LASER DOPPLER ANEMOMETRY ALIGNMENT TOOL USER MANUAL

User Manual:	LDA Alignment tool
Product:	Instrumentation
Issue:	3.0
Date of issue:	24-01-23

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AMENDMENTS

ISSUE	AMENDMENT DESCRIPTION	DATE
01	Initial release	30-03-20
02	V1.0.0.1 build	16-09-20
03	V2.0.0.1 build	24-01-23

1 Introduction

The SCITEK LDA Alignment Tool (LDA-AT) aids Laser Doppler Anemometry (LDA) setup and calculates geometrical parameters for 1D, 2D or 3D LDA systems. Geometrical parameters Beam separation and relative beam angle are calculated for all beam pairs and for 3D LDA systems the coordinate projection and transformation matrices are also calculated.

The software is designed to be used in conjunction with a traverse system (or your choosing) for 3D coordinate measurement of the location of the camera relative to the LDA system.

2 Contents of Package

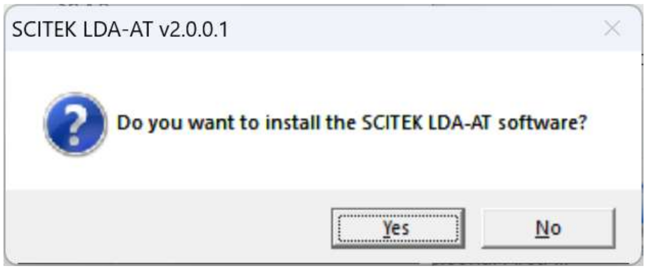
- SCITEK LDA-AT software
- SCITEK ND filter with OD 4.0 plus mounting for c-mount on Daheng cameras
- Daheng MER2-2000-6GC-P GigE/PoE camera
- 5m Ethernet cable
- 1m Ethernet cable
- Tp-link Gigabit PoE+ Injector (TL-POE160S)
- Tp-link TL-POE160S power cable
- Protective carry case
- Camera mounting plate (LDAAT-PART-0001-01)
- Traverse mounting plate (LDAAT-PART-0002-01)
- Small micro-positioning manual traverse

3 Computer Requirements

- Windows 10 64-bit operating system
- 8GB RAM

4 INSTALLATION

Please follow the steps below to install the software for the LDA-AT.

1. Please run ‘SCITEK LDA-AT Installer.exe’ found in root of the supplied USB drive.
2. 

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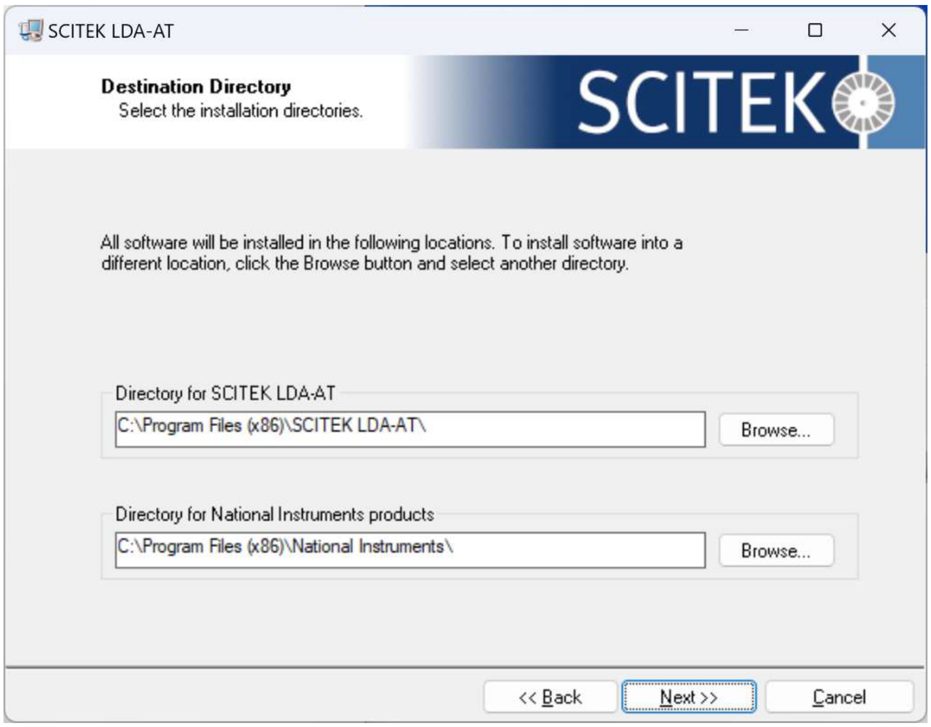
3. 

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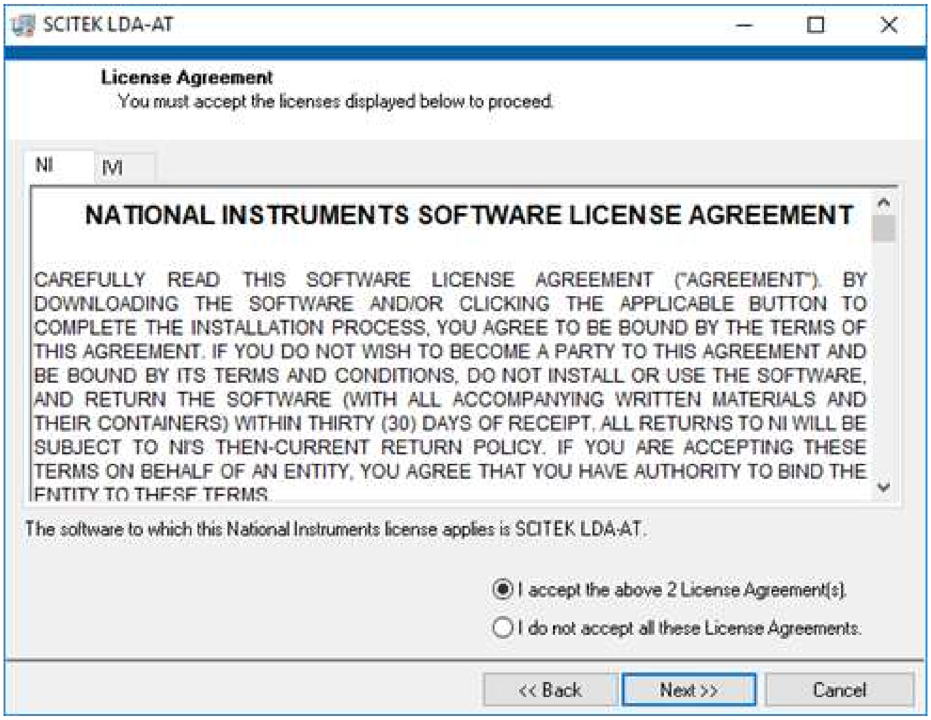
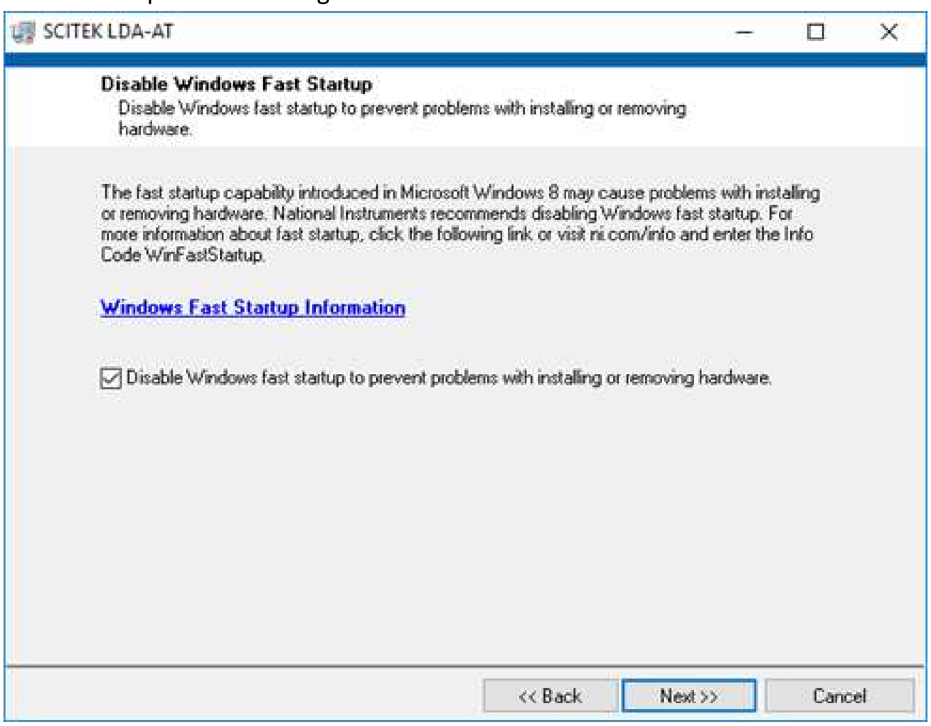
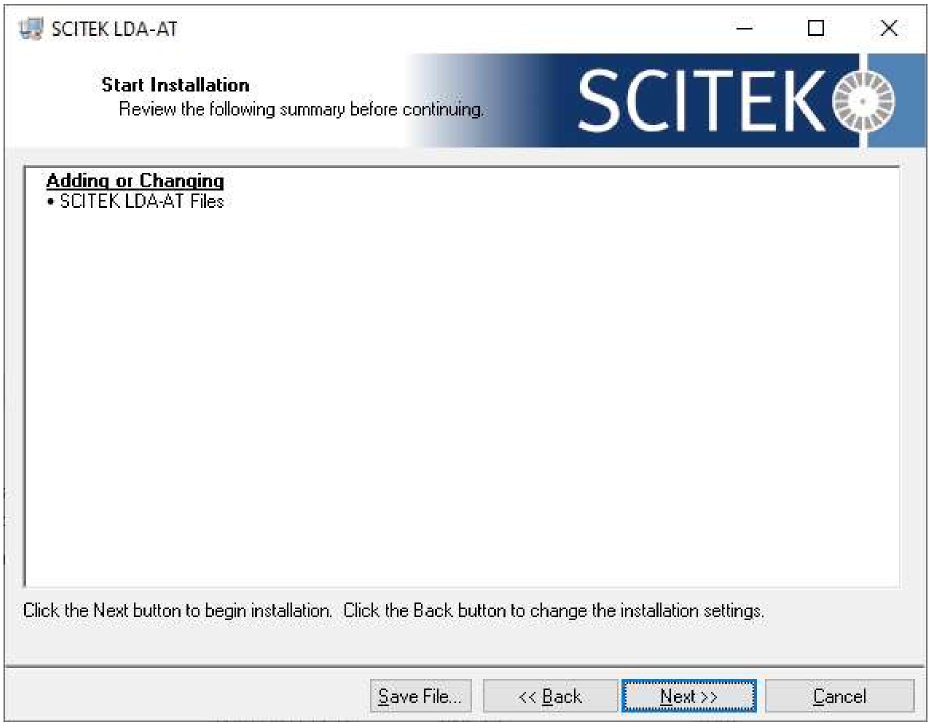
4. 

