



RobotEye RE02

3D Laser Scanning System User Manual

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Revision Table

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1 Introduction

The RE02 User Manual is provided as a guide to the connection, configuration and safe use of the Ocular Robotics RE02 3D laser scanner with the supplied RE02 Tools *software* application. For development of custom software applications for use with the RE02 system see the RE02 Network Interface Class Library Reference Manual or contact Ocular Robotics.

Chapter 2 Basics, describes the initial setup and basic use of the RE02 including information on cleaning, maintenance and safety. Chapters 3 General Description and 4 Interface, present a system description in terms of the system's Mechanical and Electrical properties and its communication and power interfaces. Chapter 5 Performance and Measurement Accuracy outlines the impact of the various system settings on system performance and the accuracy of measurements made. Chapter 6 Operation, provides a detailed explanation of the operation of the graphical user interface application supplied with the system.

CAUTION: USE OF CONTROLS OR ADJUSTMENTS OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS RADIATION EXPOSURE. IT WILL ALSO VOID YOUR WARRANTY

2 Basics

IMPORTANT – BEFORE CONNECTING THE POWER TO THIS SYSTEM OR ATTEMPTING TO OPERATE IT IN ANY WAY, READ AND FOLLOW ALL INSTRUCTIONS REGARDING SAFE OPERATION OF THIS SYSTEM CONTAINED IN SECTION 2.5.

2.1 System Components



Figure 2.1 – RE02 Packing List

The RobotEye RE02 3D laser scanning system is supplied standard with the following components, each of which can be seen in Figure 2.1:

1. The RobotEye RE02 3D laser scanning unit.
2. RE02 key control interlock and power cable.
3. Installation & documentation disk.
4. Aperture cover (Beam Attenuator).

2.2 What You Need

In order to operate the RE02 laser scanning system, you will need:

1. Power supply – A 24 volt DC 10 Amp power supply with a continuous current capacity of 10 Amps.
2. Ethernet cable – A standard Ethernet cable (Cat5e or Cat6) is needed for control and communication with the RE02 system.
3. A computer with a Windows or Linux operating system with one free 100 Megabit or Gigabit Ethernet port.

2.3 Initial Setup

Follow the steps below to set the RE02 system up for use on a computer with a Windows operating system. The steps below assume library version number RE02Lib-0.9 and RE02 system IP address 10.1.1.20. The library version number and system IP address shipped with your system should be substituted for these.

1. Connect one end of the Ethernet cable to the network port on the PC. Connect the other end to the RE02 Ethernet port.
2. Make sure the key switch on the key control interlock box is set to the OFF position. Connect the supplied power cable with interlock box to the power supply. On the unterminated end of the cable you will find two wires one black and one with a red sheath on it. The black wire should be connected to the negative terminal on the power supply. The cable with the red sheath should be connected to the positive terminal on the power supply.

Note: Make sure the power supply is not powered before connecting the cables.

3. Connect the power supply cable to the corresponding plug on the RE02 unit. Ensure the correct orientation by aligning the polarisation keys on the panel connector and the plug. If forced in the incorrect orientation, damage to the system is likely to result.

4. Installation of the RE02 system software:
 - a) Insert the disc provided.
 - b) Execute the RE02-0.9-win32.exe file to install all the necessary files into the Program Files directory.
 - c) Once installed the following files will be available:
 - i. All binaries for the RE02 reference library and RE02 Tools.
 - ii. Documentation in both HTML and PDF.
 - iii. Software examples.
 - iv. A Start menu folder RE02Lib-0.9.

2.4 Quick Start

Following the Initial setup in Section 2.3:

1. Make sure the key switch on the key control interlock box is set to the OFF position. Care should be taken at all times while operating the device and exposure to the beam should be avoided (refer to Section 2.5).
2. On the computer to be used with the RE02 system set the selected Ethernet adapter to use a static IP address of 10.1.1.X (X should not be 1 or 20) and Subnet mask of 255.255.255.0.
3. Turn on the power supply. Once the system boots up, the RE02 will move to the home position, and start with the default scan setting.
4. Start RE02 Tools, from the RE02Lib-0.9 Start Menu folder. A dialog box will appear with a drop-down menu of available RE02 IP Addresses. Select the RE02's IP Address – 10.1.1.20 and click *OK*.
5. At the *Logger Settings* tab, specify a log file directory by clicking the *Browse* button.
6. Set the timer to the desired logging duration, for example 0:02:00 will log data for 2 minutes.
7. Make sure all safety precautions have been taken (refer to Section 2.5). Turn the key switch on the key control interlock box to the ON position.
8. Press the *Start* button to begin logging. Logging will stop automatically when the countdown timer reaches 0:00:00. The scan can also be stopped at any time by pressing the *Stop* button.

9. When logging has completed, go to the *Translations Settings* tab and press the *Add* button in the Binary Conversion section to add the recently logged file.
10. Specify an output file directory for the converted files by clicking the *Browse* button.
11. Press the *Convert* button to begin conversion and wait for the process to complete.
12. Pointools View Pro and various other applications can be used to view the point cloud data that has been converted. See Section 6.2 for more information.

Note: The Key switch in the OFF position only disables the laser diode. Power remains connected to the rest of the system.

2.5 Safety

The RobotEye RE02 3D Laser Scanning System is a class 3B laser device which contains a laser which emits invisible radiation that is hazardous to the eye. All instructions regarding safe operation of this system should be strictly followed.

- **CAUTION!** - This laser device should not be aimed at the human eye. Use laser safety eyewear specifically designed for the laser wavelength emitted by the sensor whenever there is a possibility of the beam entering the eye either directly or via reflection from a surface. For the purposes of laser safety, a direct laser beam which has been deflected from a reflective surface is considered to be as intense as the direct beam.
- The user is responsible for the safe operation and maintenance of this system at all times.
- Installers of laser sensors are responsible for ensuring their safe use in accordance with all applicable regulations in the state, country or territory of use.
- Always use the RE02 system with the supplied power cable with integral key control interlock box when operating the device.
- The Key Control Interlock (Section 4.4) should always be in the OFF position before powering up the RE02 laser scanner.
- Tampering with, or deactivation of, any safety system and/or interlock potentially exposes personnel to hazardous Class 3B laser radiation, and will void warranty coverage.
- The manufacturer will not accept liability for any resulting damages caused by the non-observance of this manual or any unauthorised modification to the system.

2.5.1 Safety Features

Class 3B laser products are required to be fitted with specific safety features. These features are issued in the Laser Safety Standards ANSI Z136 and IEC 60825. The required features fitted to the RE02 System are listed below:

1. Laser Safety Warning Labels – The following laser safety warning labels are fitted to the RobotEye RE02 3D Laser Scanning System:
 - a. Laser Classification and Information Label (fitted on face near power connector)



- b. Laser Aperture Label (fitted on tube section adjacent to scanner head)



2. Remote Interlock Connector and Key Control – The Key Control Interlock box is integral to the power cable supplied with the RE02 system. It implements a captive key switch, remote interlock connector and a laser radiation emission warning light. The safety features of the remote interlock connector and key control allow an operator to disable the laser either by use of the key switch or removal of the remote interlock connector. Further description and operation information for the remote interlock connector can be found in Section 4.4.
3. Laser Radiation Emission Indicator – The indicator light on the key control interlock box when illuminated signifies that the laser is enabled.
4. Aperture Cover (Beam Attenuator) – The aperture cover prevents laser emission from the RE02 system by obscuring the aperture of the RE02 system.
5. Scanning Safeguard – A RobotEye RE02 installation can be reclassified as class 3R depending on the scan pattern, the lowest scan rate at which the laser is configured to turn on, and/or the distance from the aperture a person can approach without triggering a laser interlock device that turns the laser off. The scan rate interlock is factory configured and must be specified when ordering.

2.6 Cleaning and Maintenance

CAUTION! – Power must be disconnected from the RE02 system before any cleaning or maintenance is carried out.

User performable cleaning and maintenance of the RobotEye RE02 3D Laser Scanning System is limited to cleaning of the exterior housing and the laser window. For ANY other maintenance or repair the unit should be returned to the factory. Opening of the system enclosure will void warranty. Use the following guidelines for cleaning of the system enclosure and laser window.

- It is VERY important not to abrade or scratch the laser window during cleaning or at any other time as it has the potential to significantly degrade system performance.
- Using a soft non abrasive cloth to clean the window, make sure there are no foreign abrasive particles on the window before performing cleaning, as this may damage the window. Use no solvents, if a cloth alone is not sufficient water or Isopropyl Alcohol may be used.
- The rest of the RE02 unit housing can be cleaned with a soft damp cloth.

3 General Description

The RobotEye RE02 3D Laser Scanning System is a high performance short range laser scanning system, designed for rapid 3D cloud point imaging. The RE02 System with sample rates up to 200 kHz and high scan speeds is ideally suited to generating dense point clouds of the environment both indoors and outdoors, at ranges up to 12 meters.

The RE02's embedded RobotEye technology brings to laser scanning previously unavailable control over scanning behaviour. Three scanning schemes are currently standard with the RobotEye RE02 System. Each scan pattern is fully parameterised, so that the behaviour of the system is entirely user defined.

Full Field Scanning — When Full Field Scanning is used, the RobotEye scan parameters are the azimuth and elevation rates. Varying these parameters results in a wide variety of possible scan patterns, ranging from fast, coarse scans, to slower, more dense sampling patterns.

Bounded Elevation Scanning — In bounded elevation scanning mode, the operator is able to define a scan that covers a full 360° in azimuth but is restricted to a region of the elevation range of the RE02. Again the azimuth rate is configurable as is the line density of the scan. This mode enables the operator to concentrate the focus of the RE02 Scanner to a desired region and at the same time have complete control over the density of the samples taken in that region.

Region Scanning — The region scanning mode allows the operator to define a region within the RE02's azimuth and elevation range in which to concentrate the range scanning. The region scan mode gives the most control over the attention of the scanner with settings for azimuth rate and line spacing as in the bounded elevation scan as well as the extent of the scan region relative to its top left hand corner where it will scan repeatedly until a different scan is commanded.

