Laser light sheet profile and alignment effects on PIV performance

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HIGHLIGHTS

• Synthetic PIV simulations reveal the impacts of laser sheet misalignment and width mismatch on correlations and spurious vector frequency
• A modular laser profiling camera design is presented for robust and repeatable quantification of laser characteristics and overlap
• Preliminary results from PIV experiments studying the misalignment of laser sheets reinforce the trends observed in simulations

ABSTRACT

The sensitivity and impact of laser profile misalignment and shape mismatch on Particle Image Velocimetry (PIV) measurements are investigated in this study. While the effects of laser profile misalignment can be equivalent to an out-of-plane velocity component, light sheet mismatch can be identified and corrected prior to an experiment, decreasing PIV uncertainties. Synthetic particle image simulations are used to isolate and systematically vary laser profile mismatch parameters between successive PIV laser pulses. Two simulation cases are discussed, analysing the effects of a misalignment between two otherwise identical laser pulses, as well as a mismatch in the width of two laser profiles. Our results reveal a steady degradation in mean correlation coefficient as the laser profiles are increasingly mismatched in shape and alignment, coupled with a rapid rise in the detection of spurious vectors. These findings reinforce the need to consider laser sheet alignment and intensity distribution when seeking to capture high quality PIV measurements. The design of a modular and inexpensive laser profiling camera (see figure 1(a)) is outlined to enable robust and repeatable quantification of laser sheet overlap and beam characteristics (a sample beam profile is shown in figure 1(b)). The profiling system is also found to be a valuable tool for laser diagnostics and aiding the setup of experiments. Various potential applications of this device are presented for PIV and other laser-based measurement techniques. Finally, preliminary results from PIV experiments which involve the deliberate misalignment of laser profiles are discussed. These data reiterate the trends observed in simulations, but also emphasise the coupled complexity of laser profile mismatch behaviour in experimental scenarios, placing the idealised simulation results in some context. Collectively, our findings highlight the importance of well-matched laser profiles. A more rigorous experimental quantification of these behaviours has the potential to enhance the quality of PIV results.

Fig. 1 (a) Laser profiling camera setup, (b) Sample laser beam profile