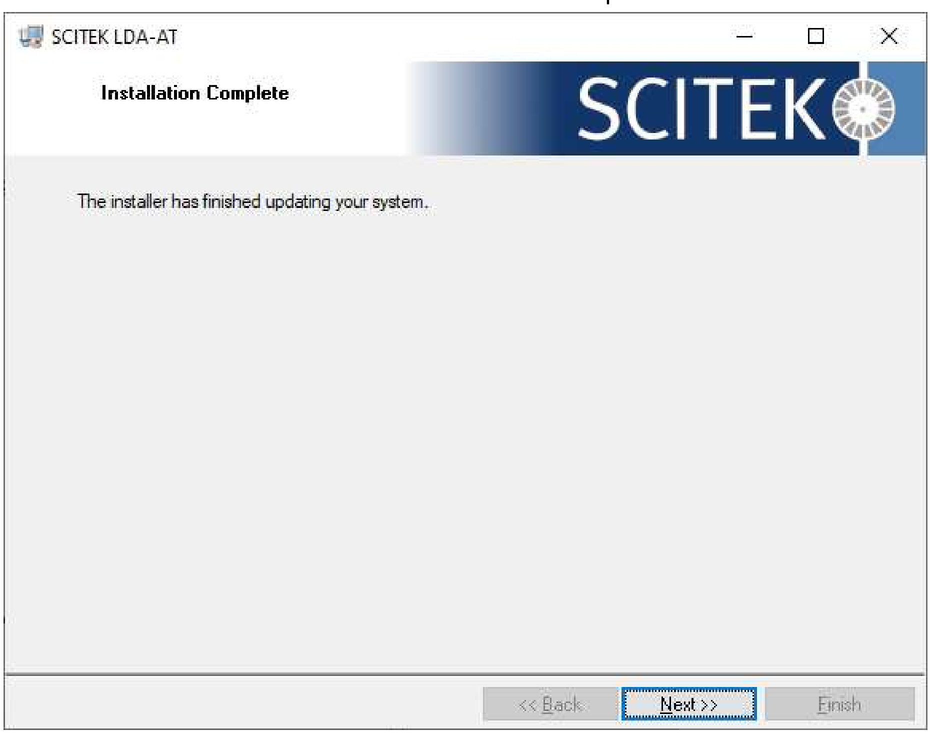
a. Accept the license agreements and click Next

5. 

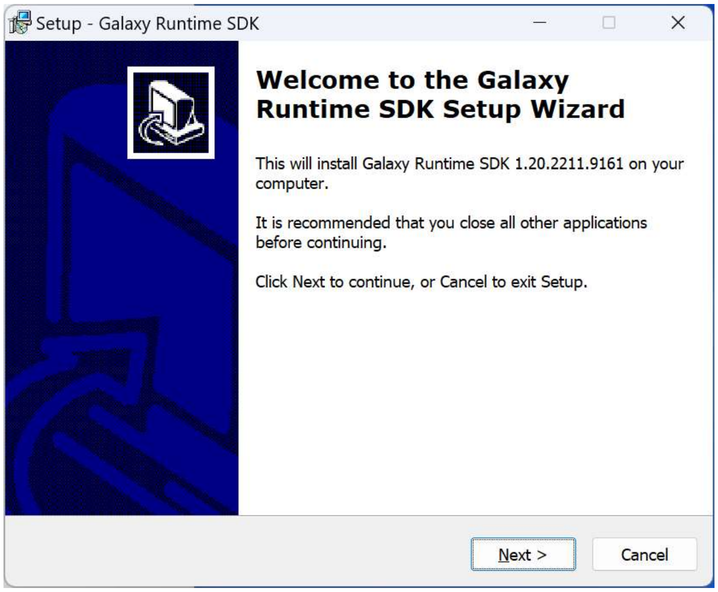
a. Click Next

6. 

   a. Click Next and wait for the installation to complete

7. 

   a. Click Next

8. 

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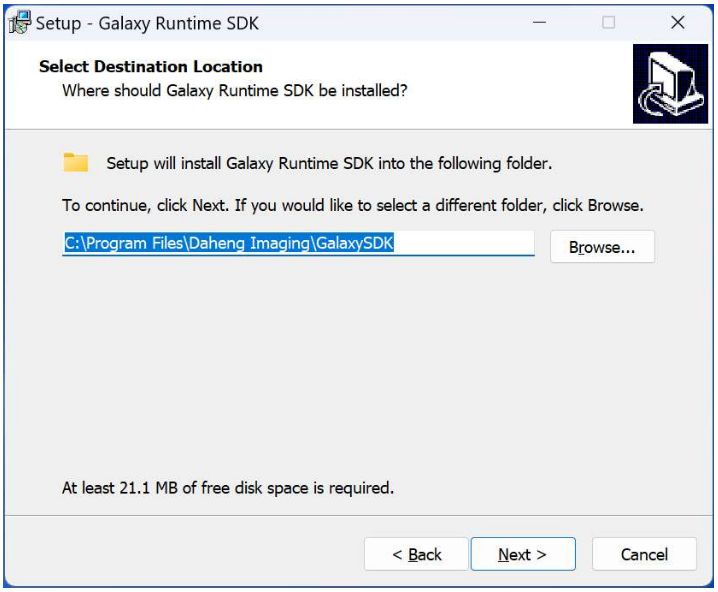
9. 

