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System of Speed-measurement by Flash Imaging Based on High Power LED

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Abstract: A non-contacted speed-measurement system for high speed moving objects is designed. During one single frame exposure time of CCD, the flashlight flares to a moving object twice and the two corresponding images of the object are captured by CCD in sequence. The movement speed of the object can be determined from the displacement of the images versus their interval time. This system has the advantage of real-time measurement, thus it breaks through the limitation of single point measurement technology in space. Moreover, it can acquire not only the spacial information of one point at different moments, but also the information of different space points at the same moment.

Key words: High power LED; Impulsator; Flash imaging; CCD

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0 Introduction

The speed-measurement of high-speed moving object is an important domain of high speed photography. Generally, the main measure methods in this field are inductive coil target[1], light screens[2], Doppler Velocimeter[3], as well as high speed photography camera[4]. The light screen is based on the principle of photo-electric conversion, however, it is sensitive to noisy light brought by experiment; Inductive coil target has many disadvantages, such as small area, sensitive to outer electromagnetism, and it can not measure the non-magneto conductivity objects; Doppler velocimeter is based on the Doppler principle, which uses in many areas, but its measurement accuracy is affected by surface characteristic of solid、photoelectric detector、circumstance condition; For the high speed photography camera, it seems that it is a good method; however, it can not be used widely because of its huge cubage and expensive cost. In this paper, a new system of speed-measurement based on flash real time imaging is proposed.

The system uses the high power LED pulse light as light source[5-7], because most of the high speed moving objects are not luminiferous themselves. It tracks the moving object through imaging in CCD, and the speed can be calculated through image processing technology. The system works following the mechanism below: during the exposure time of CCD after its shutter opened, the flash light flares twice to the moving object, so, the object is recorded twice by the CCD. On the assumption that the exposure time of CCD is long enough to record two profiles of the moving object. Finally, the speed of the object can be figured out by measuring the displacement of the two profiles.

1 Principle of speed-measurement

The flash imaging method uses pulse light source to flare the high speed moving object, which is not luminiferous itself. The images of two continuous flares are captured by CCD. The movement speed of the object can be determined by analyzing the obtained images. In the proposed system, a high power LED light is used as pulse light source, whose width of pulse light is in scale of microsecond. The LED light illuminates the moving target, after the synchronous trigger signal opens the shutter of CCD. By virtue of reflected light the CCD can record the image of the object at this moment. Therefore, if the interval Δt of the two illuminations is shorter than the exposure time of the CCD—which is about tens of milliseconds, there are two images of one object on different positions can be recorded by the CCD image. By image processing, the displacement Δs can be

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figured out, and the mean speed during the two illuminations can be solved by the formulation $v=\Delta s/\Delta t$. The posture of the high speed moving object is also captured because of CCD records, and it is able to deal with the situation that more than one object moving together. The principle scheme is Fig. 1.

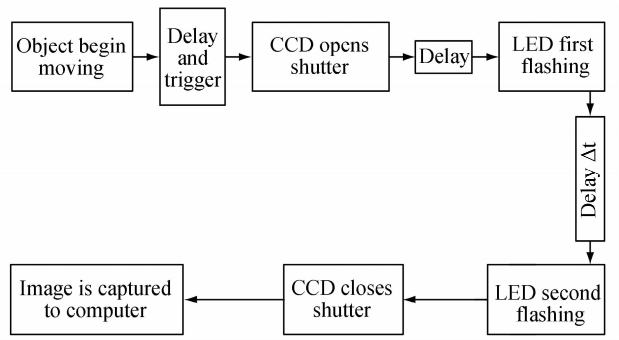


Fig. 1　Principle scheme of speed measurement

The system is composed of three parts, the LED flash system, the synchronization trigger system and the system of image capturing. Here, the LED flash system generates pulse light to illuminate the moving object after receiving the synchronization trigger signal. The synchronization system generates the LED trigger signal and the CCD trigger signal, and it is also used to set the width of pulse light, as well as the interval of two pulse light. The system of image capturing (CCD) is used to capturing the images. The total configuration of the system is shown in Fig. 2.

