

Applied Science Laboratories

EyeTrac 6 Eye Tracking System

Manual

Long Range Optics System

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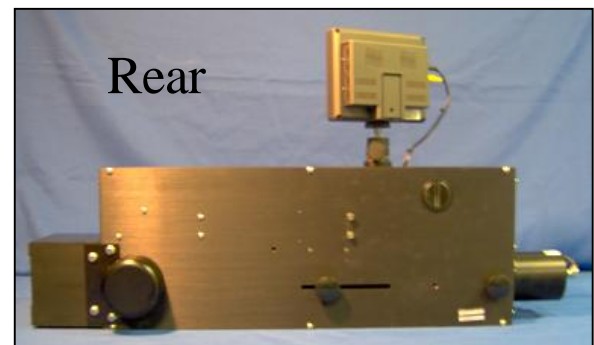
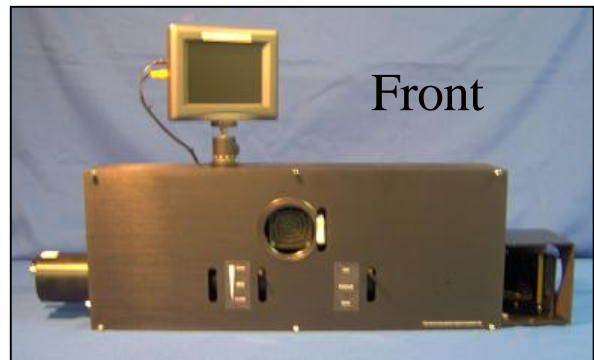
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1. Introduction and General System Description

The Long Range Optics module is designed to operate at eye to optics module distances of up to 16 ft. (5 m). (Acceptable performance may sometimes be achieved at significantly greater distances, but as signal strength decreases with distance, ability of the system to reliably recognize the pupil and corneal reflection becomes increasingly marginal.) The long distance optics module contains an eye camera with telephoto lens, an illuminator consisting of a filtered projection lamp with appropriate collimating optics, an adjustable beam splitter used to align the camera and illumination paths, and a detachable module with an adjustable mirror for aiming the camera and illumination beam. The optics module also contains a fan to cool the illuminator enclosure, and voltage converter to supply power to the fan. External views of the optics module are shown to the right. Various adjustment and fastening knobs protrude up to 1.5 inches from the component mounting panels. Additionally, connectors for the camera video, camera power, and illuminator power on the rear panel protrude from the housing. Mounting holes (tapped for 1/4-20 screws) are provided on both the front panel and the rear-mounting panel.

The front, rear, barrel, and stock all have mechanical controls that may require adjustment during setup or operation. Accessibility to these controls must be available when considering placement of the optics unit.

General configuration is for the optical path to be perpendicular to the front of the optics unit by way of the aiming mirror at the barrel. However, it is possible to reconfigure the system for the optical path to follow a straight bore shot down its length by removing the aiming mirror assembly.



The eye camera lens has easily accessible focus and iris adjustments. Zoom control is not accessible under normal operation and requires removal of the front panel. Illuminator gain cannot be directly controlled by either hardware or software. Camera gain is instead only adjustable by way of the iris.

The standard LRO system has a 15 mm extender between the camera and lens. This configuration allows focus at a minimum distance of about 14 ft. Longer extender tubes can be used to allow focus at shorter distances.

The lens inverts the image, so in order for the image to appear right side up the camera must be mounted “upside down.”

The Illuminator source is an FCR lamp powered by the 12 VDC supply included as standard equipment with the system. It must always be mounted with its element above its base, and has a nominal lifetime of 40 hours. The illuminator power should be turned off when not in use to preserve lamp life.

The light produced by the illuminator passes through a filter to remove visible light. This enables the system to function in the near infra-red spectrum. The light is directed to be coaxial with the camera lens optical path by a set of mirrors and beam splitters.

The LRO is connected to a Control Unit, which resides inside the Control Room of the laboratory. The Control Unit calculates eye tracking and pupil data and interfaces with a control PC. Monitors display the eye image and captured scene image. Depending on the system configuration, different monitor and Control Unit variations may be provided.

2. Environmental and Safety Considerations

2.1 Use of Eye Tracker in NMR Environment

The power source for the system is split between multiple leads and passed through a filter on the Penetration Panel (provided by the customer). The video signal is passed through a low pass filter before leaving the optics unit. These two measures, along with other optics module design characteristics, have demonstrably eliminated interference with imaging operations. To the best of our knowledge, our customers have not experienced either eye image interference from the NMR device or NMR image interference from the eye tracker. This system has been installed in magnets ranging from 1.5T to 4T.

The 12V / 9A current used to power the optics module must be passed through a filtered 25 pin D-type connector. If the D-type connector does not have a power filter, noise may be introduced into the magnetic environment. It is the customer's responsibility to ensure that the Penetration Panel into the magnet room is appropriately equipped.

The LRO is designed to function outside of the bore of the magnet up to 14-16 feet from the subject's eye. The generally recommended distance is approximately 9 feet. It is possible to mount the Optics Unit significantly closer, in some cases right up to the bore, with minimal or no interference to either the magnet or the eye tracker. However, this is not recommended due to the possibility of artifact introduction in some magnets. Additionally, in such cases, the camera's shutter may jam (leading to the ineffectiveness of the Iris adjustment control) and the Optics Unit cooling fan may stop leading to shortened illuminator bulb life. Some optional configurations are available to place the fan outside of the Optics Unit.

2.2 Statement of Safe Use in NMR Environments

The ASL Long Range Optics module has been used for research purposes in NMR devices since 1998. ASL has installed over 25 LRO systems over the past 3 years, and over twice that number in total. To the best of our knowledge there have been no claims of harm of any type.

The ASL Long Range Optics is a research device. It is not a medical device and should not be used for clinical applications; it does not require FDA approval.

2.3 Statement on Safety Levels of Infrared Illumination





One of the most comprehensive and authoritative sources on the subject of light source safety is a handbook entitled *Safety with Lasers and Other Optical Sources*, by David Sliney and Myron Wolbarsht, first published in 1980 by Plenum Press. Quoting from page 147 of this book, “However, safe chronic ocular exposure values, particularly to IR-A, probably are of the order of 10 mW/cm² or below”. “IR-A” refers to the spectral band between 760 and 1400 nanometers, the range in which the ASL remote module operates.








We are aware of no data, made available since the book was published, that would challenge this conclusion. Most people might wish to be more conservative than the figure cited above, and ASL’s eye tracker optics modules operate at least an order of magnitude below this level. The power of the illuminator beam varies somewhat from sample to sample. The largest irradiance value that we have measured with the ASL 6000 LRO (remote long ranged optics) module is 0.7 mW/cm², at the plane of the eye. This was at an aiming mirror to eye distance of 3 ft, which is closer than the distance actually used with an ASL 6000 LRO. Under normal use, eye irradiance will be less than 0.5 mW/cm².

The LRO uses non-coherent illumination. There are no lasers in the system.

3. System Components

Please refer to this table to aid you in identifying the various parts of your ASL eye tracker. Depending on your individual configuration, you may not have all parts pictured here and you may have additional parts not listed. Some items may not look exactly as pictured.

<i>What it looks like</i>	<i>What it is</i>	<i>What it does</i>	<i>You have if...</i>
	ASL Control Unit (CU)	<p>Performs all system processing including gaze calculation. Has attached eye and scene monitors for real-time feedback to operator.</p> <p>Some configurations may have different variations. See Section 7.6 Control Unit Variations.</p>	All systems
	Long Range Optics	Camera, Illuminator, In-room eye display	All systems
	LRO Power Supply	Power Transformer for LRO unit	All systems
	Desktop Computer Frame Grabbers	Captures video image for real-time feedback to operator on computer	Display Option A Selected

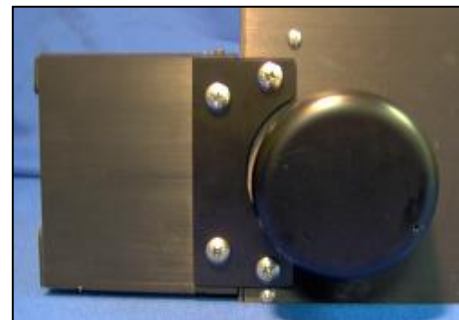
	Laptop Computer Frame Grabbers	Captures video image for real-time feedback to operator on computer	Display Option B Selected
	Scan Converter	Intercepts stimuli image from computer and sends to Control Unit	Scene Capture Method Selected
	LRO Magnet Room Power Cable	Powers optics module; connecting Penetration Panel to LRO	All systems
	LRO Control Room Power Cable	Powers optics module; connecting Power Supply to Penetration Panel	All systems
	RS-232 Control Cable	Connects CU to Control Computer	All systems
	BNC Cables	Multiple cables for distribution of video signals	All systems
	XDAT Cable	Allows digital interface with stimulus computer	All systems

4. Installation

4.1 Unpacking and Assembly of Optics Module

Initial unpacking , assembly, and alignment should be performed outside of the NMR chamber.

- 1) Locate the Optics module case and remove the external packing material. Rest the case on its bottom. *When handling the optics module take care not to damage the controls that protrude from the external surface of the mounting panels.*
- 2) Remove the optics module front cover by removing the 6 silver thumbscrews.
- 3) Remove all of the internal packing material, taking care not to touch any of the mirror surfaces. *Touching the mirror surfaces will leave fingerprints that are very difficult to remove.* For shipment, all components are mounted in their normal positions, with supporting packing material, except for the Aiming Mirror Assembly and LCD monitor, which are packed separately.
- 4) Unpack the Aiming Mirror Assembly and remove all packing material. Mount the assembly at the barrel end of the Optics Module. Two screws are used on the rear cover to mount the assembly in place. Take care not to touch any of the mirror surfaces. *Touching the mirror surfaces will leave fingerprints that are very difficult to remove.*
- 5) Locate the IR filter. It is a 2 inch square glass filter that appears to be red on one side, silver on the other, and has a white handle extending from one edge. The filter can be inserted and removed by simply pushing it in or pulling it out of its slot at the front of the illuminator cover leaving the

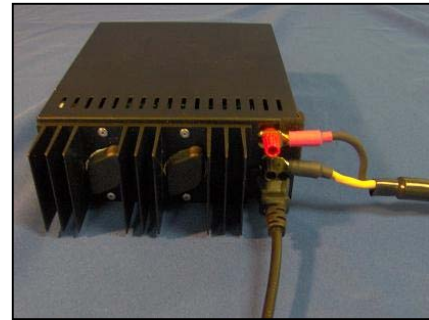
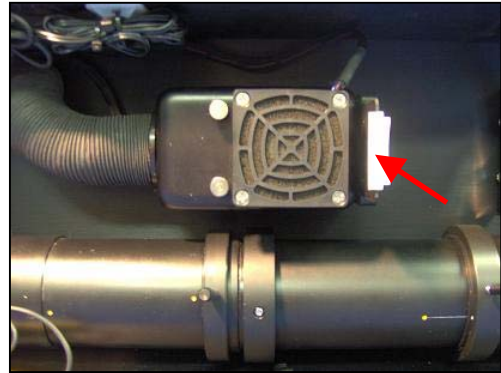


white handle exposed (facing away from the component mounting surface). When installed it should be oriented with the red colored side facing away from the illuminator assembly (toward the collimating lens and front panel) and with the silver colored side facing towards the illuminator assembly (away from the collimating lens). It will be necessary to remove the filter for the illuminator focus and alignment procedures described below. It is also prudent to remove the filter when moving the optics module about to avoid the risk that it will fall out of its slot. When not in use, be sure to store the filter in a safe place, as it is a valuable component.

