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LASER-PHOTODETECTOR TIMING STATION INSTRUCTION AND MAINTENANCE MANUAL

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SECTION 1

INTRODUCTION

A laser-photodetector station is a very useful, non-contact device for detecting the arrival of a projectile at a specific point along a ballistic range. In general, such a station consists of a low-power visible (Class I) laser and a photodetector. The laser is positioned so that its output beam is directed across the trajectory of the projectile to be detected. Normally, the laser beam strikes the PIN diode photodetector and produces a DC output signal that is proportional to laser beam intensity. When a projectile interrupts the laser beam, the photodetector output voltage diminishes rapidly to provide an electrical signal which indicates passage of a projectile. If the photodetector circuit is equipped with a comparator circuit, it also produces a pulse which can be used to trigger various other devices such as flash tubes, counters, or pulsed x-ray systems.

The analog (or direct) photodetector output signal has proven to be very useful when it has been recorded by an electronic device having a large temporal range and high resolution, e.g., a digital oscilloscope or digital transient recorder. In ballistics experiments, particularly those using powder or two stage, light-gas guns, the projectile is frequently preceded or accompanied by a variety of debris. A solid projectile produces a well defined signature as it passes through the laser beam. When the resolution of the transient recorder is adequate, a fairly good approximation to the velocity of the projectile can be obtained from a single laser-photodetector station by dividing the length of the projectile by the time which the laser beam is blocked by the projectile. However, when a significant amount of gases precede and/or accompany the projectile, it may be difficult to distinguish the signature of the projectile from that of the extraneous matter.

A laser-photodetector station can be employed on either an open or evacuated range. They can also be used with very small projectiles and at hypervelocities, situations in which use of contact detectors (such as foil switches) are prohibited because of possible damage to the projectile.

SECTION 2

SYSTEM DESCRIPTION

Each laser-photodetector system consists of the following components: (a) a Class I HeNe laser light source, (b) a PIN diode detector and associated electronic circuitry mounted in a protective enclosure, (c) a mounting structure for positioning and supporting the laser and photodetector assembly, and (d) cables necessary to attach the detector assembly to its power supply. The Spectra Physics Model 155 HeNe laser used with each system, produces 0.5 mW of 632.8 nm radiation in a beam which is 1 mm in diameter as it emerges from the laser cavity and has a divergence of 1 mrad.

WARNING THE USER OF THIS DEVICE SHOULD CONSULT THE INSTRUCTION MANUAL PROVIDED WITH THE LASER AND BE THOROUGHLY FAMILIAR WITH THE SECTION ON LASER SAFETY. WARNING

The laser and photodetector are mounted on an aluminum beam which is attached to the ballistic range beam with clamps. Four rubber shock mounts between the clamps and the beam effectively isolate the laser and photodetector assembly from mechanical and electrical shocks which might otherwise be transmitted to the station. The laser is attached to the beam using two aluminum angle brackets. Adjustment of the position of these brackets allows the orientation of the laser to be changed. The photodetector is housed in an aluminum box which is mounted on the aluminum beam opposite the laser. A mounting post, horizontal translation stage, small base, and vertical translating post holder permit the photodetector to be accurately centered on the laser beam.

A Motorola MRD500 PIN diode is employed as the photodetector. The photodetector assembly contains several transistor amplifier stages, a voltage comparator, and an indicator LED. The photodetector assembly has two BNC output connectors for analog and pulse signals and two operator-adjustable multi-turn potentiometers for setting the DC and trigger levels. (These functions are described in detail in the next section.) An indicating LED turns "on" when the light level from the HeNe laser falls below a preset value.

A 12 VDC power supply is housed in a separate cabinet. The input to the power supply is 115 VAC, 60 Hz. A long cable for connecting the photodetector assembly to the power supply is provided.

SECTION 3

SETUP AND MAINTENANCE

MECHANICAL SETUP

The first portion of a laser-photodetector station to be assembled is the aluminum cross beam that is clamped to the ballistic range beam. Since range beam dimensions vary, each cross beam must be tailored to meet the needs of the particular installation.

