Microcontroller Based Electronic Circuitry to Record High Speed Events

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Abstract

The aim is to design the microcontroller based electronic circuit which generates the time pulses; those are used to switch ON the three modulated Lasers (fitted in the source assembly) in sequential mode with a predefined exposure and delay time depending on the speed of the projectile to illuminate the high speed projectile through the lens whose shadowgraphs are recorded in corresponding digital camera (three cameras fitted in the camera assembly). To record the interaction of high speed projectile and target, ultra high speed camera is required. But such high speed camera commercial system is quite expensive. So another technique is used to develop a system which employs low speed cameras operated in snapshot mode and there are lasers on other side which are operated for few hundred ns to illuminate the projectile moving between source and camera assemblies [1-2]. To record the shadowgraph of the events projectile has to move between source and camera assemblies.

Keyword- Microcontroller, Time pulses, Modulated Lasers, Source assembly, Sequential mode, Illuminate, Shadowgraphs, Assembly

1. Introduction

The technique of measurement of time of flight of a projectile between two fixed planes is continuously employed to determine the speed of high speed object. When the projectile successively crosses through the first and the second laser screen, the start and stop pulse signal can be obtained as the triggering signal for the timer. To measure the time interval between the start and stop pulse signals, the time of flight (TOF) can be obtained and by processing and calculating, the average velocity of the flyer will be acquired. Comparing with the development of the system is based on optical principles, but applications are in field of ballistics. Ballistic is the science of mechanics that deals with the flight, behaviour and effect of projectiles. Terminal ballistic study is the study of motion and consequent effect of projectiles as they interact with their intended target [3]. Target may resist projectile at low velocity, but it may not be resistant to projectile fired at higher velocity. The target may be bulletproof vest, glass (such as in vehicle window), the body of vehicle, helmet, or a human body. After the impact of projectile on the target, the movement of debris (fragments) coming out of the target can be used to measure the stopping power of the target with regard to projectile. These data can be used to estimate the damage to a target, and damage data can be used to design the armour for better shielding. The target is said to be fully bullet proof if, upon contact with projectile, no debris comes out. The basic application of this system is to test the impact of projectile on the target. The impact data can be used to test the performance with regard to a projectile having a particular velocity keeping in view the specified requirement of target [4].

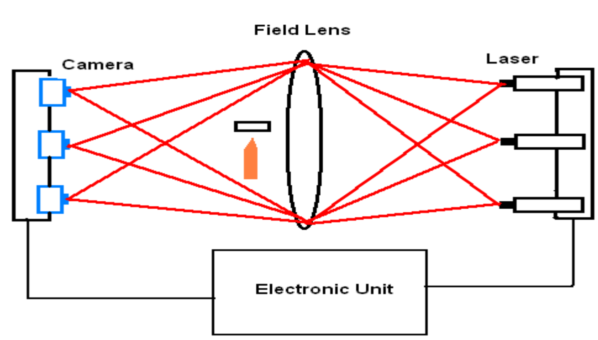

Figure1. Basic System Diagram

The system has been designed based on modulated laser diodes operated at low voltage and current. In order to take snapshot of high speed projectile, an exposure time of few hundred ns and delay time of few tens of μs are needed for the lasers depending upon the speed of projectile. So microcontroller generated pulses have been developed to control the operation of lasers thereby controlling the exposure time for cameras and shadowgraph images of moving projectile are captured with the use of cameras.