- 6) Connect the 12 V illuminator power supply shown, but do not plug the supply into the AC wall outlet until ready to turn on the lamp. The power cable is connected to the red and black leads on the power transformer and the other end of the power cable is connected to the power input on the optics manual.

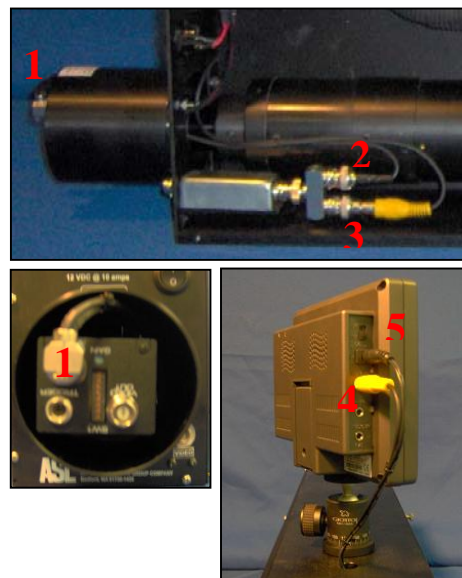
Leave all components turned *off* for now.

- 7) The LCD screen comes packed separately from the LRO module. The bottom of the LCD screen has a threaded hole that attaches to the screw on the mounting ball on the top of the LRO module. Screw this the mounting ball's rod into the LCD bottom (no tools are needed). The vertical knob at the base of the attachment tightens the ball to hold it in place. To change the orientation of the LCD screen, loosen this knob first. *Failure to loosen the knob may damage the LCD mount.*



- 8) The silver box attached to the rear panel of the LRO module is a low pass filter used to remove high frequency signals in the video signal from the LRO camera before passing it through the NMR room. Attached to the LPF on the *inside* of the LRO module is a Y-splitter.

The Eye Camera connector (1) plugs into one of the Y plugs on the LPF (2). The yellow video plug connects the other Y plug on the LPF (3) to the video in port on the LCD monitor (4). Tied to this cable is also the power cable for the LCD monitor which should also be plugged in (5).

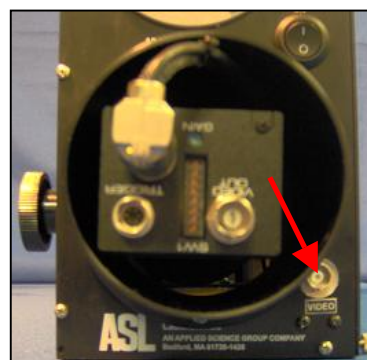


- 9) The shielded BNC video cable runs from the LRO module to the Penetration Panel. This cable carries the video signal into the Control Room.

Connect the cable to the external plug of the silver Low Pass Filter labeled “Video.”

Do not plug this cable directly into the camera (item 1 from step 8 above) or you risk introducing noise into your NMR environment.

Plug the other end of the BNC cable to the Penetration Panel in the NMR room.



- 10) These are all of the necessary connections within the NMR room. However, it will probably be more convenient to leave the cover off while completing the illuminator focus and alignment steps described in the next section.

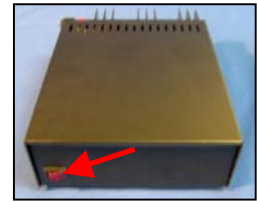
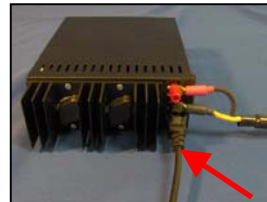
4.2 Initial Illuminator and Camera Alignment and Focus

Before the system is completely set up and brought into the NMR testing room, the Illuminator and Camera optical paths need to be aligned. While this can be performed after final setup, it is much easier to complete before entering the magnet room. Connection to the Control Unit, Interface PC and other exterior devices are not necessary for the focus and Alignment procedures

- 1) Arrange the Optics Module so that the illumination beam will shine on a wall (or other surface) at the approximate distance from the subject as is intended for use in the NMR



- 2) Connect the LRO Power Supply to a power outlet then press the power switch.



4.2.1 Initial Camera Focus

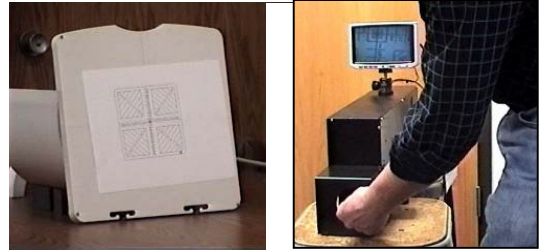
- 3) Power on the attached LCD monitor. The image will likely be out of focus and dim.
- 4) Adjust the Iris control lever to set the camera gain to full (brightest). The image in the LCD monitor should become brighter.

If the LCD monitor cuts out when you do this, it may be because the camera is being oversaturated. If this occurs, back off of the Iris until the image comes back.

- 5) Adjust the Focus control lever until the wall or surface you are viewing comes into focus. Use



a piece of paper with a visible target drawn on it and move it along the wall until it is centered in the LCD monitor. This may take some trial and error to locate the correct position. Many people find it convenient to point a flashlight at the optics from close up to find the optical path and then back away while keeping the light in view.



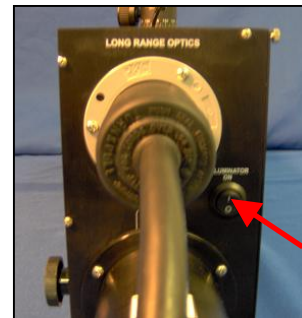
- 6) Tape the target into the proper position on the wall. Adjust the camera focus further to fine tune the image as well as possible.

4.2.2 Illuminator and Camera Alignment

- 7) Power on the illuminator, being careful that nobody is looking along the illumination beam path (without the IR filter the lamp is extremely bright).

The illuminator fan should go on as well as the lamp. The fan will intake air from the front of the optics unit to cool the lamp. Hot air will vent out the back by way of the exhaust pipe. Operation without the fan will significantly shorten bulb life.

Also be aware that the illuminator cover and exhaust pipe get quite hot and can cause burns if touched. Avoid touching these components.

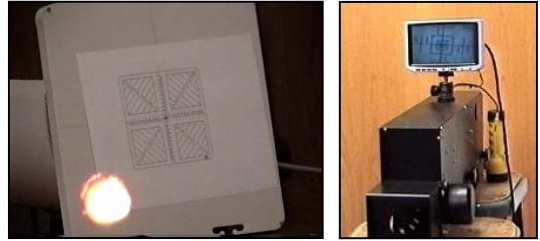


- 8) If not already removed, remove the IR filter from its slot and carefully store it in safe place. Be careful that nobody is looking along the illumination beam path as without the IR filter the lamp is extremely bright.

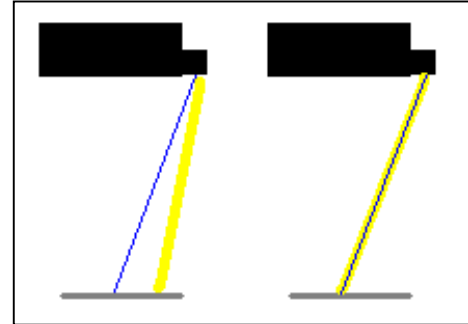


- 9) You should now observe the projected light on the wall surface. It is most likely not in line with the target.

What you will likely find is that the light spot is pointed at one place, while the image on the LCD screen will show another spot (the center of the target you previously aimed it at).



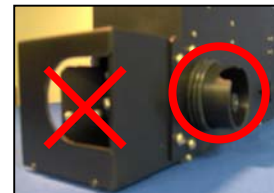
- 10) It will likely now be necessary to reduce the Iris aperture (try an initial setting of approximately 50%) to avoid over saturating the camera. If the image cuts out (becomes black) the image has likely been saturated and has cut off as a precaution. Reduce the Iris aperture further.



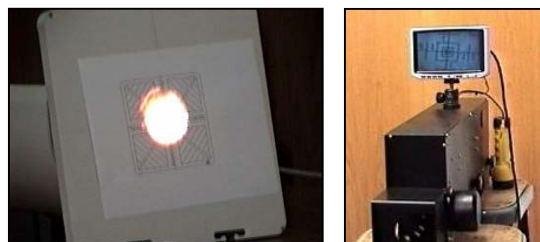
- 11) Use the beamsplitter positioning knobs (located on the rear panel) to center the illumination circle on the target spot. You will need to remove the plastic cap covering these controls.



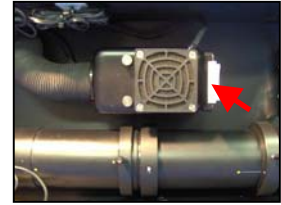
Note that it is the beam splitter, not the aiming mirror adjustments that must be used in this step. This insures that the camera and illuminator beam are aimed at the same spot at the far end of the optical path.



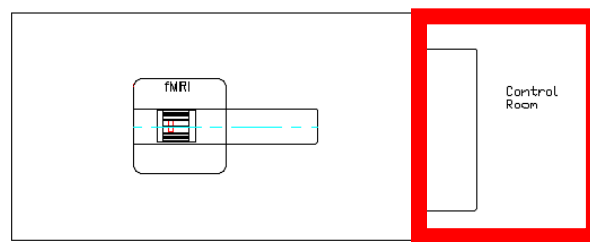
- 12) The objective of this process is to get the optical paths of the camera and the illuminator follow the same course. Therefore, the center of the illumination should fall at the center of the target when the center of the target is viewed in the center of the camera's field.



- 13) Turn off the illuminator lamp. Replace the illuminator filter. Replace the optics unit cover.



4.3 Interconnections Outside NMR Room



All cables and ports are marked with colored dots or strips. To set up the system, simply connect the matching colors.

The following section goes step-by-step through each connection.



The RS-232 Control Cable connects ASL control unit to a serial port in the back of the experimenter computer.



The HMO - P/T Switch on the control unit should initially be set to P/T.



The camera BNC cable connects from the Eye Cam Video port on the Control Unit to the Penetration Panel into the NMR room.



The Remote Scene BNC cable connects from the Control Unit to the Scan Converter. The RS-BNC will have a BNC to RCA adapter on one end.



