Warning: Read all of this document before operating system!

LaserStrobe®

Stroboscopic Video Camera Systems

Model 2ZP40N32
Revision 5/94

SYSTEM DESCRIPTION

and

OPERATING INSTRUCTIONS

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INTRODUCTION

Electric arc welding and other high-luminosity processes are normally quite difficult to monitor with the human eye because the detail of the process—the behavior of the solid or molten material in the affected area—is submerged within the luminous volume of the plasma or flame. Even worse, when one attempts to use a video or photographic camera, the viewing is further degraded by the extreme brightness variation across the image area, making it impossible to achieve proper exposure throughout the image—except possibly for small areas of comparable brightness. With arc welding in particular, one can expect to see a bright fireball in the center of the welding pool, but most of the detail at the edge of the welding pool and in the area of the welding seam and groove will be lost in darkness.

The goal with LaserStrobe is to capture a video image of the process using intense lighting from a strobe illumination unit—rather than using the light from the process itself. This manual describes a system incorporating the use of either one or two pulsed nitrogen laser strobe units, or one or more xenon strobe units.

Thank-you for your interest in LaserStrobe. We here at Control Vision are always eager to assist you in optimizing the camera's performance for your particular application. We encourage you to call us when contemplating a new application or when encountering a problem. Our goal is to provide innovative vision solutions for science and industry. To this end, if you have any questions or comments regarding LaserStrobe or this manual, please feel free to contact us.

1.0 GENERAL DESCRIPTION

The optical energy from each laser unit is transported to the viewing area with a single fiberoptic cable. The laser light reflected from the site is for an instant much brighter than either the direct or reflected light from the process itself. The system exploits this very temporary situation by capturing an image with a special-purpose video camera head that is equipped with a CCD video sensor and a means for very high speed electronic shuttering. The shutter is synchronized with the laser flash. The laser is in turn synchronized with the framing of the video sensor and is fired once for each captured video frame.

A conventional video camera does not incorporate any means for optical shuttering. The shutter interval is simply the interval between successive scans of the vidicon tube, CCD array, or other image sensing device. At the normal framing rate of 30 frames per second, the effective shutter time (exposure time) is therefore 33.3 milliseconds (or usually 16.7 milliseconds if a solid-state image sensor is used). For this system the minimum shutter time is about 50 nanoseconds and it follows that the camera exposure time is reduced by the factor of 667,000:1. The brightness of the a welding arc or plasma in the video image is likewise reduced by the same factor, but the optical contribution to the image by the laser light is not affected because the laser and shutter are synchronized.

The LaserStrobe camera unit is also equipped with a narrow-band optical filter to match the laser wavelength and further suppress the arc lighting. The net combination of both temporal and spectral filtering will typically result in a video image that is free of all of the adverse arc lighting effects except perhaps for some minor remaining evidence of the brightest core of an arc or plasma. Please note that optics for special applications, such as high magnification or long stand-off distances can be specified.

1.1 Laser Unit

Each laser unit includes (1) a pulsed nitrogen laser, (2) a small cylindrical fiberoptic feed module attached to the exit aperture of the laser, and (3) a fiberoptic cable that transports the laser energy to the welding site, using a single large-core optical fiber. (Reference Figure 1 on the next page.)

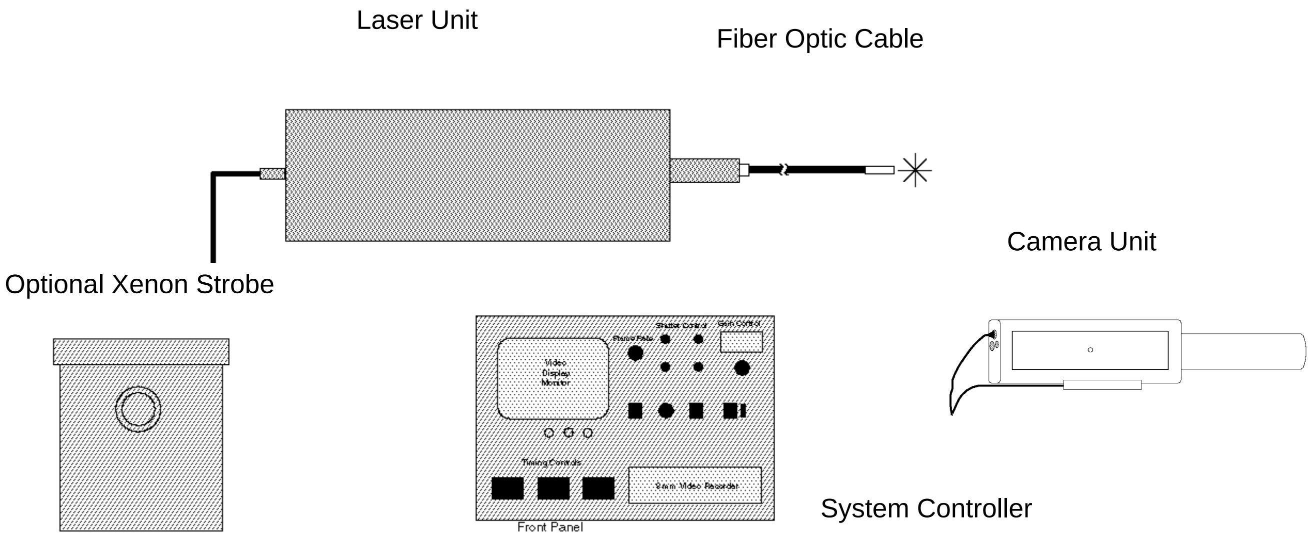


Figure 1- System Block Diagram

The laser unit produces an optical pulse of about 5 ns duration at 337 nm wavelength in the near-ultraviolet portion of the optical spectrum. It is a gas discharge laser which produces the energy for the laser pulse by means of a very rapid high energy electric discharge through a sealed laser cavity of high purity nitrogen gas. This type of laser is attractive for industrial applications because it is reliable, simple in design, and needs very little maintenance. It does not require a vacuum pump, a continuous gas supply, a cooling system, or any other sort of support equipment very often required by pulsed laser systems.

The laser unit is about 6.0 x 8.5 x 22.5 inches in size and weighs about 20 pounds. The attached fiberoptic cable assembly is typically about 12 feet long but can be configured to meet other length requirements.

1.2 Camera Unit

The main body of the camera unit is approximately 2.25 inches diagonal and 6" long. A focus tube is typically attached to the front end of this cylinder. The focus tube includes a lens cell with optics and optical filters and is supplied either in a straight end-viewing configuration. The focus tube and lens cell can be configured for a variety of filtering and magnification options, dependent upon specific applications. The camera unit is designed for mounting on a standard photographic tripod or for attachment to machinery.

The key component of the camera unit is an image intensifier tube. This tube provides the electronic shuttering capability and also amplifies the intensity of the welding site image by a factor as great as 10,000:1. The intensified image at the output screen of this tube is relayed to a small CCD video camera situated inside the main body of the camera unit. With the high gain of the image intensifier, there is enough light for good exposure of the CCD camera, even while using a laser system of relatively low average power.