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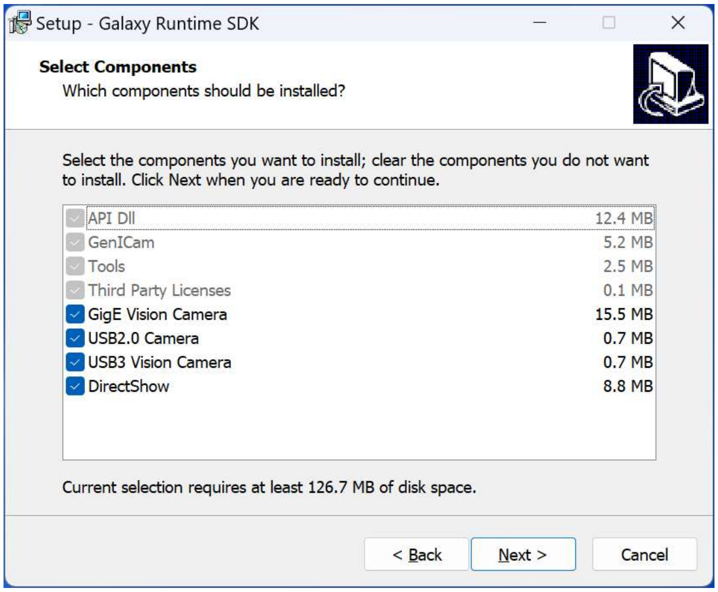
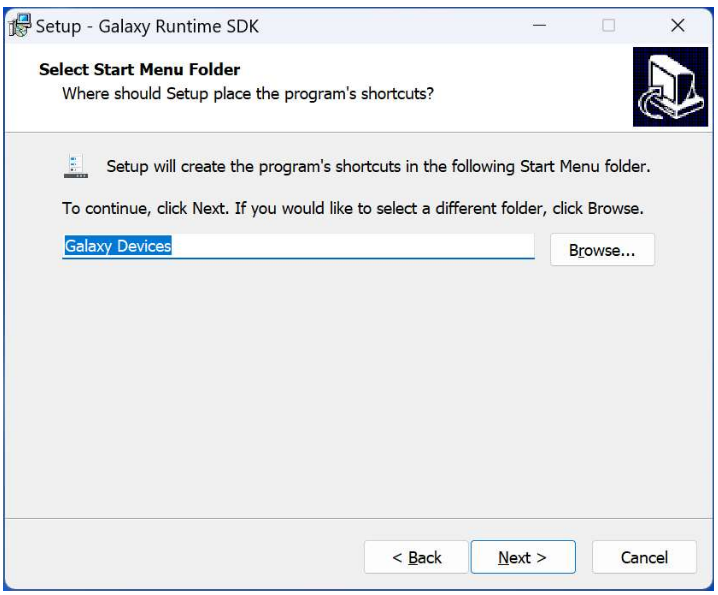
10. 

   a. Click Next

11. 

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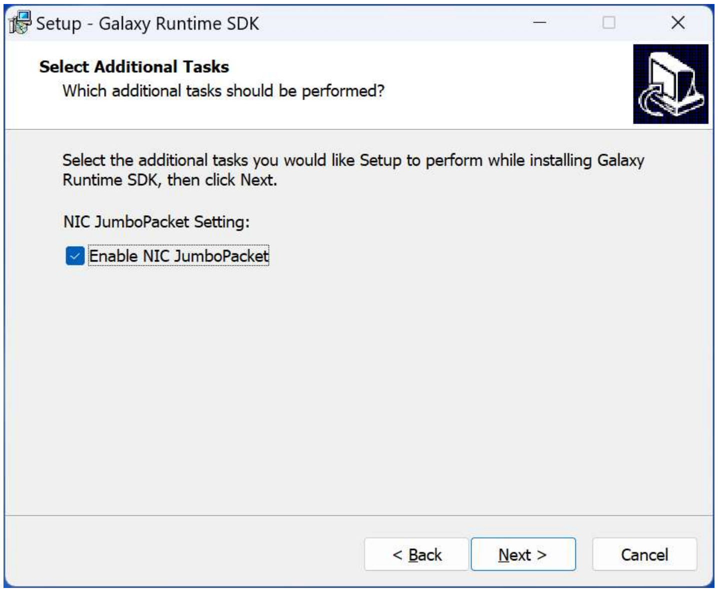
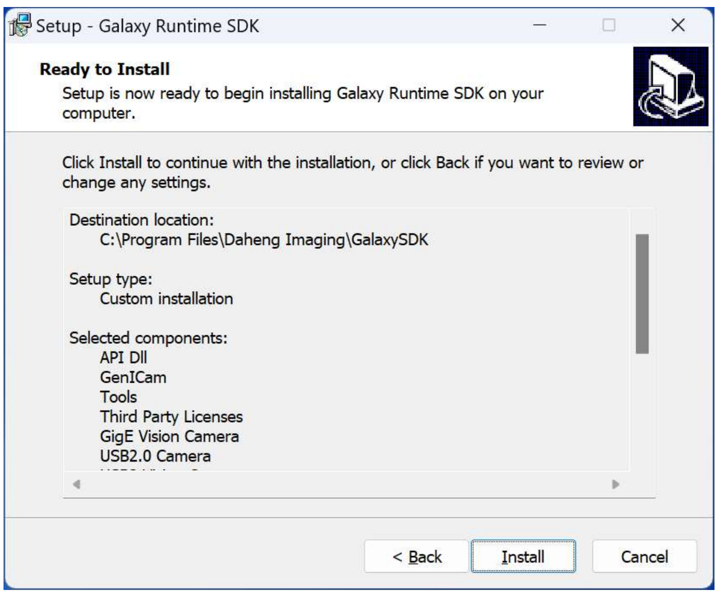
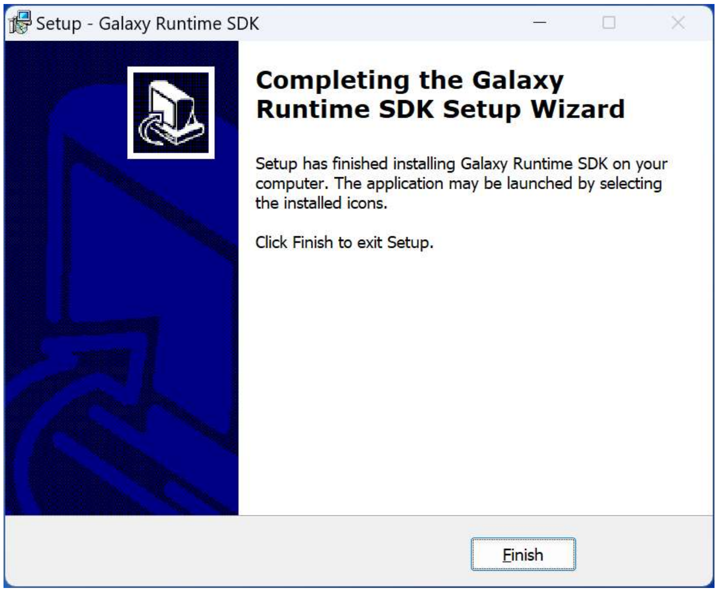
12. 

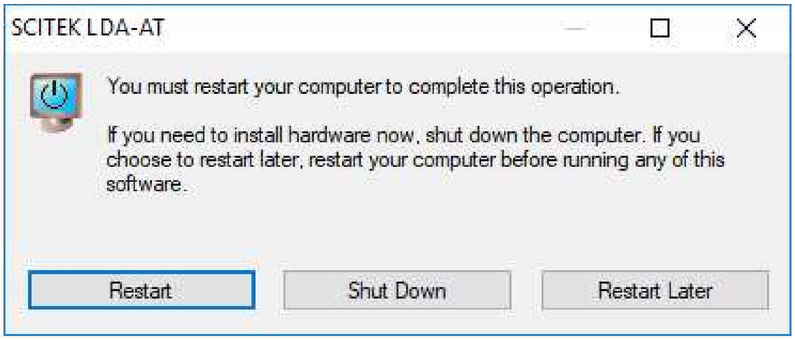
a. Click Next

13. 

a. Click Install

14. 

   a. Click Finish

15. 

   a. Click Restart to restart the computer

5 SECURITY DONGLE

The camera is the security dongle and is paired to the software. The software will start up without the camera but it will not perform any calculations without the camera attached and connected to the software.