2. Design and Description of the System

In this project, snapshots have to be taken of high speed projectile using slow speed cameras. No. of lasers and cameras used are three each. These snapshots are to be taken at different intervals. The system combines Laser diode source (output power 32mW operated at 5V) and digital cameras with provision of global shuttering and external triggering [5-6]. The micro-controller is used to control the operation of Lasers (ON/OFF). The pulses generated by the controller must be programmable. Exposure time of the laser should be 600 ns-3 μs. Delay time should be 1μs-3ms depending upon the speed of the projectile. Each laser is optically aligned to corresponding camera. Optoelectronic triggering unit is used which provides the triggering pulse to microcontroller in order to indicate that projectile is in vicinity of the system, and further microcontroller start its operation of controlling lasers by providing pulse. When it receives the trigger pulse from optoelectronic triggering unit, the microcontroller starts its work to generate time pulses. The program written in microcontroller in such a way that as once the controller senses the interrupt, it starts its process of enabling and disabling output pins connected to lasers .The lasers are ON/OFF according to time predefined by user. The exposure and delay time are set at start by the user. According to these exposure and delay time set, microcontroller is given count value till which microcontroller counts and during When high level output is given to lasers then it gets switched ON and when low level output is given to lasers it get switched OFF. Cameras used in the system are slow speed cameras. System is designed in such a way that both laser and cameras are optically aligned and cameras are used in snapshot mode [7]. Now using microcontroller base electronic circuitry, pulses are generated which are used to trigger three lasers sequentially with equal exposure time but different delay time. Both exposure time and delay time are programmable and are set according to speed of projectile whose images are to be recorded. Shutter of camera is kept ON for entire process, but exposure time for each camera is controlled by ON time of corresponding laser. So we will get the shadowgraph image of projectile captured by camera when corresponding aligned laser is triggered ON by controller. High speed photographic techniques are employed to study the terminal effects of ammunition. High speed photographic techniques are very sophisticated, and they require a very powerful light source with external optics as the illumination source and high speed photographic recording device [8]. The photography can be done in reflection mode or transmission mode (shadowgraphy). To record the images of the object (projectile), an exposure of the order of few hundred ns is required.

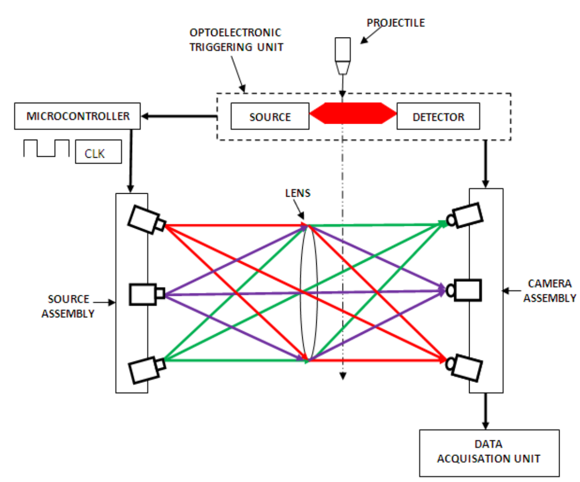

Figure.2 Schematic of System for recording Shadowgraphs of High Speed Projectile

The power of the laser required to record shadowgraph depend upon the sensitivity and active area of the film, exposure time and energy loss due to various optical component incorporated in the system and modulation of the laser. The power of the laser is calculated based upon following equation and parameter [9].

Exposure energy (E) $=E_t*A=P*T$

E_t=threshold exposure energy of the film in J/m^2 at wavelength λ, A= Area of the film to be exposed, P= source power in W, T exposure time in sec, Et=1.6*10^{-5} J/m^2 at λ=635 nm, A=2.16*10^{-4} m^2, T=0.6 us, and P=5.8 mW.

A.Opto-Electronic Triggering Unit- The optoelectronic triggering unit incorporates laser screen which is shown in Figure3

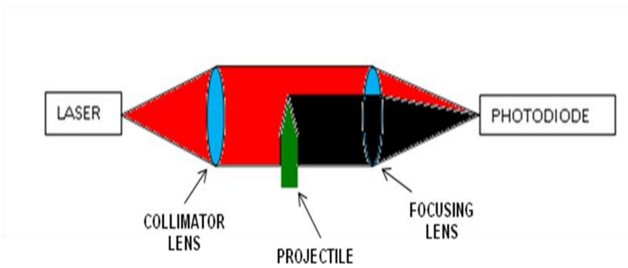

Figure3. Schematics of Optoelectronic Triggering Unit

In case of two-dimensional image, after a DWT transform, the image is divided into four corners, upper left corner of the original image, lower left corner of the vertical details, upper right corner of the horizontal details, lower right corner of the component of the original image detail (high frequency). You can then continue to the low frequency components of the same upper left corner of the 2nd, 3rd inferior wavelet transform [10-11].

B. Laser - A laser is a device that emits light (electromagnetic radiation) through a process of optical amplification based on the stimulated emission of photons. The term "laser" originated as an acronym for Light Amplification by Stimulated Emission of Radiation. The emitted laser light is notable for its high degree of spatial and temporal coherence [12].

