source of light. Little room is given in this research, and 70% is set as the threshold.

2.5 Overlapping of two or more signals

Fig 7 shows overlapping the signals. The signal from the source of light can be overlapped like Fig 7. The output voltage decreases if one of two or more sources of light is intercepted. Therefore, the threshold is installed, and the intruder is detected. Because overlapping is possible even by two signals or more, the light curtain can use a lot of sources of light.

3. Experiments

3.1 Device composition

Figs 8 and 9 show the photograph of the source light and the receiving optical device produced in this research. The receiving optical device is 75mm in length, and 85mm in width, and 155mm in height. The operation verification and decision of the threshold were done with such a device.

3.2 Device of threshold

In the experiment, ratio is defined as the output when a people intercept light from the source of light to the output when light from the source of light is received directly. Therefore, the output voltage of the photodiode was measured by the interception or not. Experiments are carried out in two environments of under the darkroom and the fluorescent lamp.

Fig 8. Source of light.

Fig 9. Light part of receiving.

Figure 9 shows the measurement directions of X axis, Y axis, and Z axis. The experimental environment was assumed that the line between source of light and receiving optical device is at an angle of degrees to X axis in the XY plane and at an angle of θ_2 degrees to X axis in the XZ plane. θ_1 is measured to every 15° in the range of 75° from 0° , and θ_2 is measured to every 30° in the range of 180° from 0° , and distance is measured to every 1[m] in the range of 5[m] from 1[m].

Table 1 shows the ratio on intercepting it based on non-intercepting the source of light. The maximum ratio is 60% from Table 1. It is assumed 70% to be a threshold more enough than 60% because it can avoid the mistakes judgement^[3].

Fig 10. Measurement axis XYZ.

Table 1. Ratio when intercepting it based on non-intercepting source of light.

distance	1[m]	2[m]	3[m]	4[m]	5[m]
darkroom	54[%]	38[%]	43[%]	30[%]	29[%]
fluorescent	57[%]	34[%]	60[%]	41[%]	33[%]

3.3 Operation verification of intruder detection

A person passes between the source of light and the light receiving optical device after the setting of the threshold by the PSoC microcomputer ends, light from the source of light is intercepted, and whether the intruder detection operates normally is verified. Each ten operation verification was done by the angle, the distance, and the experimental environment similar to 3.1 section, and whether the invasion detection had operated normally was confirmed. Table 2 shows the recognition rate of the intruder detection by each distance as a verification result under each environment. The recognition rate of the intruder detection was 100% in all environments under the darkroom and the fluorescent lamp as understood from Table 2. The intruder detection system works correctly from the verification result even if it arbitrarily sets up the intruder detection system in the distance of source of light-light part of receiving is 1m-5m.

3.4 Operation verification in two or more sources of light

In the experiment, Two or more sources of light are lit, and each source of light is intercepted severally, and whether each source of light operates as a normal intruder detection system is verified. Two or more sources of light are that the frequency modulation was done to 10[kHz], and are that quantities of light are the same.

Fig 11. Measurement in two or more sources of light.

Experiments are carried out in two environments of under the darkroom and the fluorescent lamp. Fig 11 shows measurement in two or more sources of light. Distance of source of light-light part of receiving is measured to 0.5[m] and 1.0[m], and distance of source of light A-source of light B is measured to every 10[cm].

Table 2 Recognition rate of intruder detection

environment	darkroom	fluorescent
recognition rate	100[%]	100[%]

Fig 12. Range of use in two or more sources of light.

Fig 13. The intruder detection system in two or more sources of light and two or more light part of receiving.

Fig 12 shows the distance of the source of light A-source of light B, and number of sources of light that works correctly. The intruder detection system in two or more sources of light works correctly though the limitation is distance of the source of light A-source of light B as shown in Fig 12. Figure 13 shows intruder detection system in two or more sources of light and two or more light part of receiving. It is possible to improve both the detection range and the detection accuracy by setting up in this way.

4. Conclusions

In this study, it is proposed that a light curtain for intruder detection with red high-power LED, a photodiode, and a hemisphere side mirror. System is constructed and experiments were carried out. The result achieved for this research is concluded as follows:

- (1) If it is a position in which light from the source of light can be reflected with the hemisphere side mirror, it is possible to operate as a normal system in an arbitrary place.
- (2) It is possible to operate as a system that it is normal without a detailed adjustment of the source light and the light detecting element like the existing system, just to turn the source of light to the light part of receiving.
- (3) The intruder detection system in two or more sources of light works correctly. Detection accuracy by two or more source of light and receiving optical device will be made as an improvement
- (4) When the existing system sets up the device, the installation is difficult, and it takes time in the amateur. But everyone can arbitrarily set it up widely using this system from the result of (1) and (2).

Therefore, the light curtain system with a hemisphere side mirror can be achieved. The improvement of convenience and generality was shown the progress so far because it was possible to set it up widely and arbitrarily with a low directivity LED and a hemisphere side mirror.

Future tasks include the following:

- Reduction of influence of turbulence light by accuracy improvement of band-pass filter.
- Detection accuracy by two or more source of light and receiving optical device will be made as an improvement without losing the leakage of the intruder detection area.
- Reduction of influence of turbulence light by accuracy improvement of direct current removal circuit

5. References

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