The cable currently connecting the monitor of your stimulus producing computer is instead plugged into the VGA Out port of the Scan Converter.



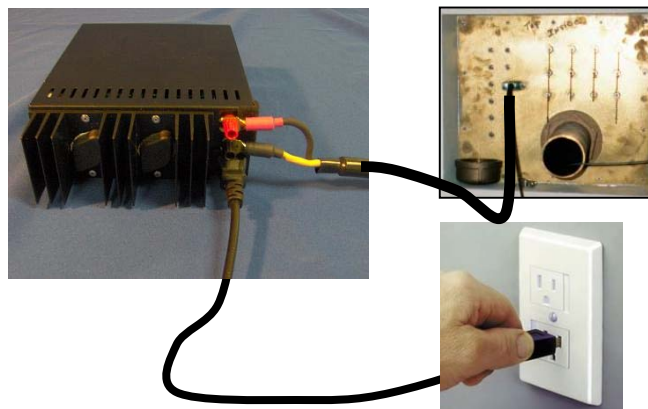
The VGA cable provided with the Scan Converter connects from the VGA In port of the Scan Converter to the VGA port on the stimulus computer.

Some configurations may include only one LCD monitor connected to the Control Unit. In this case, an external CRT monitor will be provided. See Section 7.6 Control Unit Variations for details.

Variant
 Configuration

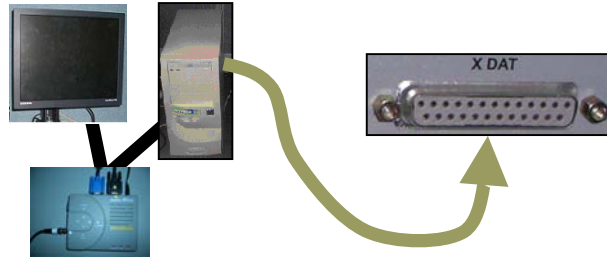


The power cable is connected to the red and black leads on the power transformer and the other end of the power cable is connected to the Penetration Panel.

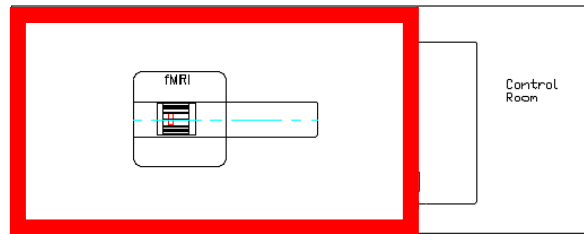


The power transformer is plugged into a wall power outlet.

If you are using an XDAT cable, this (generally) connects from the XDAT port on the Control Unit to a parallel port on your stimulus presentation computer.



4.4 Interconnections Inside the NMR Room



4.4.1 Bringing the Optics Unit into the NMR Room

After unpacking and initial alignment, the optics module is ready to be brought into the NMR room to be set up. Ensure that you have a firm grip of the unit, as it is not lightweight.

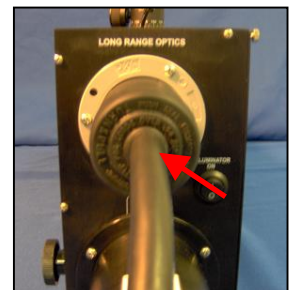
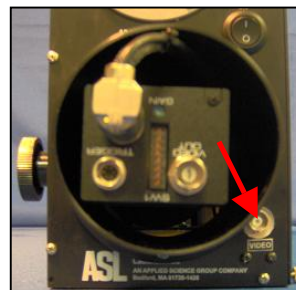
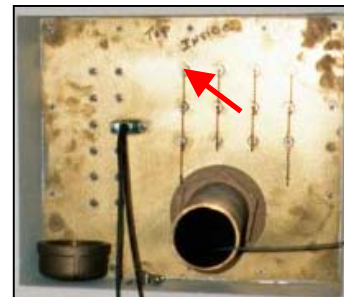
When carrying the unit to the rear of the room, walk slowly past the magnet. Most installations have limited room between the magnet and the wall on the sides. Since the field strength is stronger at these close distances, moving quickly while passing close by can cause the mirror alignment to change.

4.4.2 Interconnections of the Optics Module

The Optics Cable is connected to the BNC passthrough connector on the Penetration Panel (opposite the Camera Cable in the Control Room). The other end of the Optics Cable is connected to the Camera Connector on the LRO unit.

The Power Cable is connected to the 25-pin connector on the Penetration Panel (opposite the Power Cable in the Control Room). The other end of the Power Cable is connected to the Power Connector on the LRO unit.

The two cables should be placed in the room out of the way, preferably along the wall or ceiling. Even though these cable are heavily shielded, it is



important that they are not run close to the NMR magnet in order to eliminate any possibility of introducing artifacts.

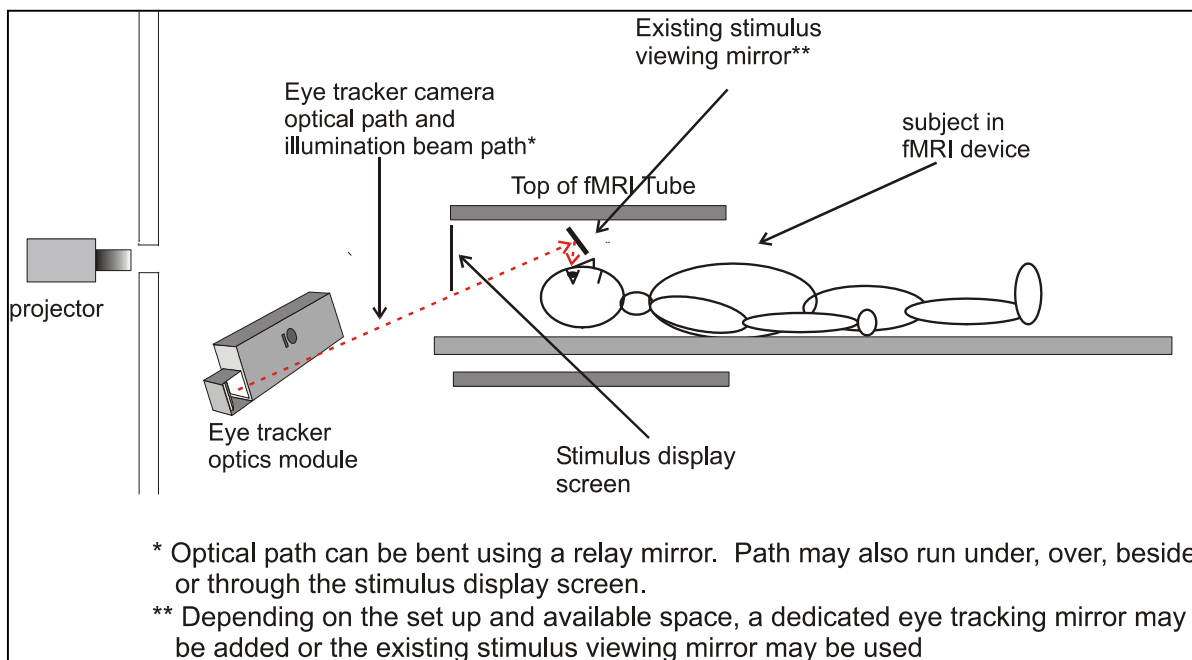
4.4.3 Configuring the Optical Path

4.4.3.1 Positioning the Optics

The Long Range Optics unit should be placed far enough from the bore of the NMR so as not to create any interference. Generally, users will place the optics unit at least 4 feet away. The recommended distance is around 8 or 9 feet. In most circumstances, the system can function out to 16 feet, however some performance degradation may be noticeable beyond 14 feet.

The optical path can be reflected over one or more mirrors in order to capture the image of the eye. Usually, the optical path will reflect off of the stimulus mirror mounted to the head coil. In some cases, due to constrained room size, the optical path will be designed to reflect off of another mirror outside of the bore.

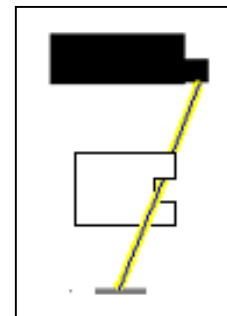
The optical path should approach the eye from below. That is, the direction of the camera's gaze should end up approaching from an angle slightly lower than the subject's direct gaze. In most cases, this will involve setting up the optics unit such that it is slightly lower than the bore opening of the magnet.



4.4.3.2 Breaching the Stimulus Screen

Most experimental fMRI setups involve a screen onto which a stimulus is project from an LCD projector or similar device. This subject views this screen by way of a mirror mounted on the head coil.

Since the Eye Tracker will be using this same mirror to view the eye, an open gap must be available for the optical path to traverse past the display screen. *There can be no obstruction of the optical path.* In the case of small stimulus screens, the path can usually be designed to pass next to the screen. However, for large screens or screens that cover the entire bore or stimulus mirror, a section will need to be removed so that the Eye Tracker's optical path can reach the subject's eye.

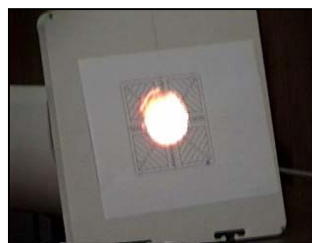
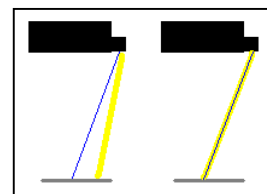
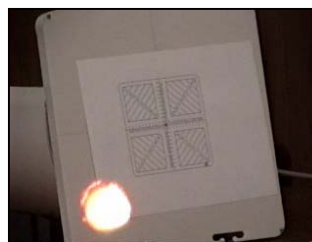


4.4.4 Ensuring Camera and Illuminator Alignment

The camera's imaging vector and the light source vector should be aligned to follow the same path. Generally, this is initially done outside of the magnet room, however it is possible to do with the optics unit in its final position inside the room. The process for doing this exactly the same as described in Section 4.2.2 Illuminator and Camera Alignment.

If at any point these become unaligned, it will be necessary to use the Beam Splitter controls to bring them back to aiming at the same point.

If they are not aligned properly, the system will not be able to properly recognize the pupil or corneal reflection, and therefore will be unable to function.



5. Operating Theory

The system functions, on the most basic level, by measuring the relationship between two features of the eye. The spatial relationship between the angle of the eye and the head is relatively stable for the direction that a person is looking within an individual person. Therefore, it is possible to measure the location of the pupil with respect to a fixed point to determine gaze direction.

The Long Range Optics produce a small reflection off the cornea of the subject. This reflection is in a stable location with respect to the optics and head and therefore can act as an anchor point. The relationship between the center of this Corneal Reflection (CR) and the center of the Pupil are the raw measured data of the Eye Tracker.

Combining these measurements with a calibration procedure allows the system to measure an individual's gaze intersection with a stimulus surface (generally a projected image on a screen).

