application note

double shutter

special feature of PCO cameras

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PCO asks you to carefully read and follow the instructions in this document.
For any questions or comments, please feel free to contact us at any time.

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double shutter application note 1.0.0

Released June 2023

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1 Overview

Different imaging applications require different recording techniques. One of them is the ”Double Shutter (DS) Mode” which is primarily used for PIV (Particle Image Velocimetry) applications.

Various types of exposure modes can be used to capture a scene changing over time. Therefore, it is important to understand and choose the right recording technique for the specific application. The figure below depicts an illustration of recorded sequences in single frame mode and double/multi-frame mode with single, double, and multi-exposures.

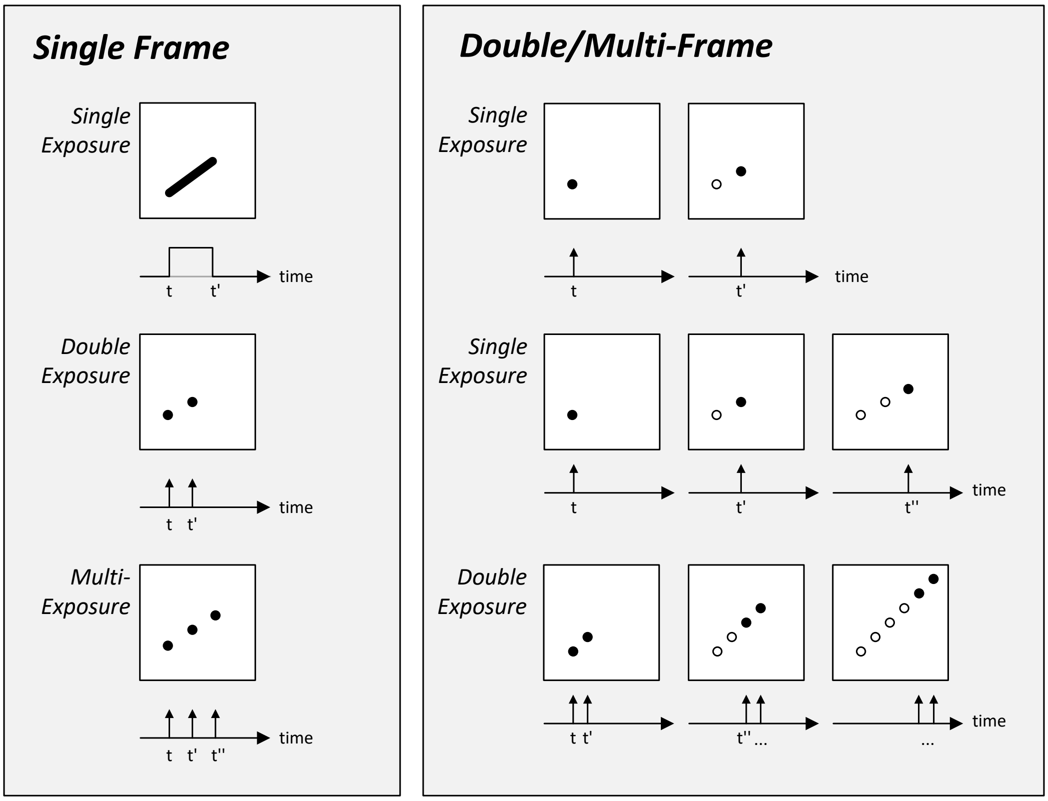

Figure 1.1: illustration of different recording techniques applying a different number of exposures and frames.

Within PCO cameras, a ”Double Shutter Mode” is implemented, this refers to double frame, single exposure as shown in the figure above.

2 Double shutter mode

The following figure shows two timing diagrams: the left diagram depicts the conventional single shutter timing while the right one despicts the double shutter timing.

In DS mode, two consecutive images ”A” and ”B” are recorded with the goal of a very short time slot between the two exposure times. The exposure time t_{exp1} of image ”A” may be any exposure time within the available range of the camera. The exposure time t_{exp2} of image ”B” can not be directly adjusted. This time is defined by the readout time t_{readA} of the first image. The time between the two exposure times is called interframing time t_{if}.

