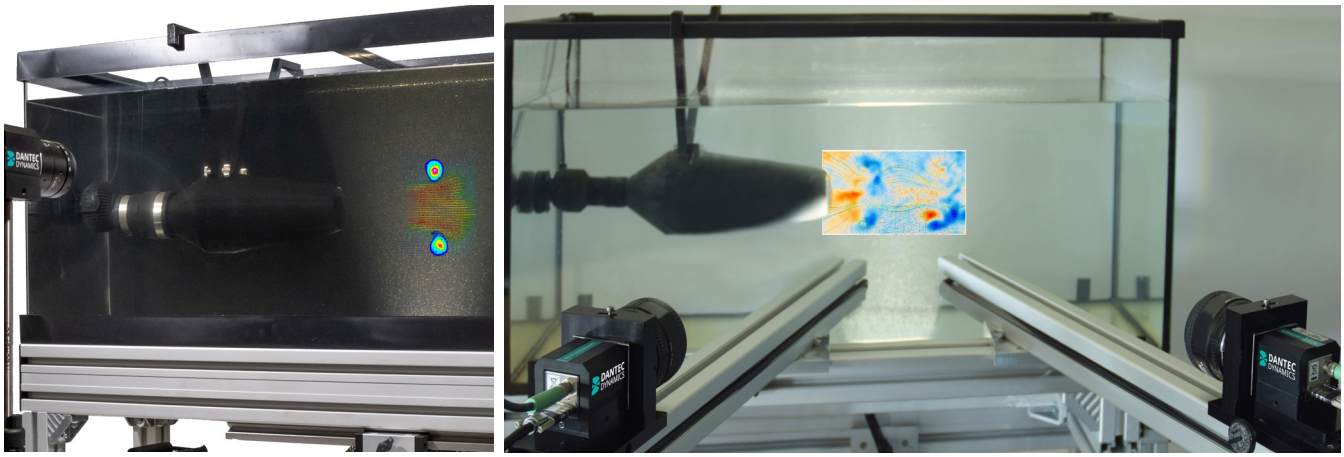
SOLUTION SHEET

# EduPIV & EduStereoPIV

## LED-Based Educational Particle Image Velocimetry Systems



*EduPIV and EduStereoPIV - turnkey PIV systems for educational use.*

### Turnkey PIV systems for educational use

Particle Imaging Velocimetry (PIV) systems allow for non-intrusive optical measurements of velocity fields in flows. Historically, PIV has been out of reach for most educational laboratories due to cost and, more importantly, laser-safety concerns.
The EduPIV series consists of systems for planar PIV and Stereo PIV. They offer a safe, affordable, and turnkey solution for introducing students to this powerful technique. These systems employ an LED-based illumination source which is safe and easy to operate while combining excellent reliability and performance. Complete with all necessary hardware, software, and table-top flow experiment, the EduPIV and EduStereoPIV systems can carry out simple and advanced PIV experiments and demonstrations without the need for any additional equipment other than a computer.
For data acquisition, image processing, and flow analysis, the system comes with DynamicStudio EduPIV software to provide students with all the latest tools for PIV.

### Key benefits

- Time resolved PIV measurements for fluid mechanics laboratory courses
- Planar PIV and Stereo PIV solutions available
- Upgrade possibility from EduPIV to EduStereoPIV and to more advanced systems
- Student training - prepare students for PIV research during and after university
- Safe operation with LED illumination – no laser required
- Powerful DynamicStudio EduPIV software offers students a comprehensive PIV experience
- Complete flow-loop and experiment with instructional video
- Simple, flexible flow loop design; easy to add student-created experiments

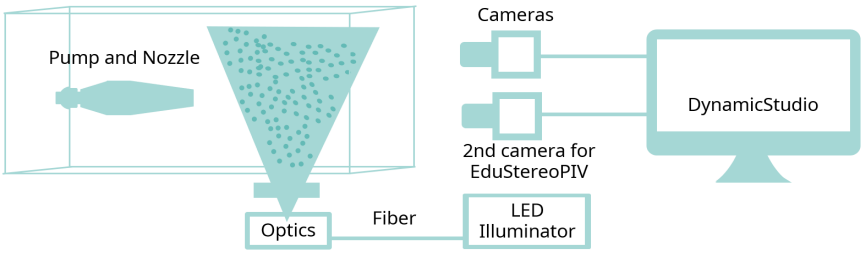
## The EduPIV and EduStereoPIV solutions in brief

