Multiplane Scanning Stereo PIV for Biofluid Applications

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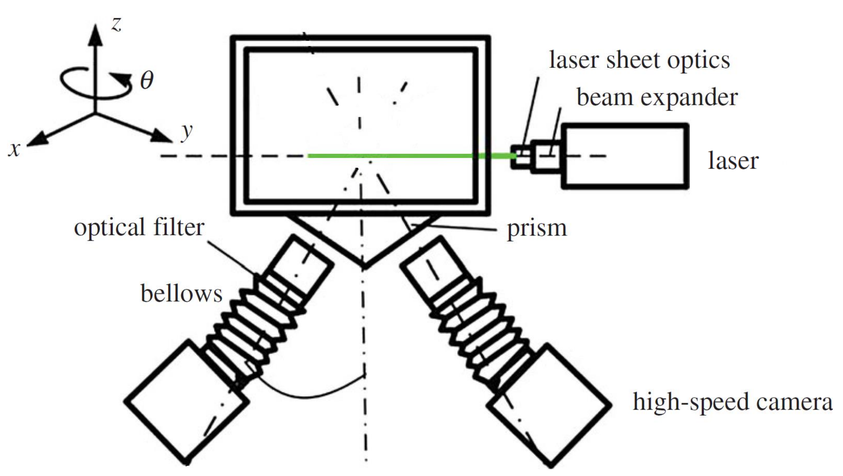
Background

Stereoscopic Particle Image Velocimetry (Stereo PIV) is a whole-flow-field laser optical technique. It permits the three velocity components measurements in a cross section flow.
The flow is usually seeded by small tracer particles illuminated by a sheet of laser light. The light scattered by the particles is recorded on two separate frames on a special CCD camera sensor.

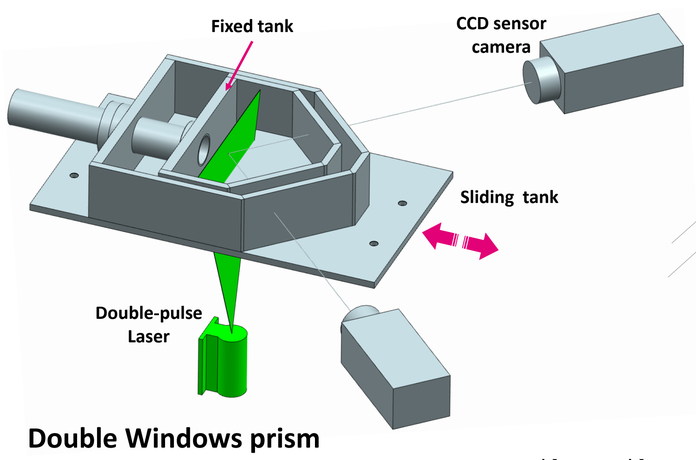


The reconstruction of the 3D object from the digital images requires prior knowledge of the mapping function between the image planes and the physical space cameras. This is achieved by means of a **calibration procedure**.

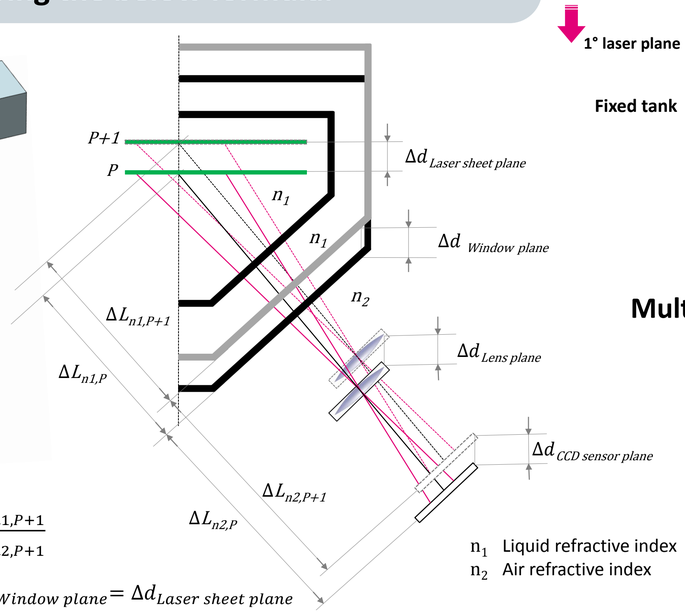
Double Windows Prism

The Stereo PIV needs a precise calibration procedure whose accuracy is directly linked with measurement errors. The usual calibration procedure consists in taking several images of a calibration target, placed first in the light sheet plane. Since cardiovascular flows are wall in by complex geometries, the calibration operation into the measurement plane is limited or often impractical.

