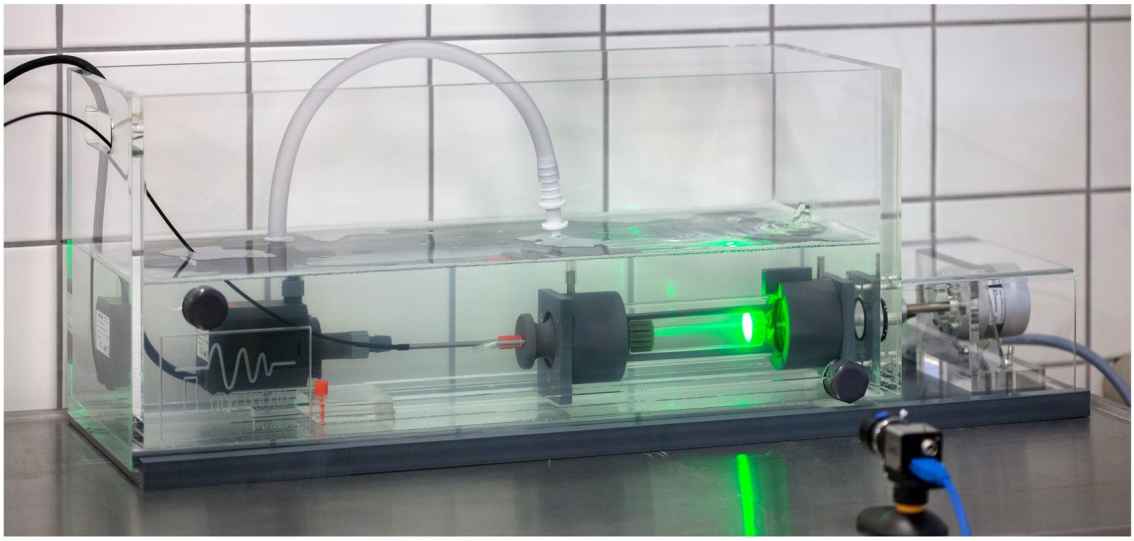
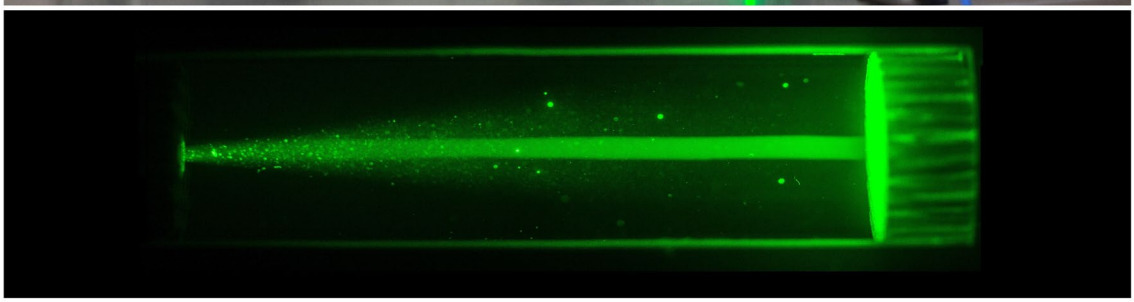
Loligo® Systems

DPTV Flow Tracking System

(Digital Particle Tracking Velocimetry)

Version 1.0.1





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1. List of parts

- NI Vision Runtime license card
- USB memory stick (Loligo®).
- USB hardkey dongle (WIBU).
- 1.3 mPixel USB 3.0 color video camera incl. grabbing software .
- 25 mm lens (other lenses are available upon request).
- 50 mW green 532 nm laser pointer
- Fiber optic light guide.
- Protection glasses.
- Green fluorescent PE micro spheres (212-250µm, 1.00g/cc), 10 g.
- User manual.

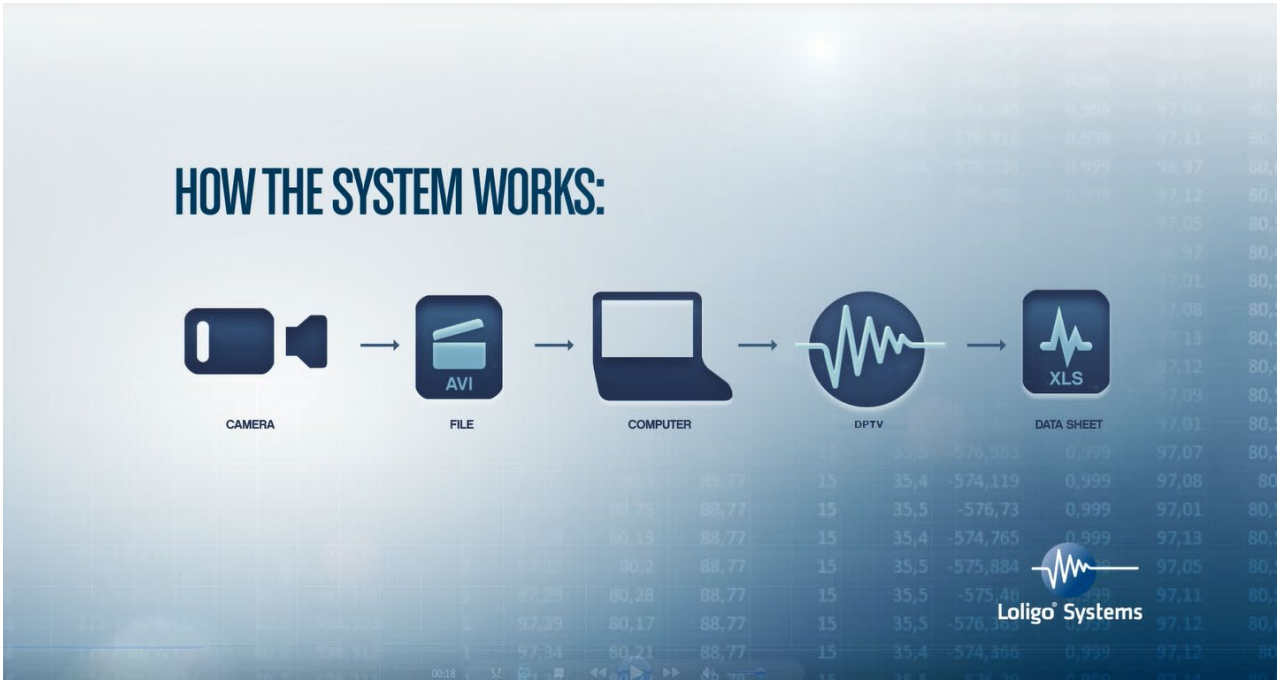
2. General

2.1 Background

The DPTV flow tracking system is designed to measure the water velocity in recti-linear or laminar-like flows e.g. in flumes or swim tunnels. Neutral density fluorescent particles are added to the flow, illuminated by a green laser and 2D video tracked. The post-analysis software subsequently track the fluorescent spheres and calculate the average flow velocity and the direction of the spheres within a user-defined area.

The system operates in two steps:

1) Record video images of a water flow seeded with fluorescence microspheres and illuminated with the green laser (see section 4).
2) Analyse the recorded .avi video file in the DPTV software (see section 5).



2.2 Minimum PC requirements

- CPU Intel P4 Duo 2GHz or similar
- RAM 4 GB
- USB ports 2 (1xUSB 3.0)
- Monitor 1024 x 768

3. Software installation

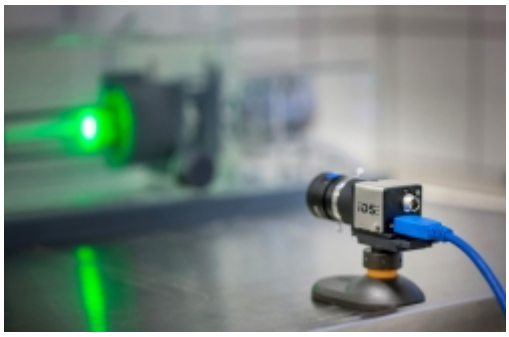
3.1 DPTV software for Windows

- Install the DPTV system software on a PC with Windows 8, Windows 7, Vista or XP.
- Insert the Loligo® USB memory stick and run DPTV_Installer.exe. Follow the instructions on the screen. For WIN8, WIN7 users please make sure to have administrator rights.
- The installation will require a restart of the PC when prompted.
- Insert the green (WIBU) hardkey protection dongle into a free USB port.
- Connect the uEye video camera to a free USB 3.0 port.
- The installation is now complete and the flow tracking system is ready for use.