Figure4. Semiconductor laser

Laser stands for light amplification by stimulated emission of radiation. Semiconductor lasers are used for the project keeping in view the following requirement. Laser operates at low voltage (5V). Laser source is used for recording the shadowgraph to provide high contrast image as compared to a incoherent source. Specifications of laser are described as: Wavelength: 635 nm, Output Power: 32 mW, Beam Divergence: $\leq$ 0.7 mrad, Modulation: DC to 5 MHz, Operating Voltage: 5V

C.Field Lens -A lens is an optical device which transmits and refracts light, converging or diverging the beam.

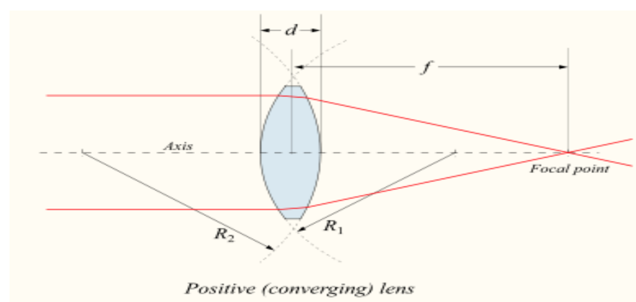

Figure5. Diverging lens

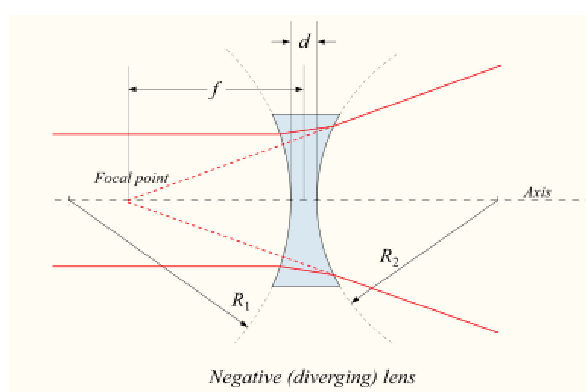

Figure6. Converging lens

A simple lens consists of a single optical element. A compound lens is an array of simple lenses (elements) with a common axis; the use of multiple elements allows more optical aberrations to be corrected than is possible with a single element [13-14]. Field lens in this project plays one of the important roles. Using this lens the intensity or the laser light falling on the projectile is focused on the corresponding camera. As number of different snapshots have to be taken at regular intervals. So, due to this, projectile must have travelled some of the distance. Hence the field lens has to be long to collect all the snapshots taken at different time intervals.

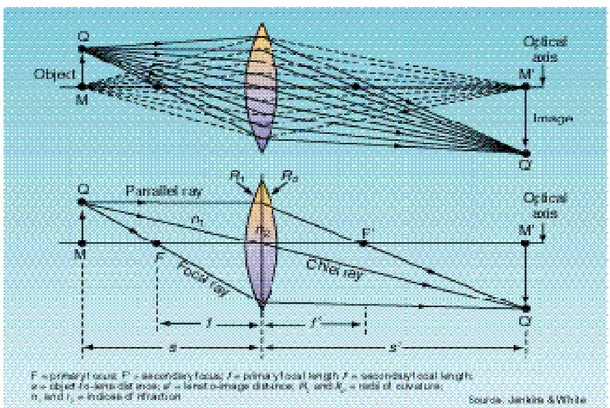

Figure7. Field Convex Lens

Using this lens, the laser light falling on the projectile is focused on the corresponding camera. As number of different snapshots have to be taken at regular intervals [9]. So, due to this, projectile must have travelled some of the distance. Hence the field lens has to be larger diameter to collect all the snapshots taken at different time intervals. Specification of lens is focal length of field lens – 1000 mm and diameter of the field lens - 500 mm

Figure8. Field lens at CSIO PHOTONICS Lab

D. Lumenera Camera - Lumenera USB Cameras provide a quick and easy means of displaying and capturing high quality video and images on any USB 2.0 equipped desktop, laptop or embedded computer [15]. Designed with flexibility in mind, each camera model has its own distinct advantage over the others, whether speed, resolution, image quality, sensitivity or price. Because they are USB based, there is no need for a frame grabber. Instead, a single cable provides power, full command and control and data transfer at speeds of up to 24 MB/s (Lu series) or 48 (Lw series). Triggering Mode: ExternalHardware/Software and Electronic Shuttering: Rolling& Global [16].