The RE02 3D Laser Scanning System is also able to reconfigure or swap between any of these scanning modes immediately, making dynamic control of the scanner behaviour easy. More detailed explanation of these scanning modes is included in Section 6.

3.1 Mechanical

The RE02 System has an environmental protection rating of IP65 and can operate in ambient temperatures of up to 40°C making it suitable for use in a wide range of industrial environments. The bounding dimensions and positions of mounting holes for the RE02 are shown in the diagrams below.

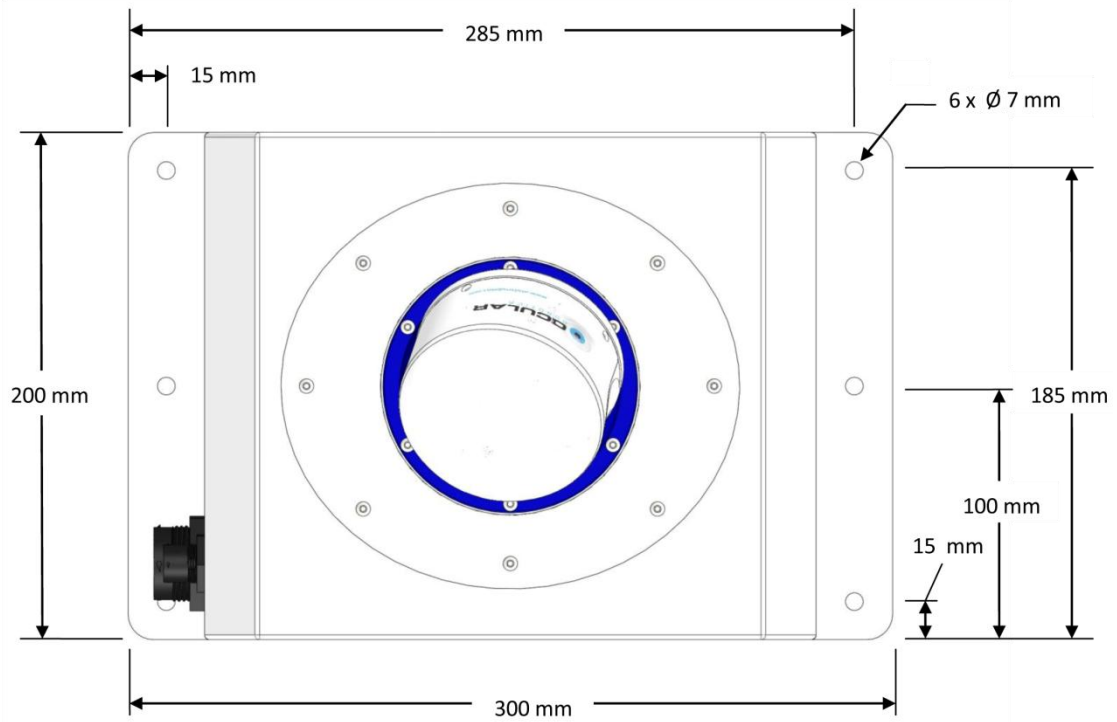


Figure 3.1 - Top View of an RE02 Unit

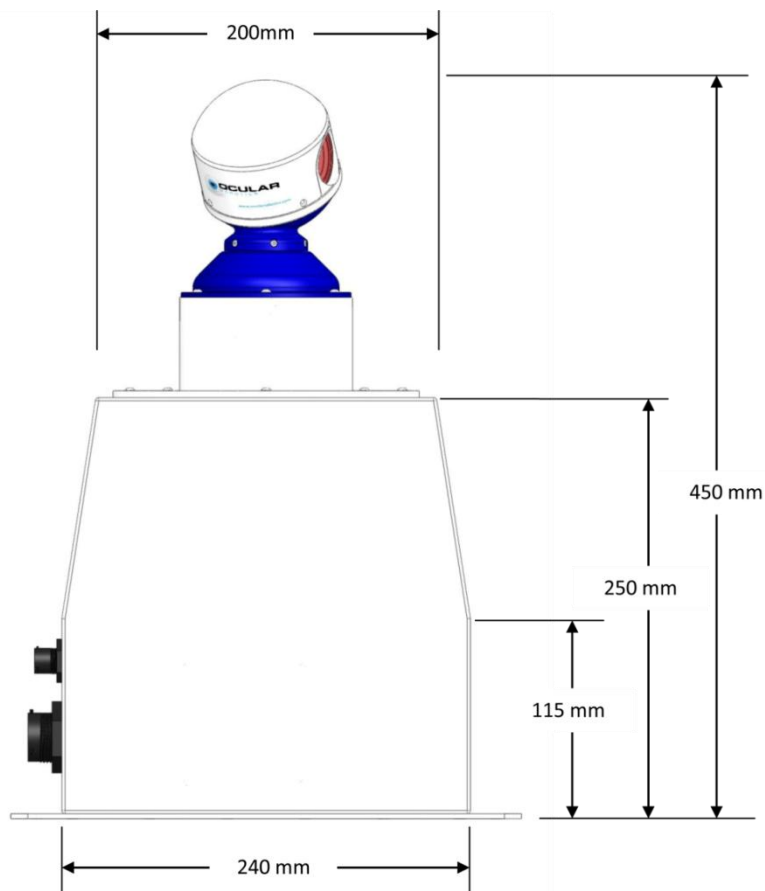


Figure 3.2 - Side View of the RE02

3.2 Electrical

The RE02 System requires a 24 volt DC power supply that has a continuous current capacity of 10 amps. The output voltage of the 24 VDC power supply used with the RE02 System should not vary by more than $\pm 15\%$ from the nominal 24V under any circumstances otherwise damage to the RE02 System may result.

4 Interface

This section of the manual describes the connection of the RE02 System to its Ethernet and power interfaces and the operation of the key control interlock box.

4.1 Ethernet

The RE02 System interfaces with a computer via a standard Ethernet cable. The RE02 supports Gigabit connectivity however a 100 Megabit connection is sufficient for operation even at the highest data sampling rates.

It is recommended that the system be used on a private network to avoid large amounts of (unwanted) data potentially being sent to all computers on the network (see Figure 4.1). Multiple RE02 Systems can be connected on a single network. However this should be done using a switch to avoid data collisions on the network (see Figure 4.2).

The RE02 is configured to allow any number of clients to receive data when in broadcast mode. The RE02 will only accept commands from the Primary Client however. This is to ensure that multiple clients cannot simultaneously send conflicting commands to the sensor. The Primary Client is determined by the RE02 in a very simple manner, it is the client that first sends data to the RE02 after it is powered up. For a more detailed explanation of the network behaviour of the RE02 System see the RE02 Network Interface Class Library Reference Manual available for download from the Ocular Robotics website.

In most situations use of a Cat5e Ethernet cable will be sufficient for operation of the RE02 system, however it is recommended that a Cat6 cable be used over long distances to avoid packet loss due to the large volume of data.

The RE02 System enclosure has an IP65 rated (when used with the mating cable plug) RJ45 connector for use when environmental conditions require. The mating cable plug is a Souriau UTS6JC18RJN and can be purchased as an Ethernet cable assembly from Ocular Robotics or through various suppliers of electronic connectors.

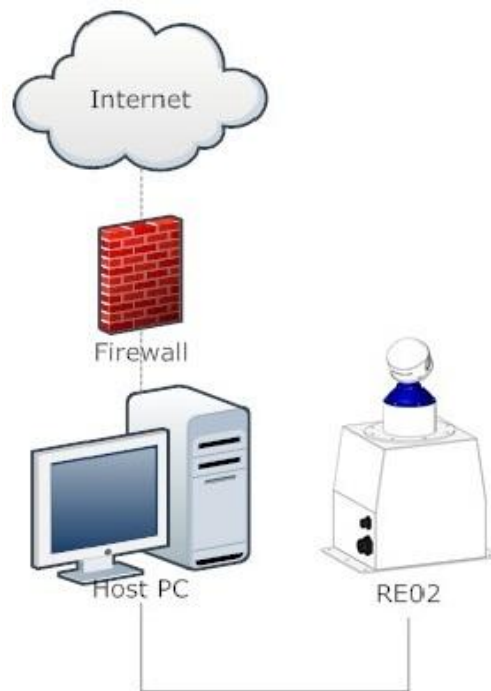


Figure 4.1 – Network Schematic for Single Host PC to Single RE02

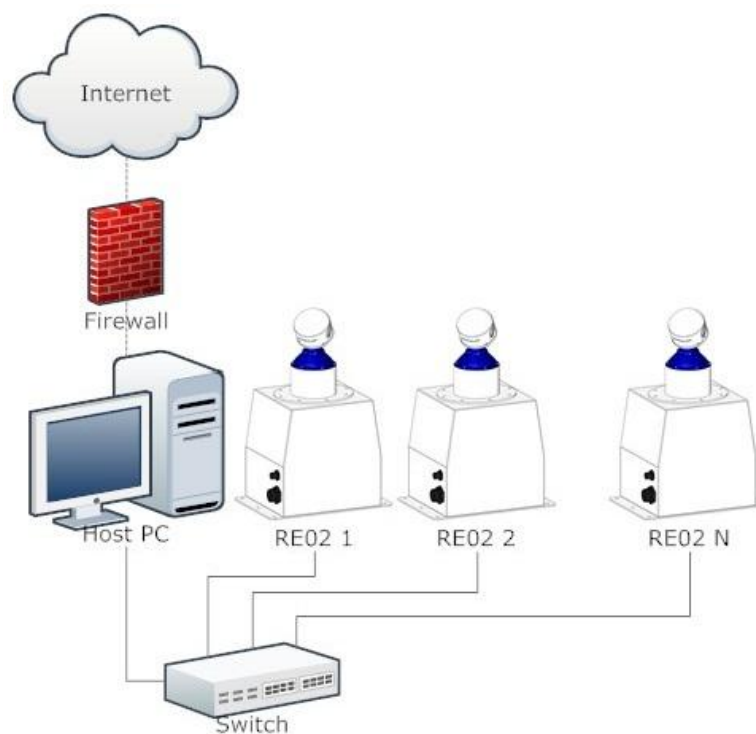


Figure 4.2 – Network Schematic for Single Host PC to Multiple RE02s

4.2 Power

Power is delivered to the RE02 with the supplied 5 metre power cable with integral key control interlock box. Operation of the key control interlock is described in Section 4.4.