4. Recording .avi files of flow with micro spheres

4.1 Start the uEye recording software (uEye Cockpit)

Connect the USB 3.0 uEye camera to a free USB 3.0 port.

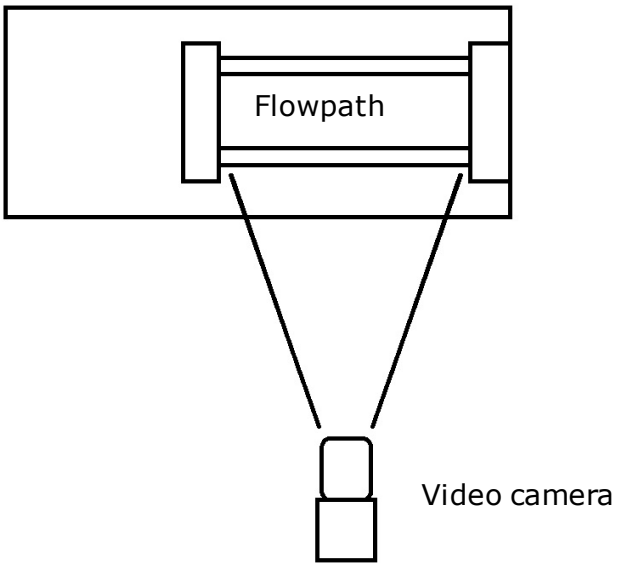


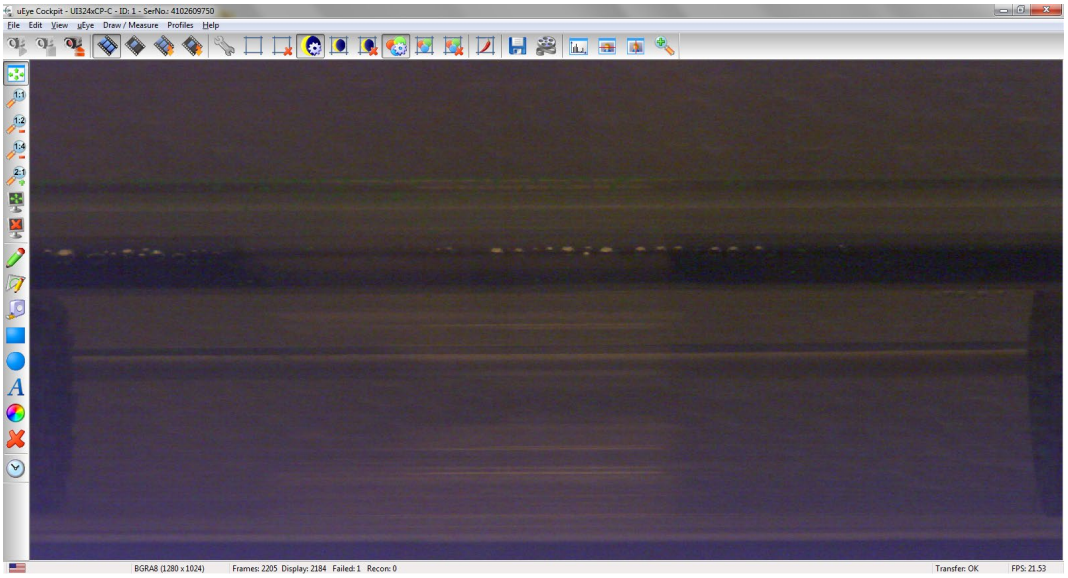
Select Start→All programs→IDS→uEye→uEye Cockpit

Select Optimal colors

Click the Open camera button in the upper right corner

Adjust the camera position to capture the part of the test area inside which water velocity should be determined.





Example of area of interest for flow determination in a 170ml Loligo® mini swim tunnel, where flow can be recorded over the in the entire experimental area (honeycomb to honeycomb). In a larger arena only a subsection of the experimental area should be included.

IMPORTANT: Once the camera is positioned and the recordings commence, the camera must not be moved. If the camera position is changed it will change the calibration values as well and a new pixel-to cm calibration is necessary.

4.2 Handling the laser pointer

Always wear the protective glasses when the laser is turned on!

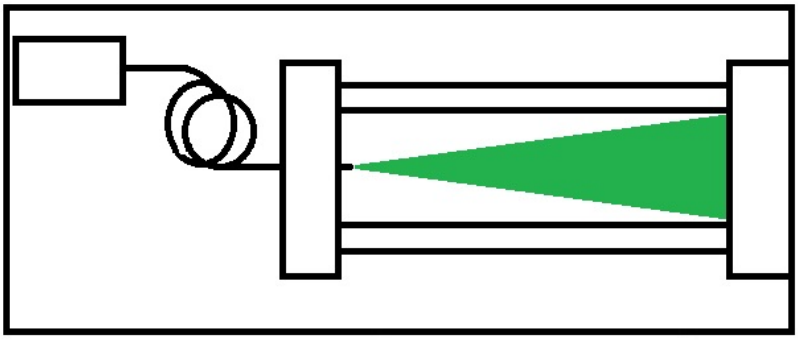
- The laser pointer should only be turned on during .avi video file recordings.

Mount the fiber optic cable onto the laser pointer using the SMA connection. The laser pointer has been specially adapted for use with the fiber optic cable, and should not be modified.

4.3 Mount the light guide in the flow channel.

The light guide must be mounted firmly so that the laser beam is parallel to the laminar flow.

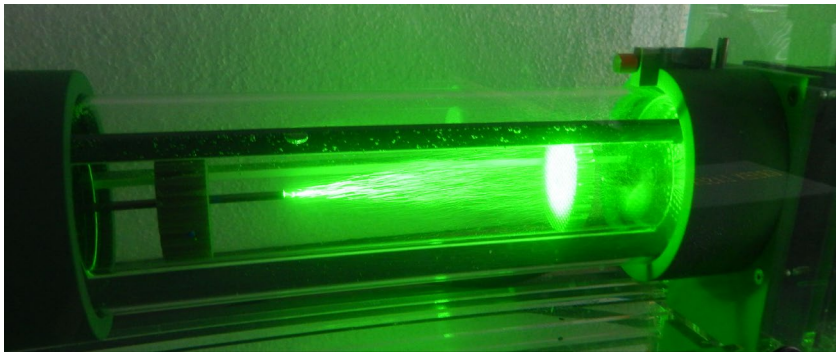
The light beam will scatter in a cone shape. For Blazca-type swim tunnels where the flow direction is reverse between the inner experimental glass tube and the outer glass tube, the light guide must be placed so that the laser beam in the recorded area is confined to the inner tube.



For Loligo® mini swim tunnels:

Insert the fiber optic cable through the end cap of the swim tunnel through the red fitting. Push the steel rod through the center of the honeycomb. For a detailed instruction on how to assemble a swim tunnel please refer to the swim tunnels user manual.

- For the 170 ml mini swim tunnel we recommend keeping the tip of the laser aligned with the end of the honeycomb during .avi video file recording.
- For the 1.5L mini swim we tunnel recommend pushing the steel rod as far into the experimental area as possible to avoid too wide a scattering of the laser beam.



Example of laser placement in a 1.5 L Loligo® mini swim tunnel.