1.3 System Controller

A separate system controller sends the appropriate trigger commands to fire each light source and initiate shuttering of the camera unit. These commands are generated by first creating a master timing pulse that is synchronized with the camera video and then by introducing electronic delay in the laser trigger and shutter channels to compensate for other inherent optical and electronic delays. The controller also accepts a variety of external electronic pulses in order to trigger shuttering of the camera based on an external event.

The controller also serves as a power supply to the camera unit and provides a means to adjust the sensitivity, shutter speed, and frame rate of the camera. It includes a video frame storage capability that is programmed to repeat a video frame produced by the camera head until replaced by a new frame. This removes the flicker that one will otherwise see in the raw camera video when operating the system at frame rates of 15 Hz or lower. The controller includes a built-in monochrome video monitor unit with a 5-inch screen.

<u>1.4 Optional Xenon Strobe</u> *If a strobe was ordered, please see Attachment 1 to this manual and refer to the MVS2020 Owner's Manual.*

2.0 DESIGN DETAILS, CONTROLS, AND ADJUSTMENTS

The following is intended to further acquaint the user with the various functional elements of the vision system and the features, controls, and adjustments that are available to tailor operation of the system to a particular application.

<u>2.1 Laser Unit</u>

The system typically incorporates either one or two Model LN300 pulsed nitrogen lasers, manufactured by Laser Photonics Incorporated, Orlando FL. A complete description of this laser and its use may be found in the separate operation and maintenance manual included with this document. One should carefully read this manual in preparation for operation of the laser, although some additional information on the use of the laser with this system is included below.

<u>2.1.1 Laser Operation</u>

Control of each laser unit is integrated with controls for the rest of the system, but has been done in a manner that does not override any of the interlocks or other safety features supplied with the laser by the original manufacturer, Laser Photonics. **<u>The Model LN-300 nitrogen laser Operator's Manual is the primary reference for the operation of the laser system and should be carefully studied by all parties involved in laser operation.</u>**

The external trigger and remote interlock signal for the laser are supplied via a six conductor cable connecting **STROBE A** and **STROBE B** on the rear panel of the controller unit with the 9 pin **REMOTE** connector on the end panel of the laser. (See Figure 2.) The laser cable must be connected to both the laser unit and the controller unit for the laser to be properly enabled.

A remote door interlock feature is supplied via a 4-pin connector on the rear of the controller unit, the supplied plug-in connector/cable assembly must be connected to the LASER INTERLOCK on the back panel for the lasers to function. An optional door switch may be installed at the end of the cable. Please

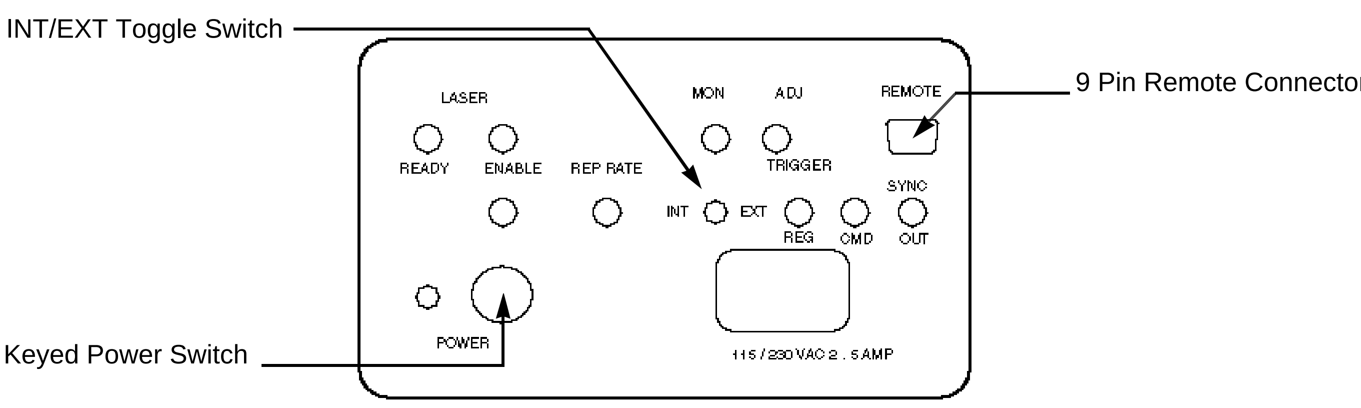


Figure 2 - Laser Control Panel

note that pins 1 and 2 of the 4 pin connector disable the **Strobe A** laser if continuity between the pins is broken, as do pins 3 and 4 control the **Strobe B** laser remote interlock.

The laser's **INT/EXT** toggle switch should be placed in the EXT position to allow control of the laser firing in sequence with the controller unit. Lasers are shipped with screw-on feet removed. It is important to install the feet in order to promote optimal airflow underneath the laser during operation.

2.1.2 Fiberoptic Feed Module

The Model LN300 laser normally generates a very highly collimated beam. However, in this case a

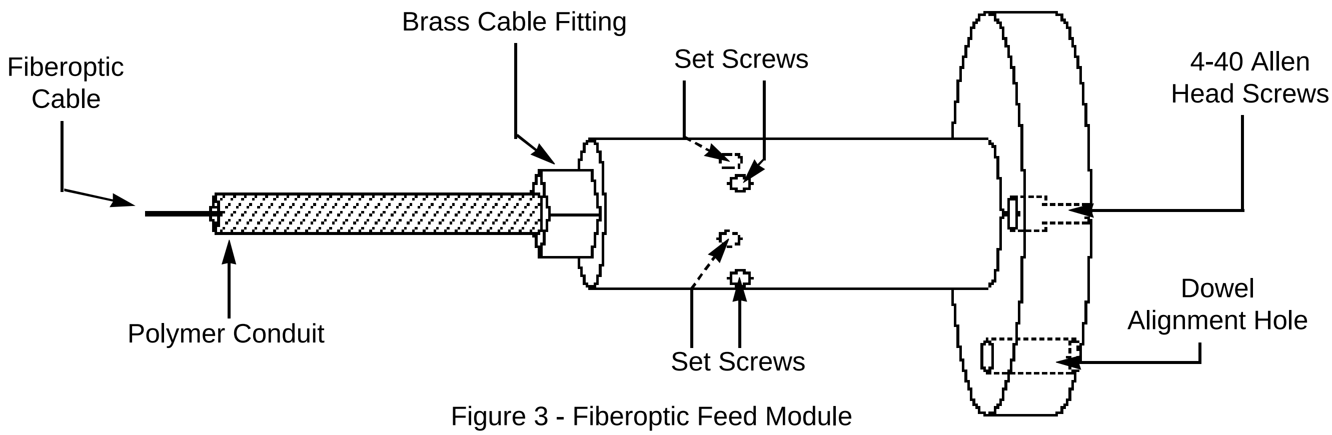


Figure 3 - Fiberoptic Feed Module

fiberoptic feed module, figure 3, is attached to the output face of the laser in order to focus the beam into a very small spot. The fiberoptic cable is permanently attached to this module and a factory adjustment is done to precisely position the polished end of the optical fiber in alignment with the focused laser spot. The laser energy is transported to the viewing area with very little optical loss if proper alignment is maintained.