Camera security dongle

6 CAMERA SETUP

6.1 NEUTRAL DENSITY FILTER

Before connecting the camera, please ensure Neutral Density filter is attached. The ND filter has an optical density of 4.0 ± 0.2 which should have a nominal transmission of 0.01%. The ND filter has been supplied to help protect the camera sensor from damage by the laser. It is recommended that the laser beams are attenuated as much as possible and test runs are made so that an appropriate laser power can be achieved so as not to damage the sensor during measurement. The operator needs to be able to see the laser spots at the focus point (where the intensity is greatest) without over saturating/damaging the sensor. It is the operator's responsibility to ensure the laser beam cannot damage the camera.

6.2 MOUNTING

Two aluminium plates are supplied with the camera along with a small micro-positioning manual traverse. The camera is to be mounted to the camera mounting plate (LDAAT-PART-0001-01) via 3x M3 screws. This plate can either be attached to a standard ¼-20 UNC thread (tripod thread) or 2x M3 screws it can be used to attach to the mounting plate to the small micro-positioning traverse. The supplied traverse mounting plate (LDAAT-PART-0002-01) can be attached to the small traverse via 4x M3 screws. This whole assembly (camera; small traverse & two mounting plates) can be attached to a traverse system or via either 4x M3 threaded holes or a standard ¼-20 UNC tripod thread. The hole layouts of both mounting plates are observed in the Appendix.

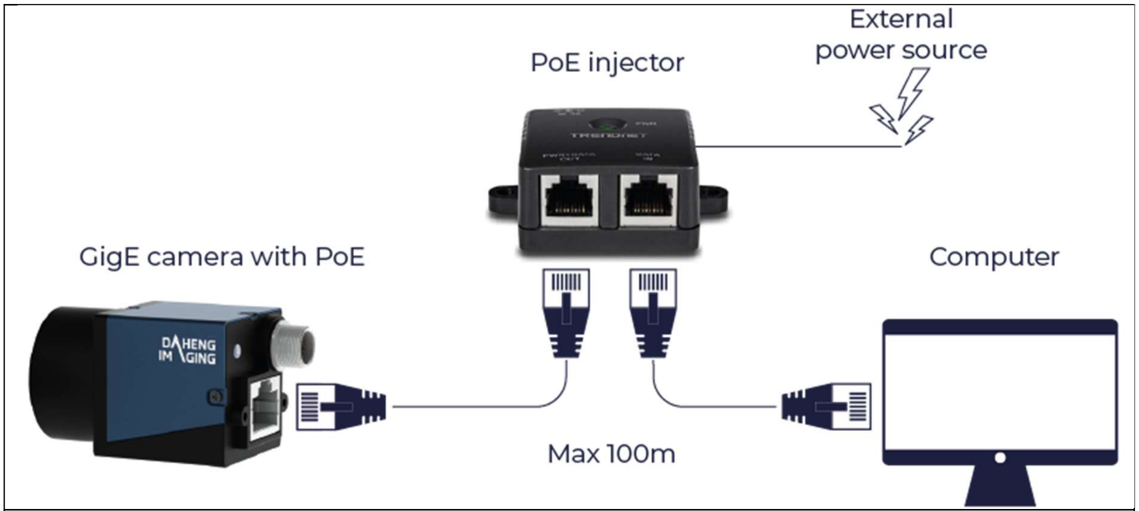
The micro-positioning traverse is supplied to help with fine-tuning of the camera position and is particularly useful when aligning the laser beams with the focal point as described in section 8.4. It is advised to lock the micro-positioning traverse in place prior to using the LDA-AT software to calculate the effective beam spacing at the front lens of the transmission optics.

	
Micro-positioning traverse	3x thumbscrew lock-offs

Camera mounted to micro-positioning traverse

6.3 CABLE CONNECTION

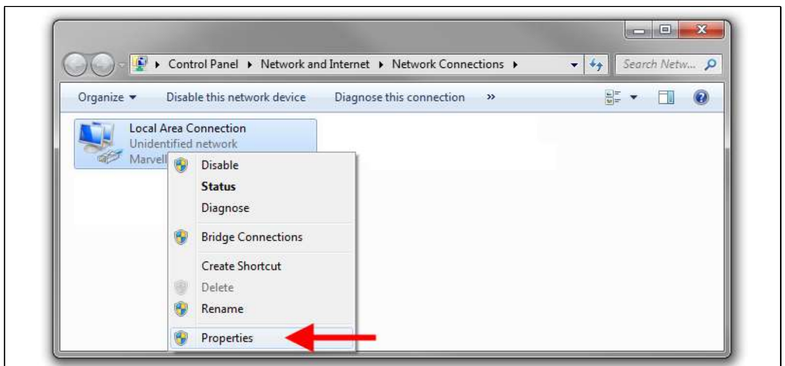
The camera has an ethernet port and GigE/PoE technology for connection to a computer. Two ethernet cables (1 metre & 5 metres) and a Power over Ethernet (PoE) injector have been supplied. Please connect the camera as shown in the following illustration. The camera should be connected to the port labelled ‘PWR + DATA OUT’ on the PoE injector. The computer should be connected to the port labelled ‘DATA IN’ on the PoE injector.



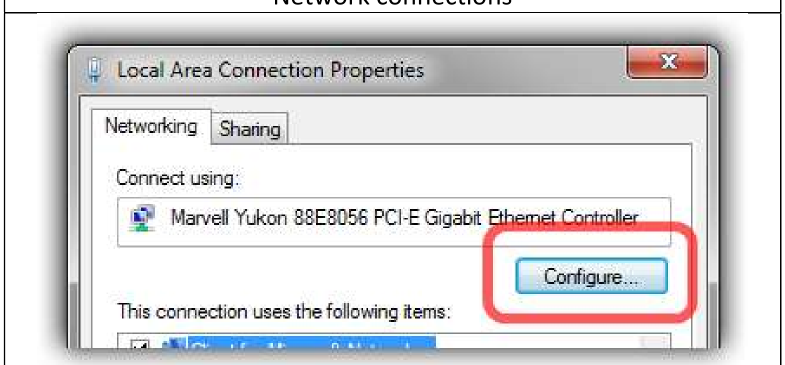
Camera connection to the computer (reference: get-cameras.com)

6.4 JUMBO PACKETS

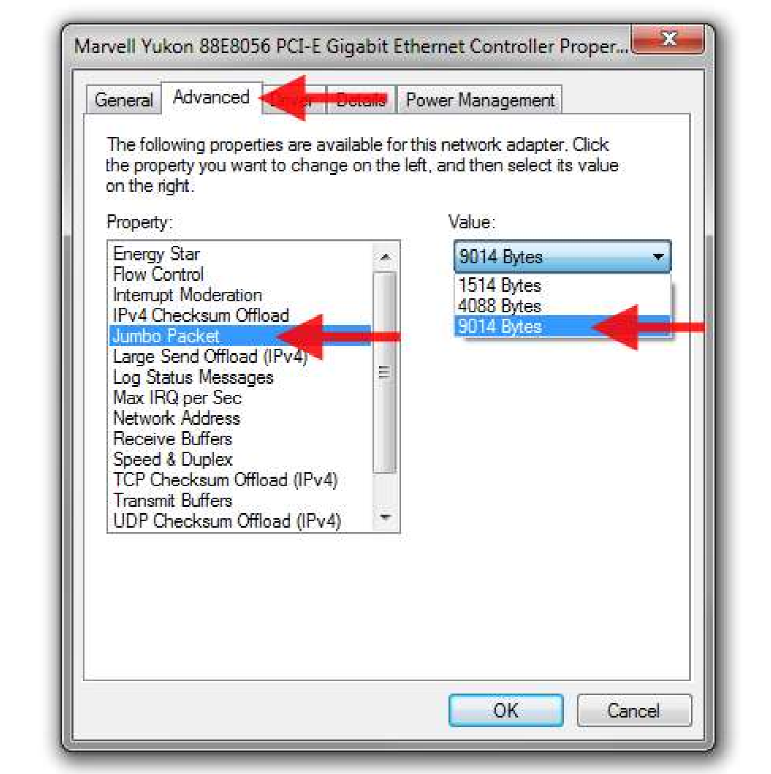
During the installation a prompt will ask whether to 'Enable JIC JumboPacket'. This is recommended where possible to reduce the network traffic overhead from the camera. If this was not enabled during installation, Jumbo packets can be enabled by adjustment of the Ethernet adapters configuration on the computer. This is shown in the following figures.