5.1 Basic Eye Biology

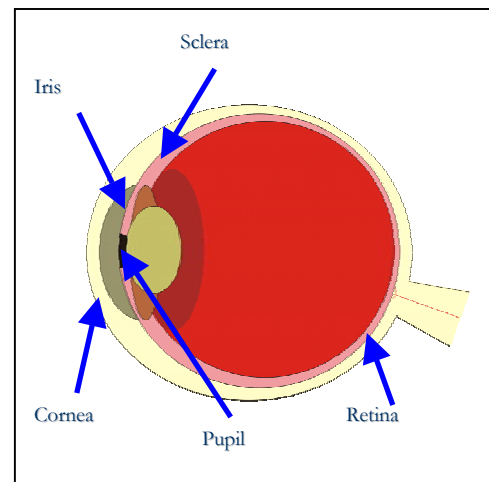
The *retina* makes up most of the surface of the back of the eye. It contains the cells that detect light and send information to the brain through the optic nerve.

The *pupil* is an aperture that allows light to enter into the eye. The pupil normally appears black since, under most perspectives, light does not exit the inside of the eye.

The size of the pupil is related to the *iris*, which is similar to a shutter that opens and closes. The iris is the (normally) coloured part of the eye.

On its way to the pupil, light passes the *cornea*, which is a thin film-like tissue that covers the eye. The cornea is mostly transparent. However, significantly, there is some amount of reflection as light passes through it.

The *sclera* is the white part of the eye.



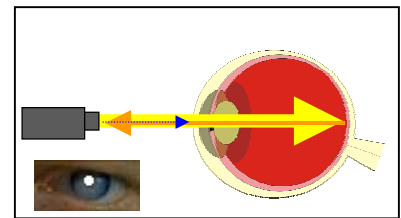
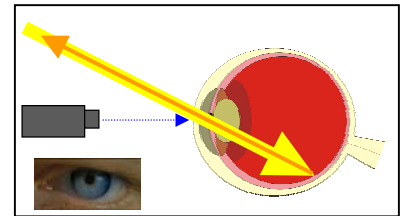
5.1.1 Eye Optics and the Pupil

Light crosses the cornea and passes through the pupil until it reaches the back of the eye.

The eye acts as a *retro-reflector*, meaning that it reflects a portion of the light back out along the same path that light came in.

This means that, normally, the pupil looks black since light rarely ever comes from the same point as observation.

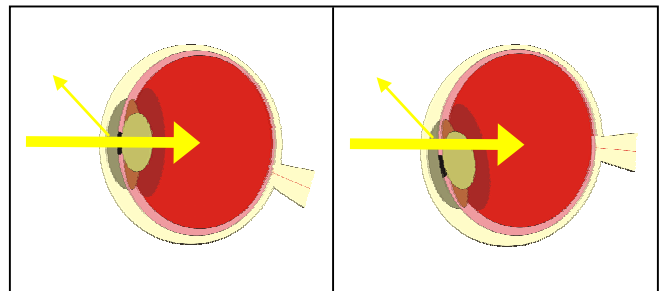
However, if the light source comes from approximately the same place as observation, the reflected light is observed and the pupil appears bright.



ASL eye trackers take advantage of this effect using near-infra red (IR) light. Since the pupil appears bright to the camera, the eye tracker can work no matter what the participant's iris color is and can function in low light conditions.

5.1.2 Eye Optics and the Cornea

The second important property of the eye for tracking is the slight reflectivity of the cornea. As light passes through the mostly transparent cornea, a small portion is reflected back. This causes a small reflection to be visible somewhere on the eye. Its relative location is related to the position of the camera (and therefore the Illuminator). Significantly, the location of this reflection remains the same no matter how the eye turns.



In most healthy individuals, the cornea is mostly smooth over the pupil and iris. The cornea is not smooth, however, over the sclera.

The *Pupil* moves with the eye and can be used to track the “center” of the eye. The *Corneal Reflection* remains fixed and can be used as an anchor point for the head with respect to the camera.

These two properties of the eye can be used together to plot the angle of the eye with respect to the stimuli.

5.2 What Constitutes a Good Eye Image

The hallmark of good data collection with your eye tracker is obtaining a good, stable image of the eye. The image you will be using is purposefully black and white and may be low in detail.

Your first task is to get the eye in view and in **focus**. Proper focus is critical. *If the image is not in focus you will not be tracking well.* Focus is adjusted by changing the focus adjustment arm (discussed in Section 6.2) slightly. The image should be crisp with smooth contrast borders.

The pupil will be a relatively large circle and the corneal reflection (CR) will be a small dot that will be *brighter* than the pupil. Everything else in the eye image should be darker than the pupil (and may even be featureless).

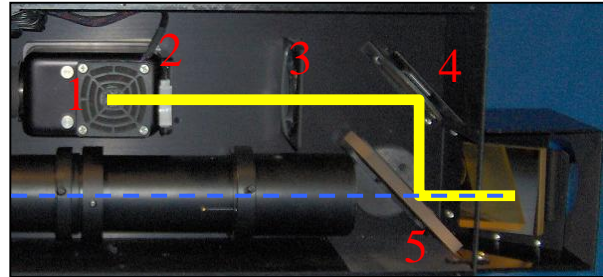
When the participant looks straight ahead (at calibration point 5), the pupil should be close to the center of the display. When they look around at each of the calibration points, the pupil should remain on the screen. When they look around the screen, the CR should not become obscured behind an eyelid or move into the sclera. If it moves into the sclera, you will lose the ability to locate the CR since this portion of the eye is very reflective and not smooth.

Due to differences in eye and face structure, some people are more difficult to track than others. Eye shape may affect the ease of maintaining the CR.

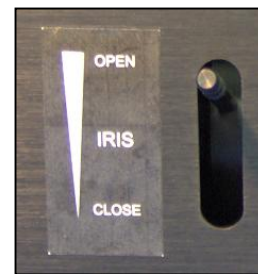


5.3 The Illuminator

The Illuminator Bulb (1) projects a beam of light that passes through an IR filter (2) that removes most of the non-infra-red light. The beam of near infrared light then passes through a collimating (3) lens, a mirror (4), and a beamsplitter (5) that redirects it to be coaxial with the imaging direction of the camera. This produces the retro-reflection effect and corneal reflection discussed earlier.



There is no method of controlling the Illuminator intensity. However, apparent Illuminator intensity and image brightness can be controlled by adjusting the Iris control lever on the optics unit. The important aspect to remember in controlling the Illuminators is that no matter how much light is put upon the eye the CR remains at approximately the same brightness.



However, the brightness of the pupil varies relative to the amount of light projected into the eye. Conceptually, there are three levels of brightness; the CR, the Pupil, and everything else.

Your goal in adjusting the Iris control is to set the amount of light at a level such that the pupil can be distinguished from the background and the CR can be distinguished from the pupil. **The CR will always be brighter than the pupil!**



Too Dark



About Right



Too Bright

5.4 Discrimination

Discrimination is the process by which the ASL system recognizes the pupil and CR in the camera image. In order to track, you *must* be discriminating properly. A valid discrimination will place stable white crosshairs just slightly to the right of the pupil and stable black crosshairs just to the right of the CR.

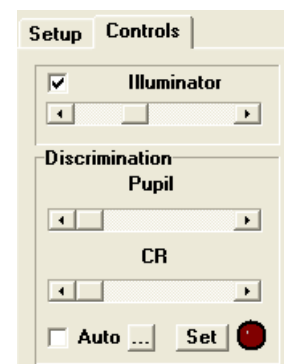
If these are not in place, you *are not* getting valid eye tracking data.

In most cases, once the Iris is properly set to regulate illumination, you can use the AutoDiscrimination feature to have these controls automatically set by the software (see Section 5.4.1). However, for some subjects autodiscrimination may fail to properly function and manual control may be necessary. See Section 5.4.2 for an explanation of how to do this.

5.4.1 AutoDiscrimination

Once the illuminators are set properly, you can press the Autodiscrimination box to enable automatic recognition of the eye features.

The discrimination controls are located at the left side of the Eye-Trac User Interface. The controls for Threshold levels for pupil and cornea reflection edge detection are adjusted with the sliders labeled “Pupil” and “CR”, under the “Discrimination” label heading. Also the Up/Down arrows adjust the Pupil slide bar and Left/Right arrows adjust the CR slide bar. The current discriminator levels are shown by the slide switch positions, with the far-left slide switch positions indicating that no edges will be noticed, and positions at the right of the slides indicating even dim edges may be detected.



In most cases you can achieve good pupil and CR recognition by using Auto-Discrimination feature. In order to start Auto Discrimination check “Auto” checkbox is located underneath “CR” slider bar.

Another alternative is to turn on auto discrimination only for a short period of time. In order to do that, press “Set” button. Experienced users may exercise this option in order to obtain initial discrimination values and then improve them manually.

If auto discrimination doesn’t work reliably in your settings, try manual discrimination described in the next section.

5.4.2 Manual Discrimination / How Discrimination Works

The camera is taking a picture of the eye 60 times a second (approximately every 17 ms or faster for high speed systems). The system then analyses each picture to find the pupil and the CR. However, the computer is unable to use gestalt recognition principles and can only interpret information about each individual pixel in the image. It does not interpret information about the image as a whole.

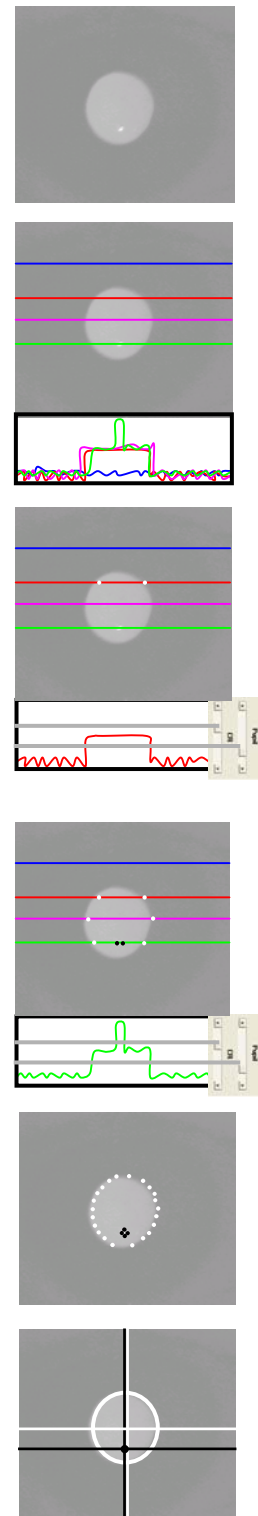
The ASL Control Unit will engage in a logical process called Discrimination to identify both features. In this process, the computer will look at the luminance (brightness) levels of each pixel by sweeping across each row in the image. It will then compare this luminance value to a pair of thresholds. If the value exceeds one of these thresholds, that pixel is considered relevant. It is the change from relevant to not relevant (one side of the threshold to the other) that determines whether a pixel is marked.