Before conducting video recordings of the flow, however, it is recommended recording a pixel calibration .avi file (see section 5.1).

One option is to mark a known distance (for example 3 cm from the tip) on the lasers steel rod and mount the steel rod in the mini swim tunnel, by pushing the laser through the center of the honeycomb, letting the steel rod protrude into the center of the mini swim tunnel, so that the marking is clearly visible.

If calibration is carried out in a different manner, skip the marking described above.

4.4 Add micro spheres to the flow

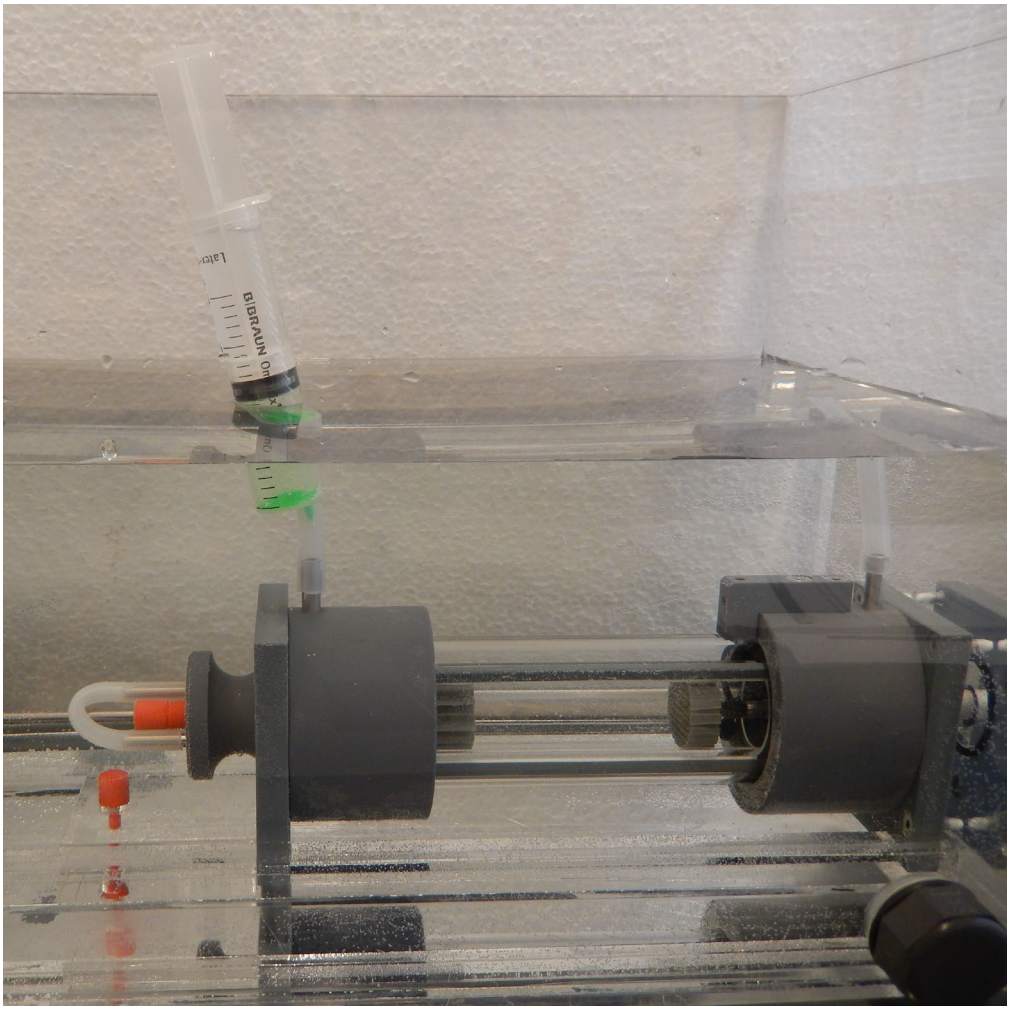
For visualization of the flow illuminated by the laser light, add the neutral density green fluorescent PE micro spheres to the flow path. The optimal micro sphere density depend on the velocity range over which the flow is calibrated and the camera speed (frames per second) at which the .avi video files are recorded. The density of the micro spheres should be adjusted so that individual spheres are clearly separated in the flow path but at the same time high enough for a good statistical analysis. We suggest an optimum around 20-30 spheres per frame in the flow velocity .avi videos (see section 4.5).

Generally a concentration of approximately 10 mg/L will suit most applications.

<u>For Loligo® mini swim tunnels</u>

It is important to add the microspheres into the swim tunnel without introducing air bubbles. Loligo® recommends adding the micro spheres directly into the swim tunnel using a standard plastic syringe.

- Weigh the appropriate amount of micro spheres directly into a stoppered 20 ml syringe. (For a 170 ml Swim tunnel ~ 2 mg microspheres is needed).
- Fill a beaker with water from the ambient tank and add 2-3 drops of detergent. Fill approximately 10 ml of the water w/detergent into the syringe holding the micro spheres. Carefully insert the plunger partly into the syringe, and mix the water and spheres. The solution may produce a little foam. Turn the syringe upside-down, and remove the stopper and extrude air and foam. Tap carefully to remove all air bubbles and foam.
- Lower the syringe with micro sphere solution into the water bath, where the water level is above the swim tunnel in- and outlet. Attach the syringe to the tubing on the inlet, and carefully inject the solution into the flow chamber avoiding introduction of air.



- Note, the detergent is added to break the surface tension. Without it the micro spheres tend to clump together. Adding too much detergent, however, will result in excess foam and high risk of bubble introduction.

Alternatively, add the micro spheres (~10 mg/L) to the ambient water around the swim tunnel and use the flush pump to get the micro spheres inside the swim tunnel.

4.5 Record .avi flow velocity videos for calibration of flumes and swim tunnels.

4.5.1 Adjusting the image size and frame rates

The frame rate at which the video is recorded (FPS) needs to be adjusted to the flow velosity, and hence the speed at which the microspheres move.

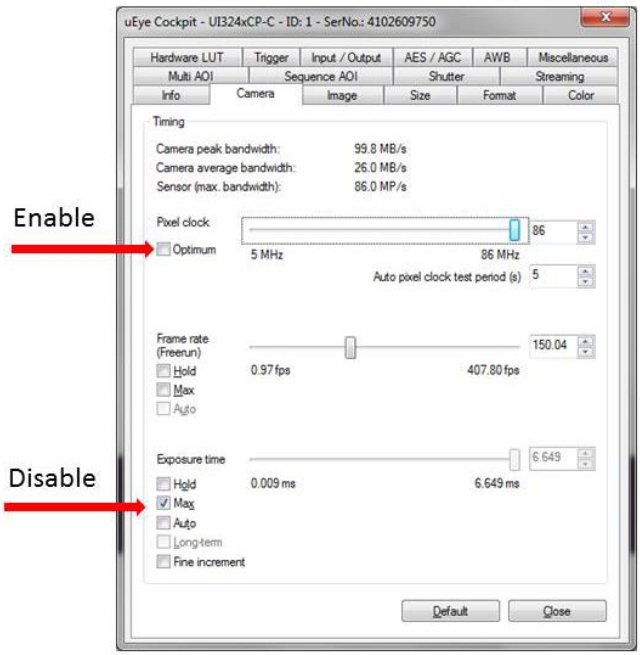
At full resolution 1280x1024 the maximum frame rate of the camera is 60 FPS (frames per second). Decreasing the resolution by drawing the area of interest will increase the FPS.

Frame rates of 150 to 450 frames per seconds are desirable to obtain a good analysis in the DPTV software.

The current frame rate is visible in the lower left corner. For a detailed description of the functions in the uEye Cockpit software, please refer to the uEye user manual for USB camera: www.loligosystems.com/Support/User manuals.