The threaded brass cable fitting and lock nut are used to adjust focusing of the laser spot and the four set screws on the optical barrel are used to adjust transverse, (X,Y) alignment of the fiber vs. the spot. The user is strongly advised to resist any temptation to make any changes to these factory adjustments. Unauthorized and un-supervised adjustment can cause permanent laser damage to the optical fiber and will invalidate the warranty on the equipment.

The fiberoptic feed module is detached from the laser during shipment and is to be re-attached with the two captured 4-40 allen head machine screws provided. The fiberoptic feed module is aligned to the laser via a dowel pin on the mounting flange. This is used to ensure proper rotational alignment of the cable system. Care should be taken to protect the 1/2" lens on the end of the fiberoptic feed module.

Each laser is custom matched to its corresponding fiberoptic feed module and fiberoptic cable. When two lasers are shipped, the lasers and cable will have a letter designation. Care should be taken to insure that the **LASER A** fiberoptic cable is attached to the A laser, and so for the B laser. Switching the cables between lasers will result in loss of optical power.

The ultraviolet laser energy is not normally visible to the human eye, but one can visually check the aiming and quality of the beam by using a white business card as a target (or any piece of paper with a whitening agent). A round pattern of fluorescence will be seen on the paper, under normal room lighting conditions, with the paper positioned 6 to 8 inches from the end of the cable. If this is not the case, then some minor optical alignment may be necessary. The user should not attempt to align the fiberoptic cables without first consulting with Control Vision personnel. Again, please be advised that improper adjustment procedures can easily result in further misalignment that cannot easily be reversed or could cause irreversible laser damage to the optical fiber!

All in-plant transit of the laser unit should be done with the optical feed module and fiberoptic cable attached, if possible .

2.1.3 Fiberoptic Cable

The fiberoptic cable is composed of a single large-core optical fiber protected by a semi-rigid polymer conduit. This conduit provides some resistance to tight-curvature flexure and serves as a barrier to other mechanical and chemical hazards. However, the best way to avoid damage is to treat the cable with care and respect. The fiber vendor specifies a minimum allowable bend diameter of 11 inches, but it is good practice to maintain a minimum bending diameter of <u>16 to 18 inches</u> to provide a good margin of safety. The cable should always be manipulated in a way that avoids kinking and minimizes twisting. The cable should first be straightened before a bend is introduced. All of these precautions are due to the rather large diameter of the fused silica core, which is about .030 inch or about 6 to 8 times larger than the typical fiber used in telecommunications.

2.1.4 Laser Safety

The laser system should <u>never</u> be operated for any reason without proper eye protection for all operators and spectators. The primary danger is from direct viewing of the laser light exiting the cable or reflected from a polished or finely machined surface. One must assume that this particular condition is always a possibility and must resist the temptation to remove protective eye wear.

The operator should be particularly cautious when manipulating the fiberoptic cable. The keyed “laser on” switch on the laser end panel (See Figure 2) should be **<u>off</u>** when the cable is being installed or when the fiber tip is inspected for contamination, etc. The cable should be respected as one would respect a loaded gun. <u>Under no circumstance should anyone place his or her head out in front of the cable,</u> even when using the proper eye protection. <u>Under no circumstance should one operate the laser (a) without firmly s ecuring the position of the fiberoptic cable and (b) without the use of a targeting surface to interrupt the beam exiting the cable.</u>

Protective eye wear provides a primary barrier to the laser energy, but some of the more comfortable eye wear does not completely block entrance of light through areas where the eye wear interfaces with the head. One can obtain maximum protection from a pair of laser safety goggles, but the risk is additional discomfort that can tend to discourage use. However, both glasses and goggles are available with plastic lenses that are totally transparent across the visible spectrum, while providing complete protection (very strong attenuation) for the 337 nm UV laser wavelength.

Other requirements for laser safety often involve the use of warning signs, warning lights, door interlocks, etc. Be kind to your eyes and consult with the manual of the LN-300 laser and your company safety organization for further guidance on the laser safety issue.

2.2 CAMERA UNIT

All of the electronic control of the camera unit is done by the system controller and is discussed in the next section. (See Figure 4, on the next page) Electronic cable attachments for the image intensifier tube are built into the rectangular mounting “foot” at the forward end of the camera. Cables and connectors interfacing with the CCD video sensor are at the rear end of the camera unit. All camera cables are bundled into a single harness, and then individually attached to the to the Controller Unit via a multi-pin connector. <u>Special care should be taken when attaching the mulit-pin connector to the rear of the camera. The connector is keyed and therefore has only one acceptable possition. The key pattern can be attained by carefully rotating the connector on the cable prior to pushing the connector onto the camera. To remove the cable, gently pull straight back. DO NOT TWIST THE CONNECTOR, THIS WILL CAUSE SEVERE DAMAGE.</u>

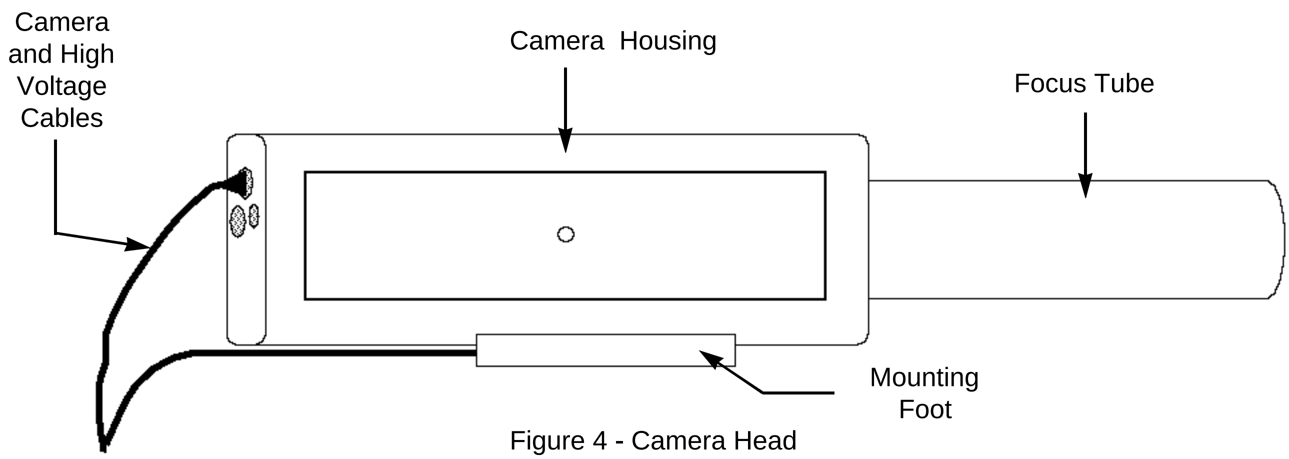


Figure 4 - Camera Head

2.2.1 Objective Lens and Filtering
Optics are factory-assembled to meet the specific application requirements. See attachment for description of lens cell

2.3 SYSTEM CONTROLLER

The following describes the functions, controls, and interfaces of both of the system controller unit, discussed in terms of what is seen on the front and back panels. (Reference Figure 5.)