Particle Image Velocimetry (PIV) is a non-intrusive optical measurement technique for research and diagnostics into flow, turbulence, microfluidics, spray atomization, and combustion processes. A fluid is seeded with small particles that follow the fluid's motion. The particles are illuminated and captured via at least one camera. The fluid motion is subsequently analyzed using PIV software. Standard 2D2C PIV (2 Dimensions, 2 Components) uses a single camera and measures two velocity components in the illuminated plane. Typically, these systems consist of a camera, a laser with some beam guiding components, light sheet optics, a synchronizer, and a PC for data acquisition, storage, and analysis.

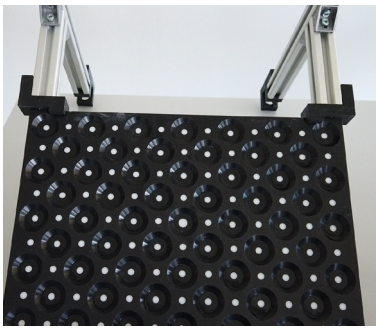
In case of a Stereo PIV (2D3C) system, a second camera and a calibration target are required which are used to project the planar vectors in the illumination plane into the 3rd dimension.

For both systems, an LED illumination source and fiber optics are used rather than a laser, and the image timing is controlled entirely by camera settings in the DynamicStudio software. The configuration of the system makes it safe and simple to operate, allowing students to focus on learning measurement principles rather than on operating complex hardware.

A complete experimental setup and measurement system is included to provide a turnkey solution for PIV instruction. The basis of the flow setup is a water tank experiment (flow loop) with a variable pump and nozzle. The nozzle produces a water jet which allows for a variety of tests to be carried out, and the flow loop can be easily reconfigured for additional tests. Micron-sized polyamide spheres are used for seeding the jet flow, and one or two FlowSense USB 2M-165 camera capture the particle motion. The images are analyzed using DynamicStudio to provide global velocity maps, turbulence statistics, scalar analysis, temporal/spectral evaluation, and flow visualization.




*Overview of the different components, timing and data flow*



*2-Level Calibration Target for easy, fast, and accurate spatial calibrations.*

## EduPIV Flow Loop Experiment

The flow loop consists of a water tank on a table-top aluminum frame with a sliding arm mount for the camera and light sheet optics. The LED and sheet optics illuminate the measurement plane and the sliding arm moves the camera and light sheet together for imaging different areas of the flow. The included pump and nozzle provide a jet flow with variable output controlled by an electronic controller. The water jet can be operated in the following modes:

**Steady Flow:** This is the first and most basic flow used to teach students the fundamentals of the PIV method. It consists of a quasi-steady, turbulent jet flow. Providing a simple (primarily) unidirectional flow allowing students to start by focusing on the PIV method rather than the flow complications. Here, students learn the basic parameters for carrying out PIV experiments: timing, seeding, camera setup, and illumination basics. Flow speed is variable up to approximately 50 cm/s with the supplied nozzle. Higher/ lower velocities can be achieved using different nozzles.

*3D-printed nozzle.*

**Periodic Flow:** The jet velocity fluctuates periodically to create a dynamic jet flow. This allows students to do temporal, spectral, and modal analysis. More consideration of PIV parameters is introduced to account for the larger variations in velocity.

## DynamicStudio

The DynamicStudio EduPIV software links acquisition, data processing, and results analysis together in a powerful user interface. To calculate the velocity fields from acquired raw images and analyze the results, the DynamicStudio Base package and add-on for 2D2C PIV analysis are used.

The EduPIV system includes our powerful DynamicStudio EduPIV software to provide students real-world PIV experience with the most advanced processing techniques available for 2D2C PIV and Stereo PIV. With data acquisition and analysis performed in the same software, there is no need to move data around. Dedicated analysis routines and customized analysis sequences allow for quick investigation and visualization of results. The software is very easy to use and includes extensive data exchange features (e.g. MATLAB) for more advanced student projects and reports.