Figure9. Lumenera Camera

E. Microcontroller based electronic circuitry - The heart of the circuit is the P89V51RD2 microcontroller [17] Specification of microcontroller are as 80C51 Central Processing Unit, 5 V Operating voltage from 0 to 40 MHz ,64 KB of on-chip Flash program memory with ISP (In-System Programming) and, Supports 6-clock mode selection via software or ISP ,Four 8-bit I/O ports , Three 16-bit timers/counters, Programmable Watchdog timer (WDT), TTL logic levels

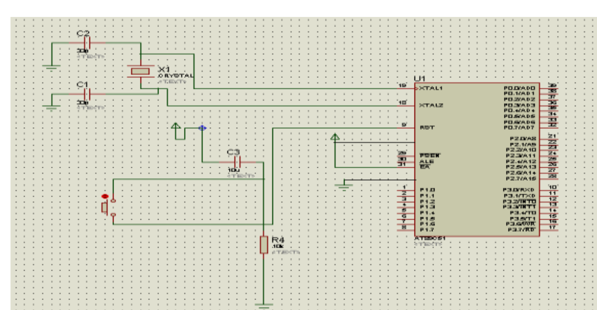

Figure10. Circuit for Pulse generator using Microcontroller

3. Working Principle- The programmable timings of the pulses i.e. ON-time, OFF-time and initial delay are set by using keypad or user friendly interface written in Visual Basics. These timings are sent to controller. When the controller receives a valid data, the signal is sent to acknowledge the successful reception of the data. Each time a new data is written to the controller the timings are updated and remains till the new timings are entered [18]. After the timings are fixed, the controller waits for the triggering signal from optoelectronic unit. When the projectile is sensed by the unit, it pushes the sensor switch. This sends an interrupt to the microcontroller. Once the controller senses the interrupt, it disables the sensor switch to prevent wrong triggering. After this controller waits for time period equals to the initial delay and switch ON the laser 1. The laser 1 remains ON for the time duration equal to exposure time set and then is switched OFF. The controller than waits for time period equals to TOFF1 and then switched ON the laser 2 for ON-time. The Laser2 remains ON for the time duration equal to exposure time set and then is switched OFF. The controller than waits for time period equals to TOFF2 and then switched ON the laser 3 ON for time duration equal to exposure time. After this interrupt for sensor switch is enabled again and controller waits for next projectile to be fired for next recording of images.

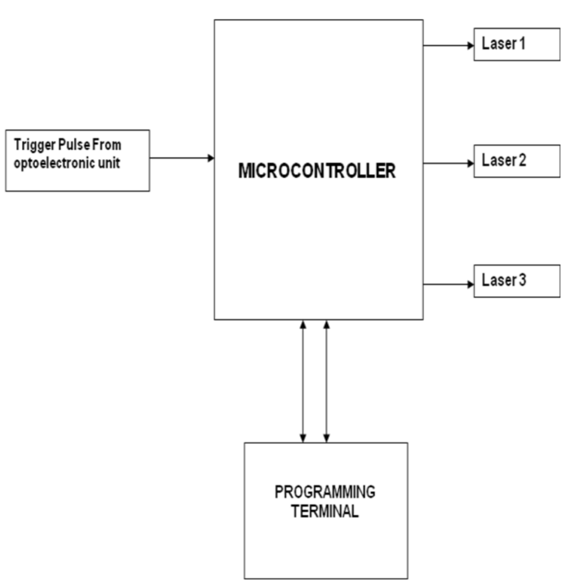

Figure11. Implementation of Project

4. Result - The Hardware design is made and experiments are performed in Photonics Lab of CSIO. Entire circuit is made on breadboard. Actual gun is not used; just the triggering input was given to the microcontroller to start its further operation.