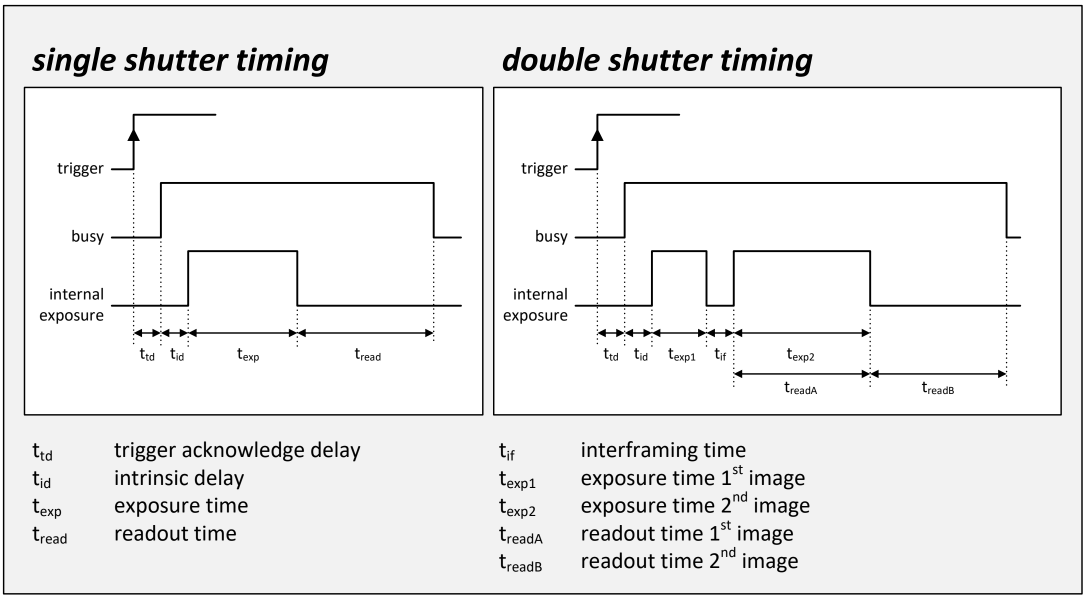

Figure 2.1: timing diagram for single and double shutter timing.

Interframing time:

The interframing time t_{if} denotes the transition time between end of exposure 1 t_{exp1} and start of exposure 2 t_{exp2}. This transisiton from image ”A” to image ”B” creates an undefined sensor situation. There is no clear separation of the images possible. Light entering the pixel during this time slot might be detected within image ”A”, image ”B”, or not at all. This scenario is depicted in the figure below.

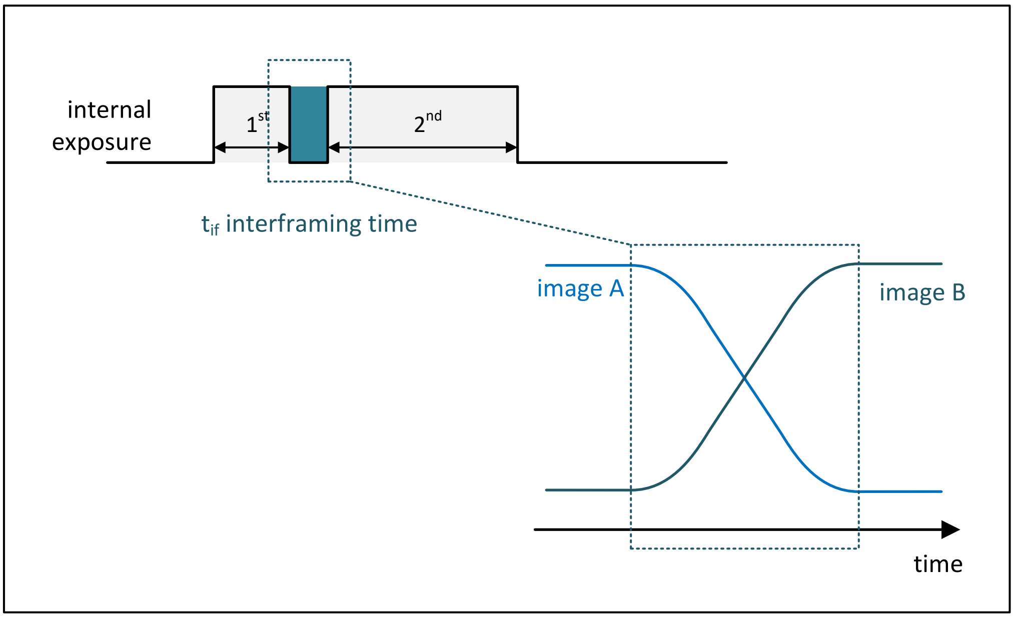

Figure 2.2: timing diagram showing the undefined state during the interframing time.