Network connections



Network connection Properties



Advanced Properties – Jumbo Packet

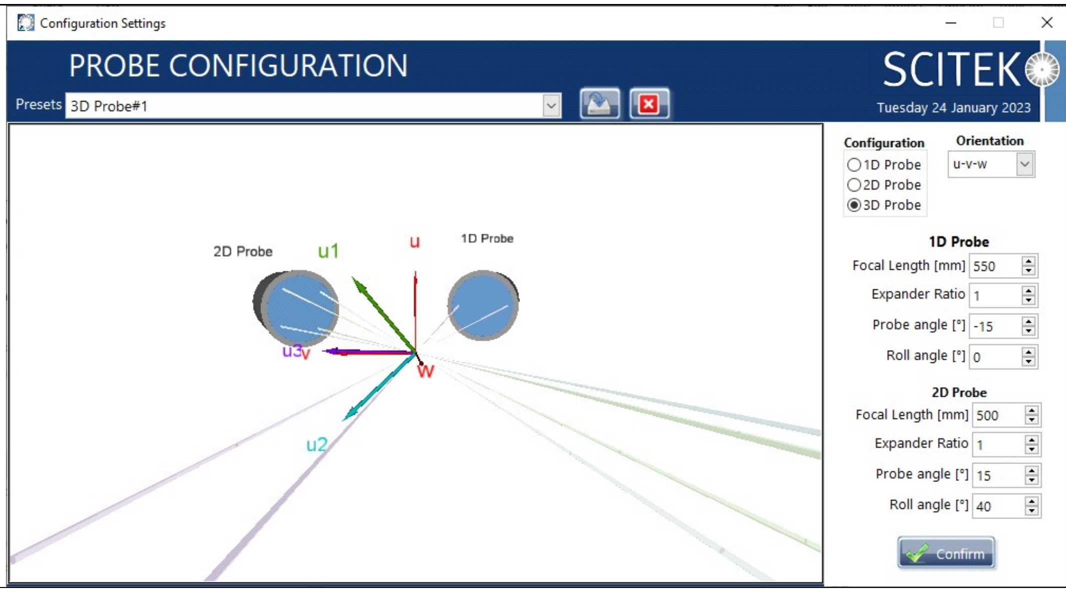
7 TRAVERSE SYSTEM

The software is not designed to control a traverse system, allowing the operator to use any 3D traverse system they deem suitable for their task. It is the operator's responsibility to ensure the traverse system is operated safely. To avoid collision and potential damage to the camera hardware it is recommended that the camera positioning throughout the measurement routine is understood and checked prior to operation.

8 LDA-AT SOFTWARE

The LDA-AT software has been developed to aid the alignment of laser beam pairs as well as the transmission optics of 1D, 2D and 3D LDA systems.

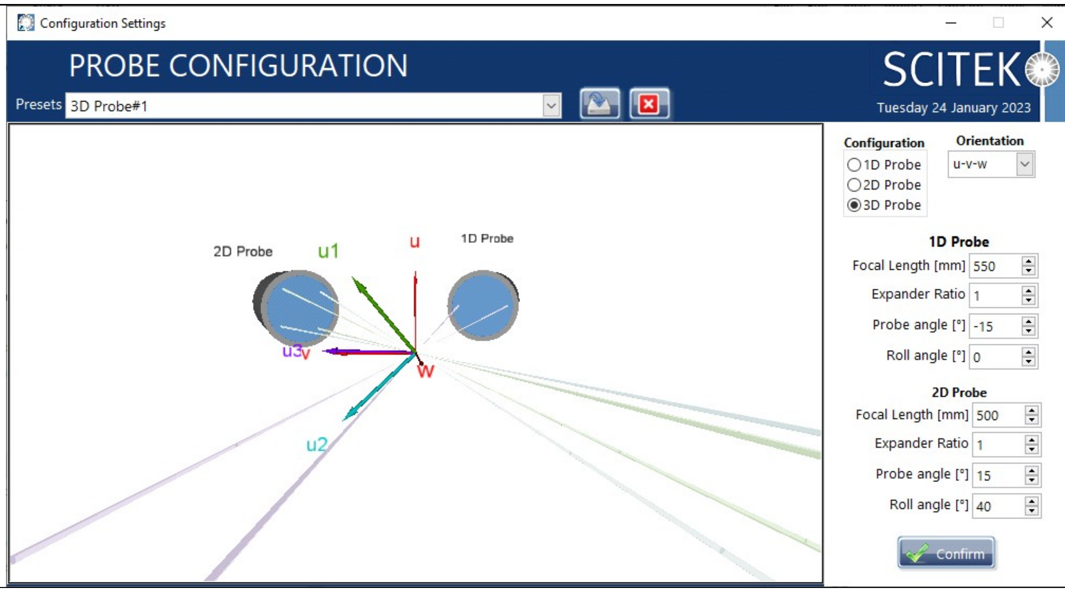
Once the software starts you will be asked to configure the software for the setup you are trying to align.



Calculation settings window

The configuration settings dialog provides the operator with a virtual environment to set up their experiment. This virtual environment is where the operator details scalar and vector parameters required for calculation of the LDA geometry. The virtual environment is meant as a representation of the experiment. It is important to ensure the parameters selected best represent the experiment the operator is trying to conduct.

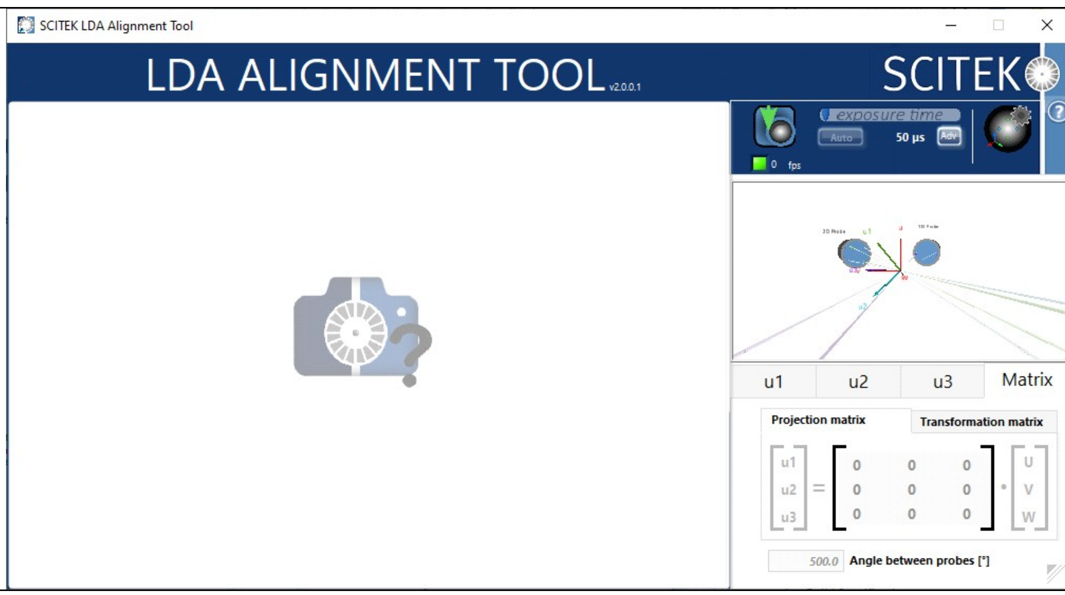
Set the LDA probe configuration either 1D, 2D or 3D. A 3D probe configuration uses both a 1D probe and a 2D probe. The orientation specifies the coordinate system of desired velocity axes which, by definition, are coincident and in the same direction as the traverse coordinate system both of which must obey the right-hand rule for coordinate systems. Your traverse is likely to be labelled differently to u,v,w whether that be X,Y,Z; A,B,C; 1,2,3 etc. Firstly the operator must orientate the u,v,w coordinate system such that it aligns with their traverse. It is recommended (although not critical) that u,v,w should be aligned with X,Y,Z (A,B,C;1,2,3 etc) respectively. From this point forward the operator must orientate their probe configuration with u,v,w and hence their traverse. For example if your traverse axes are labelled X,Y,Z and the orientation is such that X aligns with u, Y aligns with v and Z aligns with w (as shown in the image above) then from this point forward any coordinates associated with X,Y,Z are now associated with u,v,w respectively. An example of an alternative orientation is shown below, please note the roll angle of the 2D probe is such here that the measured velocity is in an opposite direction to w a desired velocity component/traverse direction. Input the focal length and expansion ratio (1 if no expansion optics are installed) of each probe. Estimate the 'Probe angle [°]' and the 'Roll angle [°]' for each probe relative to the u,v,w coordinate system. These angles do not need to be accurate but they do guide the vector calculations with rough directions of measured velocity components otherwise unknown.