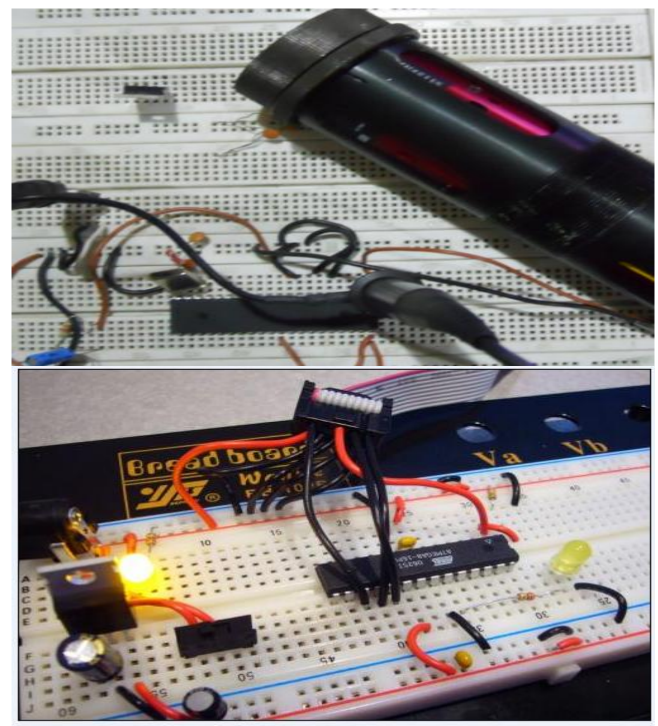

Figure12. System set up

When the microcontroller receives its external triggering it starts its operation of providing predefined pulse to operate lasers and also switch ON the cameras in snapshot mode [22-25].

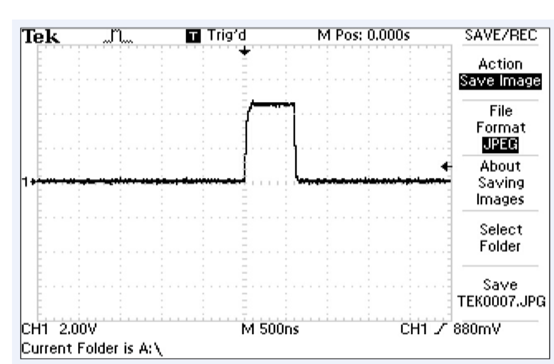

Figure13. Pulse generated with exposure time of 600ns

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After taking triggering pulse camera takes some time to ON or to open the shutter so that exposure starts. Then after sending the triggering pulse, controller sent the square waveform to the laser driving circuit. The exposure time of the camera is set through the software provided with the camera [20-21]. The laser remains ON for 600ns and just before this, exposure time of camera starts. When the exposure time is finished the photo or the snapshot is automatically sent to the computer or laptop as per required by the user. The results showing minimum pulse 600 ns is obtained on CRO as shown figure 13. Laser is operated using microcontroller circuitry and pulse is given to it. To check whether Laser s able to switch ON for such a minimum duration of 600ns Laser light is made to fall on Detector an detector output is observed on CRO. Detector output when Laser is given a exposure time of 600ns.

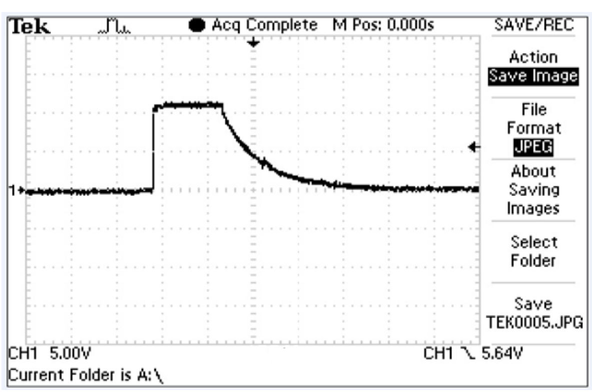
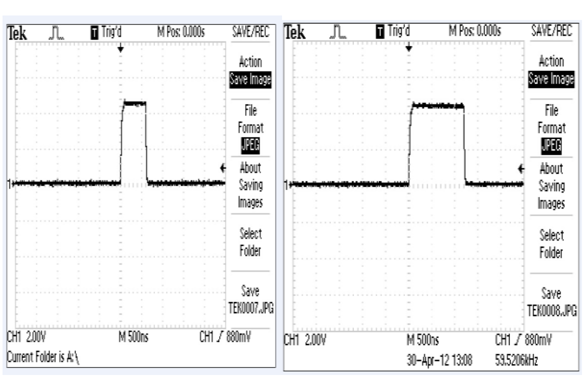
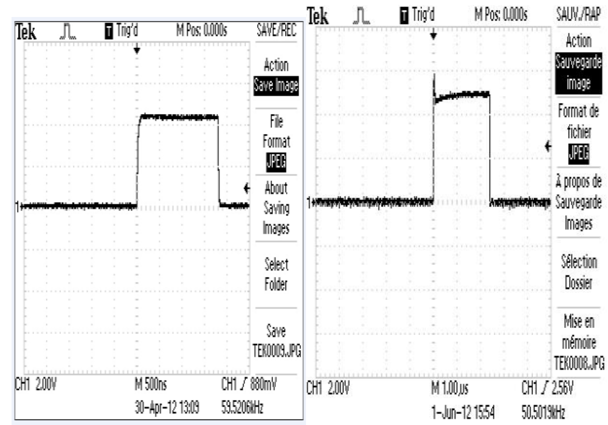