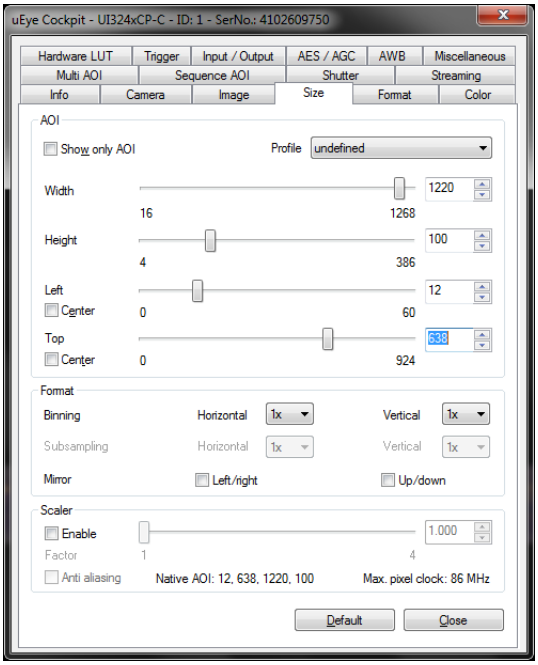
Select the Properties button (the icon is a wrench).

- Disable auto exposure time.
- Enable optimum pixel clock. The view now shows the maximum frame rate possible at the current resolution.



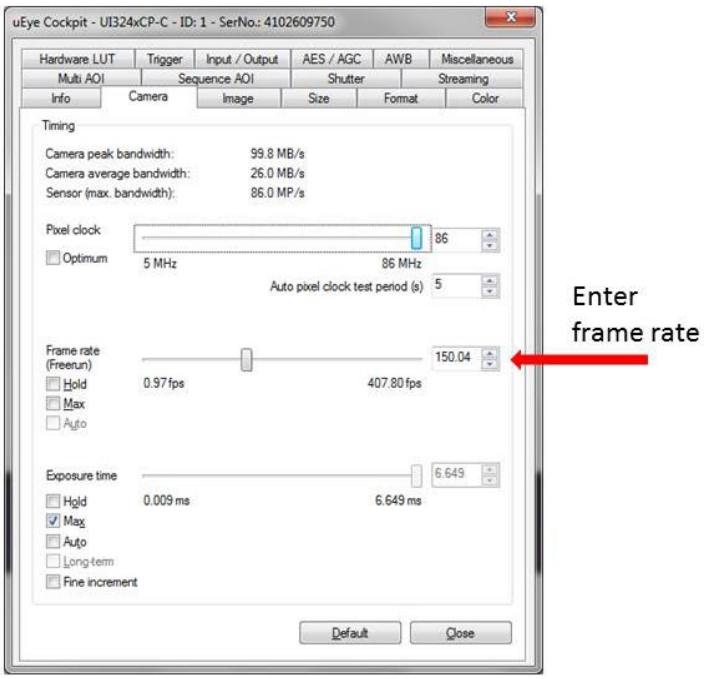
- Return to the video view.
- Click the New area of interest button (next to the properties button).
- Draw an area of interest over the flow path by holding down the mouse and drag an area. The area should ideally be 50 – 120 pixels high (see below).

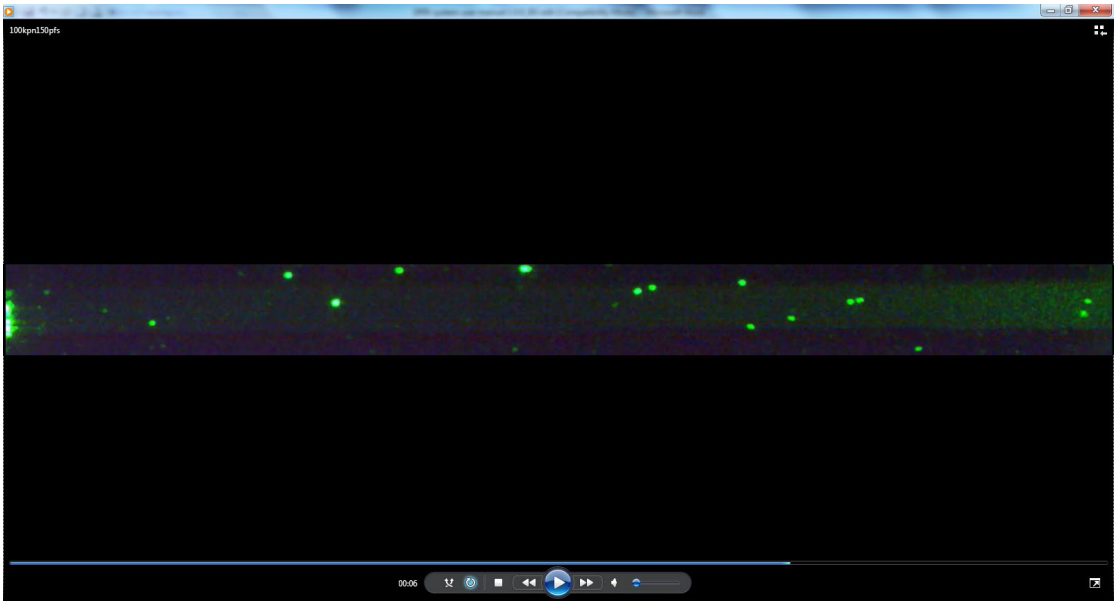
  Alternatively to using the drag and draw method, the area of interest can be adjusted in the Size View in the uEye Properties.



Select the Properties button again (the icon is a wrench).

- Enter frame rate. We recommend 150 FPS (frames per second) for flow calibration in the lower velocity range.





Example of an area of interest (1220 x 100 pixels) in a 170 ml mini swim tunnel. The area covers the complete length of the swim tunnel but not the entire height.

4.5.2 Recording flow velocity .avi video files

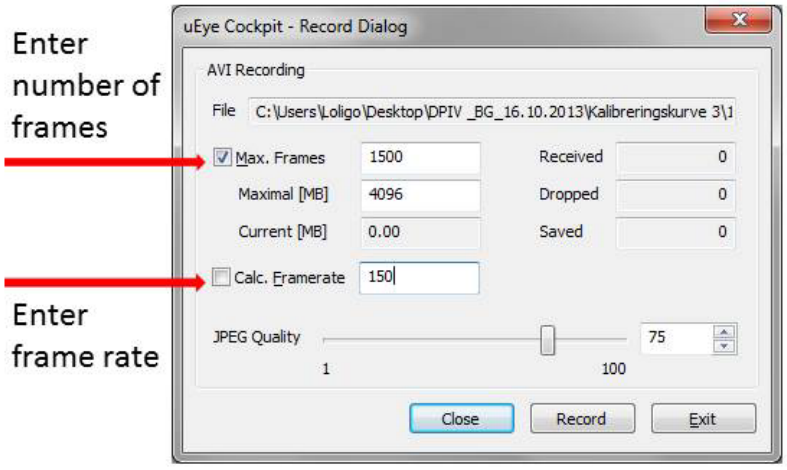
Select File→Record video sequence.

Click Create and choose a name and destination for the .avi video file.

Enter number of frames to be recorded. We recommend making a 10 second .avi file for each flow velocity data point. With 150 frames per second that corresponds 1500 frames.

Loligo® recommends recording at least 1000 frames to get good results for the velocity calculations in the DPTV software. More frames will improve the statistics of the results but the analysis time will also increase.

Enter the chosen frame rate (here 150 FPS).



During recording, the number of frames dropped by the software should remain zero (all received frames are saved). If a large number of frames are lost/dropped during recording/saving to the .avi file, the results will be erroneous. Reduce the frame rate if a large number of frames are dropped at a given frame rate.

4.5.3 Creating files for calibration curve

Record a number of .avi files at different flow velocities to produce the desired number of data points for a calibration curve.

- For optimal data analysis we suggest recording several avi. files with different frame rates for each flow speed.

