



Particle Shadow Velocimetry System

User Manual

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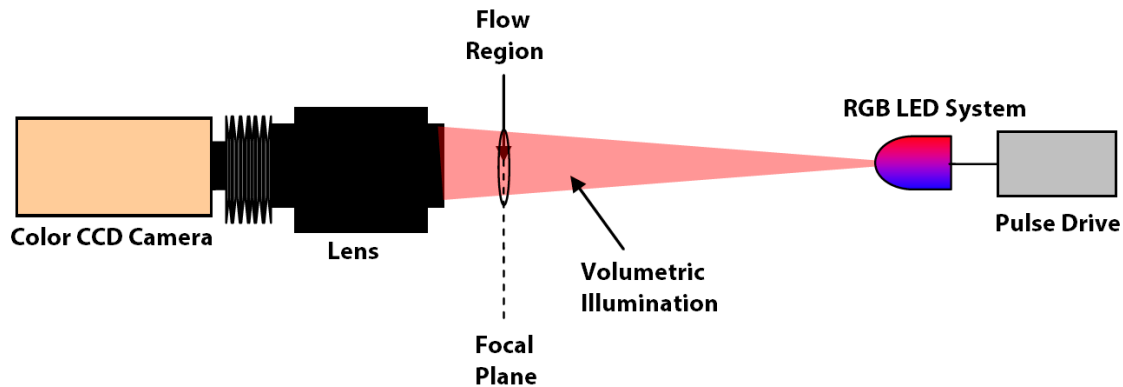
Website: www.innssi.com/psv



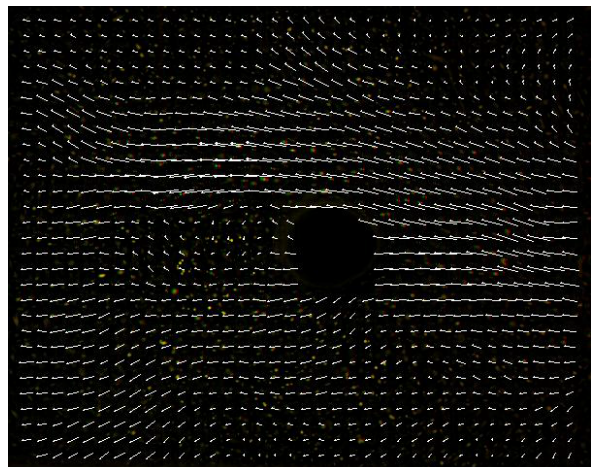
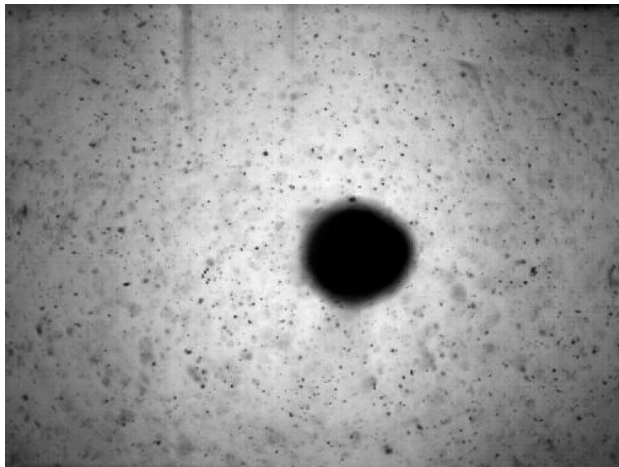
Revision Date: 5/30/2019

PSV Background

Cost and safety issues associated with laser-based particle image velocimetry systems effectively eliminate their use in undergraduate student training. ISSI has developed a cost-effective alternative, Particle Shadow Velocimetry (PSV), illustrated below:



PSV uses light extinction (particle shadows) rather than light scattering in a laser sheet, resulting in high-quality particle imaging at much lower illumination levels. These safe illumination levels can be generated by a pulsed-LED system at a fraction of the cost of a pulsed laser. Multi-color LED illumination permits the use of a low-speed camera, further reducing system cost. Different color LEDs are sequentially pulsed, at high speed, and the sequential particle images are captured in a single frame on the camera's three color planes. Narrow depth-of-field optics are used to image a two-dimensional plane within the flow volume, similar to what is achieved with a laser sheet. Measurement close to surfaces is possible because the system is not degraded by surface reflections which severely limit laser-based systems. The PSV approach is fully compatible with the seeding approaches and specifications used with conventional PIV systems.