The next figure shows an exemplary image sequence in double shutter mode. For illumination of the image sensor, a flash laser pulse was used. In sequence 1, the laser pulses have a sufficient time interval before and after the interframing time. The generated charge by the laser pulses within the image sensor is well seperated. Both images have the same characteristics.

In sequence 2, the second laser pulse is within the interframing time slot. It is to notice that the charge generated by the second laser pulse is detected partly within the image ”A” and image ”B”.

Empirical rule: To use an effective interframing time of exemplary 1 µs, it is recommended to place the end of the 1st light pulse 500 ns prior to the end of the first exposure time. The 2nd light pulse should be timed not earlier than 500 ns after the end of exposure 1.

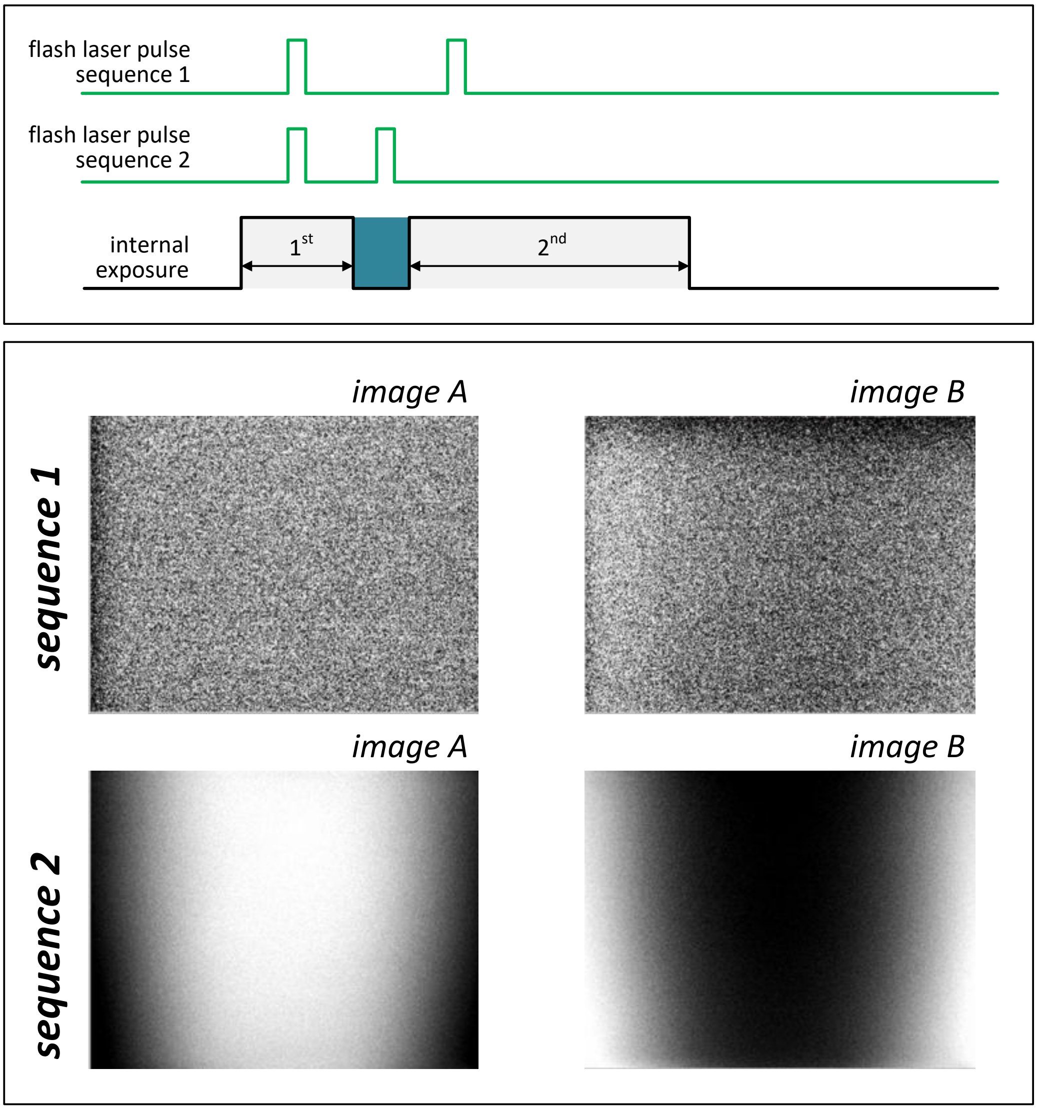

Figure 2.3: Example of two images in double shutter mode with varying light pulses to demonstrate the undefined charge collection during the interframing time. Image "A" refers to the first exposure, while image "B" refers to the second exposure. ***Top:*** *timing diagram of two sequences with flash laser pulse and camera internal exposure time.* ***Bottom:*** *resulting output images.*

3 Double shutter cameras

This is a portfolio of PCO's double shutter cameras.

3.1 pco.edge 5.5 DS

The pco.edge 5.5 is equipped with an innovative scientific CMOS sensor providing crisp images and precise measurements. It can be optionally upgraded with a water cooling system.

Camera	pco.edge 5.5 DS[1]
Resolution	2560 x 2160 pixels
Pixel size	6.5 µm x 6.5 µm
Frame rate single frame @ full resolution double frame @ full resolution	 50 fps 25 fps
Frame rate[2] single frame @ 1280 x 1024 pixels double frame @ 1280 x 1024 pixels	 105 fps 52 fps
Interframing time	120 ns
Data Interface	CLHS

3.2 pco.panda 26 DS

With the pco.panda 26 DS sCMOS camera you get a high resolution, ultra-compact sCMOS camera for particle image velocimetry (PIV) applications.

Camera	pco.panda 26 DS[3]
