Rainbow Particle Imaging Velocimetry

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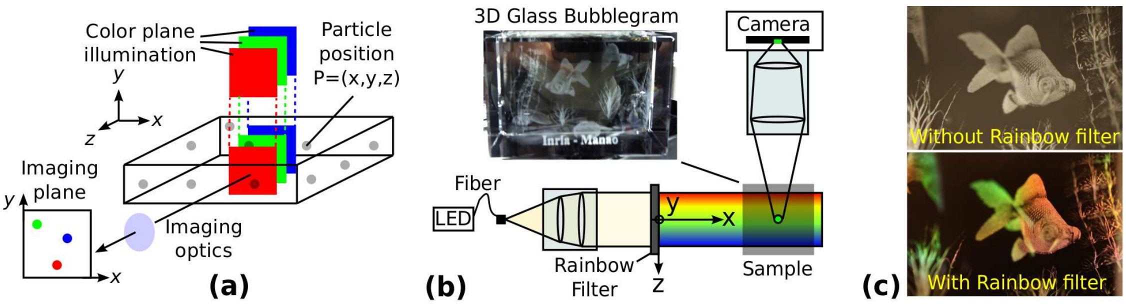

Fig. 1 : (a) Rainbow-PIV principle, (b) Initial prototype : Rainbow-PIV optical system, (c) Validation results.

We introduce a new approach for snapshot imaging of time-resolved, non-stationary 3D fluid flows. Based on Particle Imaging Velocimetry (PIV), a well-established technique for fluid flow analysis [1], we propose a novel approach for spectral encoding of the third dimension. To do so, we illuminate the flow volume with a stack of monochromatic light planes at different wavelengths (rainbow) : we call this novel approach Rainbow-PIV. With a single camera, we can record the third dimension, this is a completely new approach compared to the state-of-the-art [1, 2].

Classical Particle Imaging Velocimetry consists of imaging tracer particles seeding into a fluid and then analysing the position and the velocity of each tracer particle [3]. Here, we propose a new method of 3D particle tracking by encoding 2D spatial (x,y)-position in the imaging plane of the camera and the depth, z-position, with a color code, see Fig. 1(a). Figure 1(b) represents the initial prototype of the optical system we have developed to generate clean spectral planes towards the sample volume and detect the light scattered by the particles located in this rainbow volume.The setup is divided in two parts : A, the rainbow illumination is created with a white (uniform spectrum) collimated light source passing through a linear variable wavelength filter and ; B, the video acquisition system oriented in the orthogonal direction of the rainbow illumination to detect the light diffused by the particles. Figure 1(c) shows the validation results done on a glass bubblegram used as PIV-test phantom. We use it to validate the spatial precision of our system. However, the intensity of the diffused light is low and consequently the exposure time of the CCD is at the moment too long for video-capable acquisition system. Therefore, we are currently improving the rainbow illumination part of the optical system to increase the rainbow illumination power by two orders of magnitude. With this, we will be able to increase the signal noise ratio detected by the camera and achieve time-resolved frame acquisition.

Thus, using only a single camera, our new optical system will allow to generate in real-time 3D measurements of the fluid flow and to achieve time-resolved dense measurements of 3D velocity fields with complex 3D particle trajectories. It will provide a useful tool for studying and understanding new types of flows including turbulent flows or vortices [1, 2]. The Rainbow-PIV is the first approach for fluid flow imaging that combines both a single camera operation and a time-resolved measurements of the full 3D particle positions.

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