The laser is attached to the cross beam using two aluminum angles. One of the angles has two slots and is attached vertically to the side of the cross beam using two 1/4-20 socket head machine screws. The slots in this angle allow the vertical position of the laser to be adjusted. The second angle mounts horizontally at the top of the slotted angle using two 1/4-20 socket head machine screws. One of the mounting holes in this second angle is elongated to allow the laser to be tilted as necessary. Washers are used on all four of these screws to insure a tight mechanical coupling. The laser is secured to the horizontal angle by a 1/4-20 machine screw which passes through the angle into the bottom of the laser case.

WARNING

THIS SCREW SHOULD NOT PROTRUDE MORE THAN 3/8 INCH INTO THE BODY OF THE LASER. SERIOUS DAMAGE TO THE LASER WILL RESULT IF TOO LONG A SCREW IS USED TO ATTACH THE LASER TO THE ANGLE BRACKET.

WARNING

The orientation of the laser beam with respect to the trajectory of the projectile can be adjusted by varying the position of the two aluminum angles. The intersection of the projectile trajectory and the laser beam can be verified by placing a piece of white paper in the path of the laser and bore-sighting the gun. As the paper is moved towards or away from the laser, the "spot" on the paper will move across the field of view of the boresight. The only alignment condition which the laser beam must satisfy is that is pass through the trajectory of the projectile.

The photodetector assembly is supported by a 0.5-inch-diameter post which fits into a vertical translating post holder. The post holder is attached to a slotted base and a horizontal translation stage. The horizontal translation stage must be oriented with its' axis of motion parallel to the projectile motion. Assembly of all photodetector support components is made using 1/4-20 socket head cap screws.

IMPORTANT IN THE FOLLOWING ALIGNMENT PROCEDURES BE SURE THAT THE LONG AXIS OF THE PHOTODETECTOR ASSEMBLY REMAINS PARALLEL TO THE LASER BEAM IMPORTANT

Adjust the photodetector assembly vertically with the coarse and fine adjustments of the vertical post holder until the aperture at the front of the assembly is in the same horizontal plane as the laser beam. (A small piece of white paper held in front of the assembly can be used to locate the beam.) Position the photodetector assembly horizontally using the horizontal translation stage until the laser beam falls entirely in the aperture of the photodetector assembly. It may be necessary to reposition the base relative to the top of the translation stage to achieve the desired laser/photodetector orientation.

ELECTRONIC AND OPTICAL SETUP

Attach the power lead from the photodetector assembly to the power supply, plug in the power supply to any convenient 115 VAC outlet, and turn the power supply on. The photodetector circuitry should be operational at this time. However, it is advisable to wait about five minutes before making the following adjustments to allow the circuitry to stabilize. The red indicator LED on the photodetector assembly may or may not be illuminated at this time.

Attach a Volt-Ohm Meter (VOM) with a full scale voltage of at least 15 VDC to the BNC connector marked "LIGHT" and located at the rear of the photodetector housing. Use the horizontal and vertical adjustments of the mount to maximize the voltage at this connector. The maximum voltage should be between 5 and 12 VDC with a new laser and the red indicator LED should be off. BE SURE TO KEEP THE PHOTODETECTOR ASSEMBLY PARALLEL TO THE LASER BEAM.

The multi-turn potentiometers have been preset at UDRI and should require only a slight adjustment. However, as the components age, the following adjustments may be necessary. In addition, it is often useful to monitor the output signal produced by the photodetector from time to time to ensure that the maximum signal level is being maintained.

Step 1. Block the laser beam by inserting an opaque object in front of the photodetector assembly.

Step 2. Attach a VOM with 15 to 20 VDC range to the BNC connector marked "LIGHT".

Step 3. Adjust the potentiometer marked "BAL" until the voltage, with the beam blocked, is approximately 0.2 VDC. The potentiometer is a 15-turn pot and an adjustment of several turns may be required, particularly if the components have aged significantly or there has been a considerable change in ambient temperature.

Step 4. Remove the "blocker" from the path of the laser beam and observe the increase in the monitor signal level. The mechanical alignment of the photodetector assembly should be adjusted until the "LIGHT" signal level is maximized. This maximum signal can be as high as 11 VDC but is usually lower. A signal level of 3.5 VDC must be considered to be the lowest acceptable value. If a signal level of at least 3.5 VDC cannot be achieved, there is a serious problem with the system (see MAINTENANCE section).