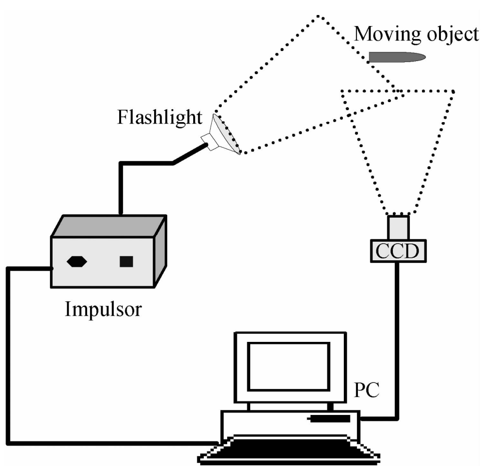


Fig. 2　The configuration of system

2　The configuration of system

2.1　LED flash system

The LED flash system is consisted of the array of LED, optical system and power supply. The high power LED has many advantages, such as energy conservation and environment protection, homochromy, rapid response and high power-one single LED has illumination power of 0.5 W. A visible light source is necessary because the central wavelength of the most spectral response of CCD lies about 530 nm. In order to match the CCD, a LED source whose central wavelength is at 550 nm is chosen, and its light beam illuminates the test area after being collimated by laser-collimated and enlarged device.

When object is moving at high speed (300～1 000 m/s), if the width of the LED light pulse is too wide that the object image will be blurry on CCD image. Generally, the most blur degree should be less than 5 mm. If the speed of the moving object is 1 000 m/s, the width of the light pulse should be less than 5 μs, which can ensure the light intensity at the test area unless the response time of the LED source less than 1 μs. Fig. 3 is the response of the LED to the trigger signal.

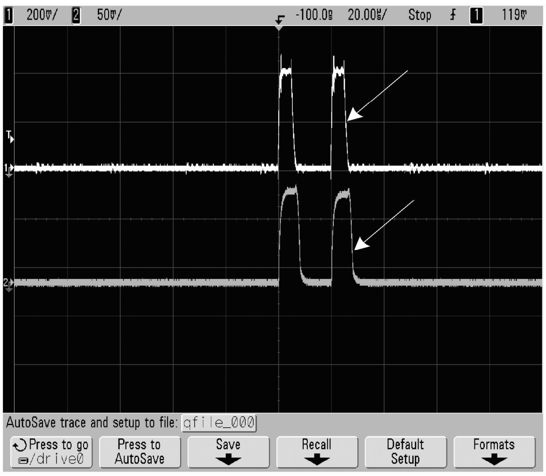


Fig. 3　The response of LED to the trigger signal

2.2　Synchronization trigger system

Synchronization trigger system is indispensable because the speed of the moving object is very high, which results in a fugacious time that the object moving through the CCD ken. In one way, the synchronization trigger system receive the trigger signal from the high speed moving target, in the way it sends the trigger signals to the LED flash system and the image capturing system to make the total process in strict synchronization state.

Impulsator, which is the core part of the synchronization trigger system, receives the trigger signal from the high speed moving object and generates corresponding signals to trigger the two other system. In addition, it sets the width of the LED pulse and the time interval between the two light pulses. In this paper, the pulse circuit is designed in the complex programmable logic device (CPLD)-EPM7128SLC84-15, which is the product of MAX7000 series of ALTERA Company. Rather than using the most middle-scale or small-scale integrate circuits or individual elements, it is easy to improve the integration of the entire system and reduce the cost by using CPLD, which has many advantages, such as high integration, good reliability, flexible to program, low price and high running speed. Here, the inner circuit of CPLD is composed of one asynchronism clear up counter (counter1), two asynchronism loading down counters (counter2, counter3), two comparators (compare1, compare2) and three shift-registers (shift1, shift2, shift3), as Fig. 4. Counter 1 makes the two comparators (compare1, compare2) count, shift register1 sends pulse width respectively to the load port of counter1 and counter2, shift register2 sends data to compare1 to generate the first pulse, and shift register3 sends data to compare2 to set the time interval of the two pulses. As a result, the width and the interval of pulse can be change for need. The software tool QUARTUSII, which widely supports all hardware description languages is used to design the inner circuit program of CPLD.