System Components

The PSV system is composed of a pulsed RGB LED, a CCD color camera, autofocus bellows, Canon® EF lens, Canon® EF lens controller and pulse delay generator.



RGB LED



CCD Color Camera



Pulse/Delay Generator



EF Lens Controller



Auto Focus Bellows

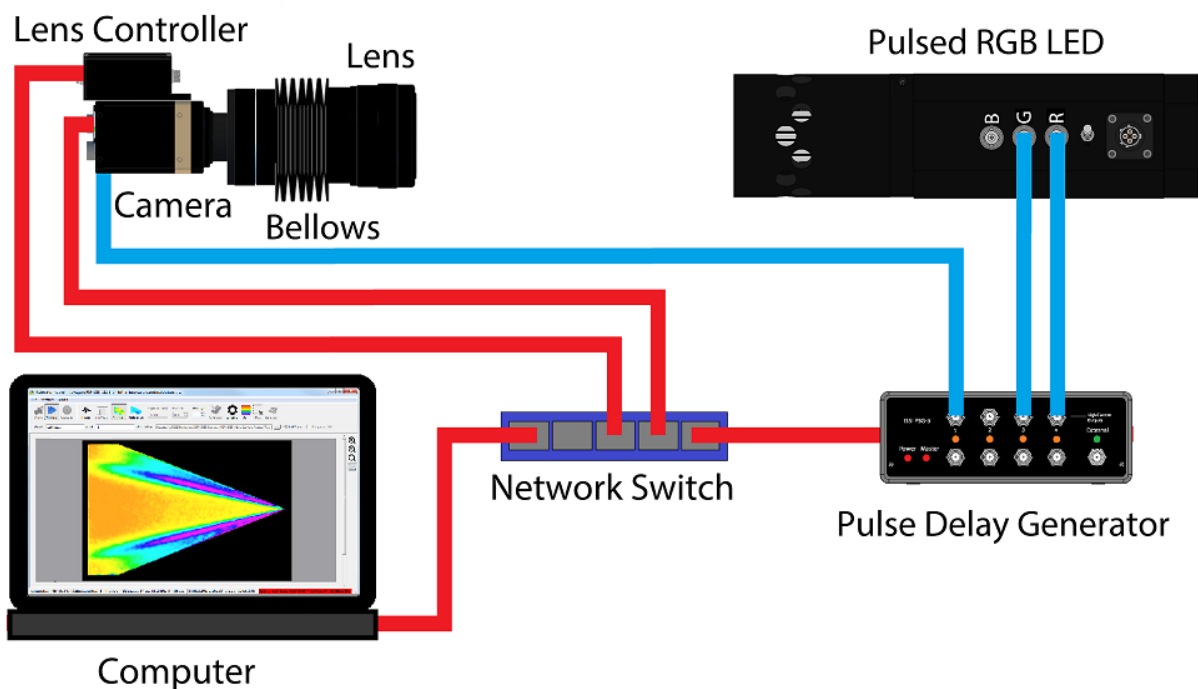


EF Zoom Lens

Network Setup

Begin by connecting each device to the Ethernet switch and connecting the power to each device. The pulse delay generator, camera and lens controller are all Ethernet controlled. Each should be directly connected via Ethernet to the switch. A fourth Ethernet cable should be connected to the computer so that all devices on the network can be accessed. Refer to the instruction manual for each device to set up communication and software. Next, connect BNC cables to the devices which will be triggered by the pulse delay generator. Connect channel 1 on the pulse delay generator to the camera trigger input. Connect channels 3 and 4 to the red and green BNC connections respectively on the LED module.

Network Configuration



The network on the PC NIC (network interface card) needs to be properly configured for communication over the network. To do this, navigate to the 'Network Connections' page on the control panel where the local networks of the computer is displayed. Right-click on the network where the network switch is connected and select 'Properties.'