2.3.1 Front Panel Description

The front panel controls are described briefly here. The user is cautioned to familiarize themselves with both the Controller front and back panels as before beginning operation of the system.
(Reference Figure 5.)

Monitor Controls - **BRIGHT, CONTR, VOLUME**

Controls the brightness, contrast and volume for the built-in monitor. Volume is used for playback of recorded video only.

The 5-inch video monitor is built into the controller to improve the utility and versatility of the system, but is not necessarily intended as the primary display unit for the system. The monitor displays either live video from the system or recorded video from the recorder/player unit. The monitor automatically switches from recorded to live video when the **SHUTTER ON** switch is depressed on the front panel. This is done as a protective feature for the system to guarantee that live video is always on display to the operator and thereby to maximize attention to proper operation of the system. The system is also equipped to display a checkerboard pattern on the monitor. If this pattern is displayed while the **SHUTTER ON** switch is depressed, a possible problem with the video system exists. Contact Control Vision immediately.

FRAME RATE control knob

Sets the shuttering and pulsing rate for the camera and strobe units in terms of frames/sec.

The frame rate control is provided on the front panel of the controller unit to provide some flexibility in viewing a given process and assist the operator in extending the operating lifetime of both laser and image tube. With the Model LN300 laser, the system can create a new video picture at a maximum rate of 30 frames per second or at slower rates of 15,10,6,5,3, or 1 frames per second.

The laser unit and the image intensifier tube are the two most expensive components of this vision system. They are also the only two significant components in the system that will exhibit some aging effects. We know that each of these components will exhibit a small degree of deterioration with each million shutter cycles or laser pulses generated, but the actual useful lifetime of the image tube for this type of application has not yet been established.

If, for example, one estimates a lifetime of about 30 million shutter cycles, it follows that this tube will need replacement after about 280 operating hours if it is shuttered at a rate of 30 cycles/second (one cycle per video frame). On the other hand, if the tube is operated at a reduced rate of one shutter cycle for each 5 video frames (i.e., 6 cycles/second) one can expect to extend the lifetime to about 1400 operating hours (which is about 3 working hours for 470 working days).

When the system is framed at reduced rates, the camera head continues to produce a video signal at 30 frame per second rate, but each “new” video frame is followed by given number of blank video frames and then another new frame, etc. Normally this would result in a very distracting flickering of the video monitor screen. However, the controller removes the flicker by digitizing and storing each new video frame in temporary buffer memory and by repeated playback of this frame again and again until the next new frame appears.

<u>The operator is encouraged to utilize the slowest frame rate possible that provides adequate time resolution of the particular process under examination.</u>

<u>**TRIGGER** control block - **MODE** toggle switch</u>

Sets the trigger mode for either **INT**ernal, **EXT**ernal or **MAN**ual.

The **INT**ernal mode allows LaserStrobe to operate with internal timing circuits, shuttering and strobing at the frame rates entered on the frame rate control knob. Once operating in the internal mode, the camera will make a new picture at the rate selected on the **FRAME RATE** knob. The system's built-in frame-grabber repeats the frame until a new image is acquired, thus eliminating any flicker in the video if the system is operating at non-standard frame rates.

The **EXT**ernal mode allows LaserStrobe to accept an external signal to trigger a video frame through the **SHUTTER TRIGGER** or **FRAME TRIGGER** connector on the back panel. Once operating in the external mode, the camera will make a new picture everytime an external signal meets specific timing criteria programmed within the controller. The system's built-in frame-grabber repeats the frame until a new image is acquired, thus eliminating any flicker in the video.

The **MAN**ual mode provides a "snapshot" video frame for camera positioning and alignment checking. Note that the toggle switch snaps back automatically to the **EXTERNAL** mode. The **MAN**ual video frame is updated by either initiating another **MAN**ual snapshot, an external frame trigger command or switching to **INT**ernal mode.

<u>**TRIGGER** control block - **SLOPE** toggle switch</u>

Selects which side of the incoming waveform will be used for triggering information, when working in the **EXT TRIGGER** mode and the **SHUTTER TRIGGER** connector on the back panel (see back panel description for an explanation of **SHUTTER TRIGGER**. **POS** for the positive slope and **NEG** for the negative slope.

TRIGGER control block -**LEVEL** control knob

Adjusts the **LEVEL** on either the **POS**itive or **NEG**ative slope of the external triggering waveform.

The **LEVEL** knob provides very precise control over the point at which the camera is triggered when working in the **EXT TRIGGER** mode and the **SHUTTER TRIGGER** connector on the back panel, given the delay entered on the front panel in the **TRIG DELAY** decade switch.

SHUTTER control block **MODE** toggle switch

Controls the shutter firing mode. The 2Z series of LaserStrobe can be operated in either single or dual exposure mode. The **SHUTTER MODE** toggle switch provides the ability to fire the **A** laser/light source, the **B** laser/light source or both the **A + B** laser/light sources. LaserStrobe is factory configured with the **A** laser/light source as the slowest laser. The **SHUTTER SYNC** decade switch reflects the delay, in micro-seconds, required to synchronize the firing of the **A** laser with the camera's shutter.

If the system is configured with two laser/light sources for double exposure operation, the **B** laser/light sourcer's delay is factory programmed into the controller and is added to the **A** laser's delay programmed into the **SHUTTER SYNC** decade switch.

SHUTTER control block - **SPEED** toggle switch

Used to select between the **FAST**, **MEDIUM**, and **SLOW** switch positions.

As has been indicated above, the intensifier tube is susceptible to excessive exposure and damage if the shutter speed is somehow inadvertently increased by some sort of electronic failure. The controller therefore includes some protective circuitry which automatically inhibits the image tube shutter signal if the duty time of this signal exceeds about 0.5 percent (where duty time is defined as the product of shutter period and shutter pulse repetition rate). Similar circuitry also inhibits the laser trigger signal if trigger pulses are generated at abnormally high rates.

SHUTTER control block - **ON** button with lighted LED indicator

Activates electronic shuttering of the image intensifier tube.

The shutter is not normally turned on until after the laser unit is first turned on with the **STROBE** switch. The laser illumination should also be adjusted first with a target. (White business card, etc.) The shutter should then be turned on only after the **SENSITIVITY** control knob on the front panel has first been turned down to avoid over exposure of the image tube.

The shutter should be turned off immediately if the video picture is seen to be saturated and brighter than normal. Excess brightness can be caused by unexpected strong specular reflections (glint) from highly polished surfaces, from liquid metal, etc. A failure of the image tube shuttering electronics or some other unanticipated failure is also a possibility, but unlikely. Again, one should take very quick action to deactivate the shutter in any of these cases before taking any additional time to consider the source of the problem. The shutter should not be turned on again without first turning down the sensor gain control by several turns.