Calculation settings window – example alternative orientation

In this Calculations Settings window preset configurations can saved and deleted.

Once the Calculation Settings have all been configured and the user clicks 'Done' the main LDA-AT window opens.

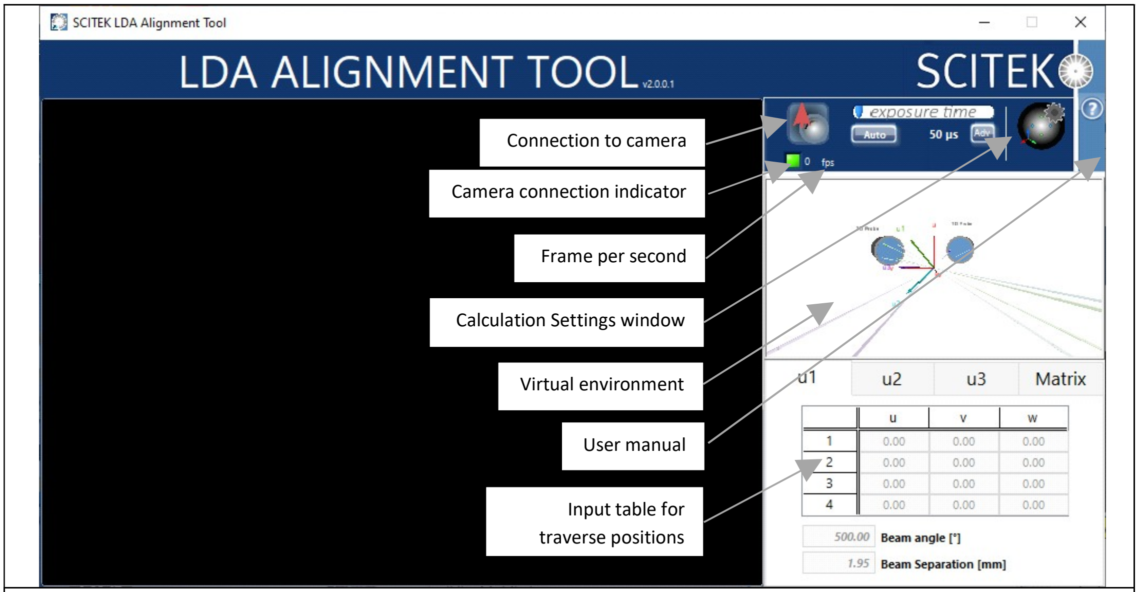


Main LDA-AT window

With the camera powered, set on to its Manual setting (M) and the USB cable attached we can now connect to the camera and an image will be displayed.

8.1 Main LDA-AT window

The ‘Connect Camera’ button is latched once pressed and can be unlatched to disconnect the camera. The interface displays the cameras live view image in the main window. Please bear in mind that once physical connection of all cables have been made the camera will not be immediately available for connection to the software. It can take a little time (around 20 seconds after physical connection) before the software is able to connect.



Main LDA-AT window

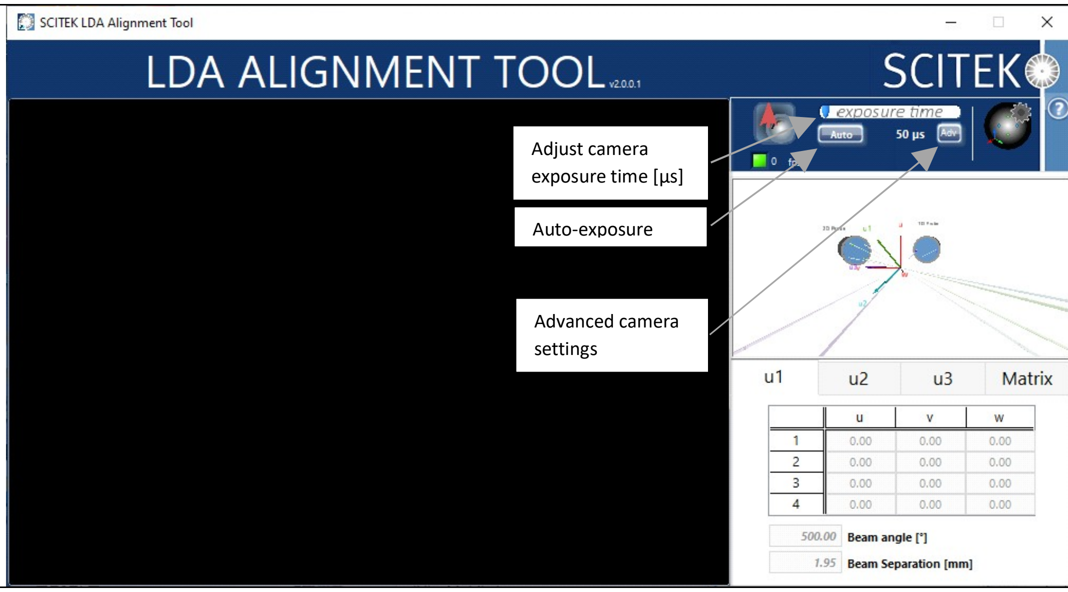
When a camera live view is being displayed there are various options available for navigation

- Zoom – Mouse wheel
- Pan (whilst zoomed) - Left mouse click and drag

Further options for the display window are available using a right mouse button click. These options include:

- Fit to window – removes any zoom and the whole image is displayed
- Centre window – displays the centre of the image
- Turn crosshair ON/OFF – displays a centre aligned crosshair with scales
- Turn profiles ON/OFF – displays centre aligned real-time horizontal and vertical intensity profiles

8.2 CAMERA SETTINGS



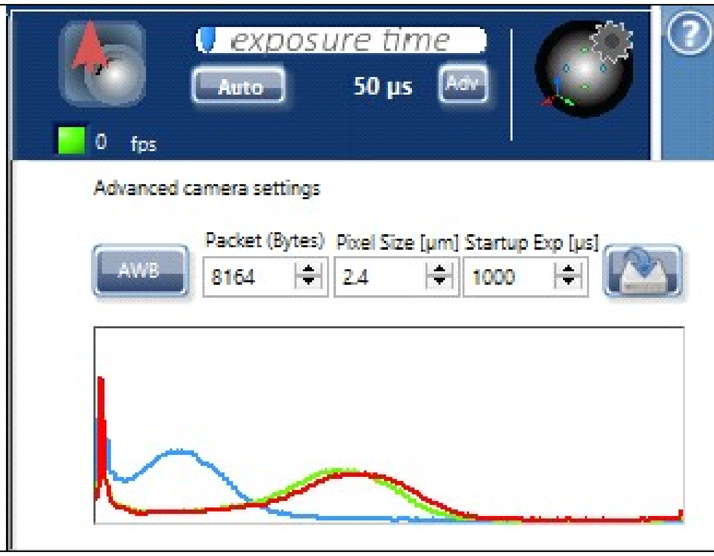
Camera settings window

Once the camera is connected real-time adjustment of the exposure time is available.