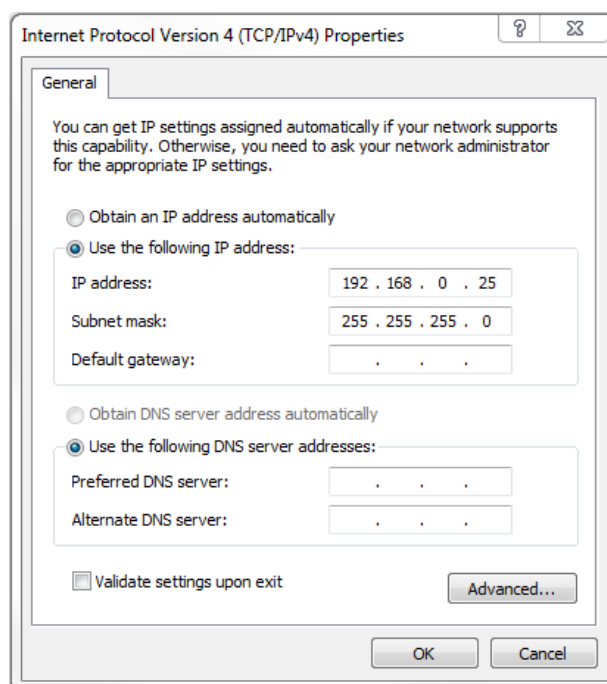
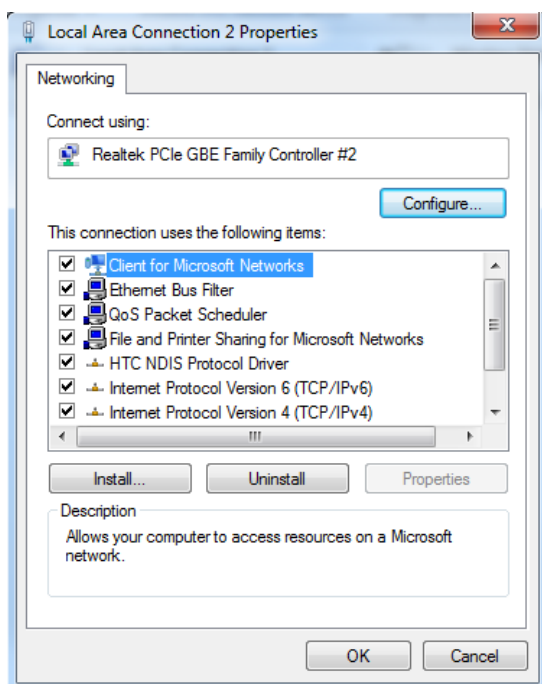
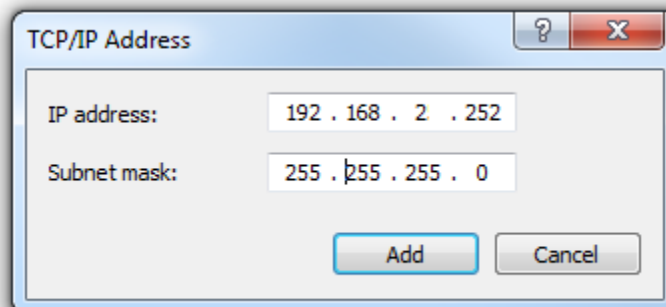
From the 'Local Area Connection X Properties' window, click on 'Internet Protocol Version 4 (TCP/IPv4)' and then press the 'Properties' button, now useable. This will open the 'Internet Protocol Version 4 (TCP/IPv4) Properties' window. This is where the IP addresses are entered so that connected devices can be reached over the local network. The settings needed for communication are **IP Address** and **Subnet mask**.

The IP address of the NIC should use the following conventions:

IP Format:

Network.Network.Subnet.Host

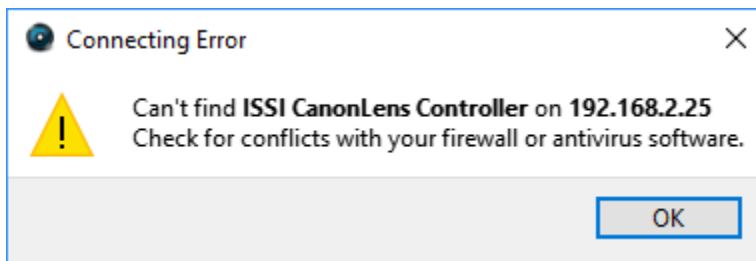
- LC-2 IP: 192.168.2.252. Can also be set by user.
- PSG-3 IP: 192.168.2.30. Can also be set by user.
- Camera IP: Dynamic. Can be set by user.
- NIC IP: 192.168.2.XXX