SENSITIVITY control knob

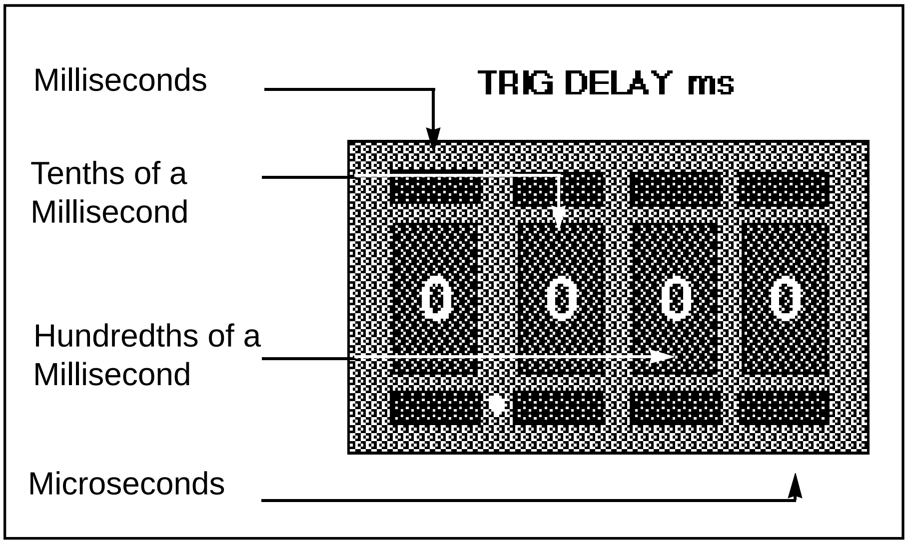
Used to adjust the light sensitivity of the image intensifier tube.

Image intensifier tubes are used primarily by the military for night vision and great improvements have been made in the technology over the last two decades. The tube used here can produce a 20,000-fold increase in the brightness of an image, when operated in an open-shutter mode under starlight conditions. This extreme sensitivity makes the tube inherently vulnerable to damage by over exposure. Fortunately, the very fast shuttering that is done with this system helps greatly in reducing the risk of damage, but there is still very good reason to be careful.

Protection for the intensifier tube comes primarily from prudent use of the **SENSITIVITY** control, which directly controls the bias voltage to the micro-channel plate (MCP) within the tube. The actual bias voltage can be observed on the LCD read-out directly above the control, although the read-out is only meant to indicate the relative degree of sensitivity. The range of control is roughly from 350 to 800 volts.

The sensor gain control should always be turned down almost to the 300-400 range before the system is initially started under new operating conditions. Thereafter, one should always start an experiment by setting the gain about 100 units below the level that one would expect to need prior to activation of the laser or shutter. The gain can then be adjusted upward after the laser is turned on to achieve adequate video signal strength. The normal automatic gain control (AGC) capability of the CCD sensor has been disabled and the gain has been fixed at the maximum level. This allows one to operate the intensifier tube at the minimum sensitivity necessary to obtain a good picture—and will result in a longer tube lifetime.

The sensor gain is set too high when portions of the video picture become saturated, i.e., when the highlights of the picture are all at a uniform maximum brightness. Also, one will find that the inherent contrast of the typical welding imagery is relatively low. This can be offset by boosting the contrast control on the video monitor.



<u>**TRIG DELAY** decade switch</u>

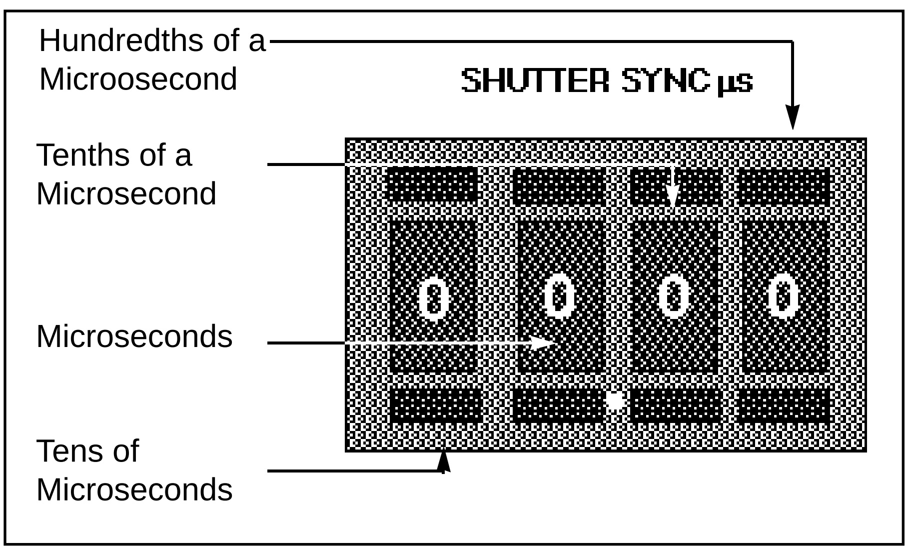
Incorporates a delay in the firing of the shutter after receipt of an external trigger signal.

The four position decade switch allows for delay adjustments from 1 microsecond to 9.999 milliseconds after receipt of the external trigger signal. The maximum delay allowable delay is determined by the timing of the trigger signal in relation to the CCD's ability to accept another video signal.

<u>**SHUTTER SYNC** decade switch</u>

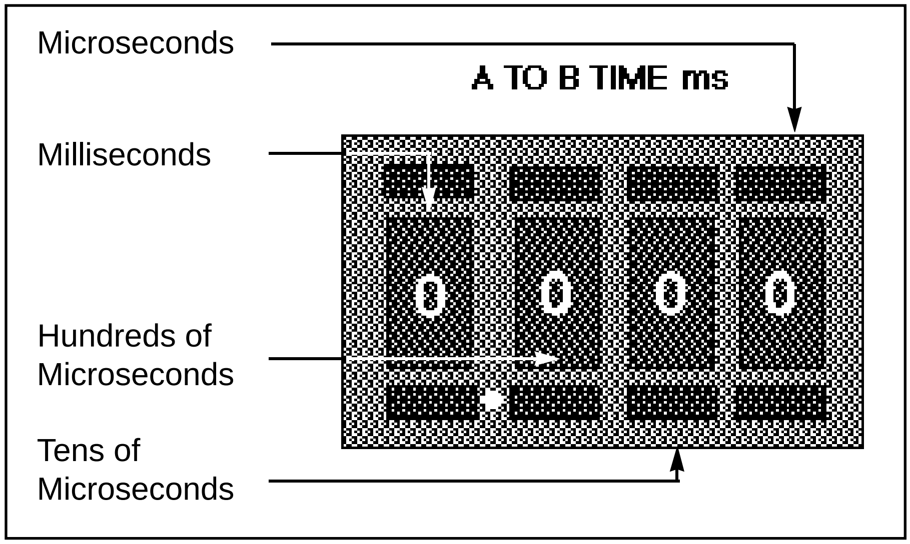
Synchronizes the timing of the shutter with strobes.

The controller unit produces a strobe trigger pulse which travels down a length of cable to the strobe units and a laser pulse is generated after a fixed internal delay of about 1.3 microsecond within this particular Model LN300 laser. A second shutter timing pulse originates within another circuit and travels via the cable harness to the camera unit with only a few nanoseconds of fixed



propagation delay. The controller unit must therefore introduce additional delay in the shutter timing channel to compensate for the laser delay and other minor relative delays in the controller circuitry. This is done with the four-decade **SHUTTER SYNC** decade switch, which provides a range of adjustment from 10 nanoseconds to 99.99 microseconds in 10 ns steps. This range is sufficient to accommodate a rather wide diversity of pulsed lasers or other pulsed light sources that might be used. Furthermore, the 10 ns precision is good enough to “fine tune” the timing of the laser pulse when the shutter speed control is set at the **FAST** position (approximately 70 ns shutter duration).