The image to the right shows this process conceptually for four select pixel rows. Beneath is a graph of the luminance across those rows. Notice how there is a sharp increase in the graph when the brightness changes. It is this increase that the system needs to detect. Since there are three distinct features that will have differing brightness levels (CR, Pupil, everything else) there will need to be two thresholds.

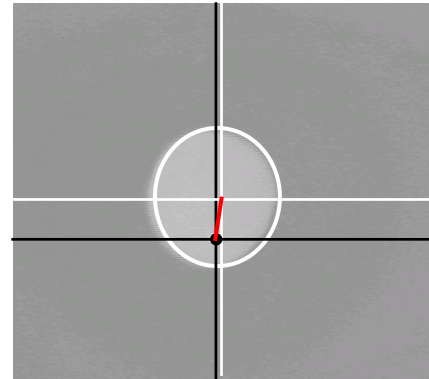
The Pupil and CR slider bars on the main window of the User Interface software directly represent and manipulate these threshold values. If you conceptually superimpose these slider bars with the brightness profiles (as seen to the right) you can see how these settings function. Every time the brightness of a row transitions from one side of a threshold to the other, the pixel is marked as relevant and a dot is drawn on the screen. The dots are white for the Pupil Threshold and black for the CR Threshold.

The dots are purposefully offset to the right of their actual locations in order to be easily visible. The actual data being interpreted and recorded is correct.

The computer does this for every pixel row in the image. In an ideal image, you would have dots in no other locations than along the actual feature borders. If the system can recognize a viable pattern, it will draw best-fit ellipses around the pupil and CR. It will then place crosshairs around the computed center points of each. It is normal for the circles and crosshairs to be slightly offset to the right



The centers of these crosshairs are the relevant pieces of information for the point of gaze calculations. The computer compares the vector between these two points. If it cannot draw this invisible line, it cannot calculate gaze direction. If these crosshairs are in the wrong place or do not exist, so that the centers are not accurate, then this vector will be incorrect and your data will be inaccurate. This is why it is so important that you maintain valid discrimination throughout the study.



If you do not have accurately placed crosshairs, you do not have accurate data. Therefore, the most important job that you as the operator have to do with the eye tracker is to make sure that it is properly discriminating. In the past, this meant monitoring and adjusting the Illuminator and two thresholds.

The ASL 6000 series has a feature that will take control of the pupil and CR discriminators and adjust them automatically (See Section 5.4.1).

Environmental changes and participant reactions (such as movements and pupil dilation) may cause changes in light levels causing the threshold levels to need to be changed. During the course of the study a number of things can happen that will change the amount of light being reflected back from the participant's eye. Fatigue and lighting conditions (including screen brightness) will change pupil dilation and therefore pupil luminance. The angle of the eye (when looking at peripheral stimuli) may cause the apparent size of the pupil to be smaller and therefore reduce the pupil brightness.

5.4.2.1 Additional Discrimination Notes

Discrimination is completely dependent on the quality of the eye image

White and Black crosshairs must be present for tracking

If crosshairs are flickering, you are tracking intermittently

If crosshairs have grabbed the wrong object (e.g. glasses reflection, tear duct, sclera reflections) the system is not tracking properly

If crosshairs intermittently grab wrong object, the system tracks intermittently

Crosshairs must be STABLE!!

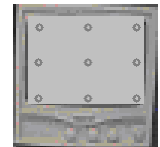
5.5 Target Points and Participant Calibration

When the system is functioning it is keeping track of the location of the participant's pupil and corneal reflection. It uses these two features to calculate what the participant is looking at. However, the relationship between the pupil and CR is different for each person. You must, therefore, teach the system each individual's pupil/CR/scene relationship prior to running them in your study. The process of doing this is called *Calibration*.

The most common calibration method is the 9-point calibration. Project a bitmap on the Participant Computer with nine numbered dots ordered in 3 rows and 3 columns like the one pictured to the right. Point 5 should be in the center of the display screen and the other eight points should be near the edges of your display area. This sample bitmap can be found on the Manuals CD provided with your system.

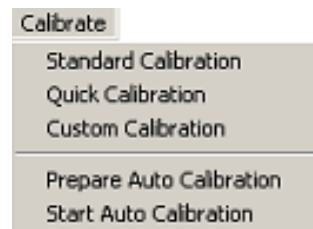


Since the bitmap is being displayed on the participant computer, it should also be visible on the Scene Monitor (since the image is being intercepted through the scan converter). You must now tell the system where these points are located in the scene. This is done by the Set Target Points procedure (See Section 6.4.2 Defining Stimuli Environment (Set Target Points)).

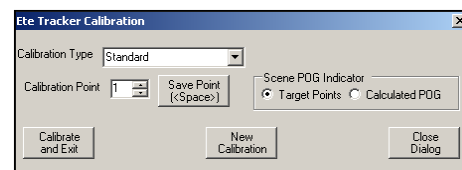


5.5.1 Subject Calibration

Selecting Standard Calibration, Quick Calibration, Custom Calibration, Prepare Auto Calibration, or Start Auto Calibration will open the Eye Tracker Calibration window in the appropriate mode. From the Eye Tracker Calibration window, you can also change the calibration type to any of these modes by way of the Calibration Type item.



The currently active calibration point (for which the system is waiting for a calibration about) is displayed in the Calibration Point item. The currently active point can be changed with the arrows on the box or by typing the desired number into the box.

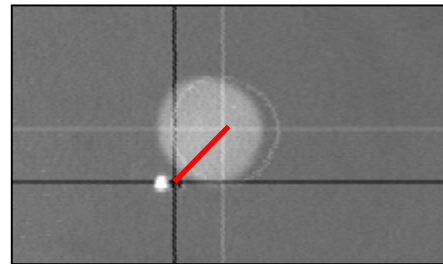


To store the calibration for the current point, press the Save Point button or press the spacebar on the keyboard. This will take the currently computed eye feature positions and use them as the values for the current point in computing the Point of Gaze calibration.

The newly input points are not used to compute POG until the Calibrate and Exit button is pressed.

5.5.1.1 Understanding Calibration

The raw data measured by the Eye Tracker is the separation between the pupil center and the corneal reflection (CR) center. The relation between these raw values and eye line of gaze differs for each subject and for different optical units and scene camera positions. The purpose of the eye calibration is to provide data that will allow the Eye Tracker processor to account for individual subject differences. The objective is to have the subject look at (fixate) on each of the nine calibration points. This procedure must be performed for every subject.



In most calibration procedures, when a subject is known to be looking at a specific point (either because of instruction or by another inductive method) the operator tells the system to calibrate (note the current pupil/CR relationship)

6. Eyetracker Operation

Eye Tracker operation with the Long Range Optics is similar to operation with most other ASL Eye Tracking systems. If you are familiar with these systems, operation of the LRO will seem familiar.

6.1 Software Installation

Two CDs are included with your system. The first is labeled “Manuals and Tutorials” and contains this document. The second is labeled “EyeTracker Software” and contains the EyeTracker user interface software (Eyetracker 6000), analysis software (Eyenal and Fixplot), and the software developer kit (SDK).

Place the “EyeTracker Software” CD into the computer to be used for eyetracker control. The installation program should automatically start. If it does not, navigate using Windows Explorer to the CD device and execute the *Setup* program.

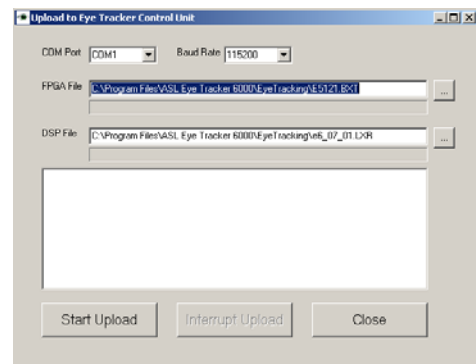
Follow the instructions of the installation program to install the software.

Detailed documentation about the software can be found in the EyeTracker User Interface Software Manual. However, the following sections should be sufficient for initial operation.

6.2 Starting the User Interface Software

The UI software can be accessed through the Start menu of Windows and can be found in *Programs > ASL Eye Tracker 6000 > Eye-Trac 6000* or in the installed directory on the computer (usually C:\Program Files\ASL Eye Tracker 6000\EyeTracking\ET6.exe).

When started, the program will first display the Upload to Eye Tracker Control Unit Screen. This procedure sends the basic operating instructions to the Control Unit. Unless the CU is plugged into a serial port other than COM1, all settings should remain as they default.



Pressing *Start Upload* will cause the program to send the system instructions to the CU. Status is indicated by the two blue bars, which must fill for this procedure to be complete.

6.3 Configuring Software for the LRO

When the software is run for the first time after initial installation, the *Basic Configuration* window will appear. This window configures basic system setting so that the software can work with the LRO. Since this software is designed to function with many other ASL systems, incorrect settings may cause improper or poor system function.

System Type should be set to *Monocular*.

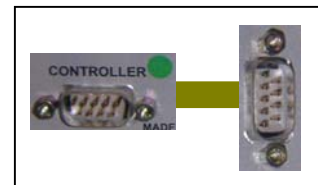
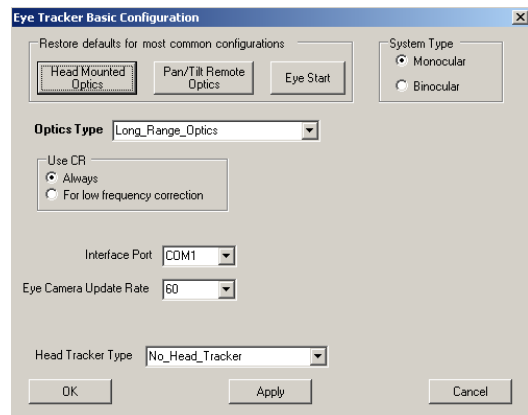
Optics Type should be set to *Long_Range_Optics*.

User CR should initially be set to *Always*. See the *6000 Manual - User Interface Software* document for a discussion of this feature. Unless you have a strong reason to do otherwise, this should remain at *Always*.

Interface Port should reference the port on the Interface Computer to which the Controller Cable is connected. This will usually be COM1.

Eye Camera Update Rate should be set as appropriate to your system and desired operating speed. See Section 6.3.1 Selecting System Operation Speed for details. Remember that this setting and the hardware sampling rate setting must match.

Head Tracker Type should be set to *No_Head_Tracker*.



6.3.1 Selecting System Operation Speed

There are two LRO system options available from ASL. The standard LRO allows for an operation speed of 60 Hz. The High Speed LRO Rev C allows for operation at 60, 120, or 240 Hz.

For the standard LRO, no additional selection is necessary and the software must remain set at 60 Hz. If you are using a standard 60 Hz system, skip to Section 6.4, otherwise continue reviewing this section.