The unterminated end of the power cable has two wires one black and one with a red sheath on it. The black wire should be connected to the negative terminal on the power supply. The cable with the red sheath should be connected to the positive terminal on the power supply.

During connection of the power supply cable to the corresponding plug on the RE02 unit, ensure the correct orientation by aligning the polarisation keys on the panel connector and the plug. If forced in the incorrect orientation, damage to the system is likely to result.

Note: Never operate the RE02 System without the supplied power cable with integral key control interlock box, see Section 2.5, Safety.

4.3 Scan Rate Interlock

The scan rate interlock is a factory configured setting that turns the laser diode off whenever the laser aperture is moving at less than approximately $300^\circ/\text{s}$ ($<1\text{Hz}$). This ensures that the laser diode is off whenever the aperture is stationary or moving at a very slow rate. The scan rate interlock may be configured at the factory to turn the laser off whenever the scan rate is below any specified speed making it possible under some circumstances to reclassify the installed system as a Class 3R laser system.

Note: The scan rate interlock must be configured during manufacture, or returned to the factory for adjustment. The scan rate interlock is NOT user adjustable; opening of the system enclosure for any reason will void warranty.

4.4 Key Control Interlock

The key control interlock box shown in Figure 4.3, is a key operated safety device implemented to allow the laser diode to be turned on and off as required. The key switch on the interlock box only turns the laser off, power remains connected to the rest of the system. The key can only be removed when it is in the off position. There is a laser radiation emission warning light on the key control interlock box that indicates whether or not the laser is activated. A remote interlock connector is included as part of the key control interlock box, when the connector is removed the laser is disabled. This

connector allows the user to connect a remote barrier switch, emergency stop switch, or similar device. The laser is disabled if the circuit is opened. The plug provided has terminals joined to allow operation with no external loop.

Figure 4.3 shows the key control interlock box with the following features:

1. Key – The key is used to turn the laser diode on and off.
2. OFF – The key switch is in the OFF position when the key is turned anti-clockwise and pointing to the OFF label.
3. ON – The key switch is in the ON position when the key is turned clockwise and pointing to the ON label.
4. Laser radiation emission indicator warning light – The laser radiation emission indicator will turn on when the key switch is in the ON position, indicating that the laser diode is enabled. There is a delay of 18-20 seconds before actual laser emission.

Note: The section above describes the operation of the key control interlock. Before operating the RE02 System read Section 2.5, Safety, for an explanation of the purpose of the key control interlock.

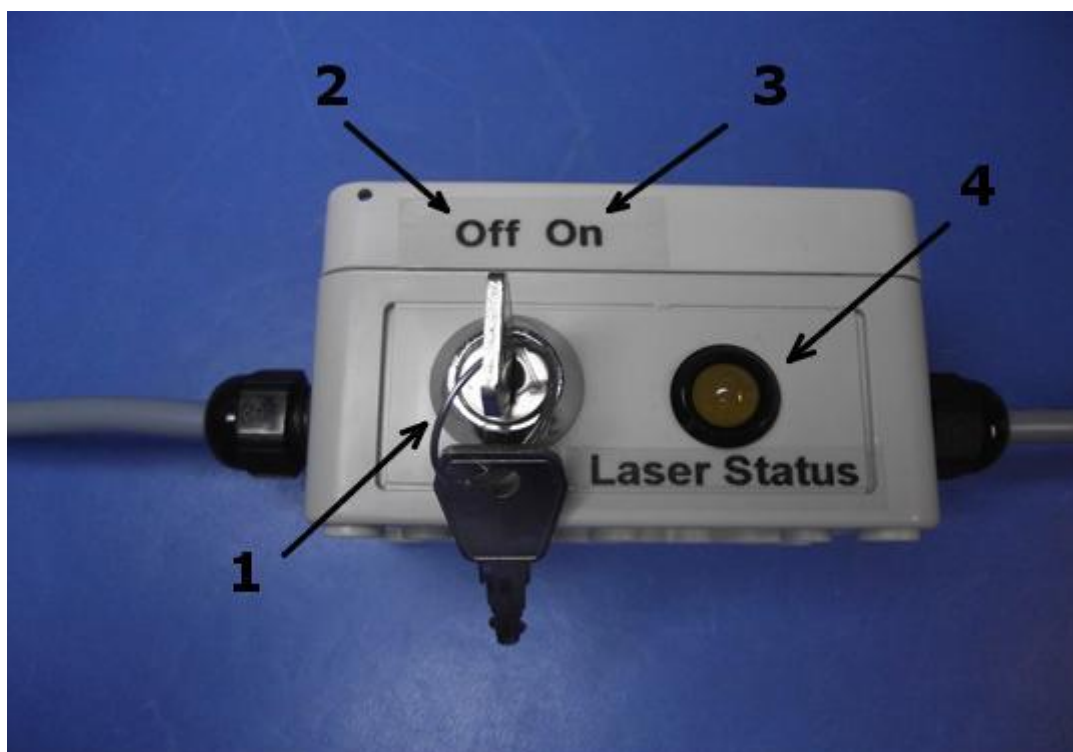


Figure 4.3 –The Key Control Interlock Box

5 Measurement Accuracy

This section outlines the expected system performance and measurement accuracy of the RobotEye RE02 3D Laser Scanning System and how system settings affect the expected performance.

5.1 Angular

The RE02 laser scanner natively records each 3D data point in spherical coordinates of *range*, *azimuth*, *elevation* and additionally *intensity*. The accuracy of the two angular components of *azimuth* and *elevation* along with the *range* measurement determine the accuracy with which each data point can be placed in 3D space.

The angular resolution of the *azimuth* and *elevation* components is 0.01° and 0.004° respectively. The angular accuracy is $<0.05^\circ$ for both *azimuth* and *elevation*. Due to the fact that the aperture position in *azimuth* and *elevation* for 3D data points is tracked separately from the aperture motion control, the accuracy of the reported *azimuth* and *elevation* aperture angles is independent of any path following errors of the aperture. This means that regardless of what type of scan mode or *azimuth* and *elevation* rates are set the angular accuracy of the positions of the points reported by the RE02 are unchanged.

5.2 Range

The range sensor used in the RobotEye RE02 3D Laser Scanning System is the AR4000-LIR rangefinder from Acuity Laser Measurement of Portland, OR.

The AR4000-LIR accurately measures range to a wide variety of surfaces and materials. The rangefinder achieves measurement accuracy nominally of 7.5mm as configured for use with the RE02, however measurement accuracy for any particular scenario will be determined by factors such as sample rate, nature of the surface being measured and ambient light levels.

The effect on range measurement accuracy due to the user settings of the RE02 comes from two sources firstly Sample Frequency and secondly Max Range. The effect of Sample Frequency comes from the fact that the lower the sample frequency the more individual measurements of the AR4000 are averaged to give each reported measurement thus ameliorating some of the sensor noise sources discussed in Appendix B. The effect of Max Range similarly when shorter maximum ranges are

specified the internal sampling frequency and measurement resolution of the AR4000 are increased allowing more samples to be averaged at increased resolution for each reported measurement.

For a more detailed discussion see Appendix B where the Acuity AR4000 Performance and Measurement Accuracy User Manual section has been reproduced.

6 Operation

6.1 Using RE02 Tools

This section describes the RE02 Tools application supplied by Ocular Robotics for operation of the RE02. The RE02 Tools are intended to provide a quick and easy method of interfacing to the RE02, gathering range data, and converting the range data into a form that is usable by third party point-cloud visualisation software. The RE02 system is also shipped with an interface library (both for Windows and Linux) to enable custom applications to be created by RE02 users. RE02 Tools itself was built using the RE02 class library. For more information on the RE02 class library, please see Section 6.3 and the RE02 class library manual.

6.1.1 Workflow

The RE02 Tools application is separated into three main sections; *RE02 Settings*, *Logger Settings* and *Translation Settings*. Each of these sections is contained within its own tab on the main RE02 Tools dialog. The tabs are arranged in what is anticipated to be the most commonly used workflow of the RE02 system. See Figure 6.3 to see the tab layout of RE02 Tools.



Figure 6.1 – The Standard RE02 Tools Workflow

Figure 6.1 shows the normal workflow for the system, which can be explained as follows:

1. **RE02 Configuration** – first, change any configurable properties of the RE02 sensor using the *RE02 Settings* tab
2. **Log to Raw Binary Files** – now that the RE02 is configured, log the data produced by the sensor using the *Logger Settings* tab. For reasons of speed and efficiency, the data is logged to a proprietary binary format
3. **Convert Binary Files for Visualisation** – finally, once the desired RE02 data has been logged to file, the data will need to be converted from the proprietary binary format to a format suitable for interpretation by a third party visualisation tool

(currently only ASCII Comma Separated Value (CSV) files are supported as output) using the *Translation Settings* tab

Although it is anticipated that the workflow described above represents the primary use case of RE02 Tools, it is not the only way the application can be used. It is possible, for example, to start the system logging data, and then change the settings of the RE02 whilst the log is still recording. This may be useful if a log containing multiple scan patterns is desired.

6.1.2 Connection

First, before executing RE02 Tools, you must ensure that the computer that will be running RE02 Tools has an IP Address that is compatible with the RE02 IP Address (or vice versa). See Section 6.46.4 for an explanation of how to do this. Upon execution of RE02 Tools, you will be presented with a dialog used to select the IP address of the RE02 sensor it is desired to receive data from. Once the IP address of the RE02 sensor has been selected, click *OK*, and the main RE02 Tools dialog should appear. You should see several indicators in the status bar, indicating the connection status (green icon), laser diode status (red icon), and number of samples per second received from the RE02 sensor, if the IP configuration was successful.