Auto-exposure: Performs a single automatic exposure on the camera.

8.3 ADVANCED CAMERA SETTINGS

Pressing the advanced settings button will show additional settings for the camera. It is not anticipated that these settings will need adjustment often.



Advanced camera settings

Auto-white balance: Average values for the 'red' and 'blue' pixels are matched to the average value for the 'green' pixels. Show the camera a balanced grey artefact and this will balance the red and blue channels to the green channel.

Packet (bytes): This is a setting for the packet size in Bytes. The packet size should be kept as large as possible for the network configuration. This will minimize CPU usage.

Pixel Size [µm]: This is the size of an individual pixel in micro-meters. For the supplied camera (MER2-2000-6GC-P) this is 2.4 µm.

Startup Exp [µs]: This is the exposure time of the camera when the camera connects. This is to help reduce the chances of over-saturating the camera with the laser. Please note it is the operator's responsibility to ensure the laser beam cannot damage the camera. Setting this to '0' (zero) will disable this functionality which will result in the camera exposure time being set by the previously saved camera parameters

Save camera parameters: This saves the current camera parameters of the camera including all the advanced settings.

Histogram: This is a helpful indicator of the current state of the camera image. Please note the frame per second may reduce whilst the advanced settings are in view. This is due to the increased processing associated with the histogram read-out.

8.4 Alignment of the laser beam pair

Once the appropriate laser power has been determined to prevent damage to the camera the beams can be aligned to cross at the correct LDA measurement zone.

If the laser beam crossing is not factory set or adjustment optics have been put into the optical path (eg expansion optics) then the laser beams need to be aligned so that they cross at the focal point of the lens. The LDA-AT can be used to visualise the alignment of the laser beam pair and ensure they cross at the focal point of the lens. The camera settings can be adjusted to suit the image required. The laser beam will be at its smallest diameter along its optical path at this focal point or beam waist. However, the beam angle incidence within the internals of the optics maybe off, such that the beam waist is not coincident with the focal point of the transmission optics lens. The initial process is to align just one of the LDA laser beam's waist with the focal point of the lens. This can then be used as the reference LDA laser beam. The second laser beam can be blocked off during this initial process.

The easiest way to align the first laser beam with the focal point is to shine an alignment light/third laser beam (different colour to LDA laser beam pair) down the transmission optics and use the LDA-AT to visualise the position of the lenses focal point. The focal point can be found by traversing the camera along the optical path of the alignment beam to a position where its diameter is minimised. The position of the first LDAs laser beam can then easily be adjusted so that its beam waist coincides with the alignment beam and ultimately the lenses focal point. The user may need to zoom in and pan on the LDA-AT display to visualise the alignment. The second LDA laser beam can then be easily adjusted so that it crosses the first LDA laser beam.

An alternative method to align the first laser beam with the focal point of the transmission lens would be to physically rotate the whole of the transmission optics and try and align the beam waist at the centre of rotation. The LDA-AT can again aid with this process by visualising the beam waist as the optics are rotated. This will require manipulation of the traverse system as well as the transmission optics to keep the beam waist in sight on the camera. This is not a perfect process and it is expected that the beam waist will not be exactly at the centre of rotation ie some 'wobble' as the transmission optics are rotated. Once happy with the first laser beam's positioning it is vitally important to align the second LDA laser beam with the first laser beam and not the centre of rotation. This is a more involved method and to some degree assumes the optical characteristics of the lens optics is geometrically concentric with the mechanical axis of rotation and in reality, this is unlikely, hence some wobble would be expected.

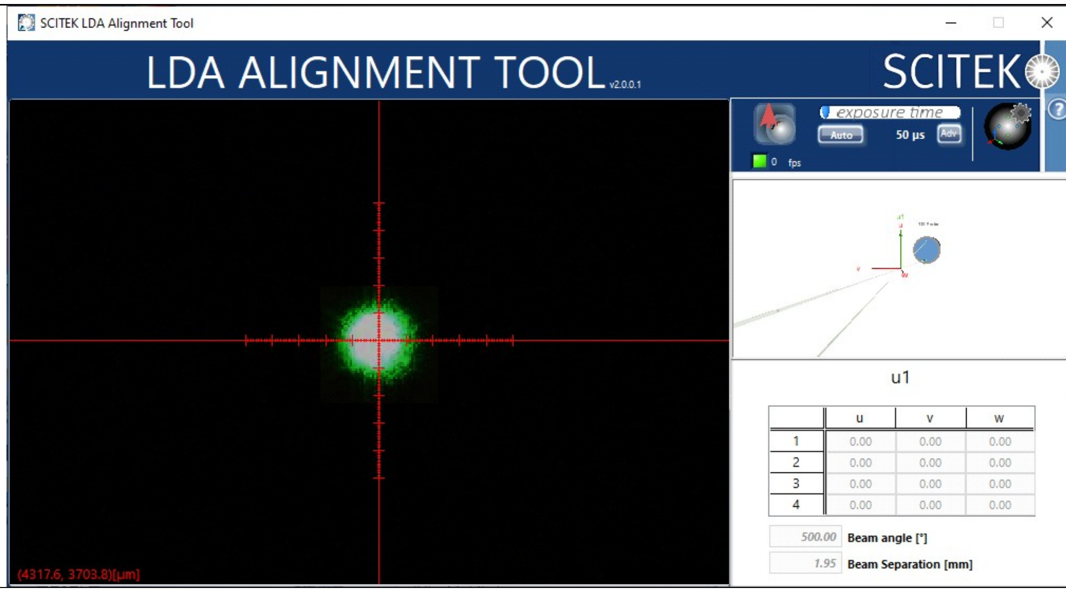
8.5 1D LDA SYSTEM

Once the laser beam pair has been aligned the LDA-AT can be used to calculate the effective beam spacing at the front lens of the transmission optics (this is the calculated separation at exit of expander lens divided by expander ratio) and the total measured angle between the beams. Please note if you require the separation at the exit of the expander lens please set an expander ratio of 1 in the Configuration settings dialog.

A total of four measurement locations are expected for each laser beam pair. For each laser beam two measurements either side of the intersection point are required ideally as far from the crossing point as permitted to minimise uncertainty.

For the measurement process it is important that the traverse home/zero position does not alter throughout the process.

For each measurement location the camera is positioned so that the laser beam spot is centred on the crosshair. Note the coordinates from the traverse into the input table making sure the coordinates for u,v,w are correct for your traverse. Repeat this for all four locations. The order of input of these four points is not significant, the software calculates which points correspond to each laser beam. The total beam angle and effective beam separation are instantly calculated and shown on the user interface below the input table.