If you have a High Speed system you must set both the software Camera Update Rate setting in the Interface Software configuration window and the hardware dipswitches on the back of the camera.



The hardware speed is set on the back of the camera using a series of dipswitches. A small tool may be required to change these switches. *Remember to only use a non-ferrous tool if you are performing this in the Magnet Room.* A toothpick or small plastic tool is a simple item to acquire and use for this.

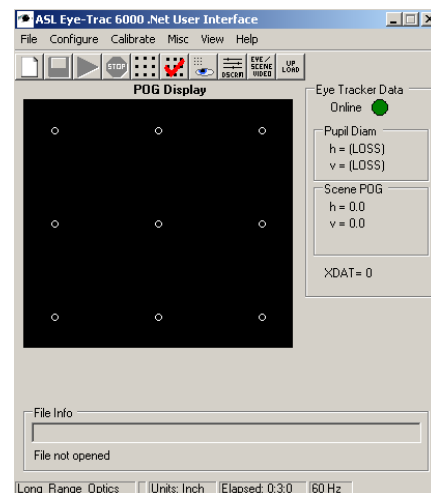
MODE	S4	S5	S6
60 Hz	OFF	ON	ON
120 Hz	OFF	OFF	ON
240 Hz	ON	OFF	OFF

See Section 8 High Speed Camera Option for details on system operation at higher speeds.

6.4 Interface Software Overview

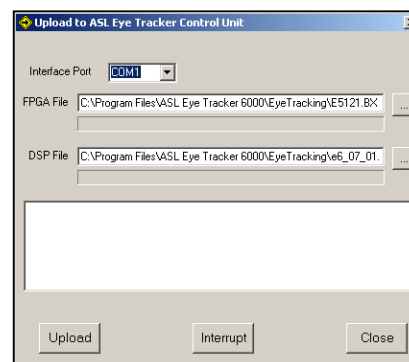
The ASL User Interface Software interfaces with the Control Unit and Eye Tracker Optics to control functions of the Eye Tracking system and to record data. Software operation of the LRO system is, in general, less complex than most other Eye Tracking systems since aiming, focal, zoom, and illuminator controls are hardware based.

For details about all functions of the UI Software, see the *6000 Manual - User Interface Software* document.



6.4.1 Uploading to Control Unit

The Interface software serves to upload instructions to the ASL Control Unit (which actually performs most system operations and data processing). Whenever the ASL Control Unit is powered down, its memory is cleared. On the next system power up, the operator must upload to the CU using the UI Software. When the UI Software is first loaded, it will query the Control Unit and, if there are no instructions present, will display the Upload Dialog. The operator should never have to change the settings on this window. Simply press the **Upload** button and wait for the blue status bars to fully proceed.



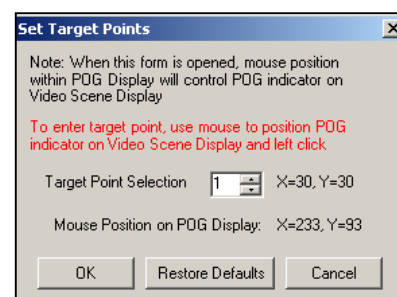
When the Control Unit is properly connected to the Interface computer and has instructions loaded the Online indicator in the software will be green. If this indicator is ever red, the system will not be able to function properly. If this is the case, check the Controller Cable connection, Control Unit power connection, and upload to the Control Unit as described above.



6.4.2 Defining Stimuli Environment (Set Target Points)

The operator must define the locations of the Target Points that will be used to calibrate each Subject's Point of Gaze (as discussed in Section 5.5 Target Points and Participant Calibration). Generally, the Target Points are displayed as an image on the Stimulus Screen by way of a computer driving the Stimulus Projector. As described in Section 4.3 Interconnections Outside NMR Room, this image is being intercepted, split, and fed into the ASL Control Unit through the Remote Scene BNC port. The operator must use the Set Target Points procedure to define the target points in this image in terms of the Eye Tracker's coordinate frame.

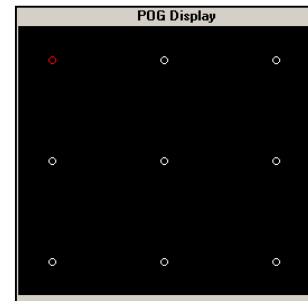
The Set Target Points window is a dialog that is very useful many procedures including defining calibration points, synchronizing external systems, and mapping coordinate system conversions for data analysis. The primary purpose of



Set Target Points mode, however, is to define the spatial locations of the target points used for calibration in the POG coordinate system.

6.4.2.1 Mouse Position on POG Display

When the mouse cursor is moved into the POG window on the main interface screen while in Set Target Points Mode, STP returns the designated coordinate location within the POG coordinate frame.



6.4.2.2 Scene Monitor

When the mouse cursor is moved into the POG window on the main interface screen while in Set Target Points Mode, the system will also take control of the superimposed Point of Gaze crosshair on the scene monitor. The crosshair's position will be a direct translation of the mouse position on the POG display. This feature allows you to translate your environment's coordinate system to the eye tracker's POG coordinate system.



6.4.2.3 Target Point Selection

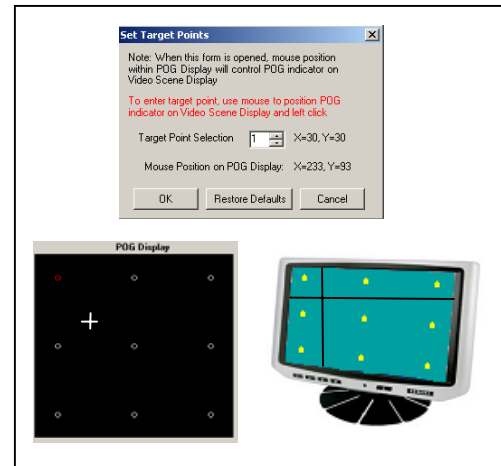
The scroll box indicates the currently selected and active Target Point. Use the arrows to select a different point. The current coordinates for the selected Target Point are indicated next to the box. The selected Target Point is also indicated in red on the POG window on the main interface screen.

6.4.2.4 Moving Target Points

While in Set Target Points mode, pressing the left mouse button while the mouse cursor is in the POG Window will reset the currently active Target Point to that position within the POG coordinate frame.

Since the POG cursor on the scene display matches the relative positions in the POG Display, you can line up the eye tracker's representations of the Target Points with the target points used within your environment to calibrate the subjects.

This is necessary to produce meaningful calibrations that can be remapped back onto the stimuli.



However, this procedure should only need to be performed once unless aspects of the stimulus display are changed.

6.5 Targeting the Eye

Since the Long Range Optics unit has no automatic tracking capability, some form of subject head stabilization is required. Generally, the bed and pad used to stabilize the head in the Magnet's head coil should be sufficient.

It is probably most convenient to initially aim and focus the unit using an artificial target rather than a human subject. The Model Eye provided with the system can be used for this purpose. The Model Eye consists of a black plate with a painted 4 mm white circle to simulate the pupil. The Model Eye provided with the LRO system does not include the ball bearing (simulating the CR) included with other systems due to magnetic environment constraints.

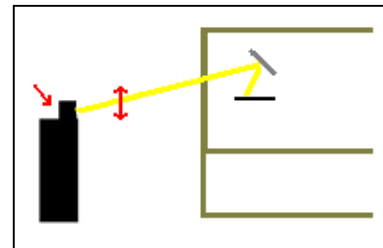
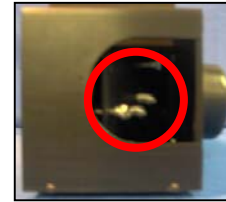
When pre-aiming the system, the IR filter can be removed so that objects can be more clearly seen in the eye monitor. *The unfiltered light is extremely bright. Do not remove the IR filter with a person's eye along its target line.* The filter has a white handle and can easily be lifted out of its slot. The Model Eye, which does not return a collimated retro-reflection



as does the real eye, will probably not be visible at distances used by the long range optics unit unless the filter is removed.

Before proceeding, be sure that the optics unit is well aligned as described in Section 4.2.2 Illuminator and Camera Alignment.

Initially, leave the LRO unit cover off to allow access to the lens focus ring. Place the model eye at the expected position of the subject's eye. If the optics unit is looking directly at the eye, use the aiming mirror to place the Illuminator Beam over the Model Eye, and then to center the pupil image in the eye monitor. To adjust the aiming mirror, turn the adjustment knobs behind the mirror mount to tilt the mirror in two degrees of freedom. If a relay mirror is being used, then the aiming mirror must be used to center the beam on the relay mirror, and the relay mirror must then be angled or positioned to center the eye image in the eye monitor. Use the camera lens focus ring to sharply focus the model eye image (or other target).



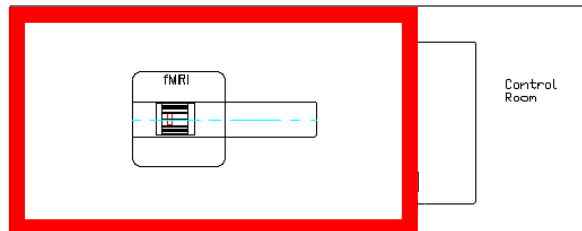
Replace the IR filter (red side towards the LRO unit front panel) and then position a human subject. Adjust the aiming mirror, entire optics module, or relay mirror to center the eye image, and use the focus ring to focus the eye image, just as when using the model eye above. When focusing, try to make the corneal reflection (CR) as small and sharp as possible.

The Long Range Optics unit has an adjustable aperture labeled **Iris**. It is important that the pupil appears noticeably brighter than the background image, and that the Corneal Reflection is noticeably brighter than the pupil. The CR will usually be at or near video saturation level. If the pupil becomes too bright, it will not be possible to distinguish the CR within the pupil and the Iris must be reduced. If the pupil becomes too dim, it will not be distinguishable from the background image and the Iris should be opened. If the pupil image remains too dim even at maximum camera gain, it may be necessary to dim the ambient illumination or the display being viewed by the subject in order to increase the subject's pupil diameter and consequently the pupil brightness. (Pupil brightness is roughly proportional to the square of pupil diameter). When using the long range optics module it is likely that optimal camera gain will be at or near maximum gain.

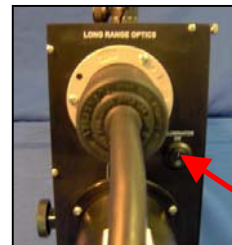


Once the position of the eye is initially targeted, it should be easy to set up the Eye Tracker for new subjects. Most people's eyes will be in approximately the same location within the Bore, and therefore only minimal aiming will be required for each subject. Of course, this is only true if the LRO unit's position is to remain fixed within the room.