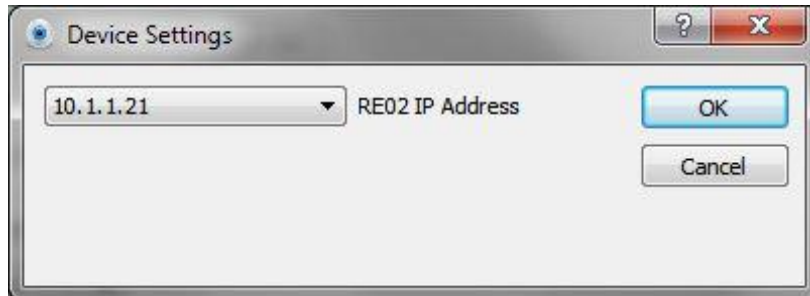


Figure 6.2 –The Device Connection Dialog

6.1.3 The RE02 Settings Tab

On the RE02 Tools dialog, the *RE02 Settings* tab is displayed by default. This tab allows all of the RE02 sensor's configurable settings to be altered. The tab is broken into three sections: *Scan Patterns* is used to set and configure the RE02's current scan pattern (the path the RE02's aperture will trace); *Frequency and Range Settings* is used to configure the RE02's sample rate (which will affect data acquisition rate and range accuracy) and maximum range, and *IP Settings* which is used to configure the IP settings of the RE02 sensor if the factory defaults are not suitable for your network configuration.

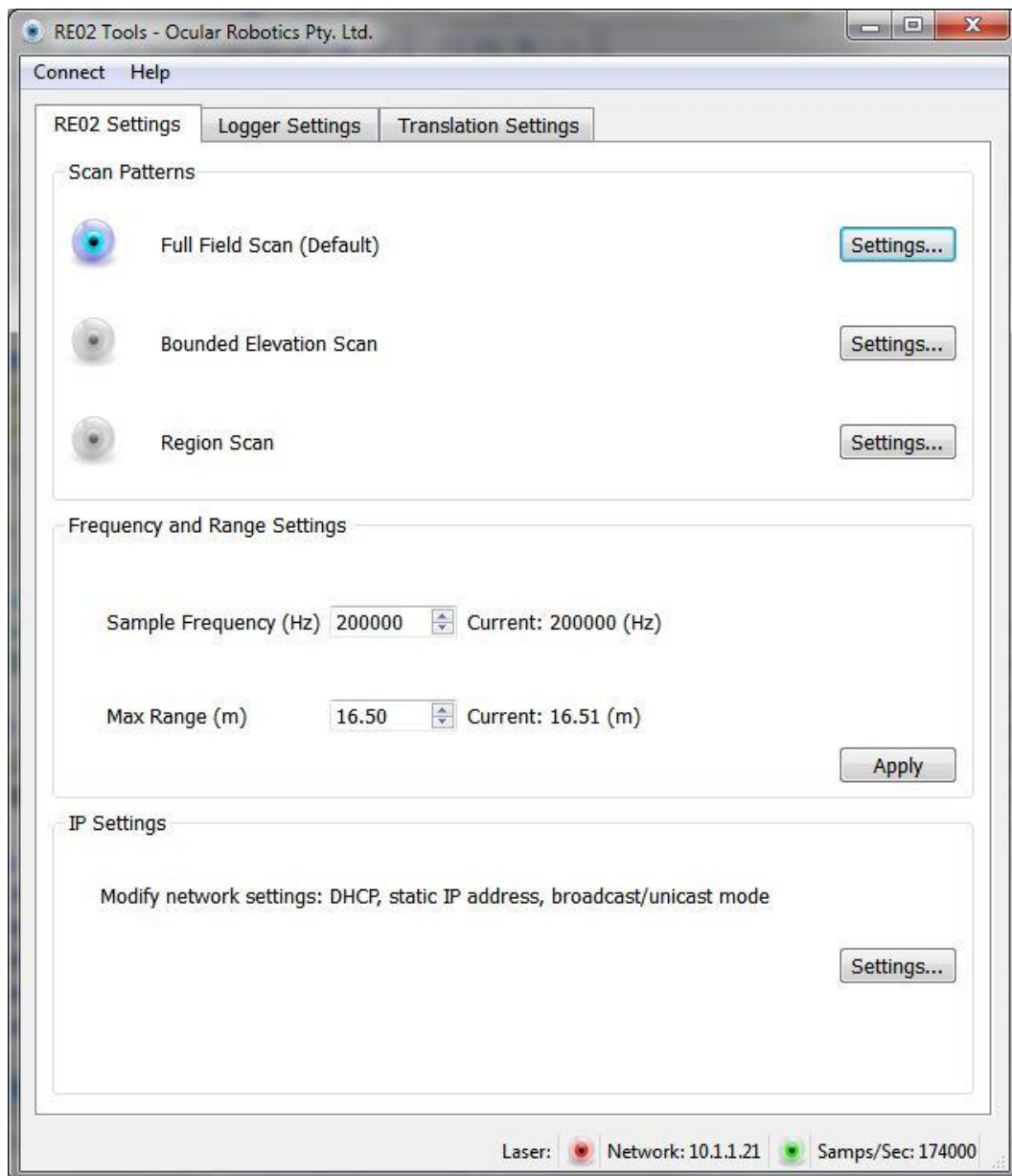


Figure 6.3 - RE02 Tools, Showing the RE02 Settings Tab

6.1.4 Scan Patterns

The RE02 currently supports three configurable scan patterns; the *Full Field Scan*, *Bounded Elevation Scan*, and *Region Scan*. The currently executing scan pattern is indicated by the blue Ocular Robotics eye logo. These scan patterns are able to be altered, or switched between on-the-fly (usually within a couple of milliseconds of the command being sent) which is an unprecedented capability for a 3D laser scanner. Each scan pattern is fully parameterised, meaning that the parameters (or variables) that define the way the aperture moves can be altered by the user to create the arbitrary scanning behaviour demanded by a given application. Users are encouraged to explore

the range of options available to them, so that an 'optimal' configuration can be found for the problem at hand.

The settings for each of these scan patterns will be examined in the following sections.

6.1.4.1 The Full Field Scan

Parameters:

Azimuth Rate – in Hz (min: 0, max: 10, default: 3)

Elevation Rate – in Hz (min: 0, max: 2, default: 0.1)

The Full Field Scan is the default scan setting for the RE02 sensor. Once the system has powered up, it will begin scanning in this mode.

This mode is completely parameterised by two variables: the *Azimuth Rate* and *Elevation Rate*, which are given in units of Hertz (Hz) or sweeps per second. An *Azimuth Rate* of 1Hz is therefore equivalent to one rotation per second in azimuth, or 360 degrees per second. An *Elevation Rate* of 1Hz is defined as one sweep from one extent of the total elevation range to the other (i.e. -35 degrees to 35 degrees) per second, or 70 degrees per second.

It is important to note however, that, for a given *Elevation Rate*, the Elevation velocity of the RE02 laser aperture **is not constant**. This is due to the non-linear nature of the RE02's scanning mechanism. Instead, the Elevation trajectory (and therefore, also the velocity) will vary sinusoidally with respect to the given azimuth. The relationship between elevation and azimuth in this scan mode is given by:

$$Elevation = 35 * \sin(\omega * Azimuth) + C$$

Where the angular frequency ω is calculated from the input parameters as:

$$\omega = \frac{Elevation Rate}{2 * Azimuth Rate}$$

This can be seen in Figure 6.4, where the picture in the *Full Field Settings* dialog shows an example of an RE02 trajectory in aperture space when *Azimuth Rate* = 10Hz and *Elevation Rate* = 1Hz over a period of one second. As expected, in a one second period, the RE02 aperture has rotated in azimuth ten times, and has swept in elevation from the bottom to top extents exactly once. The 'bunching' at the top and bottom of the diagram are slowdowns one would expect at the top and bottom of a sinusoid.

The full field scan is primarily of use when it is desired to obtain data from the full range of apertures available using the RE02 sensor. Because of the configurable nature of the scan pattern, it is possible to obtain a 'coarse' scan, followed by a 'dense' scan if desired, simply by changing the *Azimuth* and *Elevation* Rate parameters at the appropriate moment.

