

Hybrid-integrated prism array optoelectronic targeting system

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Abstract

This investigation proposes a cost-effective, compact, and robust optoelectronic targeting system for measuring ballistic impact velocity and the distribution of projectile motion. The major elements of this system are four photo-gates hybridized by compound one-dimensional prism array and analog/digital electronic components. The number of light sources and photodetectors used in a photo-gate was reduced to one pair of light source and photodetector. The average velocity and location of the projectile are determined according to the measured time intervals ($\sim 10^{-8}$ s) passing each pair. The system can accurately measure the velocity of a bullet as it leaves a gun barrel, as well as the velocity at specific points along the trajectory outside the firearm. Additionally, the system uses a widespread low-powered laser pointer as a light source. Compared with other optoelectronic targeting systems that use high-powered lasers, the proposed system is both economical and safe.

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1. Introduction

Early on, the US Army Aberdeen Test Center designed a setup that could test bullet velocity and position, called the Aberdeen target velocimeter, as shown in Fig. 1. This setup tests the speed using a contact testing technique. When a high-speed bullet penetrates a tinfoil, the contact friction results in a big error, which affects the precise value of the tested bullet speed. Recently, since the maturing of optoelectronic techniques, several optoelectronic components have been gradually adopted in velocimeters and optoelectronic targeting. Most of them are non-contact, non-destructive optoelectronic testing methods, and thus can improve on the shortcomings of the Aberdeen velocimeter.

In 1973, Crittenden et al. [1] proposed an optoelectronic target that significantly reduces the error of the Aberdeen velocimeter. However, this design, besides

requiring the installation of sensors in the vertical and horizontal axis, also increases the number of shooting light sources, and thus is very costly. The number of sensors installed increases testing and maintenance, while the passing rate is difficult to maintain, and the selling price naturally becomes prohibitive. Bailey and Bates [2] (1981) proposed another improvement of the optoelectronic target system. In this system, a single light source is introduced into a fiber optic strand. Using the optical fiber, the light source is distributed on the *X*- and *Y*-axes. Although this method may be able to significantly reduce the cost problem associated with the emitted light, the optical fiber sensors remain the main source of additional costs. Thus, the price of Bailey's system is likewise high. Testing and maintenance increase with the number of sensors installed, and passing rate becomes difficult to maintain. In 1987, Deck [3] proposed another optoelectronic targeting system based on a multi-optical source emission that improves on the one laser source system. Using the planar mirror reflection principle and a bundle of laser sources, the reflection from a plane mirror produces a

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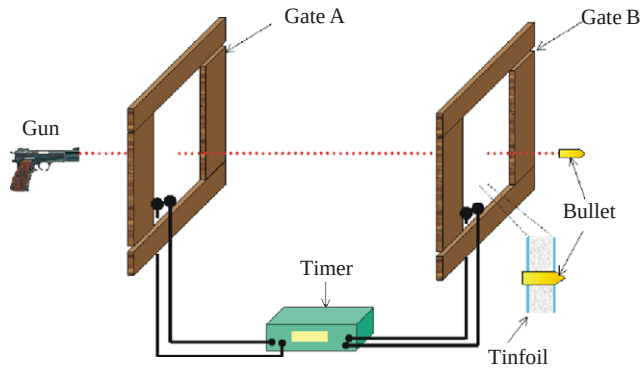


Fig. 1. Schematic of the Aberdeen velocimeter.

fan-shaped light curtain. Nevertheless, the ratio between the optoelectronic target of this design and the possible testing range is approximately 40%. Consequently, the actual optoelectronic area must be enlarged based on the ratio of the required testing area. This increases manufacturing costs and convenience of use.

This investigation designs a novel optoelectronic targeting system using the prism array principle [4,5]. The proposed system is an improved “hybrid one-dimensional prism array optoelectronic velocimeter” [6,7], which is a non-destructive and non-contact, automatic optoelectronic testing system. The system can accurately measure the velocity of a bullet as it leaves a gun barrel and the velocity at specific points along the trajectory outside the firearm. Additionally, a back-end software can analyze the bullet distribution to calculate the accuracy of the gun being fired. This is crucial with respect to external trajectory research on initial firing speed tests, trajectory test values, and air resistance values testing. Furthermore, the system uses a widespread low-powered laser pointer as a light source. Compared with other optoelectronic targeting systems that use high-powered lasers, the proposed system is both economical and safe.

2. Principle

Since the establishment of the hybrid one-dimensional prism array optoelectronic velocimeter can only test the average speed of the bullet (or the object being tested), no way exists of testing the position of the bullet during its passage through the system. Thus, this investigation designs a hybrid one-dimensional prism array optoelectronic target to improve the original structure of the optoelectronic velocimeter. The initial idea is to arrange the prism array opto-gate of the velocimeter, as illustrated in Fig. 2 (the average speed of the object to be tested when passing through opto-gates A and D, and the time taken by the object to be measured when passing through opto-gates A and D as well as C and

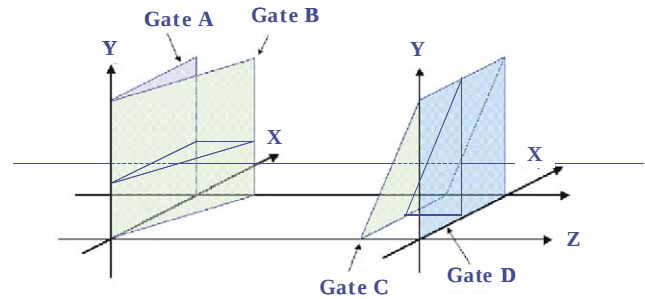


Fig. 2. Schematic of the proposed optoelectronic targeting system.

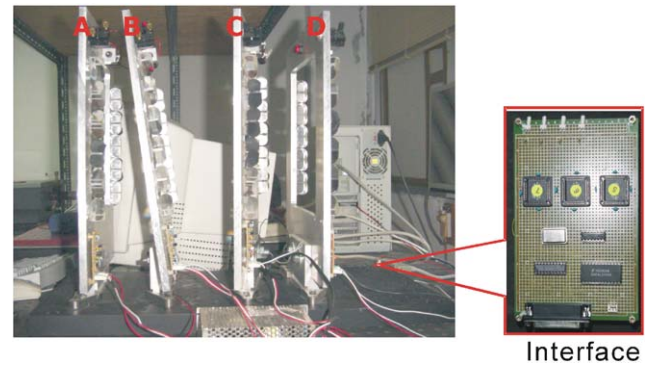


Fig. 3. Photograph of the proposed optoelectronic targeting system.

D). Moreover, trigonometric principles are used to estimate the position of the object as it passes through A, B, C, and D.

The proposed optoelectronic target system is assembled as shown in Fig. 3. The opto-gate assembly is responsible for detecting the object as it passes through opto-gate A. When the object interrupts the optical signal, the enlarged optical signal produces a TTL signal and starts the timer of the interface counter module. When the object passes through opto-gates B, C, and D, these TTL signals separately stop the timer of the counter module. The count value obtained is stored in a register. A specially designed software reads the number stored in the counter through a serial connection using the SPP Mode transmission protocol. The time taken by the object to pass through opto-gates B, C, and D is also analyzed. Next, the average speed and position are analyzed as it passes through the optoelectronic target system.

The experiment uses an optical network, and the main optical components are the right angle prism and the Porro prism, as shown in Fig. 4. Using a prism, the laser light can be redirected by total internal reflection. The optical network is created by using several prisms to create a geometric permutation. The use of prisms to form the optical network has several advantages: good stability, high reflectivity, and the absence of multiple images. Thus, this investigation uses right angle prisms

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