Resolution	5120 x 5120 pixels
Pixel size	2.5 µm x 2.5 µm
Frame rate single frame @ full resolution double frame @ full resolution	 6 fps 1 fps
Frame rate single frame @ 1280 x 1024 pixels double frame @ 1280 x 1024 pixels	 29 fps 15 fps
Interframing time	1 µs
Data Interface	USB 3.1 Gen1

[1] at minimum exposure time
[2] The ROI must be set symmetrically
[3] at minimum exposure time

4 Quick start guide

The following instructions will guide the user through the first startup of the camera in DS mode.

STEP 1

Install the latest version of pco.camware and PCO driver.

STEP 2

Connect the camera to the PC via the interface cable. Make sure that the status LED turns green. The camera is ready for operation.

STEP 3

Start **pco.camware.**

The software should find your camera automatically. If not, the user can do a rescan to connect with your plugged camera. The command ***Scan cameras*** can be accessed via the ***Main toolbar*** or the ***Camera Overview*** window.

Menu -> **Camera** -> **Rescan**

A new view window should open automatically. The user can also open a new ***View Window*** manually via the button ***New View Window*** located in the ***Main toolbar*** or the ***Camera Overview*** window.

Menu -> **View** -> **New View Window**

STEP 4

Change the camera properties from ***”Basic”*** to ***”Expert”*** (see following screenshot on the next page).

Camera properties -> **Basic** -> **Expert**

After the properties have been set from **”Basic”** to **”Expert”**, the **”Double Image”** mode can be activated. When starting an exposure, this opens a second window that displays the second image. First exposure will be shown in the upper window as ”A” and the second exposure will be shown in the lower window as ”B”. The exposure time of the first image can now be set, the exposure time of the second image corresponds to the readout time of the first image.

Note: The second window opens **after** starting an exposure.

For more information, please check the user manual of **pco.camware** available at the PCO website.