With a dual laser system, the slowest laser is always configured as the **A** laser. The system adds delay to the **SHUTTER SYNC** time when firing the faster **B** laser.



A TO B TIME decade switch

Incorporates delay between the firing of laser **A** and laser **B** when operating in the double shuttering mode.

The four position decade switch allows for delay between **A** to **B** laser firing adjustments from 1 microsecond to 9.999 milliseconds. Note: **A TO B TIME** must be as long as the **SHUTTER SYNC** time, as a minimum. (A minimum of0.002 milliseconds.) This is due to the fact that the **SHUTTER SYNC** must be accomplished for the first laser before the second laser can be fired. See 3.1.6, Double Exposure Operation, for further explanation.

STROBE button with LED indicator

Takes the laser out of a standby power condition and initiates the actual firing of the laser at a pulse rate corresponding to the setting on the **FRAME RATE** control, with the shutter **TRIGGER MODE** in the **INT**ernal position, or at a rate corresponding to incoming signals, with the shutter **TRIGGER MODE** in the **EXT**ernal position.

POWER keyed button with LED indicator

Provides power for the system controller, camera unit, and laser. The key must be used.

Power for the system controller, camera unit, and laser is activated by means of the lighted keyed switch labeled **POWER** on the front panel. All system circuitry is energized with the power switch, but no video imagery will appear until the other controls are properly activated and adjusted.

2.3.2 Back Panel Description

The back panel connections are described briefly here. A more detailed procedure discussing the purpose and function of each control will be given later in this document. The user is cautioned to familiarize themselves with both the front and back panels as before beginning operation of the system. (Reference Figure 6.)

<u>VIDEO OUT</u> <u>connector block</u>

A standard RS 170A video signal is available at three BNC jacks in the **VIDEO OUT** block.

The **STROBED** signal is the real-time video taken from a point in the system “upstream” from the built-in frame grabber. A picture will be generated only at the time indicated with the **FRAME RATE** control knob. If the system is being used in the **EXT TRIGGER** mode, a picture will be generated only at the point that a external signal meets specific timing constraints.

The **CONTINUOUS** signal is a real-time video signal taken "downstream" from the built-in frame grabber. This video will be represented on the built-in 5" monitor. The signal will drive a standard 75 ohm load and can be used to feed an auxiliary monitor during normal operation or in the event of a failure of the 5-inch monitor. This signal could be used for a second recorder because it carries the identical live video seen on the 5-inch screen. The **CONTINUOUS** jack will not playback recorded video.

The **CONTINUOUS/PLAYBACK** output will also drive a 75 ohm load and would normally be used for a second monitor because it carries both the continuous signal and will playback recorded video as well.

<u>AUDIO</u> <u>connector block</u>

The **MIC IN** connector will accept a standard microphone jack for recording information on the 8mm tape recorder. The **OUT** connector allows for audio output. In the case of live recording, this will be the audio from the microphone. It is also possible to record a previously recorded 8mm tape using the **CONTINUOUS/PLAYBACK** output, for video, and the **AUDIO OUT** connector, for audio.

<u>EXT TRIGGER</u> <u>control block</u>

The **EXT TRIGGER** control block adjusts LaserStrobe's ability to accept either positive or negative going waveforms as trigger signals. This adjustment is made by changing the **POLARITY** switch location. Note: Most applications will probably put out positive waveforms. Consult the technical specifications of the external trigger generator for more information.

The **SHUTTER TRIGGER** connector is used to connect LaserStrobe to its external trigger source. The connector is a standard BNC connector. When operating in the **EXT TRIGGER** mode, the camera will interrogate each incoming signal to determine if it falls within proper timing constraints. If the signal meets the timing acceptance test, a picture is taken, if not, the signal is ignored until a signal meets the timing acceptance criteria. The frame-grabber will simply repeat the last picture until a new frame comes into memory. This eliminates flicker from the video. The **SHUTTER TRIGGER** mode of externally triggering the camera is to be typically used for higher speed, periodic events. Note: the **FRAME RATE** should be set to 30 frames/sec to maximize the acceptance of external triggers.

The **FRAME TRIGGER**, however, accepts the first trigger signal before an available video framing window and will take a picture at this window. The **FRAME TRIGGER** signal does not have to fall within the same timing constraints as the **SHUTTER TRIGGER** but it lacks the precise delay controls available on the front panel's **TRIG DELAY** decade switch, **SLOPE** and **LEVEL** controls and the **POLARITY** control on the back panel. For this reason, the **FRAME TRIGGER** requires a conditioned pulse coming into the system. The **FRAME TRIGGER** mode of externally triggering the camera is to be typically used for lower speed processes.

<u>TIMING OUT</u> <u>connector block</u>

The **TIMING OUT** connector block provides three distinct timing signals from the LaserStrobe system controller. The **PRETRIGGER** connector puts out a signal coinciding with the time out of the **TRIG DELA**Y circuit. The **TRIGGER** connector puts out a signal equivalent to the **SHUTTER SYNC**. The **SHUTTER** connector puts out a signal equivalent to the opening of the camera's shutter. These timing references are used for field diagnostics and will typically not be used by any user.

VIDEO SYNC connector block

The back panel also includes a **SYNC SEPARATOR** block that is available either for synchronizing the LaserStrobe video signal as a “slave” to the signal from a second video system or, conversely, for synchronizing the second video system, using the LaserStrobe system as the “master”. The output signal is 0 to -4v un-terminated and 0 to -3.5v terminated.

In order to derive an external video sync signal from a external video source, the **VIDEO IN** would come from the second system. The internal sync separator would then strip the sync information from this signal (while discarding the picture information) and would simultaneously produce a composite sync signal at **COMP OUT** and horizontal and vertical drive signals at **HORIZ OUT** and **VERT OUT**, respectively.

In order to slave a second video source to LaserStrobe, **VIDEO IN** would be connected with a short cable to the **CONTINUOUS** video output. The second video system could then be slaved to LaserStrobe either via the composite sync channel, labeled as **COMP OUT**, or via the horizontal **HORIZ OUT** and vertical **VERT OUT** drive channels, depending upon the external sync signal requirements of the slave system.

LINE FUSE, 5A

The single 5.0 amp fuse is for all power utilized within the controller. Additional fuses are located within the controller on the various outputs of each of the D.C. power supply. One spare fuse has been supplied.

AC IN / AC OUT

The controller requires 115 Volt, single-phase, 60 Hz A.C. power. A special power entry module is used to suppress high frequency electrical noise on the power line. An un-fused A.C. outlet is provided for power for an auxiliary monitor or video recorder, but is not recommended to power the strobe units because of potential problems with electrical noise generated by either a laser or xenon strobe.