For Loligo® swim tunnels:
The motor control unit controls the speed of the mini swim tunnel propeller in steps from 0 to 1000 rpm (rounds per minute) or 1500 rpm (170 ml and 1.5L mini swim, respectively). In a Loligo mini swim tunnel this correspond to approximately 0 to 50 cm/s.

- For a 170ml swim tunnel we recommend calibration from 100 rpm to 400 rpm in steps of 50 or 100 rpm using a frame rate of 150 FPS.
- For a 1.5L swim tunnel we recommend calibration from 200 rpm to 800 rpm in steps of 100 rpm using a frame rate of 150 FPS.

At higher flow rates a higher frame rate is necessary for a good result.

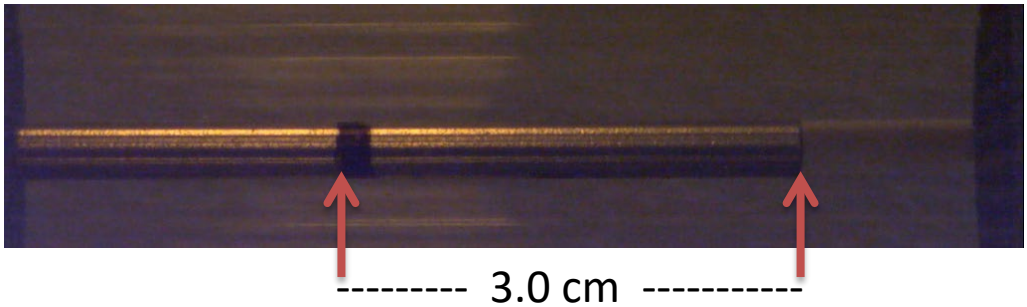
- For optimal data analysis we suggest recording several avi. files with different frame rates at each flow speed.

4.5.4 Recording a calibration video file

In order to calibrate the video image (pixel size) it is necessary to know the distance (in cm or mm) between two physical objects in the image. When creating the flow velocity video .avi files the image size is reduced (only the area of interest is shown) and no physical objects are recognizable. Therefore we suggest recording a pixel calibration video .avi file using the standard default uEye Cockpit settings prior to recording the flow velocity recordings.

The calibration image can be produced in a number of ways:

1) Mark a known distance (for example 3 cm) on the lasers steel rod. Insert the steel rod in the flow and visible for the camera. Record a short .avi video file (for example 200 frames) with the fixed camera setting.



Remove the laser steel rod from the flow and place in the measuring position (see section 4.1) and continue with the flow velocity video recording.

Alternative pixel calibration methods:

2) Place a ruler in the flow and visible to the camera and record a short .avi video file for pixel to cm calibration. In Loligo® mini swim tunnels the end cap does not need to be in place for the recording of the calibration .avi video.

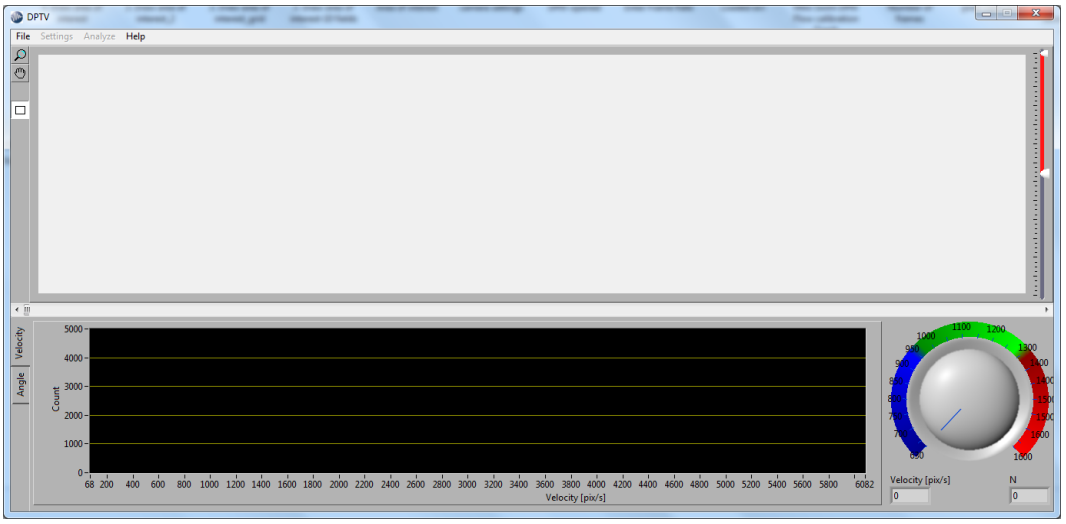
3) Measure the distance between two fixed objects in the flow, and make a short avi file where both are visible for the pixel to cm calibration.

Make sure that the video camera is not moved between making the calibration video and the flow velocity video recordings.

5. Analyzing video files

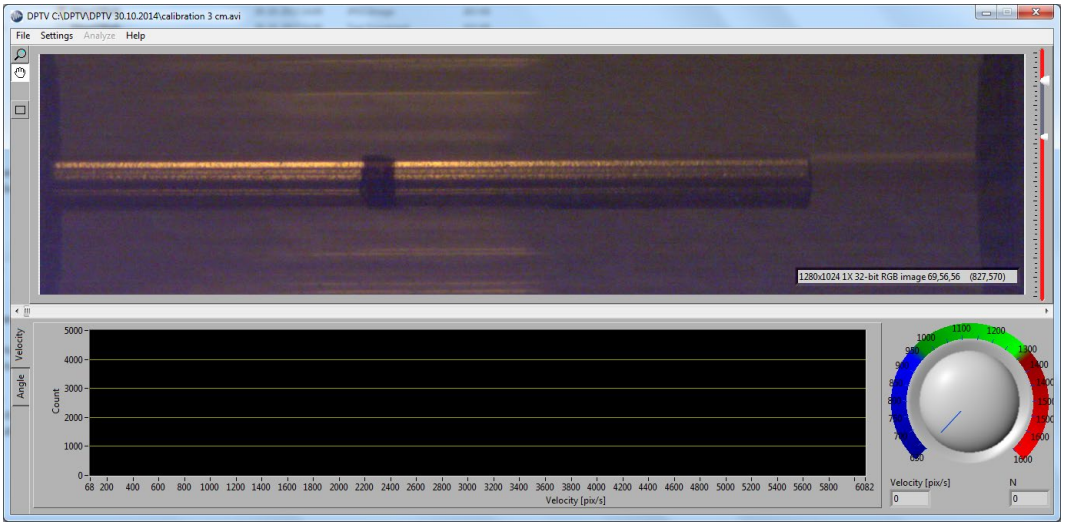
Start the DPTV system software by selecting Start→All programs→DPTV system.

It may take a few seconds to load the program initially. Watch the Windows task bar to monitor the loading process.



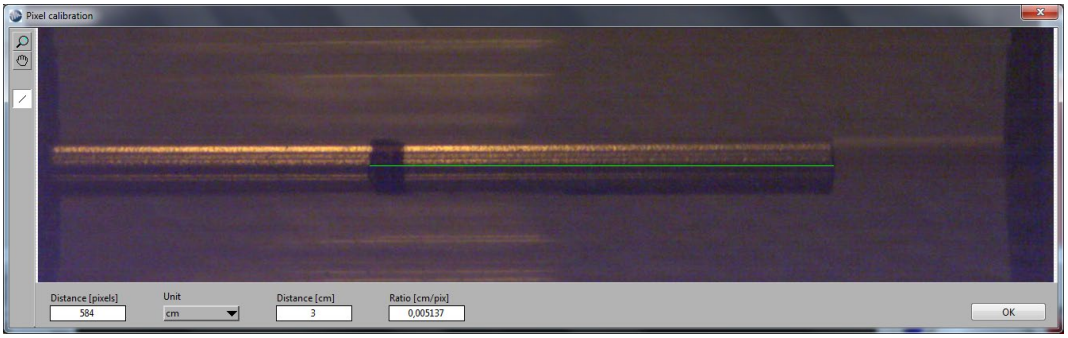
5.1 Pixel calibration

Select File→Load file and select the recorded pixel calibration .avi file.