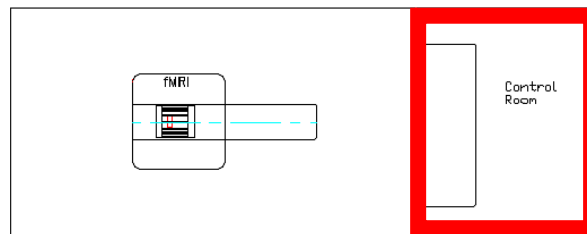
6.6 Setting Up a Subject



1. Place your subject in the head coil and bore of the magnet as normal.
2. Ensure that the IR filter is in place in the LRO unit. The unfiltered light is extremely bright and will cause discomfort.
3. Turn the system and Illuminator power on. Turn on the LCD monitor.
4. You should see an image in the LCD monitor. Assuming the system has not been changed or moved since setup or your previous subject, the image should show a location fairly close to the subject's eye. Adjust the Aiming Mirror to find and center the subject's eye in the monitor. You want the eye positioned such that, as the subject looks around the stimulus scene, their pupil remains on the screen and the CR does not fall below an eyelid or into the sclera. See Section 5 Operating Theory for more details about positioning.



5. Adjust the Focus control so that the image is crisp. It is best to use the Corneal Reflection as your reference for focus.
6. Adjust Iris control to set the brightness of the image at an appropriate level. You are attempting to set a level such that the pupil is at an intermediate brightness between the CR and the background; and that, as the eye moves around, this distinction is maintained. See Section 5 Operating Theory for more details about brightness.
7. Turn off the LCD monitor attached to the LRO. **It is important to turn off the LCD monitor during scanning. The pulse sequences of the NMR can damage the LCD monitor if it is left on.**



8. Load the Interface Software on the Interface Computer and upload to the Control Unit as described in Section 6.2 Starting the User Interface Software.
9. You should see the eye image on the Eye Display (monitor) and your stimulus scene image on the Scene Display (monitor).
10. **Discriminate:** If the eye image is set up correctly, you should be able to activate Autodiscrimination. This will cause the system to perform its thresholding routine to locate the Pupil and the CR. If it functions correctly, you will see a white ellipse around (though slightly offset to) the pupil and a small black ellipse similarly placed around the CR. Corresponding white and black crosshairs should appear through the centers of the pupil and

CR. This is explained in more detail in Section 5.4 Discrimination. The crosshairs *must* be stable and over the correct objects or you will not be collecting valid data.

11. **Calibrate:** The system must be calibrated for each subject. This is done by displaying a calibration image on the stimulus display and having the subject look at each point in turn while performing the calibration routine described in Section 5.5.1 Subject Calibration. It is recommended that the user use the Standard 9-point calibration.
12. How you record data will vary based on your equipment and software configurations and your experimental setup. If you are using the imbedded ASL data recording methods, see the *6000 Manual – User Interface Software* document Section 5 on data files and recording data.

7. Parts Details and Maintenance

7.1 Illuminator Life Counter (option)

Some systems may have a digital timer on the Stock panel (underneath the power connector). This timer will count up the cumulative time that the Illuminator bulb is powered. The *Reset* button adjacent to the timer will reset the clock to zero.



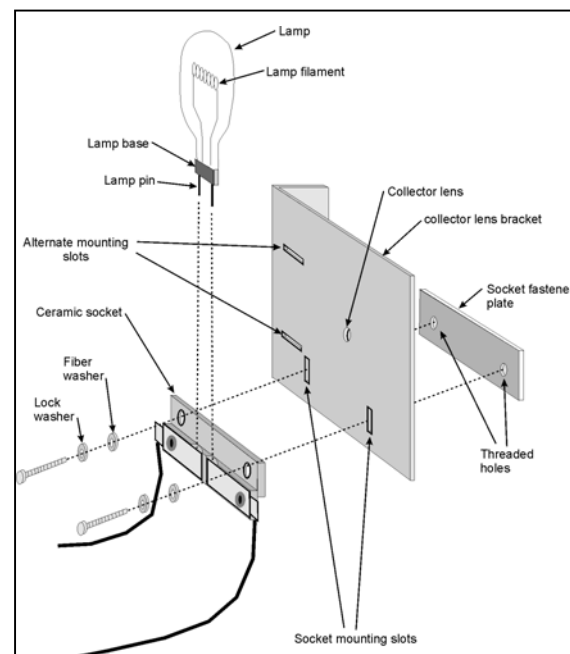
Since the Illuminator bulbs have an expected viable life of approximately 40 hours, monitoring this timer can improve system performance.

Note that the bulbs may function significantly past the point at which they have degraded to the state that they no longer provide sufficient light for effective eye tracking. Bulbs have been reported to have turned on past the 80 hour mark, however beyond 60 hours it is almost certain that bulb degradation will have taken place past acceptable limits. ASL recommends replacing the Illuminator bulb after 40 hours.

If airflow through the unit is blocked, or if there is a failure of the cooling fan, then the life expectancy of the Illuminator bulb may be significantly reduced.

7.2 Illuminator Lamp Assembly

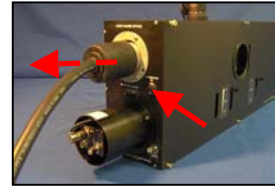
The LRO system uses a standard FCR (12 V) type bulb. It is important that the lamp element always be precisely centered with respect to the collector lens that is part of the illuminator assembly (as shown to the right). Note that removing a lamp from its ceramic socket can often cause the lamp bulb to break. When replacing a burned out bulb this obviously does not matter, but when removing a bulb for other purposes, care should be taken never to touch the crystal. Skin oil will cause the crystal to crack or cloud prematurely. If the crystal must be handled, hold it with a piece of lens tissue, plastic, or powder-free latex glove.



Use only an FCR (12V) type bulb. Other bulb types will result in poor system performance.

7.2.1 Replacing a burned out (or clouded) lamp

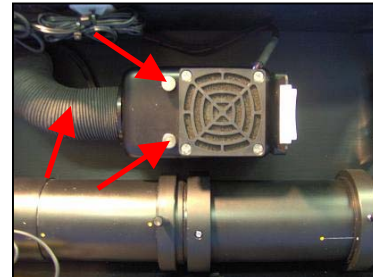
1. Be sure that Illuminator power is OFF. Unplug the power cable from the optics unit.



2. Remove the IR filter and store it in a safe place. Remove the Optical unit cover. If the Illuminator has recently been on it will be **very hot**. Wait for the Illuminator assembly components to cool before proceeding (about 15 minutes).



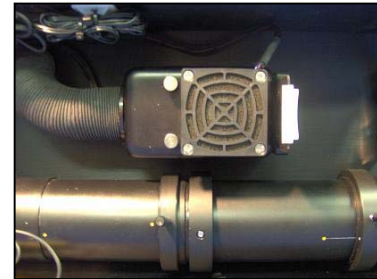
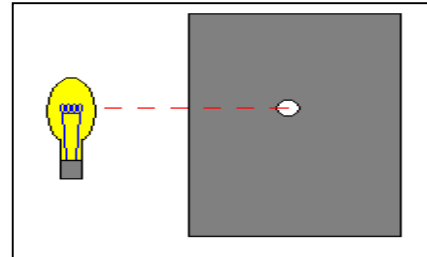
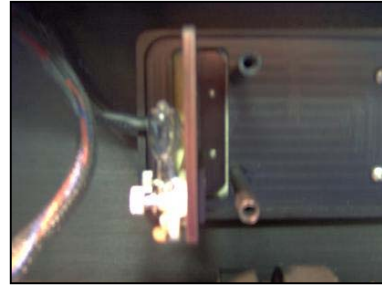
3. Remove the exhaust tube from the Illuminator cover and the back optics panel by pulling it gently away. Remove the Illuminator cover by removing the two illuminator cover fastening screws and lifting the illuminator cover, with fan attached, away from the component mounting plate. The cover will remain tethered by the wires supplying power to the fan but there is plenty of slack to allow placing the cover out of the way (for example by resting it on the illuminator side panel).



4. The Illuminator Lamp and Collector Lens mounting structure will be visible once the Illuminator Cover has been removed. If the lamp bulb will be used again in the future, do not touch the lamp crystal. **Skin oil will cause the crystal to crack or cloud prematurely.** If the crystal must be handled, hold it with a piece of lens tissue, plastic, or wear powder-less latex gloves.



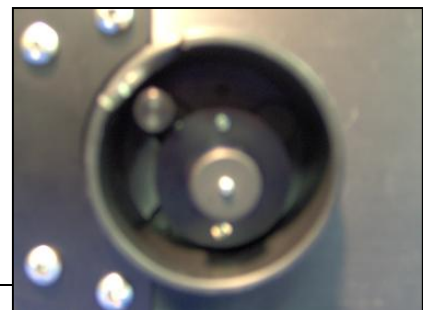
5. Pull the bad lamp bulb out of the socket.
6. Locate the replacement lamp bulb. New bulbs are usually sealed in plastic bags. Open one end of the plastic bag to expose the metal leads. Using the plastic bag to hold the crystal, insert the leads all the way into ceramic socket. *Do not touch the crystal directly; skin oil will cause the crystal to crack or cloud prematurely.*
7. If necessary, loosen the socket fastener screws just enough to allow the socket assembly to move in the mounting slots on the collector lens bracket, and position the assembly so that the lamp element is precisely centered over the collector lens. Re-tighten, but do not over-tighten the socket fastener screws. The socket should be just snug enough that it does not move.
8. Replace the Illuminator Cover and Exhaust Tube. It is easiest if the fastener screws are first completely removed from the cover. Being careful to line up the Illuminator power wires with the slot at the base of the cover (so that they are not caught between the cover and base plate), press the cover onto the Illuminator Assembly base plate so the it is securely seated. The fastener screw holes should line up with threaded standoffs to hold the fastener screws. Insert the fastener screws carefully so that they mate with the standoffs, and tighten.
9. Replace the IR filter (silver side towards illuminator lamp) and the optics unit cover.



7.3 Gross Illuminator Alignment

Use the following gross alignment procedure if a target cannot be located in the eye monitor with the Illuminator Filter removed as described in Section 4.2 Initial Illuminator and Camera Alignment and Focus.

1. Shine a bright flashlight on the same wall or surface as the Illuminator light beam. Move the flashlight beam around



on the wall to find the spot at which the eye monitor (LCD) brightens. This is the approximate spot at which the eye camera is aimed. Use the Beam Splitter adjustments to aim the illumination beam at the same spot; then return to Section 4.2 Initial Illuminator and Camera Alignment and Focus. If it is not possible to find a spot on the wall where the flashlight causes the eye monitor to brighten proceed to step 2 below.

2. Aim the flashlight directly into the optics unit aiming mirror. Move the flashlight up, down, and side to side, but always pointed so as to keep its beam aimed at the optics unit aiming mirror. Find the flashlight position that causes the eye monitor to brighten, then have a second person use the beam splitter controls to aim the illumination beam at the flashlight. If necessary move very close to the optics module to find a place where the flashlight brightens the monitor, then attempt to maintain the “bright” affect while backing farther away from the optics unit. Once successful, return to step 1.