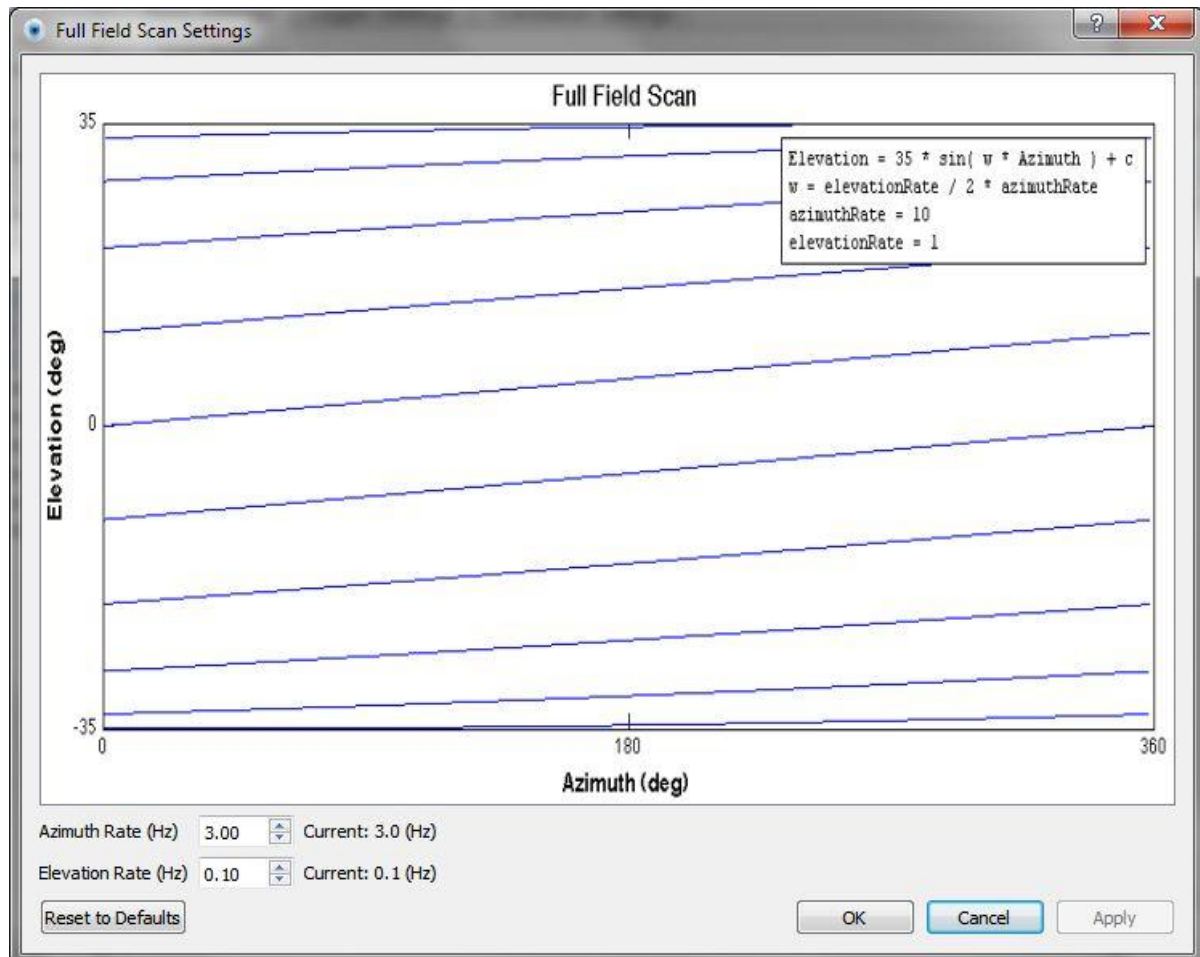


Figure 6.4 – The Full Field Scan Settings Dialog

6.1.4.2 The Bounded Elevation Scan

Parameters:

Azimuth Rate – in Hz (min: 0, max: 10, default: 3)

Line Spacing – in degrees (min: 0.1, max: 5, default: 0.5)

Lower Elevation – in degrees (min: -35, max: 35, default: -20)

Upper Elevation – in degrees (min: -35, max: 35, default: 20)

The *Bounded Elevation Scan* pattern is similar to the *Full Field Scan* with two important differences. First, the lower and upper extents in elevation can be configured, thus limiting the RE02 sensor's vertical field of view, and second, the parameterisation is in aperture space, meaning that the scan trajectory won't exhibit the 'bunching' at the top and bottom of the scan shown by the *Full Field Scan*.

In this mode, the vertical extents of the scan in aperture space are defined by the parameters *Lower Elevation* and *Upper Elevation*. The *Line Spacing* parameter defines the vertical spacing, in degrees, between the (mostly horizontal) scan lines. See Figure 6.5 for an example of how these parameters affect the trajectory of the RE02 sensor.

An application where the bounded elevation scan is useful is in capturing a 3D image of a specific section of an environment. For example, to scan just the upper section of a room, the *Lower* and *Upper Elevation* settings can be adjusted as desired to prevent the sensor from taking unwanted measurements of the lower section of the room.

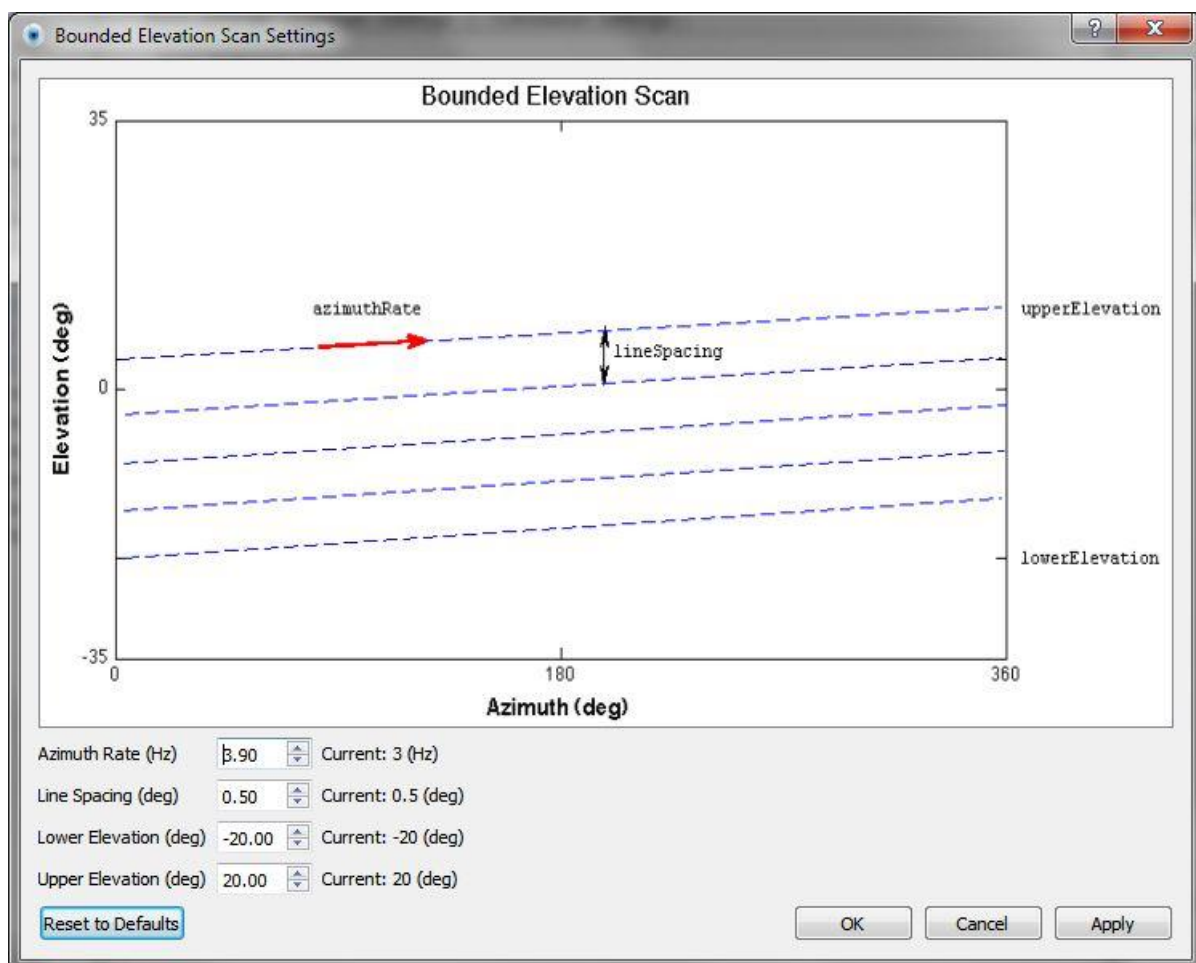


Figure 6.5 – The Bounded Elevation Scan Settings Dialog

6.1.4.3 The Region Scan

Parameters:

Azimuth Rate – in Hz (min: 0, max: 10, default: 3)

Line Spacing – in degrees (min: 0.1, max: 5, default: 0.5)

Initial Azimuth – in degrees (min: 0, max: 360, default: 20)

Initial Elevation – in degrees (min: -35, max: 35, default: 20)

Delta Azimuth – in degrees (min: 0, max: 360, default: 30)

Delta Elevation – in degrees (min: 0, max: 70, default: 30)

The *Region Scan* pattern is a parameterised scan pattern intended to allow a user to focus in on a subject in the environment and obtain dense 3D data from just that area, and no others. The scan pattern is similar, but not identical to a standard 'raster' pattern used in many applications, such as television and computer graphics. The specific pattern used for the RE02 sensor can be seen in Figure 6.6, which also shows the parameters used to define the specific trajectory required.

When viewed in aperture space, the pseudo-raster pattern is scanned over a rectangular region which is defined by the *Initial Azimuth*, *Initial Elevation*, *Delta Azimuth* and *Delta Elevation* parameters. The *Initial Azimuth* and *Initial Elevation* define the coordinates of the top-left corner of the scan rectangle, while *Delta Azimuth* and *Delta Elevation* define the width and height of the rectangle respectively. As with the *Bounded Elevation Scan*, the *Line Spacing* parameter is the distance, in degrees, between the horizontal scan lines.

The region scan is useful when it is desired to scan a specific region of space or a specific object where a 360 degree view of the environment is not required.