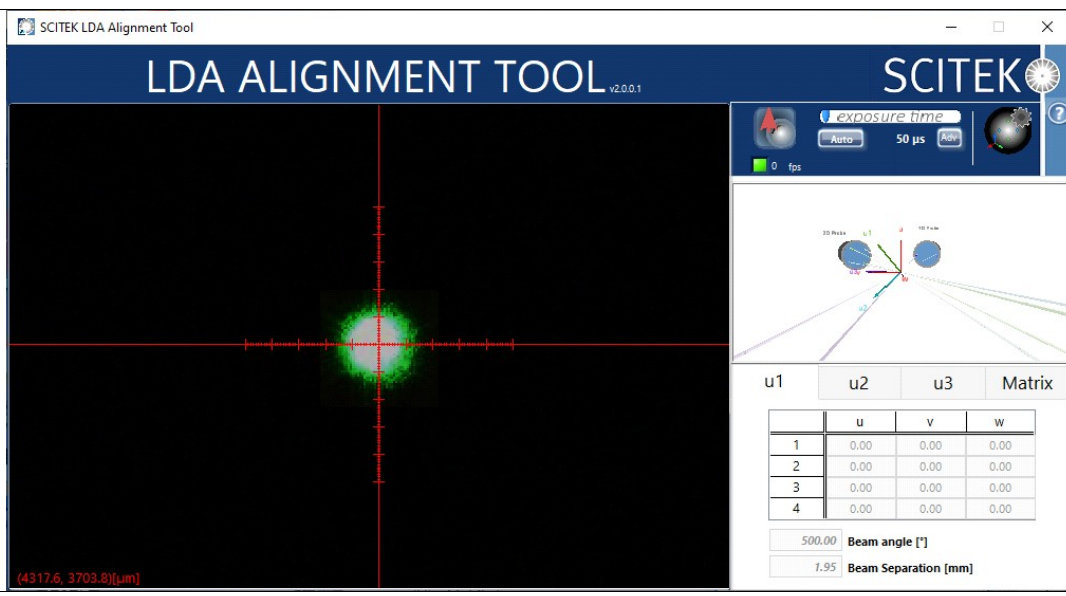
Example 1D measurement

8.6 2D LDA SYSTEM

The process for measurement on a 2D LDA system is the same as that shown for a 1D LDA system except as there are four beam pairs where two input tables for velocity components u1 & u2 respectively are required to be completed. A single 2D LDA probe is assumed.

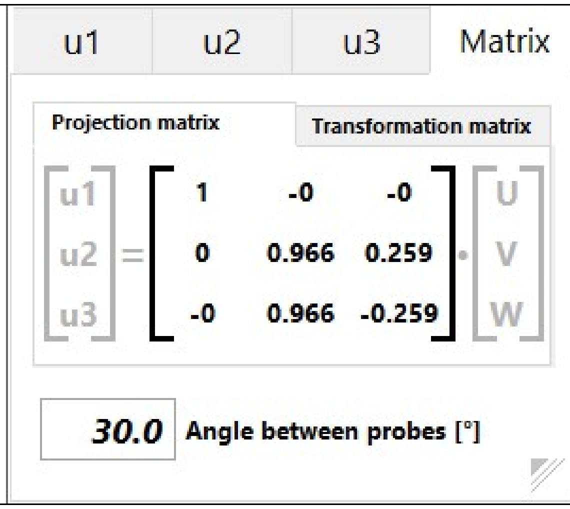
8.7 3D LDA SYSTEM

With 3D optics it is assumed that a 2D LDA arrangement is used for velocity components u1 & u2 and a 1D LDA probe is used for the final velocity component u3.

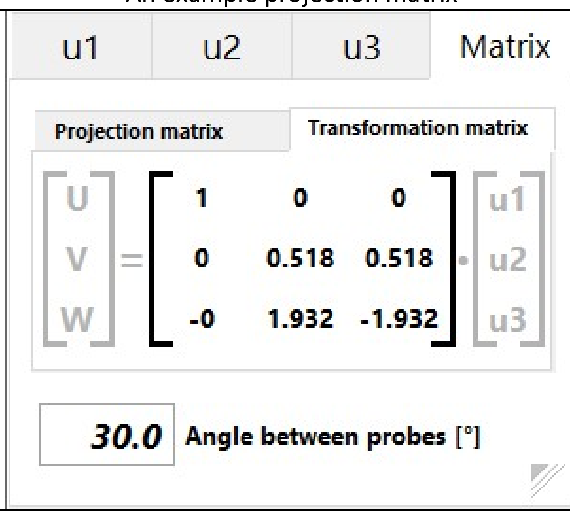


Example 3D measurement

The Projection matrix and the transformation matrix are shown on the ‘MATRIX tab and once all measurement point coordinates (twelve coordinates in total for a 3D system) have been inputted into their corresponding tables the resulting Projection matrix and the Transformation matrix can be used. Examples of which are shown below.



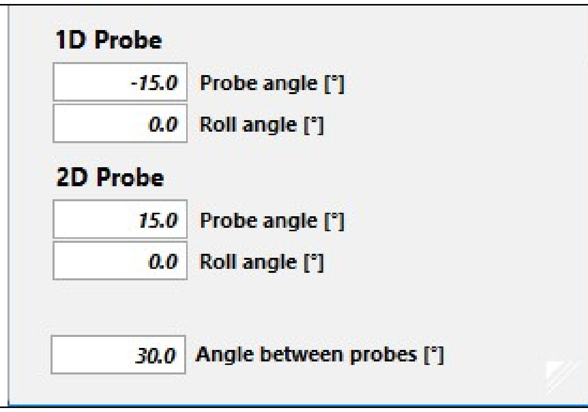
An example projection matrix



An example Transformation matrix

The Transformation matrix is used to convert the non-orthogonal velocity components (u1, u2, u3) to the orthogonal components (u,v,w) and is the inverse of the Projection matrix. LDA software requires the Transformation matrix to perform the coordinate transform – calculating u,v,w orthogonal components using u1, u2 & u3. Their relationships are shown on the user-interface.

In the bottom right hand corner of the MATRIX tab is a button  which, if pressed, reveals the additional information of the calculated probe angles. Pressing the bottom right-hand corner again will hide this information.



Calculated probe angles - additional information

9 SAFETY

9.1 LASER SAFETY

Please follow the LDA manufacturers guidelines on laser safety

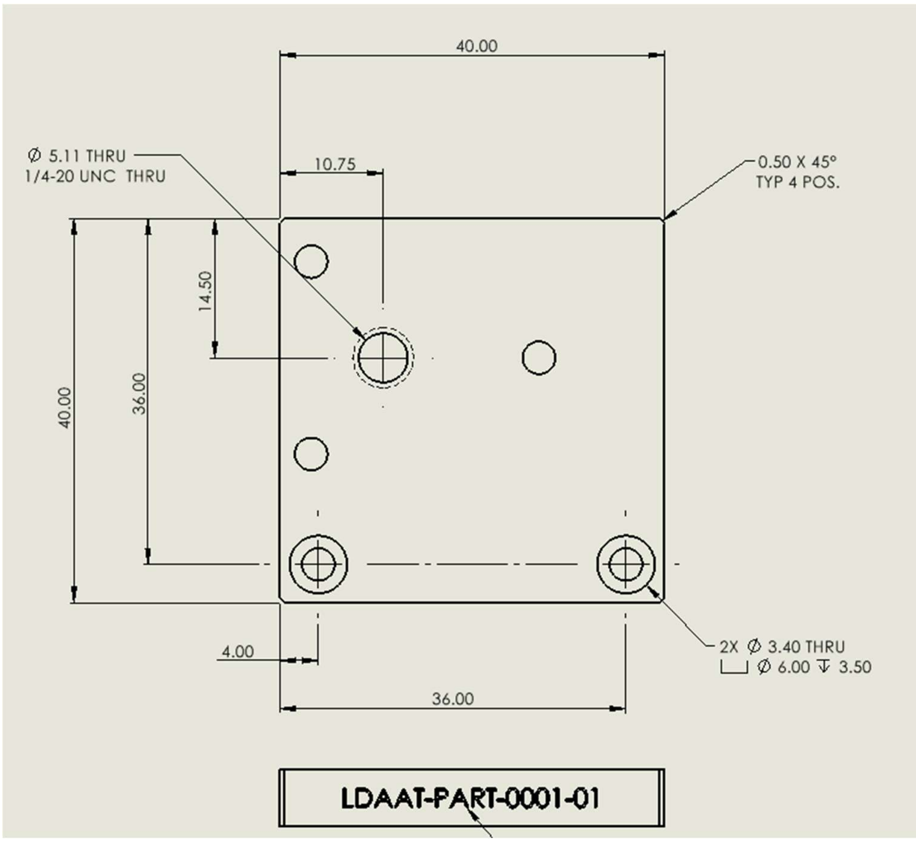
10 MAINTENANCE AND CLEANING

Keep all hardware clean and inspect for damage prior to and after installation.

No parts are designed to be serviced by the end user.

11 APPENDIX

11.1 CAMERA MOUNT



11.2 MICRO-POSITIONING TRAVERSE MOUNT