Use the hand tool to scroll the image.

Select Settings → Calibration to open the pixel calibration window.



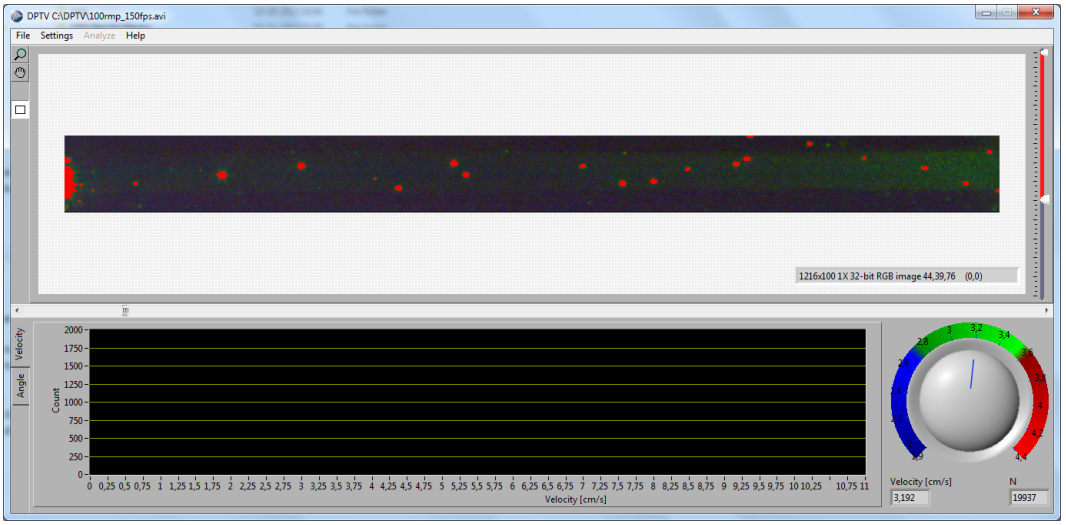
Use the hand tool to scroll the image to visualise the marked steel rod (or ruler or objects with a known distance).

Click the line tool and use the mouse to draw a line marking the known distance. Enter the known distance and unit. The pixel to cm ratio is now calculated.

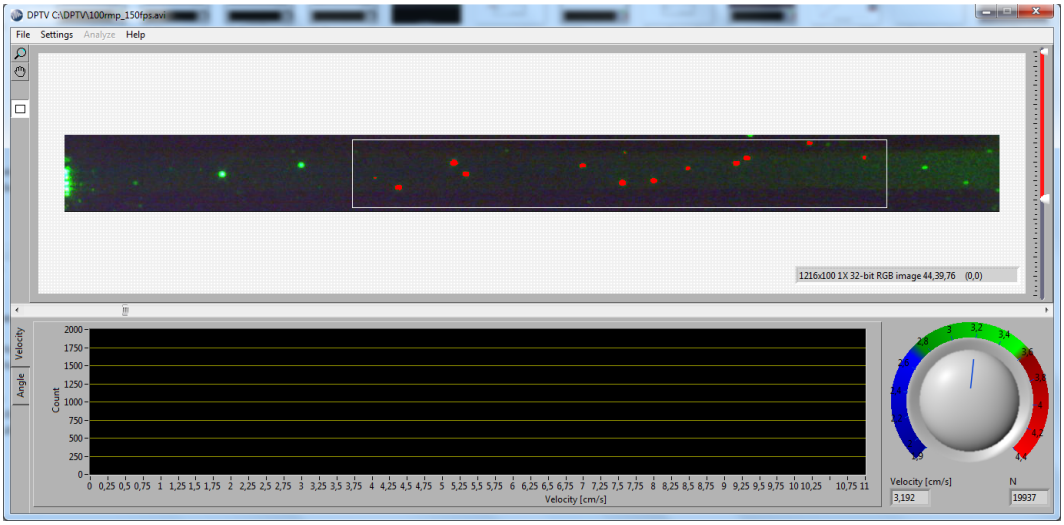
Select OK to save the calibration for the subsequent avi. file analysis.

5.2 Micro sphere flow file analysis

Select File→Load file and select a recorded .avi video file.



- Click on the rectangular button to the left and draw an area of interest.

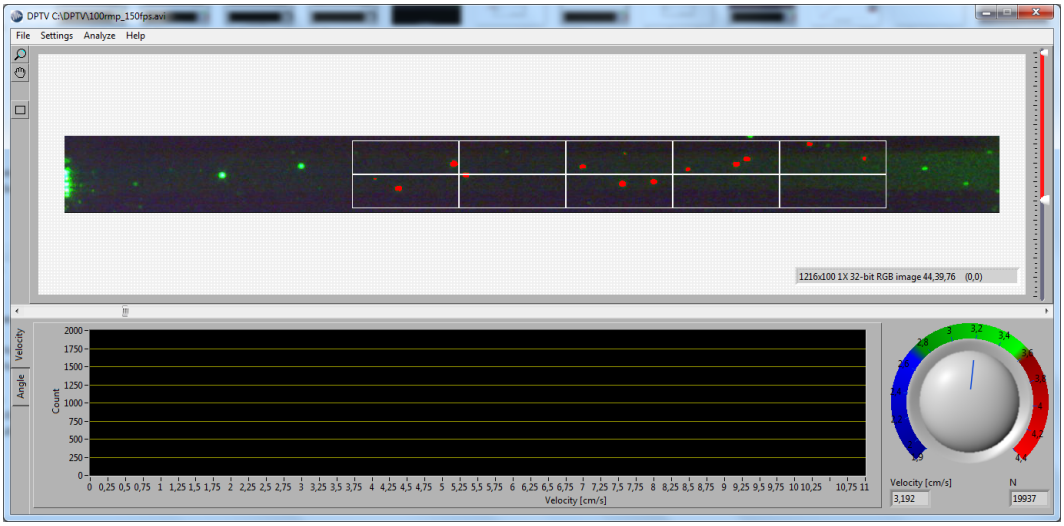


Now only the micro spheres inside the area of interest are marked red, all micro spheres outside the area will remain green.

- Use the threshold bar on the right side, to increase or decrease the red color intesity of the marked microspheres.
- Use the filter function erosion/dilatation if necessary in Settings→Filter.

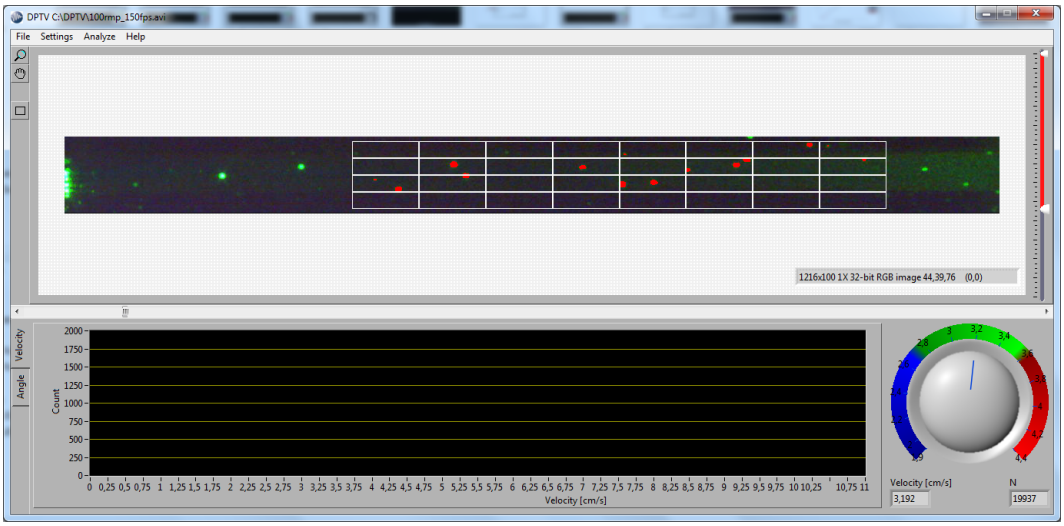
  Erosion and dilatation is a set of image processing operation that removes or add pixels on object boundaries. Using a 3×3 set of coordinate points (a so called structuring element) each pixel is compared to its neighbours, removing or adding any pixel that does not match its neighbouring (foreground or background, respectively) pixels.