STROBE connector block

The **A** and **B** strobe units interface to the back panel via the two 8-pin receptacles marked **STROBE A** and **STROBE B**. The mating cables incorporate identical plugs on each end that couple to the controller and laser by a non-rotating insertion that is keyed by the red marks on both the plug and receptacles. Detachment is done very simply and quickly by pulling straight out on the knurled barrel.

A remote door interlock feature is supplied via a 4-pin Laser Interlock connector. The supplied interlock plug connector/cable assembly must be connected to the **LASER INTERLOCK** receptacle on the back panel. This satisfies the laser interlock requirement. An optional door switch may be installed. Please note that pins 1 and 2 of the 4 pin connector disable the Strobe A laser if continuity between the pins is broken, as do pins 3 and 4 control the Strobe B laser remote interlock.

Please note that the the 8-pin and 4-pin connectors are removed by gently pulling the connector straight out. DO NOT TWIST THE CONNECTORS. THIS ACTION WILL BREAK THE PINS AND SEVERELY DAMAGE THE EQUIPMENT.

CAMERA CABLE connector

The camera unit interfaces with the back panel of the controller by means of a cable harness and multi-pin plug connecting into the receptacle labeled **CAMERA CABLE**. **The system should never be powered up without this harness securely connected to the controller and the cable should never be detached with the system power on. Failure to follow these instructions could result in extensive**

damage to electronic circuitry of the camera unit and controller and <u>will also expose one to electrical shock</u> from the 6.5 kilovolt high voltage power cable.

3.0 OPERATING PROCEDURES

3.1 SYSTEM START-UP

Your LaserStrobe system has been shipped to you after rigorous testing in our Idaho laboratory. The system can be set-up and used by following straightforward procedures. The user is encouraged to completely read the following discussion before attempting to start-up and use LaserStrobe.

3.1.1 Unpacking

Your system has been packed in high impact resistant instrument cases. Care should be taken when unpacking your LaserStrobe. If visible damage is noted, please call Control Vision immediately.

The Camera Unit is tethered with a long cable. Care should be taken to not allow the connector end of the cable to fall on the floor or be crushed.

The fiberoptic cable vendor specifies a minimum allowable bend diameter of 11 inches, but it is good practice to maintain a minimum bending diameter of <u>16 to 18 inches</u> to provide a good margin of safety. The cable should always be manipulated in a way that avoids kinking, minimizes twisting, i.e. it should first be straightened before a bend is introduced.

In order to avoid potential shipping damage, the laser units will normally be shipped with the adjustable feet unscrewed from the bottom on the units. The feet should be screwed back into four places. The feet are used to provide a stable, level foundation and to enhance airflow underneath the lasers during operation.

3.1.2 System Set-Up

After unpacking and inspecting all components, the system can now be configured for use. We have found that a heavy-duty instrument cart provides an excellent platform from which to operate the system. Examine the area in which LaserStrobe will be used and place the equipment in the most "user friendly" arrangement, keeping the bending and kinking of fiberoptic cables to a minimum. Keep in mind that the camera and laser control cables are typically 20 feet long, providing flexibility when locating the controller.

A heavy duty camera tripod or some other sturdy platform is recommended for placing the camera head. Four 1/4-20 mounting screw locations are provided. Custom cradles, extension arms or mounting brackets can be ordered if necessary.

After placement of the three major system components, the fiberoptic cables can be attached to the strobe units. Two 4-40 captured socket head cap screws are provided on the fiberoptic feed module. The feed module also has an index hole corresponding to the dowel on the mounting flange of the laser. The index hole insures proper rotational alignment of the feed module. Attach the feed module with the screws. We have provided a ball-type 4-40 hex head wrench works for this. Care should be taken to hold the fiberoptic cable while mounting the feed module to the laser.

The fiberoptic cables can now be extended and directed toward the area of interest. Typical camera set-ups mount the fiberoptic cables alongside the camera head using the supplied fiberoptic mounting bar. Each cable will have a hexagon support nut designed to be attached to the cable at the brass transition between the protective polymer conduit and red obedient portions of the cable. The support nut is attached to the fiberoptic cable by tightening the 8-32 hex screw. The screw should be tightened onto one of the set points machined into the brass fitting.

The mounting bar has a series of holes, providing flexibility for cable placement. The bar can be mounted to the camera by using one of the provided plastic ratchet handles. The cables are then mounted to the bar also using a plastic ratchet handle. By loosing the ratchets, the user can adjust both the angle of the mounting bar and the cable in relation to the camera. Once a satisfactory distance and angle is obtained, the plastic ratchet handles must be tightened to maintain fiberoptic cable position.

3.1.3 Power-up

After setting-up LaserStrobe, one can now turn the system on.

Several steps are required to properly power up the system. Failure to follow these steps could result in damage to the equipment and potential electrical shock.

1. Plug in the controller and strobe units.

2. Plug in the camera using the multi-pin connector to the back of the controller and the pin connector to12 pin connector on the end of the camera. The mating portions of the connector will maintain rotational alignment for plug-in.

3. Plug in the strobe trigger cables to the back of the controller and the back of the strobe units. Insure that the **A** cable is plugged into the **STROBE A** outlet on the back of the controller. Plug in the **B** strobe cable into the **STROBE B** outlet on the back of the controller, if applicable.

4. Turn the key on the **POWER** button. The yellow LED indicator shows that the system's circuits are energized.

3.1.4 Strobe Activation

After power-up, the shutter and strobe can be activated. One should always use extra caution during initial start-up of a newly delivered laser system or during restart of one that has been relocated or reconfigured to an installation in some way. In these cases the following procedure applies:

1. Check that the laser power switch is off and the key is removed

2. Check that the fiberoptic cable is securely supported at the end with the red obedient cable end properly aimed at the desired target.

3. Verify the proper attachment of the Fiberoptic Feed Module using the two captured #4-40 allen head screws.

4. Verify that the laser cables are connected to the back of the lasers and back of the control panel.

5. Insert key and turn laser power on.

6. A five minute warm-up period is required before the laser will be enabled to fire.

7. After the warm-up period, and if all checks and interlocks are satisfied, the green **READY** light on the rear of the laser's panel will be illuminated. Note: The 4 pin Laser Interlock connector must be plugged in the **LASER INTERLOCK** receptacle on the back panel of the controller before the lasers can fire.

The laser system is now ready to be used. Again, caution should always be used when preparing the laser for use.

8. To activate the strobe, push the **STROBE** button. The red LED indicator shows that the strobe's circuits have been activated.

9. The strobe will now pulse at the rate selected with the frame rate knob, or upon receipt of an external trigger pulse if the system is operating in the **EXTERNAL** trigger mode.

3.1.5 Shutter Synchronization, Camera Alignment and Focus

After the strobe has been activated, the shutter may now be turned on and synchronized to the strobe units.

1. The strobe and camera should be pointed at the area of interest. A target must be placed into the space representing the area of interest and aligned with the desired focal plane. Typically, a white business card will suffice since the whitening agent in the paper naturally fluoresces with ultra-violet light and the writing will provide a good reference for focusing quality. With the **SHUTTER MODE** switch set in the **A** mode, the **SENSITIVITY** set in the 300 to 400 range. Furthermore, one should check be sure to set the **A to B TIME** decade control switch on the front panel to 0.002 milliseconds. It is important that the **A to B TIME** decade switch always have a number greater than zero in it.