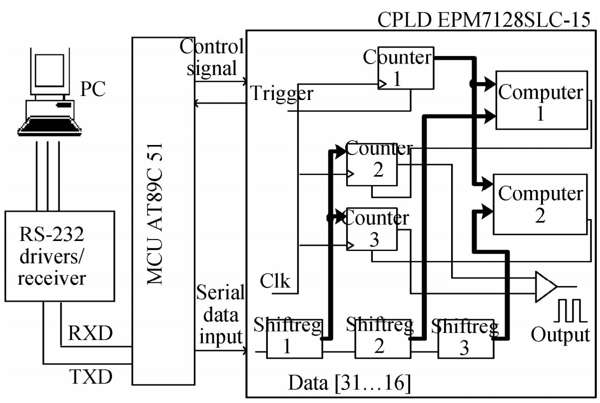
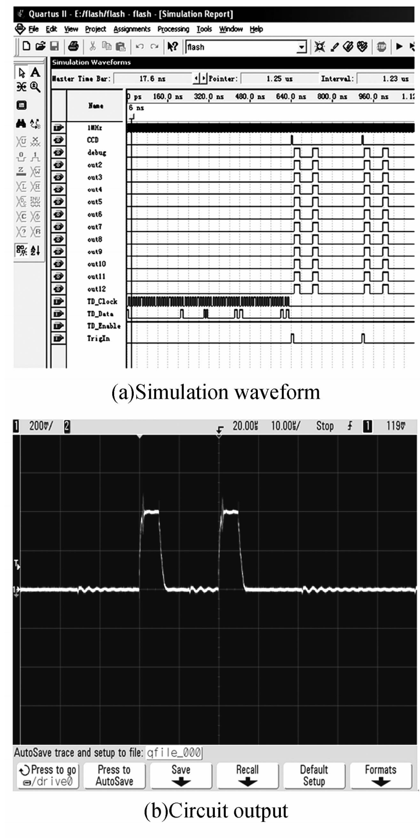


Fig. 4 The configuration of impulse generation circuit

The data in the shift register is easy interfered by the common-mode interference so that the stability of the system is infected because the ability of CPLD on anti-interference is low. Whereas, the COM port can restrain the common-mode interference very well. It has low bit error rate and the high transmission speed. So, the COM communication is adopted in this system to protect the data in the shift registers and improve the stability of the system. On the other hand, the optocouplers are used at the pulse output to insulate the common-mode interference between LED flash system and the synchronization trigger system. Here the MCU is used for COM communication, and the communication protocol is programmed under the development environment Keil C in version 3.



(a)Simulation waveform

(b)Circuit output

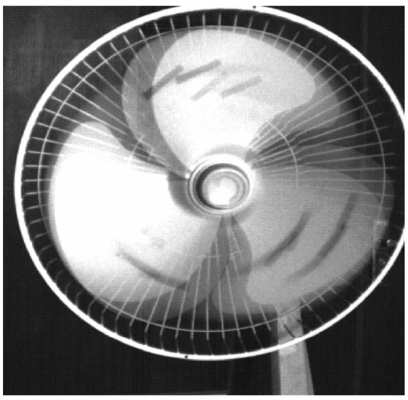
Fig. 5 Simulation curve of impulse circuit and circuit output