- Click again on the rectuangular button to the left.
- The Area of interest is now Default divided into 5x2 sections.



Select Settings -> Grid size

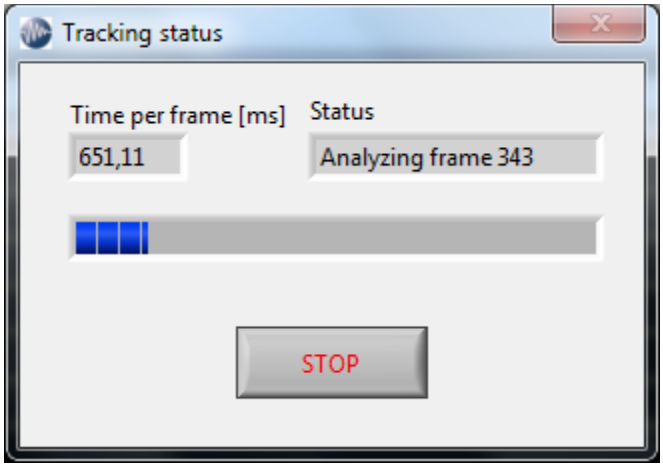
- Change the number of subsections desired for the analysis. Click two times on the rectangular symbol for the chosen grid to be launched.



Select Analyse

- The DPTV software will now track the microspheres frame by frame and caluclate the velocity and angle for every frame.

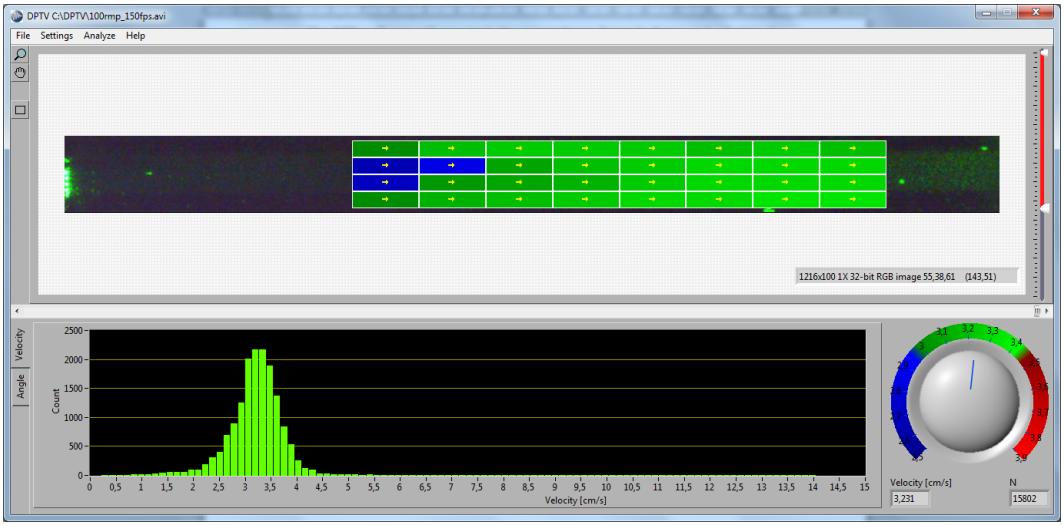
While analyzing the .avi file the Tracking Status window is shown.



- The tracking time of an .avi file depends on the frame rate, the number of frames, the size of the area of interest, the grid size and the sphere density, and can take several minutes.
- The analysis can be stopped at any time and the results shown for the sub sample of frames analyzed.
- When the Tracking is finished the grid in the area of interest will appear in color.

Place the mouse on the image but outside the grid and right hand click on the mouse.

The velocity distribution for the area of interest will now be shown in the bottom half of the window and the average velocity shown in cm/s.



Place the mouse over a cell in the grid, right hand click on the mouse, and the velocity distribution for the chosen cell will be shown in the bottom half of the window.

5.3 Evaluation of the DPTV data:

5.3.1 Velocity distribution

The velocity value calculated by the DPTV software should be carefully evaluated.

The distribution should show a normal distribution as in the example above.

- If the distribution is bi-phasic the average velocity calculated is erroneous. A biphasic distribution is most often the result of limitations in the video recording software and a new .avi file with a different frame rate for the given velocity needs to be recorded and analyzed in the DPTV software.
- If the distribution is skewed (has a tail) the average velocity is also flawed.

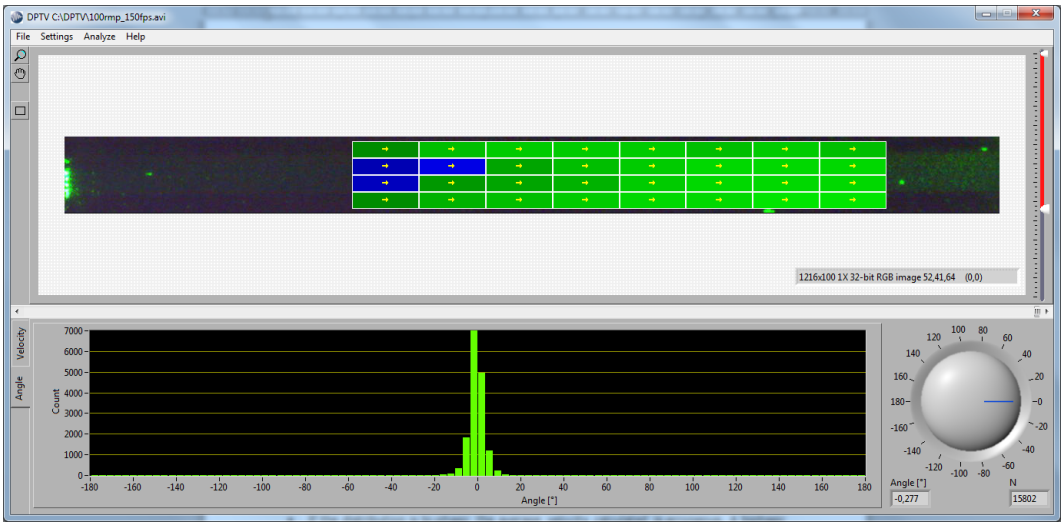
The velocity distribution in each section of the grid can be evaluated by placing the mouse over a section and right hand click. This also shows the value of the average velocity inside the section in the lower left corner.

Each section is colored according the deviation in mean velocity in the section relative to the mean velocity in the entire area of interest. The color coding allows for a fast evaluation of the data.

5.3.2 Flow direction (angle)

Select Angle

The second panel in the lower half of the DPTV window shows the distribution of the direction of the spheres during the analysis.