A *Double Windows prism* was developed to permit us to implement Multiplane scanning measurements of Stereo PIV within a complex geometry without repeating a laborious calibration. It ensure the relative positions the stereo PIV apparatus throughout the scanning, preserving the below formula.



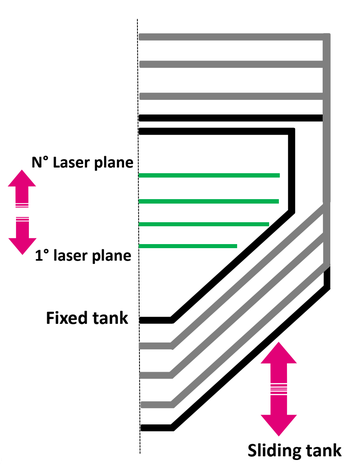
Double Windows prism



$$\frac{\Delta L_{n1,P}}{\Delta L_{n2,P}} = \frac{\Delta L_{n1,P+1}}{\Delta L_{n2,P+1}}$$

$$\Delta d_{CCD\ sensor\ plane} = \Delta d_{Lens\ plane} = \Delta d_{Window\ plane} = \Delta d_{Laser\ sheet\ plane}$$

n_1 Liquid refractive index
n_2 Air refractive index



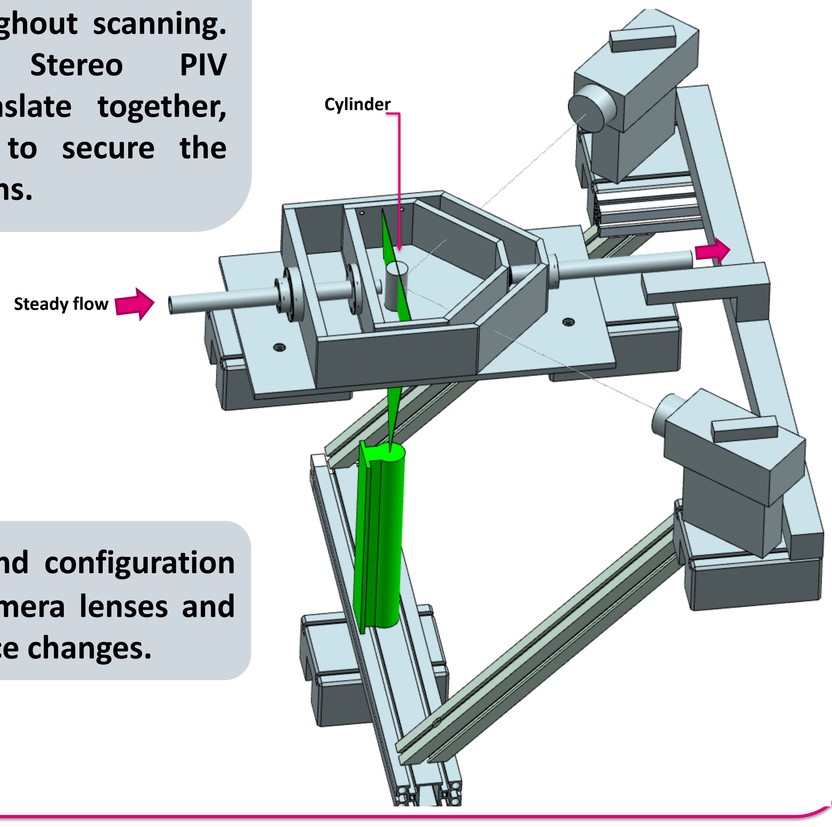
Multiplane scanning technique

"Multiplane scanning"

The stereoscopic camera configuration has the side-effect of introducing a strong prespective distortion. The air–liquid interface must be parallel to the measurement plane; liquid prisms are usually used at the interface to compensate for the aberrations due to the different refractive indexes of the air and the liquid flow.