For further details on the software performance, please consult the separate data sheet on the DynamicStudio Software.

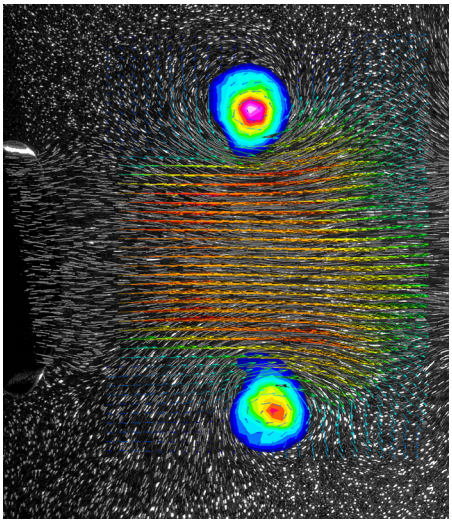


*Figure 1.*

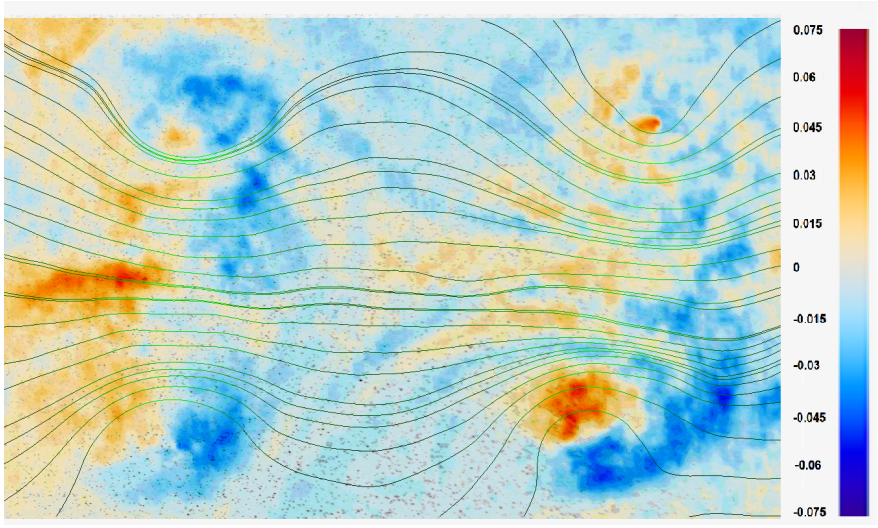



*Figure 2.*

*Figure 1. Particle motion from vortex ring with overlaid instantaneous PIV vector and scalar data. Vortex core identification based on 2nd invariant Q-values.*
*Figure 2. Stereo PIV result of a jet flow, the red colors indicate flow towards the spectator, blue colors represent flow away from the spectator.*

## Camera and lens

The FlowSense USB 2M-165 camera offers the ideal solution when it comes to performance and ease of use. With its USB interface, the camera can be used with a USB 3.0 PC or laptop without the need for frame grabbers or other hardware. At 1920 x 1200 pixels, the CMOS sensor is capable of 165 frames per second and higher frame rates with reduced region of interest. For both the EduPIV and the EduStereoPIV system, a low-distortion 35mm lens is provided. In case of the 2D2C system, it is an f/2.1, c-mount lens to provide the optimal magnification and field-of-view for the EduPIV flow loop. In the case of the 2D3C system, it is an F-Mount lens to allow for enough tilt angle of sensor to the lens; additionally, it offers a slightly brighter aperture with f2.0 and a larger image diameter. The camera is mounted to a sliding arm on the flow loop to move the area of measurement quickly and easily within the tank.


*FlowSense USB 2M-165*

## LED illumination and sheet optics

To provide safe and reliable illumination, an LED light source is used. The 150W illuminator provides the intensity needed for the short exposure times used in PIV measurements.
The output of the illuminator is coupled to a multi-mode fiber optic bundle. On the output end of the fiber bundle, the fibers are arranged in a row to create a line of light. The line is focused with a rod lens to form a sheet of light. The focal point (or saddle point) of the light sheet can easily be adjusted by moving the rod lens up and down. The compact line light and rod lens are affixed to the same sliding arm as the camera so they move together to measure in different areas of the tank.