Figure14. Detector output on CRO

CRO OUTPUT



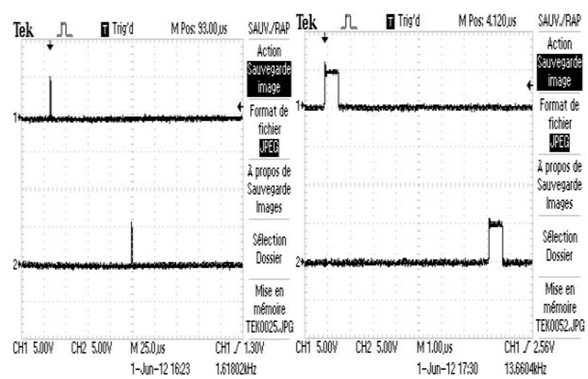
(a) (b)



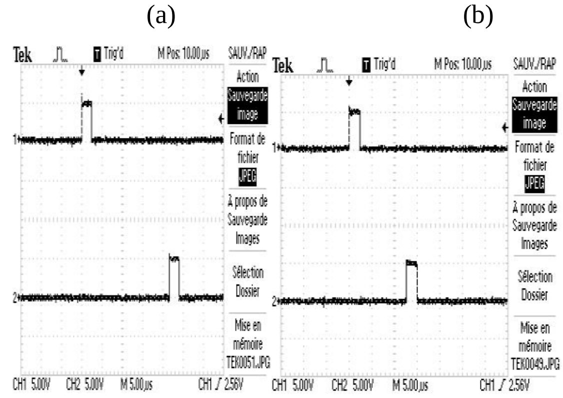
(c) (d)

Figure15. (a) Pulse duration of 600ns (b) 1200ns (c) 1800ns (d) 2400ns

Exposure and Delay



(a) (b)



(c) (d)

Figure16. (a) Delay of 6.5 µs (b) 18 µs (c) 85 µs (d) 110 µs

Images Captured by Cameras: Three shadow graphs with exposure time 600 ns (Demonstration of the electronic and optical system)

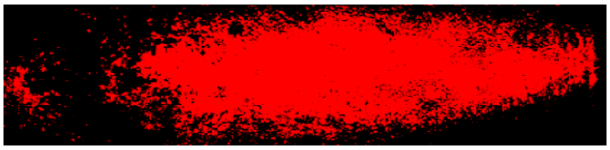


Figure16. Laser Beam

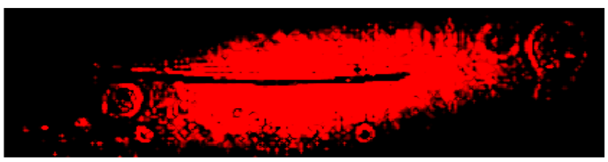


Figure17. Hair - 0.08 mm Dia

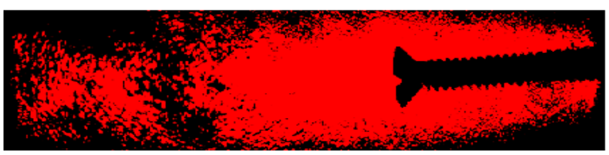
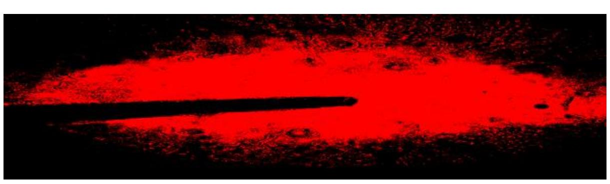
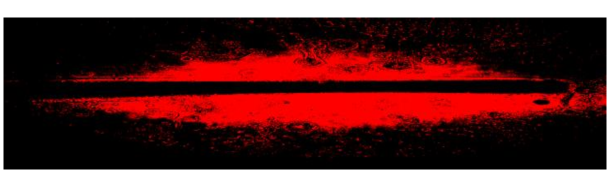


Figure18. Screw – 4.6 mm Dia



(a)



(b)

Figure19. (a) (b) Shadow graphs of metal stick at different time

5. Conclusion- The main advantage of the described system are as follows:The design of the system is innovative, compact, and inexpensive. System has been designed using microcontroller based electronic circuitry which generates the pulses to control triggering of Lasers and cameras are used to record snapshots of high speed projectile. Both exposure time and delay time are programmable. Such type of developed controller can be used for any type of application in which high speed phenomenon are involved.