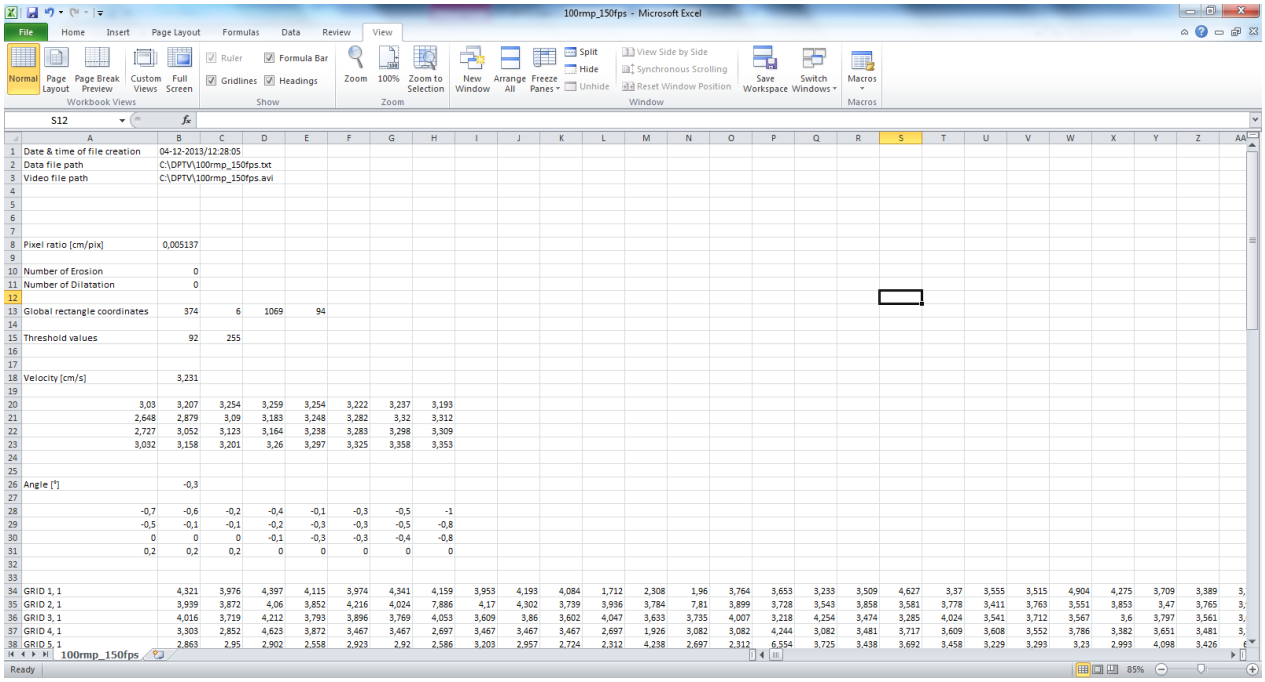
5.3.3. Saving data files

Select File→Save file and enter a name and destination to save the file.

The data is saved to a txt.file that can be imported directly into Excel.

The data file include the mean velosity in cm/s in the area of interest, the mean velosity within each cell of the grid and the mean velosity for each sphere counted in each cell.

The data file also include the mean angle (°C) at which the spheres travelled, the mean angle within each cell of the grid and the mean angle for each sphere counted in each cell.



Example of a DPTV Excel data file from the analysis of the .avi video file shown above.

To exit the DPTV software click File→Exit.

6. Flow velocity calibration curve

Plot the caltulated flow velocities as a function of motor unit setting and calculate the linear regression.

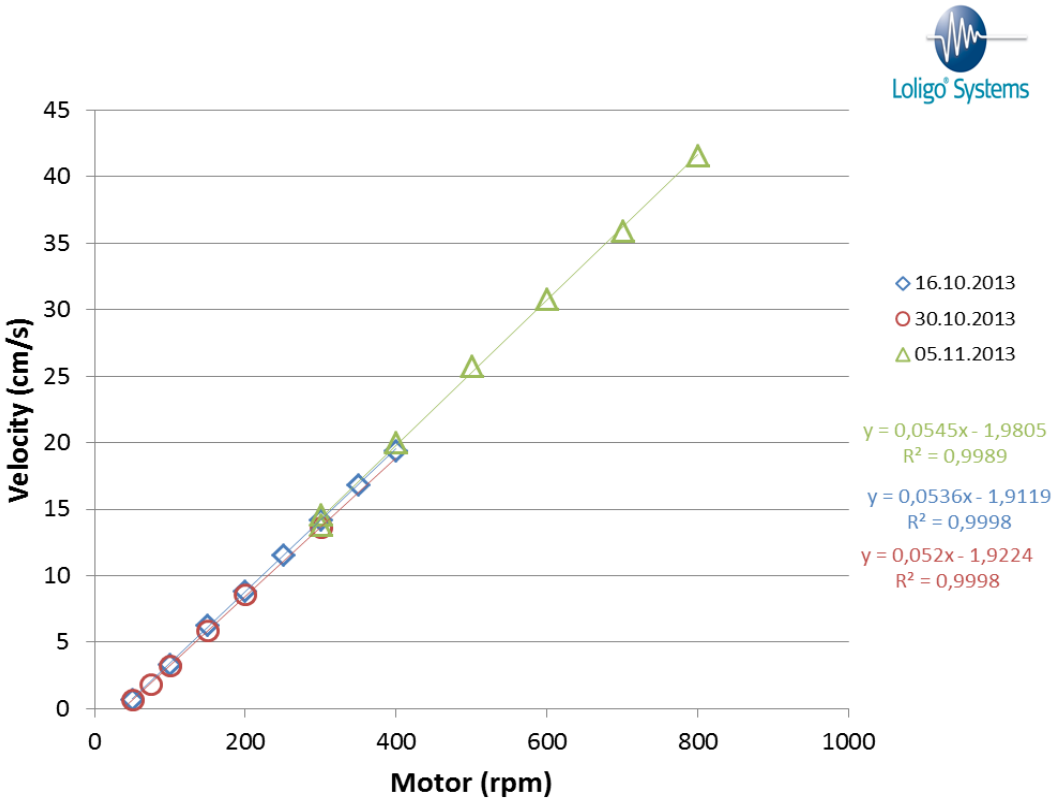
For Loligo® swim tunnels the velocity as a function of propeller speed is linear throughout the entire range.

Therefore it is not nessesary to measure flow velocity covering the entire velocity range. The limitations of the video camera and the rate with which it can satisfactorily save frames makes it difficult (but now impossible) to produce acceptable videos at high flow velocities.

We therefore recommend making 3-5 calibrations points in the 50 to 350 rpm (rounds per minute) interval.

The graph below verifies that

1) Flow in a Loligo® swim tunnel is linear in the flow velocity range.
2) the flow velocity measurement is reproducible with the DPTV software.



Example of velocity data from a Loligo® 170ml mini swim tunnel. Each graph show flow velocity measured in the same swim tunnel on 3 separate occasions.

7. Troubleshooting

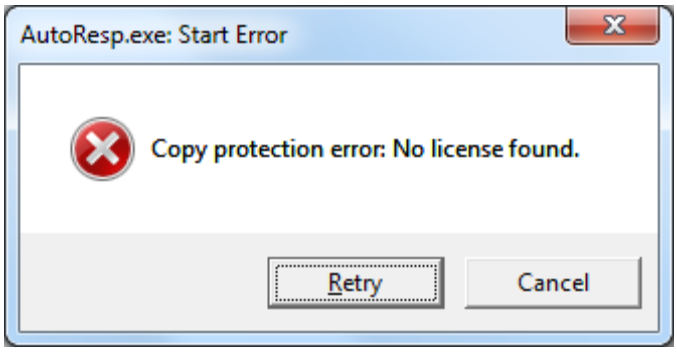
7.1 Run DPTV software on PC always with administrator rights

1. Right click on the DPTV system icon.
2. Choose properties.
3. Go to compatibility.
4. Enable "Run this program as an administrator"
5. Click OK.
6. Now open DPTV software by double clicking the icon.
7. Choose Yes, to confirm that you want to start the software as admin.

Next time you want to open DPTV software as administrator only do step 6 and 7.

7.2 WiBu software protection

The DPTV software is protected with an USB hardkey dongle (WiBu), and will only run if a valid dongle is connected to an USB port on the computer. If not, the error message below will appear.



Plug in the WiBu hardkey dongle and wait to let it be recognized by Windows. Only then can DPTV software be used.