*LED fiberoptic guide and sheet optics*

## Pump, Controller and Nozzle

The pump is simple to operate and mounts in the tank via a magnetic base. The pump is connected to the 3D-printed nozzle via a rubber boot which allows for quick and easy removal or replacement. With this flexible design, students can design and print their own nozzles or conditioners to create and measure various flows.
The pump controller allows for quick manual adjustments and can be adapted to external control for more complex experiments. The nozzle has a 5 cm diameter and provides a flat jet profile.

*Pump and controller.*

## Stereo System and Upgrade

To teach and train the basics of Stereo PIV, the 2D2C system can be upgraded, or an EduStereoPIV System can be ordered directly. With this system, it is also possible to measure the third velocity component of the flow within the light sheet plane, which results in 2D3C data. For that, an additional camera, Scheimpflug-mounts, and a calibration target are delivered in addition to the standard EduPIV system.

With the Scheimpflug-mounts, the depth of field problem is corrected when looking at a plane with an angle. As with standard systems, the mounts tilt the sensor plane instead of the lens. This has multiple advantages since the field of view remains the same when tilting the sensor with a lens fixed. If the lens was tilted, the field of view would change, so the camera would have to be moved and aligned again. Furthermore, it is possible to fine align the sensor position to the pivot point. This is necessary to compensate optical and manufacturing tolerances. Combined with the bright 35mm f2.0 F-Mount lenses, the optical set-up is ready for anything including more advanced measurements in or outside this flow-loop. To accommodate the Scheimpflug mounts and the bigger lenses, the camera rig for the EduStereoPIV system is also redesigned and uses bigger profiles compared to the standard EduPIV system. This adds more stiffness and reduces the likelihood of cameras moving out of alignment.


*Scheimpflug mount for EduStereo PIV system with camera and 35mm f2.0 lens.*

To reference the position of the cameras and the relation between them, it is necessary to spatially calibrate them. This is done by the Dual-layer, double-sided target which is part of the system and adds additional value, offering you a calibration with just a single image of the two cameras. This process sets the industry standard with its fully automatic point detection algorithms. With it, the setup can be calibrated down to a reprojection error of below 0.15 pixel. This already great value can be further refined down to below 0.05 pixel by applying calibration refinement, which almost eliminates calibration errors.

## Technical specifications

| Component | Model | Details |
|---|---|---|
| ***Common parts*** | | |
| **Software** | DynamicStudio<br>EduPIV software | Base package<br>2D PIV<br>Complete Image Processing Library<br>POD analysis<br>MATLAB, Octave, CFD Link, and much more |
| **Camera(s)** | FlowSense USB 2M-165 | 160 frames per second<br>1920 x 1200 pixels<br>USB 3.0 Interface |
| **LED** | EduPIV LED | 120 W illumination<br>110/220V input |
| **Light Sheet** | Fiber Light | Fiber-optic line light guide |
| **Optics** | | Adjustable Focus Rod Lens<br>35° divergence angle<br>7.6 cm sheet width at aperture<br>4mm minimum sheet thickness |
| **Pump** | | 0.2 – 0.5 l/s<br>Possibility to set sine and square functions<br>12 VDC |
| **Nozzle** | | Jet diameter at exit: 5 cm<br>Flow range: 2 - 5 cm/s |
| **Flow Loop** | <br>Lens | 80 x 35 x 40 cm<br>112 liters |
| ***EduPIV*** | <br><br>Rig<br><br>Lens | 35mm Low-Distortion<br>f/2.1 – f/16 aperture<br>35mm focal length<br>C-mount<br>Lockable focus and aperture<br>Height adjustable camera post |
| ***EduStereoPIV*** | <br>Software<br>Rig<br>Scheimpflug | f/2 – f/22 aperture<br>35mm focal length<br>Nikon F-mount<br>Stereo PIV Add-on<br>Robust rig for 2 cameras<br>2x Scheimpflug mounts |

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