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References

[1] R. C. Kalonia and R. K. Varma, "Laser-based projectile speed measurement system" CSIO, Optical Engineering, Vol 46, No. 4, 044303,1-5 (April 2007).

[2] R. C. Kalonia, Gautram Mitra, G.S Singh , Manpreet Singh, V.S Sethi, M.S Yadav, R. K. Varma, "Multiple laser flash shadowgraphy system for terminal studies of small–calliber projectiles " Optical Engineering 49(6), 064303, 1-6 (june 2010).

[3] W.G. Hyzer, Engineering and scientific High-Speed Photography, Macmillan, New York (1962).

[4] A.S. Dubovik, Photographic Recording of High-Speed Processes, Rev. ed.,Wiley , New York (1981).

[5] T.E Holland, "High speed Photography," in applied optics and Optical Engineering Vol. IV, Academic Express, New York (1987).

[6] C.Cranz and H.Schardin, " Kinematographie auf ruhendem Film and mit extreme hoher Bildfrequenz," Z.Phys. 56, 147-183 (1929).

[7] B.Stasicki and G.E.A. Meier. "Computer controlled ultra-high speed video camera system," Proc. SPIE 2513, 196-208 (1995).

[8] J.W Dally and R.J. Sanford, "Multiple Ruby Laser for high speed photography," Opt. Eng. 21, 704-708 (1982).

[9] B.Stasicki, W.J. Hiller, G.E.A. Meier," Light pulse generator for high speed photography using semiconductor devices as light source," Opt. Eng.21, 821-827 (1990).

[10] B.Bretthauer, G.E.A Meier, B.Stasicki, "An electronic Cranz-Schardin camera," Rev. Sci. Instrum.62, 364-368 (1994).

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[11] B.H. Timmerman, et al. "High speed digital shadowgraphy for high frequency shock tracking in supersonic flows," in 17th sypnosium on measuring techniques in Transonic flow in Cascades and turbo Machines, Stockholm, Sweden, (2004).

[12] "Multiple spark system," catalog, Drello, Ing. Paul Darwell Gmbh & Co. KG, Germany.

[13] "Hadland SVRII camera system," Catelog DRS Hadlnand Limited, United Kingdom.

[14] Zhou. et.al., "CCD camera shadowgraph system with nitrogen laser light source," in 18th international Symposium on Ballistics, SA, Nov,15-19, 1999.

[15] D.L. paisley, "Recent advancement in high speed photography and associated technology in U.S.A," Proc SPIE 1032, 6-15 (1988).

[16] Gould, R. Gordon (1959). "The LASER, Light Amplification by Stimulated Emission of Radiation". In Franken, P.A. and Sands, R.H. (Eds.). The Ann Arbor Conference on Optical Pumping, the University of Michigan, 15 June through 18 June 1959. p. 128. OCLC 02460155.

[17] "laser". Reference.com. Retrieved May 15, 2008.

[18] Conceptual physics, Paul Hewitt, (2002).

[19] Lumenera USB Camera User's manual Release 3.5, Lumenera Corporation.

[20] Muhammad Ali Mazidi, Janice Gillispie Mazidi, Rolin D.Mckinlay, "8051 microcontroller and embedded systems ", Delhi, India (2011).

[21] Muhammad Ali Mazidi, Janice Gillispie Mazidi, Rolin D.Mckinlay, "PIC microcontroller and embedded systems",Delhi, India (2008).

[22] P89V51RD2 8-bit 80C51 5 V low power 64 KB Flash microcontroller with 1 KB RAM , Datasheets, Koninklijke Philips Electronics N.V. 2004.

[23] Zhexin, Jia, Ke, Gong, "Optoelectronic system for high-speed flyer velocity measurement based on laser scattering" Tsinghua University, Beijing, China (2009).

[24] Maria Y. Fernandez, Ramon Zaera, "Cost-effective optoelectronic system to measure the projectile velocity in high-velocity impact testing of aircraft and spacecraft structural elements" Spain (2007).

[25] Nicholas J. Paulter, Donald R. Larson, "Reference Ballistic chronograph" NIST, Mailstop8102 (May 20, 2009).