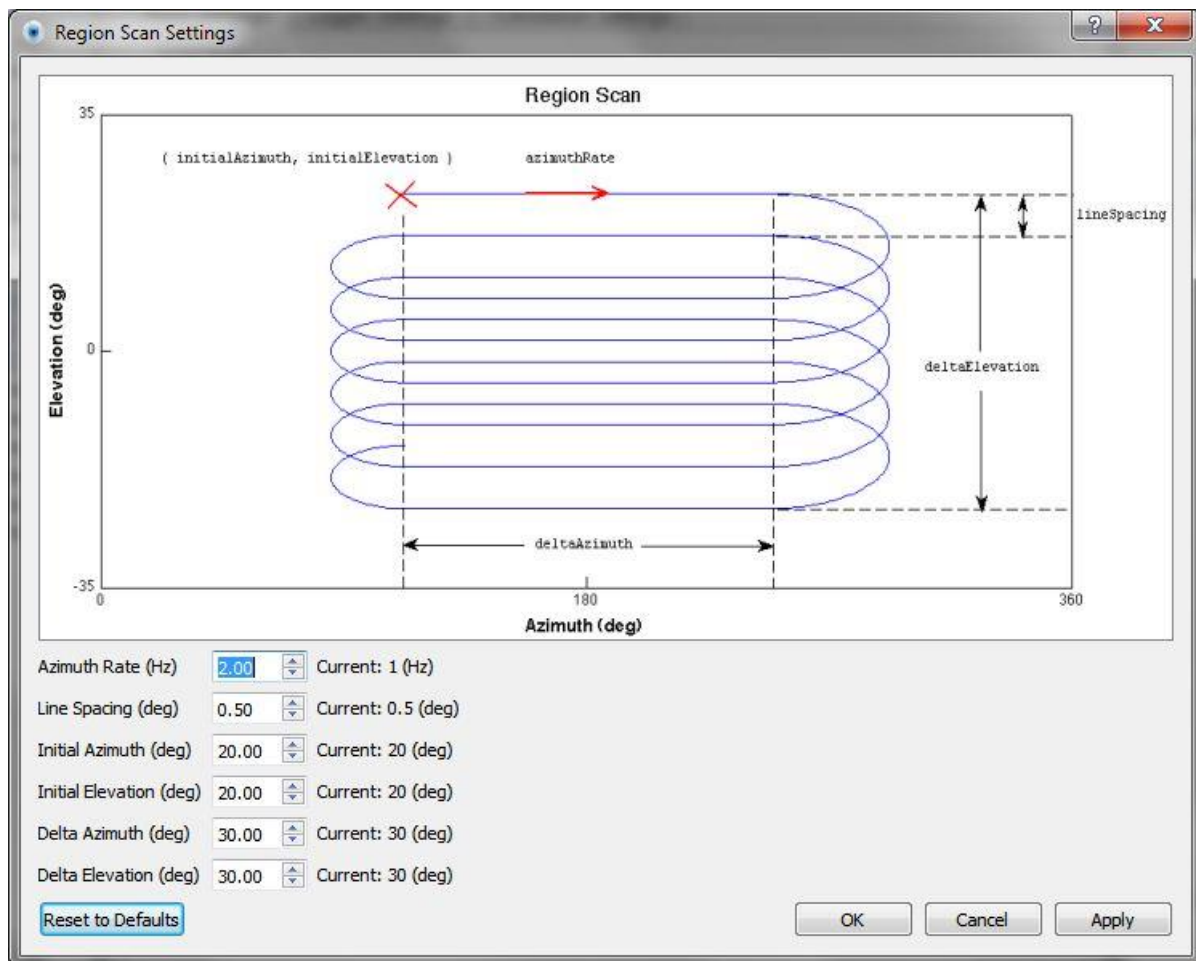


Figure 6.6 – The Region Scan Settings Dialog

6.1.5 Frequency and Range Settings

Parameters:

Sample Frequency– in Hz (min: 50, max: 200,000, default: 200,000)

Max Range – in meters (min: 0, max: 16.51, default: 16.50)

Using these settings, users can specify the desired sample frequency and the maximum range for the laser sensor.

Note that the maximum sample frequency of 200,000Hz may result in range data that is less accurate than data produced at lower sample frequencies, however the higher the sample rate, the faster that a given data density can be achieved.

6.1.6 RE02 Network Settings

By default, the RE02 sensor will be delivered with a factory defined *Static IP Address*. In Figure 6.7 it can be seen that the RE02 sensor has the static IP Address 10.1.1.20. For a given network configuration (contact your network administrator, if necessary, for advice) this may not be desirable. In such cases, you can configure the sensor with another static IP address, or you can enable *DHCP* (Dynamic Host Configuration Protocol) for automatic IP configuration. In either case, it is necessary to temporarily connect to the RE02 from a computer with compatible IP settings to effect the change.

6.1.7 RE02 Transmit Mode

The transmit mode of the RE02 can be configured to one of two settings, *Broadcast*, or *Unicast Mode*.

In *Broadcast Mode* all RE02 range data is sent to the broadcast address on the local subnet of the RE02. This enables any clients connected on the same network subnet to receive and use the data. However, this has the potential to be problematic on a shared network where the broadcast data may degrade network performance for other users.

Unicast Mode puts the RE02 into a mode whereby the range data is sent only to the 'primary' client. The 'primary' client is defined by the RE02 system as the first client to send data to the RE02 unit after power-up (or change of network configuration). In a fully switched network, this will result in the RE02 data only affecting the network performance of the RE02 sensor and the primary client computer, and no other computers on the network will 'see' the data.

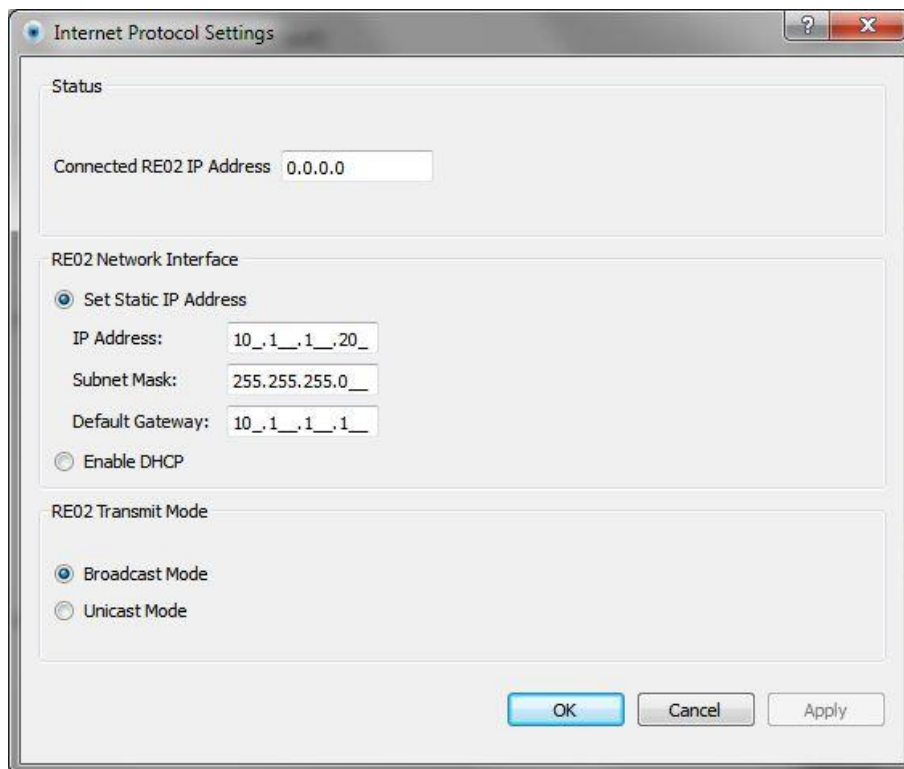


Figure 6.7 – The Internet Protocol Settings Dialog

6.1.8 The Logger Settings tab

The *Logger Settings* tab contains all of the settings used to configure and execute the logging system. As can be seen in Figure 6.8, the *Logger Settings* are divided into four main sections: the *Binary Data Format*, the *File Settings*, *Logging*, and the *Notes* section. Each of these four primary settings will be examined in detail in the sections that follow.

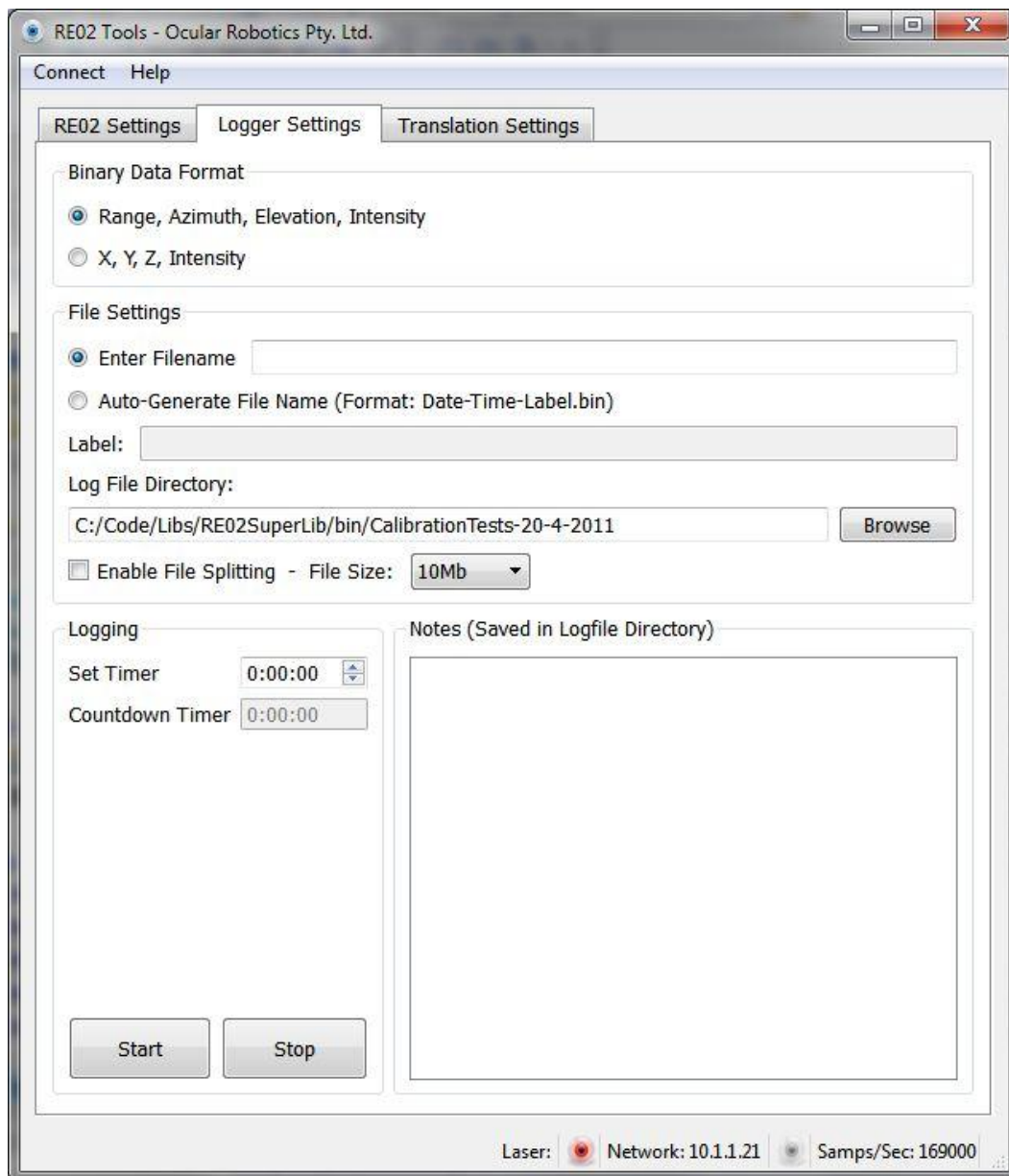


Figure 6.8 – RE02 Tools, Showing the Logger Settings Tab

6.1.8.1 Binary Data Format

As described previously, the RE02 Tools log the RE02 sensor data in a proprietary binary format. Within the files, however, the data can be stored in the original polar form (*Range, Azimuth, Elevation, Intensity*), or in a conventional Cartesian format (*X, Y, Z, Intensity*).