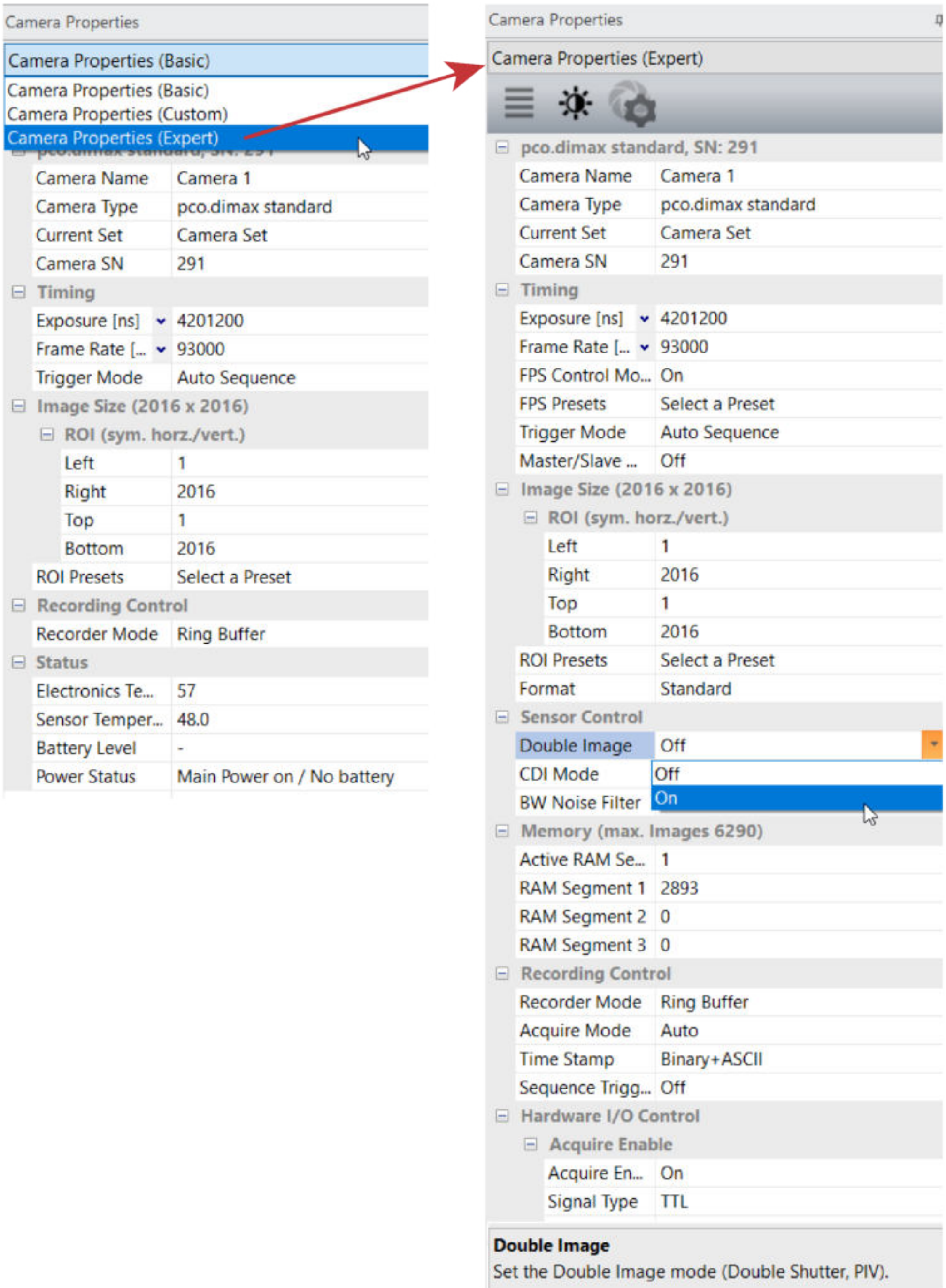

Figure 4.1: change of the camera properties.

Double image

The maximum frame rate of the double image mode (where frame rate is defined as the frequency of the double images) will drop to just half the value compared to the standard mode. The double image mode will work only in the trigger modes ***Auto sequence***, ***Soft Trigger*** and ***External Exposure Start***.

Note: to achieve a blur free second image, the environment should be kept dark and the exposure duration of the second image determined by a flash light.