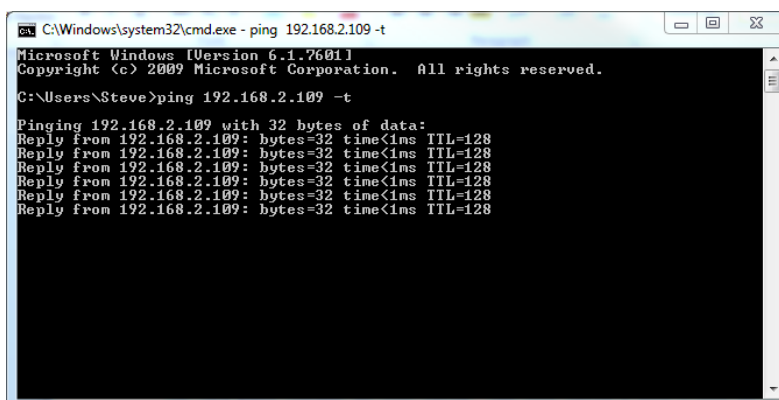
The NIC IP address should have the same network and subnet addresses but a unique host, the last line of the IP address. The host can be any value 1-254 but different from the host address of the device. The subnet mask should be set to match that of the devices which, by default is 255.255.255.0. The **Default Gateway** and all other fields can be left blank.

Additional subnetworks can be configured for the same NIC. In the 'Internet Protocol Version 4 (TCP/IPv4)' window, the **Advanced** button will open the 'Advanced TCP/IP Settings' window. IP addresses of any subnetwork can be added for that NIC here. If multiple devices are being used on the same network and they have differing subnetworks, this option provides communication for all devices without the need to change IP addresses for each device.

If the lens controller is not connected properly a connection error (below) will be displayed. First, reset the device via the reset switch which will restore the default IP address.

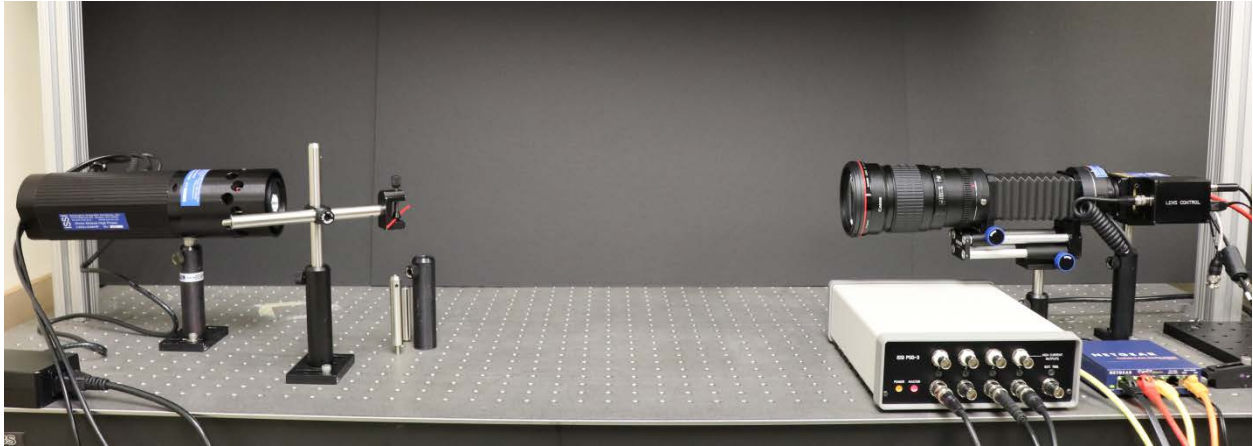


If connection problems persist, check the connection of the Ethernet cable between the computer NIC and the each device on the network. To check that there is a physical connection, ping the IP address of each device from the Command Prompt. To do this, open the command prompt window and enter: ***Ping XXX.XXX.XXX.XXX -t***