2. The shutter **SPEED** toggle switch should be then set to the **SLOW** position and the **TRIGGER** mode should be set to the **INT** position. At this point, the shutter may be activated by pushing the **SHUTTER** button. The yellow LED indicator shows that the shutter is on.

3. The shutter will now cycle at the rate selected with the **FRAME RATE** knob. Select a frame rate of 6 or 10 frames per second.

4. Visually align the target with the camera and laser. Lasers have been factory synchronized. Skip steps 5 through 8.

5. The **SHUTTER SYNC** control can be adjusted in increments of 1.0 microsecond until an image appears on the video screen. The image should not have any flicker evident. This indicates that the shutter is open during the time that the laser is firing. The timing should be adjusted to obtain the lowest and highest acceptable setting. The optimal setting will then be half the distance between the two extremes. Typical delays for this model laser are in the 1.3 to 1.6 microsecond range.

6. Watching the system's display monitor, the fiberoptic cable end and the camera can be manipulated to optimize the image position.

7. Turn the shutter speed to the **MEDIUM** position and to further tune the timing in increments of 0.1 microsecond (in both positive and negative directions) to re-acquire the clear, non-flickering image.

8. Turn the shutter speed to **FAST** and repeat the process using .01 microsecond increments (in both positive and negative directions) until the non-flickering image is again acquired and optimized for maximum brightness and stability on the monitor screen.

9. Manipulate the camera and fiberoptic cable to optimize the video image. The goal here is to create an image which entirely fills the monitor, without over-filling, resulting in the most efficient use of light and the largest field of view. The fiberoptic can be manipulated by loosening the ratchet handle on the cable and fiber-optic mounting bar.

10. Once the image fills the display monitor, the camera may now be focused by sliding the lens cell assembly back and forth until a clear, crisp image is defined on the monitor. It is important to take time in focusing the equipment, resulting in better quality images.

11. The system is now ready to make video. As discussed above, it is important to cycle the strobe and shutter only when necessary. Turning off the strobe and shutter when not in use will extend the lifetime of the system.

3.1.6 Double Exposure Operation

After **STROBE A** has been synchronized with the shutter, as discussed in 3.1.5, the system can now be configured for double exposure operation.

1. The strobe and camera should be pointed at the area of interest. A target must be placed into the space representing the area of interest. Typically, a white business card will suffice since the whitening agent in the paper naturally fluoresces with ultra-violet light and the writing will provide a good reference for focusing quality.

2. Watching the system's display monitor, the fiberoptic and camera can be manipulated until the target is visible on the monitor. Shutter synchronization has already been done using only Strobe A for illumination. One should also check to be sure that the **STROBE A** cable is in fact connected to the **STROBE A** output receptacle and that the **STROBE B** cable is connected to the **STROBE B** output receptacle on the rear panel of the controller. Furthermore, one should check be sure to set the **A to B TIME** decade control switch on the front panel to1.0 microsecond. It is important that the **A to B TIME** decade switch always have at least 0.002 milliseconds entered on it.

3. With the shutter mode switch set in the **A** mode, the **SENSITIVITY** set in the 300 to 400 range, the **SHUTTER SPEED** toggle switch should be then set to the **SLOW** position (approximately 1.0 microseconds). At this point, the shutter may be activated by pushing the **SHUTTER** button. The yellow LED indicator shows that the shutter is on.

4. The shutter will now cycle at the rate selected with the frame rate knob.

5. Switch the **SHUTTER MODE** switch to the **B** position. Since, by design, the **A** laser is inherently the slower laser, the system is factory adjusted to add a fixed delay to the **SHUTTER SYNC** time, (A laser delay) in order to fire the **B** laser.

6. Switching between laser **A**, lasers **A + B** and laser **B** will show slight changes the scene. Due to slight differences in the positioning of **A** laser and **B** laser. Also the brightness of **A + B** mode will be greater than single laser mode.

With the system timing properly synchronized for operation in both **A** and **B** modes as described in the above two sections, one need not make any further adjustments for operation in the double-exposure mode. This mode is designated as mode **A + B** on the front panel. The time interval between exposures (i.e., between firing of the **A** and **B** strobes) is set with the decade switch control **A to B TIME** on the front panel below the monitor screen. The allowable range of this control is 1microsecond to 9.999 milliseconds and the accuracy well within 0.1 percent of the indicated value.

Again, within the 1 microsecond to 9.999 millisecond range, the system will maintain unchanging synchronization of the **B** strobe with the **B** shutter. This is essentially guaranteed by the design of the system, which incorporates common circuitry for both strobe and shutter delay.

However, it is very important to understand that the system is not designed to operate with zero **A to B TIME**. In other words, an entry of 0.000 in the **A to B TIME** decade switch is not a valid number and will totally disrupt synchronization of the system in the double-exposure mode and the single-exposure "A" and "B" modes as well.

If using the system in the passive mode, that is without any illumination, the **STROBE** button must still be depressed. The strobe cable, however should be disconnected prior to depressing the strobe. These actions will allow the system to be used for double exposures while operating in the passive mode.

3.1.7 External Sync Operation

LaserStrobe can be operated in an external trigger mode by setting the **TRIGGER MODE** switch to **EXT**. This setting allows the camera to accept externally generated signals as trigger commands. It should be noted here that the camera will only take pictures at the **FRAME RATE** selected on the front panel. In the external trigger mode, however, shutter commands are initiated from outside the system and pictures are taken at available frame times based on the **FRAME RATE**.

3.1.7.1 **SHUTTER TRIGGER** Mode

The **SHUTTER TRIGGER** mode will be the most common mode of externally triggering the LaserStrobe system. It is important to gain an understanding of how this mode works in order to use it effectively.

The **SHUTTER TRIGGER** mode triggers the LaserStrobe system based on incoming signals meeting specific timing criteria. This timing criteria is essentially a window within which a video picture can be taken. The **FRAME RATE** control dictates the frequency of windows generated by the system. When the system is operating in **SHUTTER TRIGGER** mode, any signals that arrive outside of the window will not generate a picture. Only those signals that arrive within a window will generate a picture. The built-in frame grabber compensates for variability in picture taking by simply repeating the last frame until an a new picture is generated. It should be noted that the best results can be obtained by making sure that the **FRAME RATE** control is set at 30 frames/sec.

3.1.7.2 **FRAME TRIGGER** Mode

The **FRAME TRIGGER** mode is available for externally triggering the LaserStrobe system. It is important to gain an understanding of how this mode works in order to use it effectively.

This differs from **SHUTTER TRIGGER** mode described previously. In this mode of external triggering, the system takes a picture at the next available frame after receipt of a signal. The signals coming in do not have to conform to the rigorous timing tests dictated by the **SHUTTER TRIGGER** mode. The **FRAME TRIGGER** mode does not allow for control over the incoming trigger signal, thus requiring a conditioned signal as input. The **POLARITY** control on the back panel and the **SLOPE** and **LEVEL** controls on the front panel are not applicable for the **FRAME TRIGGER** mode.

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