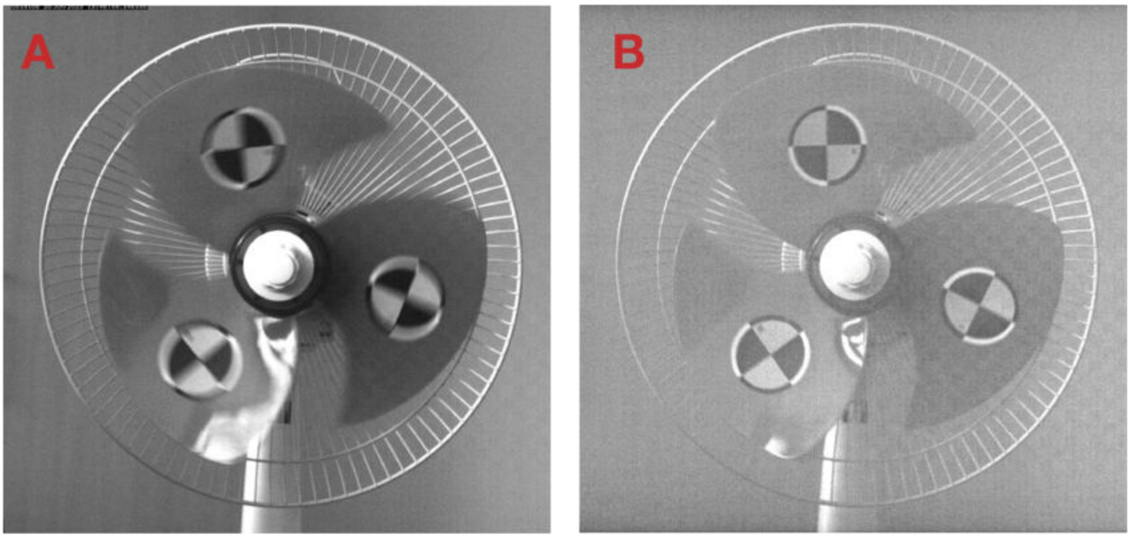

Figure 4.2: two pictures made in double shutter mode.

5 Application example

PIV Tour de France: German F1-Technology helps André Greipel

Source: ILA, Frank Michaux

André Greipels latest victories in the Tour de France are supported by Formula 1 technology July 24, 2015 - Bike and clothing of André Greipel in the Tour de France is developed by means of German technology also used in Formula 1. During wind tunnel measurements at the Technical University in Dresden (Germany) the same technology Formula 1 teams use to develop their racing cars, was used to analyze the performance of bike and helmet. This measurement technique called Particle Image Velocimetry not only allows visualizing the airflow around the bike and rider, but also accurately measures the flow in detail. Development engineers use these results to optimize the performance of bike and clothing and help André Greipel in this way to reach new sportive achievements.

Particle Image Velocimetry (PIV) is an optical measurement technique. Small particles are illuminated by means of a powerful laser. The movement of these particles is recorded by a sensitive camera, a special version of the pco.edge 5.5. Finally, a dedicated software package can accurately calculate the direction and speed of the flow.

This PIV technique has been used successfully for several years by leading Formula 1 teams to optimize the performance of their racing cars. It has become a standard part of the wind tunnel. In F1, every hundredth of a second can decide on the pole position. In cycling, improvements in efficiency of bike and helmet for example can give the rider the extra energy reserves he needs at the end of the stage to take the win.

Figure 5.1: parts of Ridley Bikes' road bike and André Greipel's Lazersport helmet were measured and analyzed by the PIV system.

At the start of 2015, PIV was also used in a joint project set-up by Flanders' Bike Valley in Belgium. This allows the manufacturers of bikes and clothing to come together and optimize their product range. In this case, parts of the bike (Ridley Bikes) and the helmet (Lazer Sport) of André Greipel were measured and analyzed by the ILA PIV system. The development engineers of Ridley and Lazer Sport used these results to further improve the performance and help Greipel in this year's edition of the Tour de France. The measurement system is a cutting edge technology for sports aerodynamics. In the near future the objective is to perform more measurements which exactly represent professionals and semi-professionals in order to adjust wear, helmet and bike.

Bert Celis, coordinator Flanders' Bike Valley: "The know-how of Flemish Companies regarding aerodynamics and cycling technology is worldwide leading edge, but was until now rather divided. Each company had their own knowledge about their own product range. For the first time in history this know how was grouped during one week for joint tests. Together with the expertise of Euregional partners like ILA this resulted in the ideal cocktail for innovations…" Toon Wils, Engineer Ridley Bikes: "It is very interesting to participate in tests of other cycling products and to learn from each other. Most of all the cyclist benefits from a total approach where every detail is fine-tuned and fitted within a total mind blowing concept."

List of Figures

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