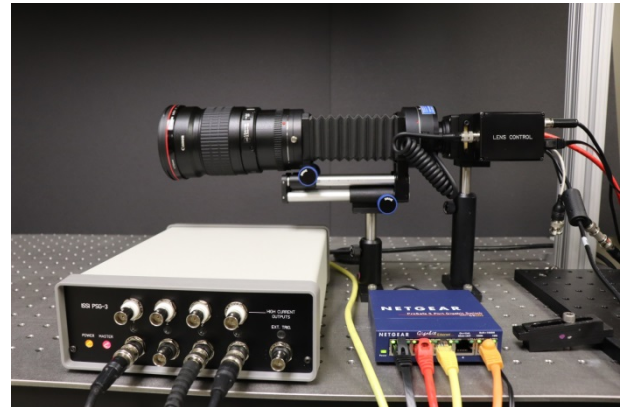
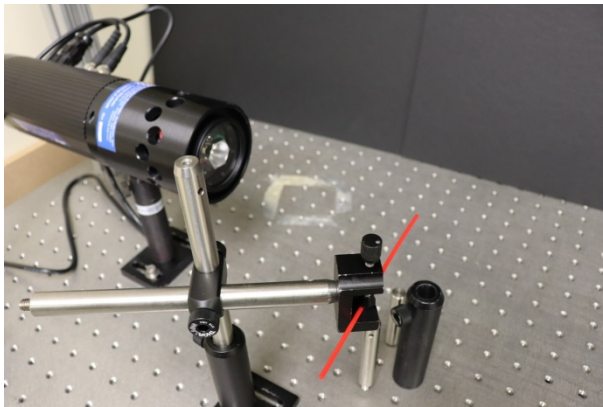


Experimental Setup

The camera and optics are placed opposite the pulsed LED with the flow field of interest in between. In PSV the setup permits the DOF, the field-of-view (FOV), and the working distance to be adjusted by introducing spacers or bellows between the camera body and lens. In a simple setup that uses bellows, the required extension of the bellows attachment is the product of the magnification and focal length.



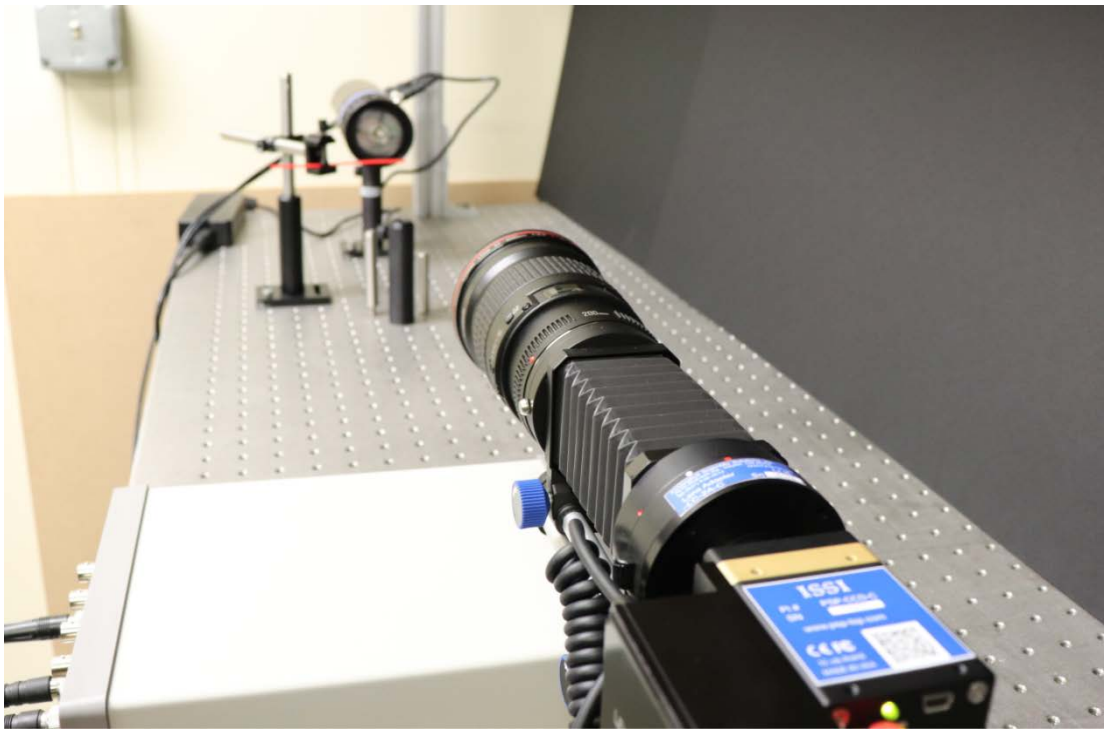
The autofocus bellows allow for the Canon® EF lens controller to be used to control the focus and aperture of the attached Canon® EF lens. Adjustment of the bellows allows the field of view to be adjusted.