Step 5. Momentarily block the laser beam again, noting the maximum and the minimum "LIGHT" signal levels.

Step 6. The second potentiometer (marked "LEVEL") can now be adjusted. This potentiometer is connected between +12 VDC and ground and is used to adjust the point at which a decrease in the photodetector signal will cause a trigger signal to be generated. Since this potentiometer has 15 turns, the triggering level will change by approximately one volt per turn (12V ÷ 15 turns). Normally, this potentiometer is adjusted so that an 80 percent reduction in the magnitude of the light signal will cause a trigger signal to be generated. If the minimum "LIGHT" signal is 0.2 VDC and the maximum "LIGHT" voltage is 8 VDC then an 80 percent reduction in "LIGHT" signal level will correspond to a setting that produces about 1.6 volts (or approximately 1.6 turns from the end of the potentiometer). This completes the electronic setup.

The indicator LED is very useful for functional testing of the laser-photodetector station before each firing of a gun system. Normally, this LED is dark. Passing an opaque object, e.g., pencil, finger, etc., through the laser beam should always cause the indicator LED to glow. If the LED does not come on when the beam is blocked, the LEVEL potentiometer should be readjusted.

MAINTENANCE

The laser-photodetector station requires minimal maintenance except for regular monitoring of the DC level produced by the photodetector. Low output signal level can be caused by degradation of range windows or a reduction in laser beam intensity. Degradation of range windows should be detected during routine cleaning. A reduction in laser beam intensity can occur gradually or suddenly. In general, a 0.5 mW laser cannot be expected to last longer than about 2 years. If the range alignment of the photodetector assembly cannot increase the diode signal to an acceptable level, then the laser must be replaced or repaired.

SECTION 4

HELPFUL HINTS

There are several sources of noise which may make the interpretation of the photodetector signal difficult: (1) intense radiation produced by extremely bright propellant gases or plasmas, (2) momentary changes in the index of refraction of the medium in the path of the laser beam, and (3) electrical noise produced by poorly-shielded equipment being operated in conjunction with the gun or photodetectors.

In some cases, the optical "notch" filter which is supplied with the photodetector assembly does not provide adequate protection against the intense light which a gun firing can produce. However, a judicious selection of laser photodetector station location(s) can minimize this difficulty.

The simplest means of reducing the optical signal from extraneous light sources is to locate the photodetector assembly further away from the range centerline by mounting it on some support other than the one provided. The incoherent radiation from light-emitting gases inside the range will fall off as the square of the reciprocal of the distance between the photodetector. This procedure has drawbacks, however, since the laser and the photodetector may be attached to separate mounts and independent mechanical vibrations of the laser and photodetector may result in unwanted and false signals.

A more effective method of reducing the amount of stray light is to reduce the field of view of the photodetector. Instead of allowing light from all angles to reach the photodetector through a large window on the range, an extension tube or similar device with an opening some distance from the photodetector aperture is positioned so that the angular field of view of the photodetector is severly restricted. In this way, only light from gases directly in front of the photodetector can be "seen" by the photodetector. The diameter of the He-Ne Laser beam is considerably less than 5 mm under nearly all circumstances so a relatively long, small-bore tube can be used. A further refinement of this technique can be made if a second, larger bore tube with a blackened interior surrounds the laser beam as it enters the range tankage. If the dimensions of this second tube are chosen properly, only the interior of the second tube and the laser beam will be visible to the detector. This arrangement has been effective, for example, when used just inches away from the muzzle of a high-performance, 20 mm powder gun. In some applications it is possible to utilize a more intense laser to overcome background light or obscuring gases.

Interference due to electrical noise, however, can only be reduced by moving the photodetector assembly away from the gun range. Because of the very low divergence of the laser beam, the photodetector assembly can actually be located a considerable distance away from the range if an appropriate lens is used to collect the laser light and direct it into the photodetector. The photodetector assembly could also be housed in a Faraday cage since the laser light can pass through a wire mesh with little loss of intensity.