One goal is to use The *Double Windows Prism* to evaluate the aberation velocity error by measuring the flow filed arround cylinder, performing <u>one calibration</u> in two different configuration A and B.

A- Keeping the distance camera Air-fluid interface constant throughout scanning. The whole Stereo PIV apparatus translate together, which permit to secure the relative positions.

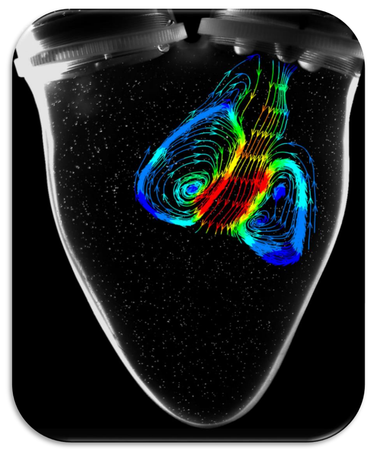


B- In the second configuration the distance camera lenses and Air-fluid interface changes.

Biomedical application

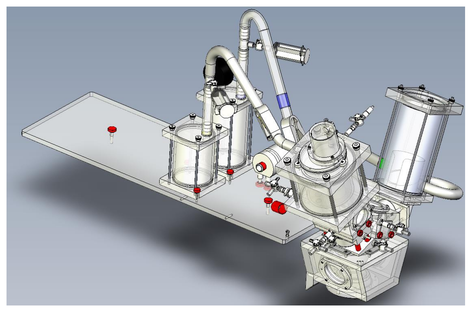
"Intracardiac Flow Mirror Healthiness"

The evolution and spatiotemporal characteristics of the intracardiac flow field have physiological, clinical embryological, and pathological interest. Several studies aimed to evaluate and describe cardiac flow based on intracardiac flow, using measurements obtained by modern medical imaging (4D-MRI, echocardiographic[2]) or flow diagnostic techniques such as particle image velocimetry[3].

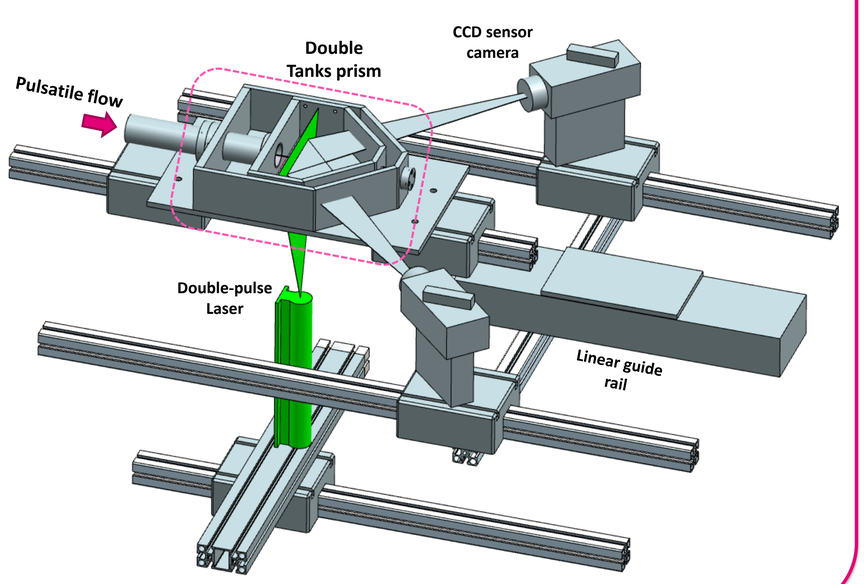


Streamlines of transmitral jet downstream a 25mm Mitral Biocor™ by St. Jude Medical is obtained using PIV. ***Image credit: Kheradvar A. and Falahatpisheh A.***

The aim of this project is to map the 3D intracardiac spatiotemporal structure flow by mean *phase-locked Stereo-PIV*. The *Double Windows Prism* developed permits the flow field measurment in the whole left ventricle model without repeating the complex stereo calibration. It consisted of coupling Stereo-PIV apparatus and cardiovascular simulator *Vivitro system*.



The Pulse Duplicator System simulates the function of the heart by generating pulsatile flow through prosthetic heart valves placed in the Model Left Heart, allowing the user to vary the peripheral resistance and compliance of the system.



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