The pulse delay generator is used to control the pulse width, delay time and frequency of the camera and pulsed LED. A network switch is also included to communicate with each of the hardware components over the local network.

**Camera Trigger Connection****Pulsed LED Trigger Connections**

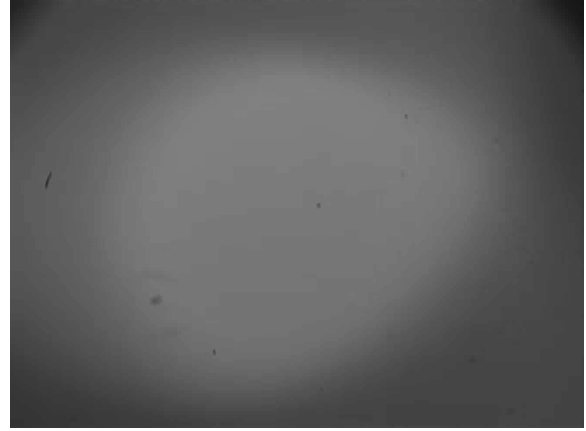
The pulsed LED is aligned 180-degrees from the camera lens. The LED is placed at a distance from the camera such that the LED is out of focus to the camera.



The LED must be out of focus relative to the camera so that the image background is near uniform. If the LED array is in focus relative to the camera, the background will be non-uniform and not provide the proper backdrop for particle shadow velocimetry. The LED and camera should be aligned to fill as much of the field of view as possible with an even background illumination.



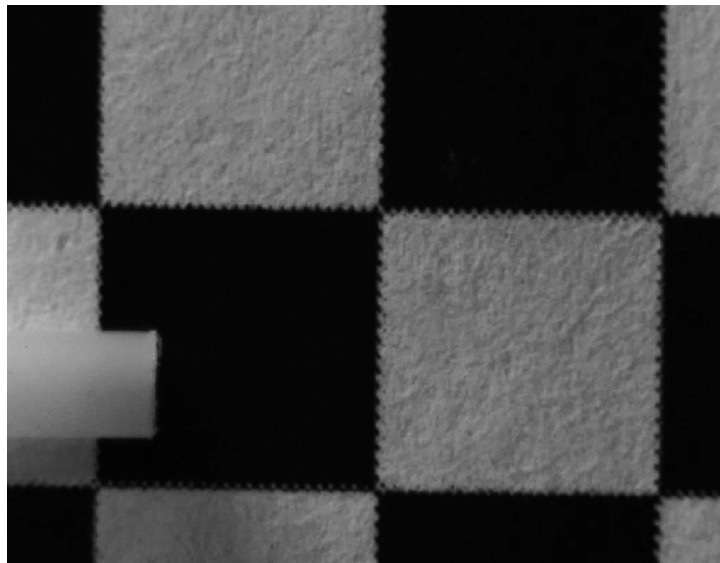
LED Array Misaligned and in Focus



LED Array out of Focus



Above is an example of the correct focus and LED-camera distance so that the LED is completely out of focus.

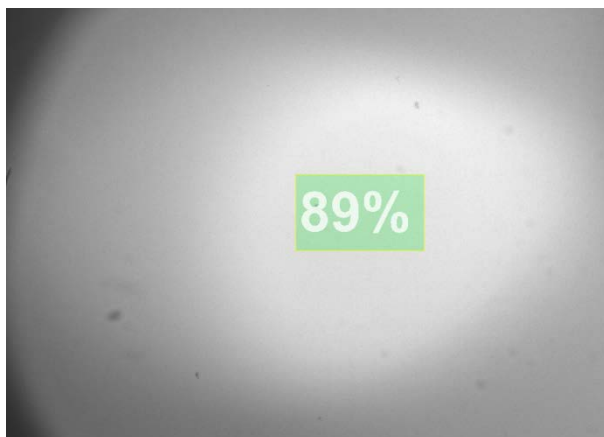
Next, the flow field area should be focused. A printed target is used to focus the camera on the desired flow field location. Adjust the bellows on the lens so that the appropriate field of view comes into focus. Fine adjustments to focus can then be made by using the lens controller software. Once the field of view is in focus, the focus setting can be saved by the lens controller.