The inclusion of this feature is primarily intended for Ocular Robotics' internal use, and the defaults are unlikely needed to be changed.

6.1.8.2 File Settings

By default, the logfile produced by the logger will be given the name typed into the *Enter Filename* text box and be given the suffix “.bin” (i.e. don't include a file suffix in the filename). If the *Auto-Generate File Name* is selected, the logger will automatically save the logfile with a file name given by the format: Date-Time-Label.bin, where the *Label* is entered into the appropriate text field. This is useful when recording multiple logs in a single location at different times of day for example, so entering the current location in the *Label* text box results in meaningful file names for later analysis.

The *Log File Directory* must be set before logging can begin. It sets the default location that subsequent logfiles will be saved to.

The *Enable File Splitting* option allows the logfile to be split into 10, 20, 50 or 100Mb 'chunks' during logging. This is a useful feature when it is anticipated that the integrity of the logging computer may be compromised (e.g. power failure), or if file size limitations may be encountered, as it reduces the amount of data that can be potentially corrupted under these circumstances.

6.1.8.3 Logging

The *Start* button will initiate the logging process once all the logger settings have been configured. The *Stop* button can be pressed at any time, terminating the logging process and saving the logged data in the folder specified.

Note: Before pressing *Start*, check that the safety interlock key is in the ON position. This will turn the laser diode on so that meaningful measurements can be obtained.

Caution: Care should be taken while operating, and exposure to the beam should be avoided. Make sure appropriate safety equipment is worn, and no one is in the vicinity of the laser diode before turning the key to the ON position (See Section 2.5 for more information).

The *Set Timer* option allows the user to pre-program an amount of time that they would like the logger to run for. The time format used here is HH:MM:SS. If this option is used, the *Countdown Timer* will display the remaining time left for the current log.

6.1.8.4 Notes

The *Notes* section allows the user to write notes for the scan before the scan commences. This is useful for writing down observations or any other details which might be useful in later analysis of the data. This file will be saved in the same directory as the Log file.

6.1.9 The Translation Settings Tab

The *Translation Settings* tab contains all of the settings used to configure and execute the file translation process. As can be seen in Figure 6.9, the *Translation Settings* are divided into two main sections: the *File* section and the *Conversion Settings* section. Each of these settings will be examined in detail in the sections that follow.

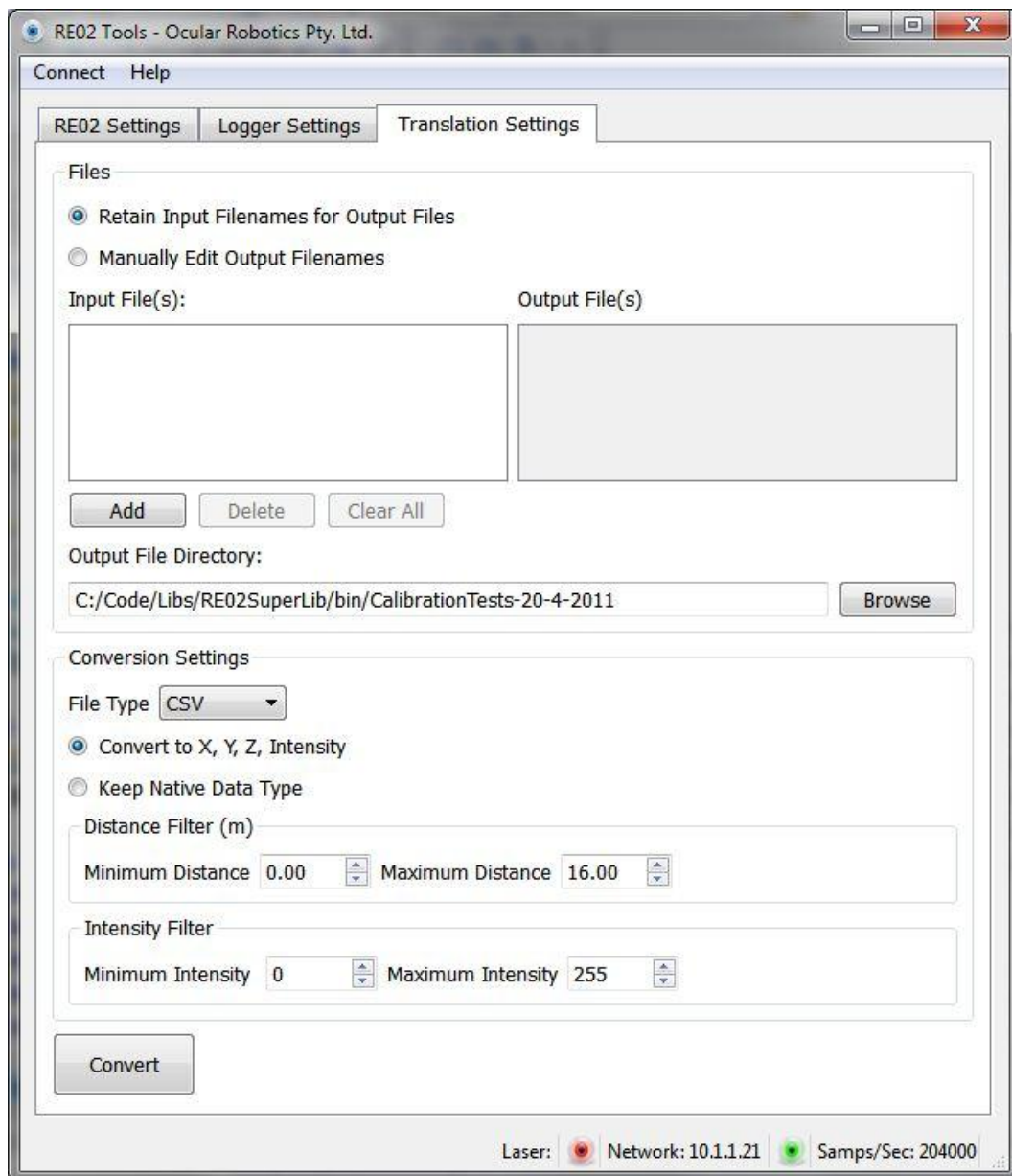


Figure 6.9 - RE02 Tools, Showing the Translation Settings Tab

6.1.9.1 Files

Files are added in the *Input File(s)* box, by clicking the *Add* button. More than one file can be selected if it is desired to convert a batch of files using the same settings. By default, the files produced during the conversion process will have the same filename as the input files (although they will be given a suffix appropriate to the output file type (by default “.csv”). Alternatively, if *Manually Edit Output Filenames* is selected the output filenames in the *Output File(s)* box can be manually edited by double-clicking on them.

The *Output File Directory* must be set before conversion can begin. It sets the default location that subsequent output files will be saved to.

6.1.9.2 Conversion Settings

Currently ASCII Comma Separated Value (CSV) files are the only supported output format. The *File Type* drop-box is included here for future expansion.

As with the *Binary Data Format* option, the *Keep Native Data Type* and *Convert to X, Y, Z, Intensity* options are primarily intended for Ocular Robotics' internal use, and the defaults are unlikely to be needed to be changed.

The *Distance Filter* option allows for data outside of the given *Minimum Distance* and *Maximum Distance* to be filtered out during the conversion (i.e. data outside of the given range will not be transferred to the output file). Similarly, the *Intensity Filter* removes data from the output file that falls outside of the given *Minimum Intensity* and *Maximum Intensity*.

6.1.10 Logging Scenarios

This section presents several different scenarios where the non-default options of the RE02 Tools application may be of use.

Scenario 1: Storage Capacity is Limited – Although the file sizes generated by RE02 Tools can be estimated based on the sample frequency and log duration, it is possible to exceed the available storage capacity of the computer used to record the data. Using the file splitting feature of the *Logger Settings* Tab (see Section 6.1.8.2) will minimize the amount of data that could potentially be lost once the available storage capacity has been exceeded.

Scenario 2: Logging for a Specific Duration of Time – In many circumstances it is desirable to log data for a specific amount of time. This may be based on the particular RE02 scan settings and sample frequency used. In this scenario, the *Set Timer* option (see Section 6.1.8.3) allows the log duration to be precisely specified. Remember the log can be prematurely terminated simply by pressing *Stop*.

Scenario 3: Cleaning up the Data – In any 3D scanning system, there may exist a certain amount of 'noise' in the data, which it is desirable to remove. The RE02 Tools allow a very simple filter to be applied to the data during file conversion in order to achieve this task. Data with low intensity tends to contain outliers, and these may be very simply removed using the *Distance Filter* and *Intensity Filters* on the *Translation*

Settings tab respectively (see Section 6.1.9.2). More advanced data cleanup can be performed using a variety of third-party applications.

6.2 Point Cloud Visualization

Once a 3D scan from the RE02 has been recorded, it is often desirable to view the resulting point cloud for analysis. The CSV files produced by the RE02 Tools are able to be imported by a variety of third-party visualization applications; however this example will only show the import process for the application used internally at Ocular Robotics: Pointools View Pro.

Note: Pointools View Pro does not recognize the .csv file extension. Make sure that the files produced by RE02 Tools have been saved with a manually set filename ending with a .txt file extension, or simply rename the files to be imported into Pointools View Pro to end with a .txt extension (the internal file format is still CSV, however).

1. Open Pointools View Pro.
2. Click File -> Import and open the file (which should now have a .txt file extension).
3. An XYZ import options window will pop up showing a preview of the data in its columns.
4. Change Intensity Units from *0 to 1 (floating point)* to *0 to 255 (byte)* (as shown in Figure 6.10) and click Ok.
5. It will ask to *Save As* a .pod file, click Save.
6. The point cloud should now be displayed.

