Demonstration and characterization of a new interferometric particle imaging configuration for bubbles

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Interferometric Laser Imaging for Droplet Sizing (ILIDS) is a popular technique for measuring the diameter of droplets. The main advantages of this technique are its non-intrusiveness and the possibility to measure micro-droplets over a relatively large field of view with a regular objective. Although some successful attempts were made to apply this technique to micro-bubbles, the technique is still not being used actively in the field. In the present article, a different configuration will be presented that measures accurately the bubble diameter under 90° with perpendicularly polarised light. An example of this is shown in Figure 1.

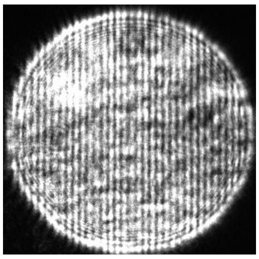


Fig. 1 Example image taken under 90°

A frequency analysis of this interference pattern reveals that there are in fact two frequencies present as shown in Figure 2. In the paper, we will prove that this additional frequency is due to light that has 4 interactions with the bubble. Since the relative location of this secondary peak can be predicted accurately, it can be used to make our measurements more robust by requiring that this specific frequency signature is present. Since this approach presents a real improvement in robustness over the traditional ILIDS configuration, we called this approach extended ILIDS in accordance with extended GPVS.

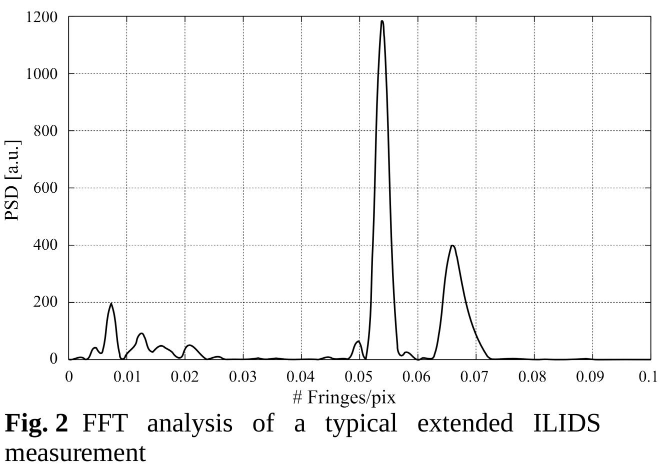
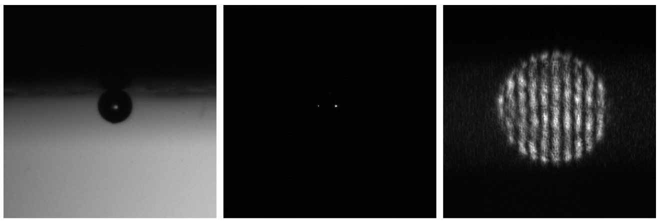


Fig. 2 FFT analysis of a typical extended ILIDS measurement

The second part of this paper deals with different ILIDS calibration procedures. Up to our knowledge, four different procedures are current but their associated uncertainties have not yet been stated clearly. Next to simple fringe counting and performing a full calibration on a known target, there is also the possibility to do a so-called 'experimental' calibration where the disc size needs to be measured in pixels and a 'theoretical' calibration where everything is calculated through the thick lens approximations. We will derive the necessary theoretical formulas for these procedures in two distinct cases; when the camera is focused at infinity and with a two-step calibration procedure where the out-focus magnification is calculated from the in-focus magnification. A comparison of the theoretically calculated disc-size with the experimental size in both cases, reveals that the highest precision is obtained with a two-step calibration where a sharp focus is obtained when the camera is half-way between the measurement volume and the ILIDS position. In this case, uncertainties of 1% seem achievable.



a) b) c)

Fig. 3 Measurements of the same bubble with a) backlighting, b) GPVS and c) ILIDS

Finally, a direct comparison of measurement of the diameter of the same bubble with backlighting, GPVS and ILIDS was performed as shown in Figure 3. These results were in excellent agreement and for the present case the differences were smaller than 1%.