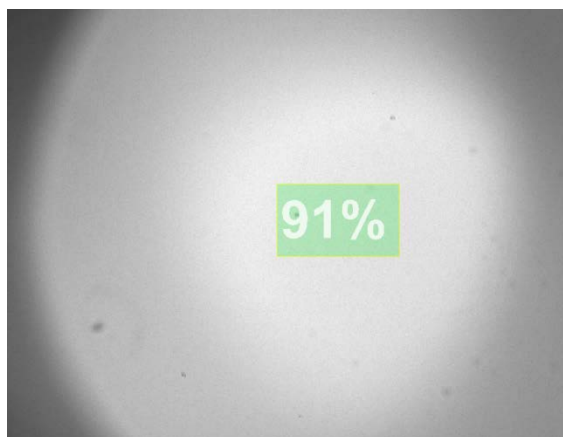
Target in Focus

Balancing the Signals

The signals from the red and green channels can be viewed in ProAcquire. Use the   buttons to view each channel. Adjust the pulse width for each color output on the LED until the maximum signal is ~90% of dynamic range on each image.

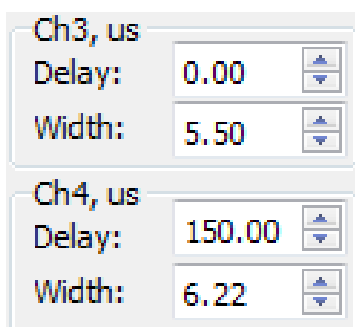


Red Signal

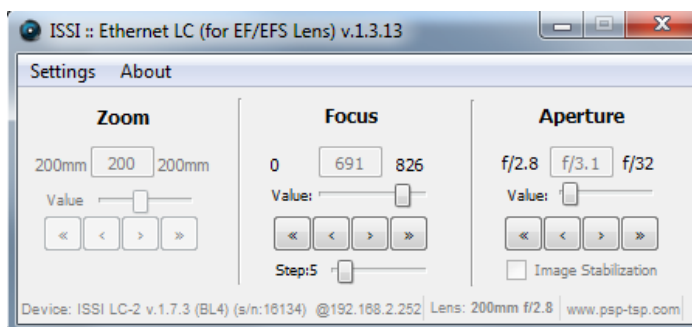


Green Signal

Quick adjustments to the pulse width can be made by using the pulse delay generator software to adjust. The aperture can also be adjusted on the lens controller if needed. It is recommended the aperture be set fully open or near fully open to defocus the LED and minimize the depth of field.



LED Settings Lens



Controller Interface

For acquisition, the pulse delay generator is used as the master controller for the experiment. The camera should be set to external trigger, exposure control mode so that the timing settings are set by the pulse delay generator.

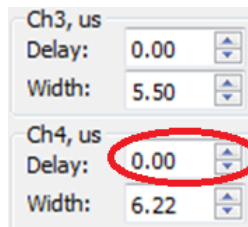


Channels 3 and 4 of the pulse delay generator will separately control the pulse width of the red and green channels and the delay time between them. The delay time between red and green will be dictated by the flow speed of the flow field studied.