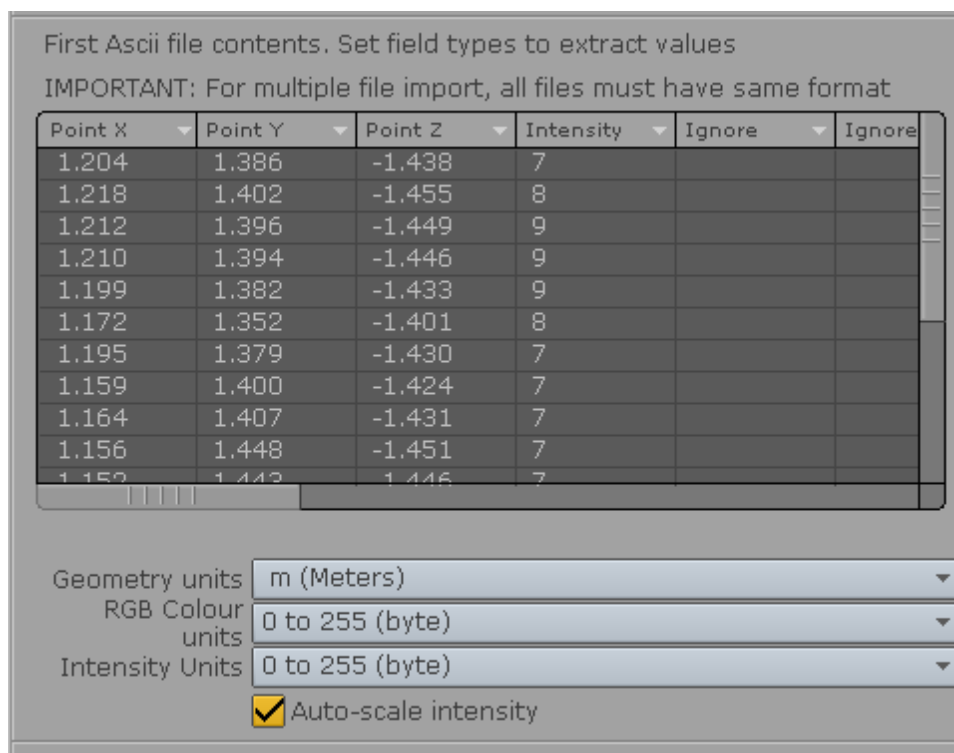


Figure 6.10 – Pointools View Pro Import Options

6.3 The RE02 C++ Class Library

Ocular Robotics provides a C++ class library for interfacing to the RE02 sensor for both Windows and Linux platforms. The library is intended to enable rapid development of custom applications, or to enable the integration of the RE02 into existing data processing pipelines. The RE02 Tools application uses the RE02 library to interface to the RE02 sensor.

The library is distributed with several small examples to illustrate its use. The examples are:

1. A Console Interface – showing how data can be sent to and received from the RE02.
2. A Logger – a multi-threaded logging application illustrating the standard RE02 file formats.
3. A Binary to CSV Converter – a very simple application for converting data from the logger to an ASCII CSV format.

For more detailed information, please refer to the RE02 Class Library Reference Manual, available from the Ocular Robotics website, or as part of the library install package.

6.4 Network Configuration

This section illustrates the steps involved in setting up the network adapter settings on the computer connected to the RE02 unit. The following steps assume a Windows operating system; however the Linux configuration will be similar.

1. Find the *Network Connections* folder, under the *Windows Control Panel* (the exact steps vary with different versions of Windows – contact your system administrator if you are unsure how to do this).
2. Right-click on *Local Area Connection* and go to *Properties*.
3. In the *Networking* tab, go to *Internet Protocol Version 4 (TCP/IPv4)* and then *Properties* (Refer to Figure 6.11).

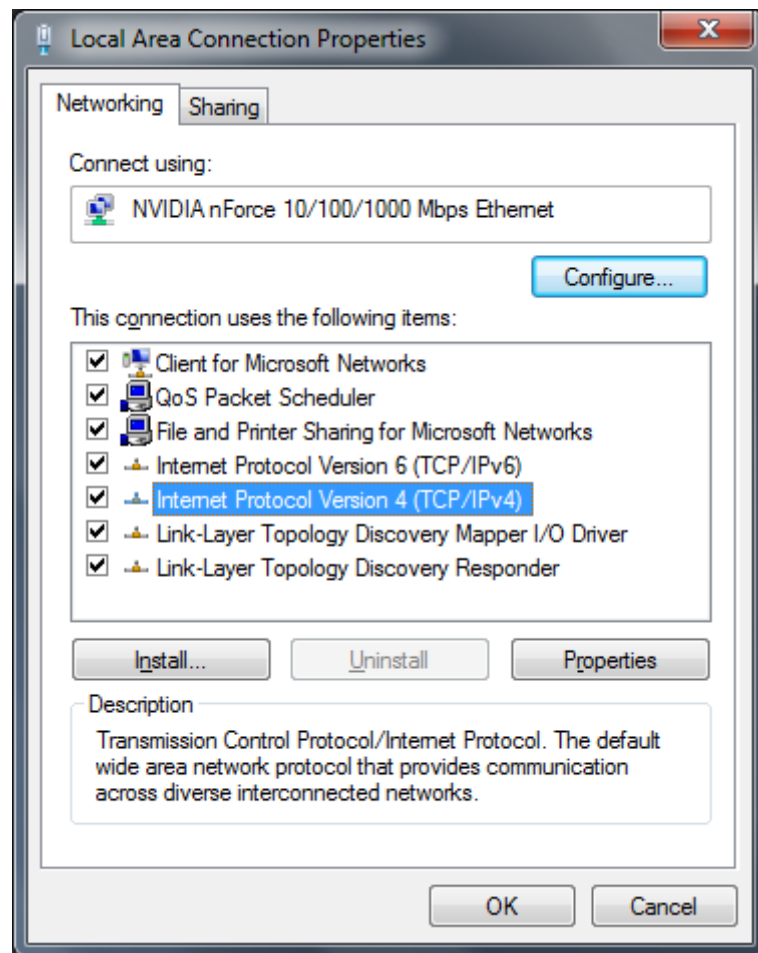


Figure 6.11 – The Local Area Connections Properties Dialog

4. In the *General* tab, select *Use the following IP Address* (Refer to Figure 6.12).

5. Enter the *IP address*: 10.1.1.X (X should not be 1 or 20) (assuming the RE02 sensor is using the 10.1.1.20 IP address).
6. Enter the *Subnet mask*: 255.255.255.0 and click *OK*.

You should now be able to communicate with the RE02 sensor using RE02 Tools.

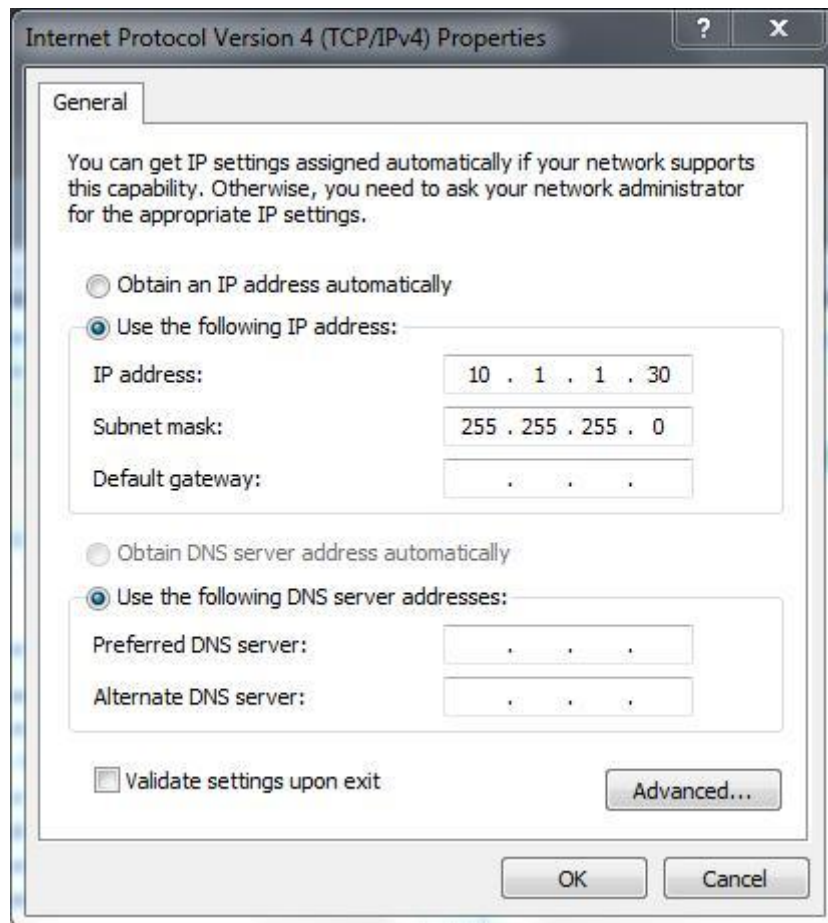


Figure 6.12 – The TCP/IPv4 Properties Dialog

7 Specifications

Mechanical		
Maximum Azimuth Rate		20Hz
Maximum Elevation Rate		3Hz
Azimuth Axis Resolution		0.010°
Elevation Axis Resolution		0.004°
Azimuth Range		360° Continuous
Elevation Range		70° (±35°)
Weight		8.5kg
Electrical		
Communication (minimum 100 Megabit)		Gigabit Ethernet
Supply Voltage		24VDC
Power Consumption	— Typical (average)	<1.5 A
	— Maximum (peak)	10.0 A
Rangefinder		
Laser Class		3B
Laser Wavelength		780 nm
Laser Power		20 mW
Laser Divergence		0.5 milliradians
Range (Reflectorless)		12 metres
Range Accuracy		7.5mm
Maximum Sample Rate		200 kHz
Minimum Sample Rate		50 Hz
Environmental		
Operating Temperature Range		-10°C - +40°C
IP Class Rating		65
<i>Note: IP Rating valid only when both supplied power & optionally supplied Ethernet cable connectors are fitted.</i>		
Software		
RE02 Class Library Support		Windows/Linux
RE02 Tools Support		Windows/Linux

APPENDIX A

RobotEye RE02 3D Laser Scanning System

Datasheet

APPENDIX B

Acuity Laser Measurement - AR4000-LIR

Performance and Measurement Accuracy