7.4 LRO Power Cable

The cable that powers the Long Rang Optics module comes in two sections. The first section runs from the Power Supply in the Control Room to the Penetration Panel. One end has two clips (colored red and black) that are the positive and negative electrical leads to connect to the Power Supply. The other end has a 25-pin D Connector for connecting to the Penetration Panel.



The second section is for use inside of the Magnet Room. One end has a 25-pin connector for connecting to the Penetration Panel, while the other end terminates in a three-prong twist lock connector that connects to the stock end of the LRO module.



The 25-pin connector separates the 12V / 9A current into 25 individual 0.8V / 0.36A signals. This greatly reduces the possibility of the system introducing EM noise into the magnetic environment.

7.5 Penetration Panel Requirements

The NMR facility in which the ASL LRO is to be installed must have a Penetration Panel between the magnet room and the control room in order to run the necessary power and signal cables.

The panel must have an available 25 Pin filtered D Connector for connection to the Power Cable (See Section 7.4 LRO Power Cable) and a BNC Pass Thru connector.

7.6 Control Unit Variations

Depending on system requirements, some Control Units and peripheral monitors may vary in configuration.

7.6.1 Dual LCD Monitor

The standard Control Unit configuration includes two color LCD monitors attached to the top of the Control Unit. One monitor provides the Scene image and the other monitor provides the Eye image.

This configuration is provided with the base 50 and 60 Hz systems. No connection to external monitors is necessary.

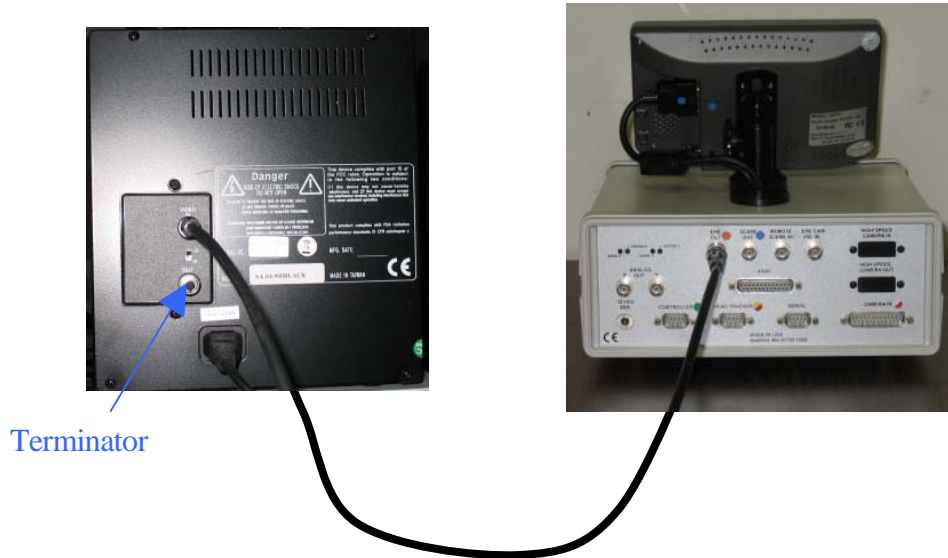


7.6.2 Single LCD Monitor + Single CRT Monitor

With some high-speed camera configurations, it is necessary to use an externally synched CRT monitor instead of an LCD monitor. In this case, a Control Unit with only one LCD monitor may have been provided. This monitor will be configured to be the Scene Monitor.



An external CRT monitor will provide the Eye Monitor image. It should be connected to the Eye Out port on the back of the Control Unit with the provided BNC cable. Additionally, a small Terminator Plug should be connected to the second BNC port on the back of the CRT monitor.



8. High Speed Camera Option

The high speed camera option provides the capability to measure eye position with a selectable update rate of 60 Hz, 120 Hz, or 240 Hz. Signal intensity (apparent image brightness) decreases in inverse proportion to update rate. Performance may be less robust at higher update rates, and at some distances and conditions that yield acceptable performance at 60 Hz, performance may become unacceptable at 120 or 240 Hz.

The camera rear panel has a set of dipswitches. Switches 4, 5 and 6 are used to set the camera to single speed 60 Hz field rate, or double speed 120 Hz or 240 Hz field rates as shown in the table below. Switch 8 is used to switch automatic gain control (AGC) on or off. All other switches should normally be in the off position.

The AGC switch is normally set to ON. When the camera is used in the 60 Hz mode this generally results in the most appropriate image. Gain can be made higher or lower than the automatic setting by moving switch 8 to OFF, and turning the gain pot. Counter-clockwise adjustment will increase the gain while clockwise adjustment will decrease gain.

When the camera is held so that the labels on the rear panel appear right side up, the switches are OFF when moved to the left, and ON when moved to the right.

MODE	S4	S5	S6
60 Hz	OFF	ON	ON
120 Hz	OFF	OFF	ON
240 Hz	ON	OFF	OFF

MODE	S8
AGC OFF	OFF
AGC ON	ON

8.1 Single speed mode (60 Hz)

To use the eye tracker in 60 Hz mode, set the HS camera switches for 60 Hz as shown in the table. With the system fully booted and the PC interface program running, pull down the Basic Configuration menu and be sure that Eye Camera Speed is set to 60. Simply follow the normal instructions for eye tracker operation.

8.2 Double speed mode (120 or 240 Hz)

When used in 120 Hz or 240 Hz, the camera is in a “double speed” mode, meaning that pixels are scanned at twice the normal rate. Use of 120 Hz or 240 Hz modes will result in a few of differences from normal operation.

The eye monitor image will look different, as it will display multiple scans of the image.

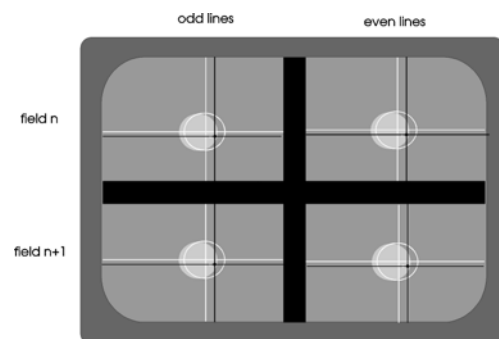
Less information will be displayed on the PC interface computer screen because there is less time to transfer information to the Interface PC. All important information (including all data that is normally recorded by the interface PC) remains.

The eye camera will appear to be somewhat less sensitive to light intensity, since the camera pixels have less time to charge up for each image field.

At 240 Hz, only half the usual vertical eye camera field of view will be available since only half the usual number of video lines can be scanned. At 120 Hz the eye camera field of view is completely normal.

8.2.1 120Hz operation

To use the eye tracker in 120 Hz mode set the HS camera switches for 120 Hz as shown in the table. On the Basic Configuration window set the Eye Camera Speed to 120 Hz. The eye monitor vertical sync adjustment may need to be turned to stabilize the monitor image. Once that is done the image should look like the sketch shown. The screen will appear to be divided into 4 images. Actually, only 2 images consisting of two sequential video fields are shown, but for each field the odd lines appear to form an image at the left of the monitor while the even lines appear to form an image on the right image. In other words the two images at the top of the monitor show field 1 (odd and even lines respectively), while the two images at the bottom show field 2.



The monitor shows multiple images because pixel are scanned twice the normal rate (double speed), while the monitor maintains the usual constant sweep rate. Thus all the pixels on line 1 have been displayed by the time the monitor electron gun has swept half way across the screen. Line two is displayed as the monitor sweeps the rest of the way across the screen. When the monitor electron gun finishes sweeping all the way across the monitor it retraces and begins displaying camera line 3; and so forth and so on.

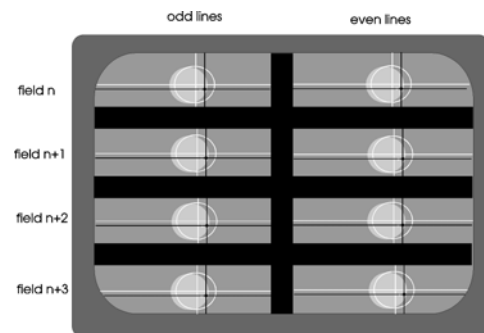
It is not really necessary to understand the above mechanism to use the system, it is only necessary to expect a screen divided into 4 images, and furthermore it is only necessary to look at any one of these. Each of the 4 images contain the same information normally seen in the single eye camera image when using the system at 60 Hz. After switching from 60 Hz to 120 Hz mode it will probably be necessary to either increase the illuminator intensity or the discriminator settings since the image will have dimmed. If necessary the camera gain pot can also be used to maximize camera gain as previously described.

Some data items will be omitted from the Interface PC display as previously described.

Follow all normal instruction manual directions for subject set up, discriminator adjustment, and data recording. When data is recorded on the Interface PC, 120 samples per second will be recorded. Note that the scene camera image continues to update at 60 Hz (or 50 Hz) and the scene monitor display should look completely normal and can be video taped in the normal fashion. If desired a 50 Hz PAL format camera can be used as the scene camera rather than the standard 60 Hz NTSC format camera.

8.2.2 240Hz operation

To use the eye tracker in 240 Hz mode set the HS camera switches for 240 Hz as shown in the table. In the Basic Configuration window set the Eye Camera Speed to 240 Hz. The eye monitor vertical sync adjustment may need to be turned to stabilize the monitor image. Once that is done the image should look like the sketch shown. The screen will appear to be divided into 8 images. Actually, only 4 images consisting of four sequential video fields are shown, but for each field the odd lines appear to form an image at the left of the monitor while the even lines appear to form an image on the right image. In other



words the two images at the top of the monitor show field 1 (odd and even lines respectively), etc.

The explanation for the appearance of multiple images in the 240 Hz mode is the same as for the 120 Hz mode. In the 240 Hz mode the pixel update rate is still double the rate used at 60 Hz just as it is in the 120 Hz mode. Since the pixel rate is only doubled and not quadrupled for 240 Hz, only half the normal number of video lines can be used. Thus, by the time the monitor sweep has reached the bottom of the monitor 4 (rather than 2) fields have been displayed.

As in the case of 120 Hz operation it is only necessary to look at one of the 8 images. The eye image will appear still dimmer than in the 120 Hz mode. Illumination level and/or discrimination settings may need to be increased, and if necessary the camera gain can be set to manual and maximized with the gain pot as previously described. Because of the decreased camera sensitivity, it may be necessary to operate with more subdued ambient lighting (resulting in a larger and brighter pupil) than when operating at slower update rates.

Unlike the 120 Hz mode the 240 Hz image has only half the normal vertical field of view. The horizontal field of view is unchanged. The result is that the optics must be positioned more carefully in the vertical axis so that the eye image is centered and remains in the camera field of view as the subject looks up and down. If pupil diameter is large the useable vertical field may be slightly reduced from the normal 35-40 degrees.

Some data items will be omitted from the Interface PC display as previously described

In all other respects, follow the Instruction Manual directions just as for 60 Hz operation.