2.3 Image capturing system

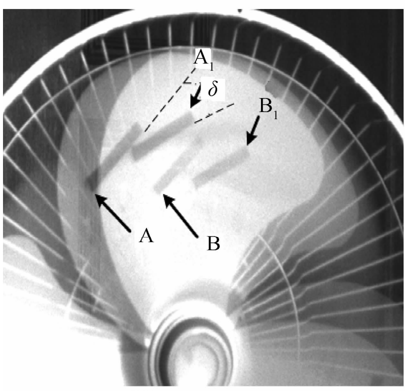
This part includes narrowband light filter, pre-optical-acceptor, digital CCD camera, and image readout system and personal computer. Because the test environment is very execrable, it is necessary to improve the signal noise ratio (SNR), so the narrowband light filter is used in this part. The pre-optical-acceptor is used to focus the reflected light to the digital CCD. The digital CCD camera is scientific, resolution 1K×1K, and capturing speed 30 frames per second. The readout system can capture, process and display image. It can adjust the image lighteness and contrast, save image data and read out image files. However, the main functions of the readout system are to confirm the space coordinates of object, repair the parallax, recognize the characteristic points and calculate the speed. In addition, the software can set the width and interval of light pulse, as well as delay time through RS232 COM port in long-distance.

3 Application

In the field of engineering and scientific research, it needs measure the rotation speed, such as testing the rotation speed of engine, electromotor, windlass, etc. The proposed system can measure not only the speed of objects that moving linearity, but also the rotation speed of rotation objects. The principle of measuring rotation speed is as the way to measure the object that moving directly, where the difference is that it needs measure the rotation angle not the displacement. The rotation speed can be figured out as $n=\delta/\Delta t$, in which the δ is the rotation angle and the Δt should less than the period of the rotation. Fig. 6 is the rotation speed-measurement of the fanner, where the two parallel lines A and B on the fanner leaf are the signs. First of all, the two lines lie in A and B when the flash light first flares and they lie in A_1 and B_1 when the light second flares, the angle δ is the rolling angle during the two flares.



(a)The original picture



(b)Part zoom out

Fig. 6 Measurement of velocity of fanner

In order to verify the measurement precision, here, the cymometer method is compared to test the fanner rotation speed. The two results are the same from the contrastive results in Table 1. Comparing the cymometer method, the precision of the flash image method is high and can be widely used. Compared to other methods, the flash imaging method is more convenient, because it can measure the displacement Δs and the angle δ by eye, do not have to know the angel of the light and the target, and estimate the scale of the speed. For the high speed target, the error is so small that it can be ignored, so the flash image method is practicable.

Table 1 The contrastive results of flash imaging method and cymometer method

Flash imaging	Cymometer
$\delta=16.5°$	$f=22.72$ Hz
$\Delta t=2$ ms	
$n=22.78$ r/s	$n=22.72$ r/s

4 Conclusions

This flash image system has been successfully used to measure the bullet speed. Through the image processing, the displace Δs is figured out, if the interval Δt has known, then the speed of the bullet can be solved by the formulation $v=\Delta s/\Delta t$. Through the speed detecting, the width of the light pulse should not be too wide, if not CCD can not capture the clear object image; The flash image system must be Synchronization, or else CCD will not capture the object image; To the greatest extent to use the higher sensitive CCD, to improve the accuracy of the speed measurement. The flash imaging system which takes the LED pulse light as the light source, flares the target and captures the object image by CCD, then determines the speed through image processing. It breaks through the limitation of single point measurement in space, it can not only records special information of more than one point in different moments but information of different points at the same moment in one image. It is good for researching the states of moving objects in real time, which beyond the ability of optoelectronic detecting technology. In conclusion, this flash image system is the compositive development result of laser technique, digital signal processing technique, computer technique and image processing technique.

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基于大功率 LED 的闪光成像速度测量系统

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摘　要:设计出一种非接触式高速运动物体速度测量系统,在 CCD 单帧曝光时间内利用闪光灯对飞行中的物体进行两次闪光照明,CCD 对两个不同位置的飞行物体成像,设定两个光脉冲之间的时间间隔以及测量出两个物体像之间的距离即可算出其飞行速度.该系统能够进行实时测量,突破了空间单点测量技术的局限,可在同一幅图像上记录下不同时刻多个空间点目标的图像信息,以及同一时刻不同空间点目标的图像信息,从而可以获得目标运动的瞬时速度.

关键词:大功率 LED;脉冲发生器;闪光成像;CCD

LEI Juan was born in 1983. At present, she is a M. S. degree candidate and her current interests focus on ultrafast eletrics and ultrafast diagnostics.