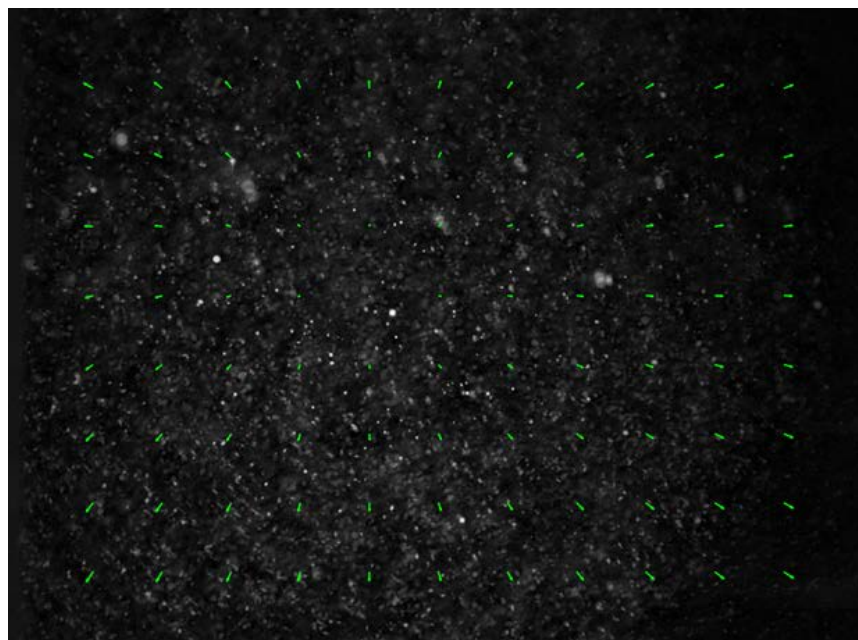
Data Acquisition

Calibration Images

Prior to acquisition of data images, calibration images needed for post-processing should be acquired. Set the delay between red and green outputs on the RGB LED to 0.00. (On the pulse delay generator, set the delay time for the second pulse signal to the RGB LED to 0.00.) While running the seeded flow at a typical test condition, acquire ~50 images which will serve as calibration images. These will be post-processed using PIV software to create a color correction map, which will correct for pixel shift due to lateral chromatic aberration.



Zero Delay for Calibration Images



Calibration Image with Vectors Representing the Processed Correction Map

Flow Images

After calibration images are stored, images of the flow field can be acquired. The timing of the pulse delay generator will control the LED and camera acquisition of the flow field. The delay set between the red and green pulses of the LED should be such that an 8-10 pixel shift is observed between the red and green channels. This is dependent on the flow speed in the area of interest. Particle size should be 3-5 pixels

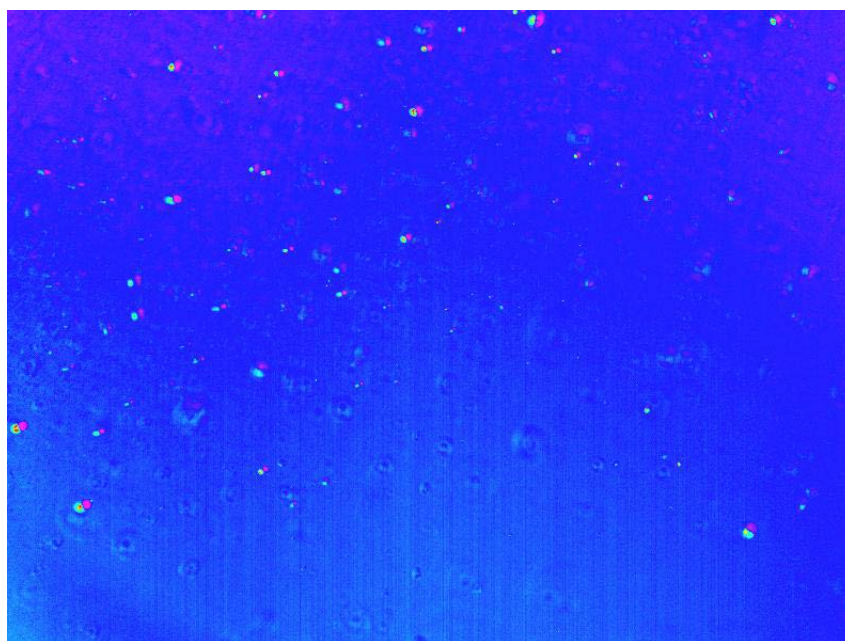


Red Signal



Green Signal

If the timing is set up correctly, the particle shift can be easily observed by taking a ratio of the red and green images.



Red-Green Shift

Post Processing

Commercial off-the-shelf PIV code can be used to process PSV data, after inverting the PSV images. First, the calibration images should be processed to get a mean vector field, which will likely radiate out from near the center of the image. This represents the chromatic aberration caused by the lens. After obtaining this field, the remaining images can be processed and the calibration vectors can be subtracted from the vectors in the data images to obtain the corrected vector field.

ISSI is developing a PSV Processing program for post-processing of PSV data, which will automatically perform this calibration. This program will be available in 2019 for the commercial PSV system.

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